HIPPARCHOS

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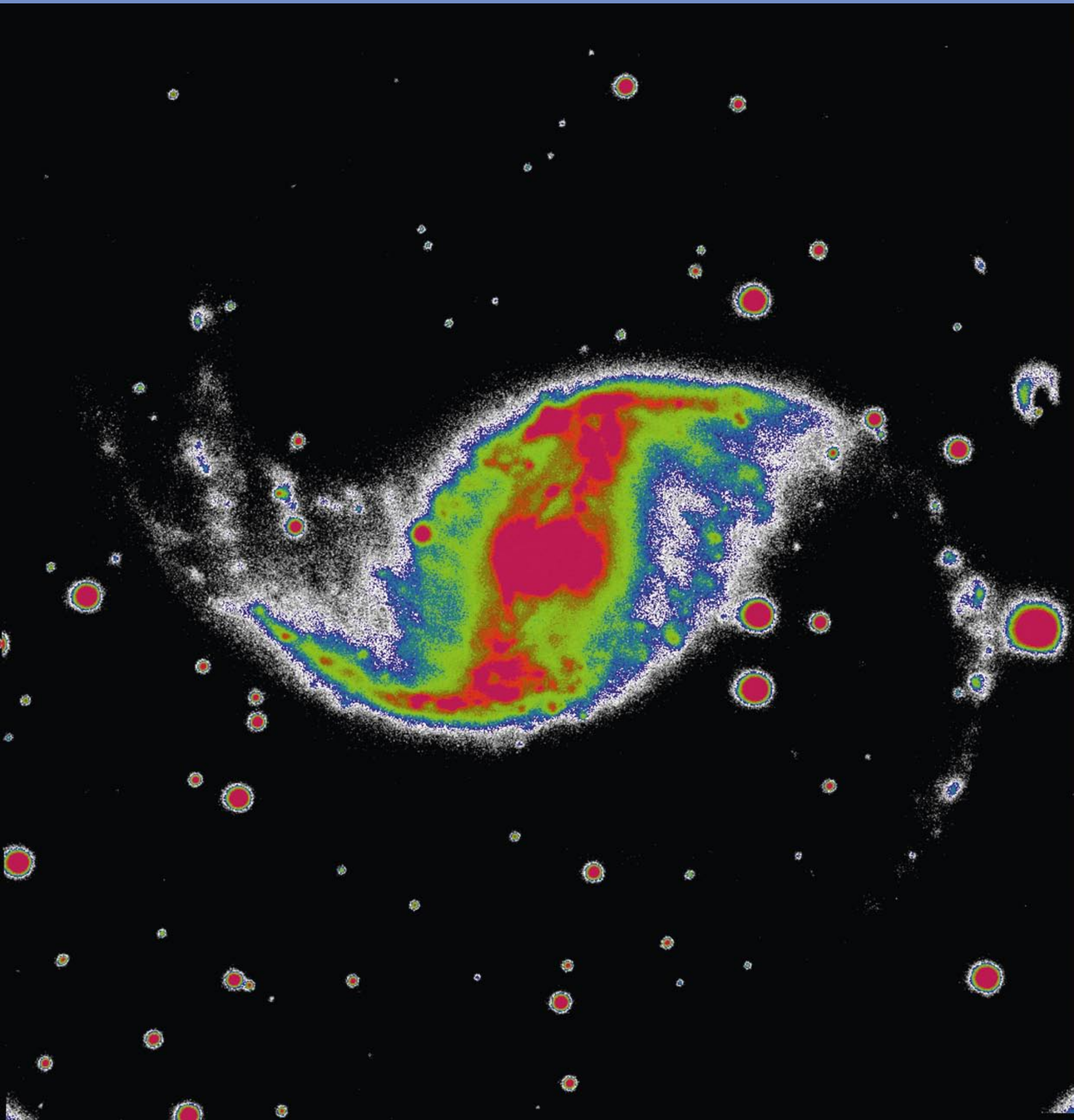

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Hipparchos is the official newsletter of the Hellenic Astronomical Society. It publishes review papers, news and comments on topics of interest to astronomers, including matters concerning members of the Hellenic Astronomical Society.

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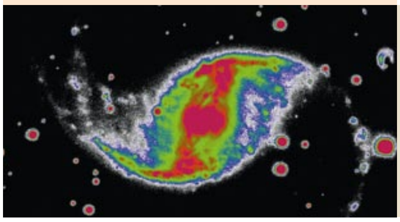

Cover Image: A pseudo-color image of the barred-spiral galaxy NGC 1530 (B filter) in Camelopardalis.
Exposure date: November 28, 2016, Location: Helmos Observatory ("Aristarchos" telescope), Greece
Observers: Panos Patsis, Manolis Xilouris, John Alikakos

Message from the President

The current issue of *Hipparchos* finds our Society with a new Council that emerged from the elections during the General Assembly of June 2016. As the previous councils of Hel.A.S. have already established traditions of high quality in many fronts, my colleagues and I have a lot of challenges to meet just to maintain the standards. *Hipparchos* is one of them and looking at the soon-to-be-finished issue I feel that, at least in this case, our goal has been accomplished.

The article of Jason Spyromilio of ESO on the occasion of the 30th year anniversary of SN 1987A brought back many memories. I was a young post-doc at MPE Garching and I vividly remember the excitement that this extraordinary event brought to the community: there were discussions on a daily basis, weekly informal group meetings, frequent institute seminars ranging from the light-curve and radioactive isotopes to the Kamiokande and IMB neutrinos – for this last topic the community was divided among the enthusiasts and the sceptics and heated discussions were frequently erupting. Everybody was waiting for fresh news from the South, colleagues were flying to Chile to observe, even we (along with past Hel.A.S. president Nikos Kylafis and past Council member Joseph Ventura), perhaps carried by the overall atmosphere, applied Monte-Carlo codes to examine the degradation of Co-56 nuclear lines and the subsequent emergence of the radiative signatures coming from a newly formed possible pulsar. All these memories came back by reading Dr. Spyromilio's review of the important knowledge that was gained from the good piece of luck that was SN 1987A.

Demosthenes Kazanas of NASA/GSFC gives a review on accretion disk winds as applied both to small scale (X-ray binaries) and large scale (Active Galactic Nuclei) black holes. Using X-ray spectroscopy and results from radiation transfer codes, he argues in a very convincing way that, as their profiles imply, the winds in question cannot be radiation driven but must be of magnetohydrodynamic origin. This is an intriguing idea that aims in unifying black hole accretion in a dynamic range spanning at least eight orders of magnitude.

Not too many years ago only a few people were working on the Interstellar Medium (ISM) and the field was in a state of limbo. Nowadays things have changed drastically, mainly through the advancements of Infrared Astronomy and Dimitra Rigopoulou of Oxford University reviews the role that the Far InfraRed SPectroscopic EXplorer (FIRSPEX) is expected to have in understanding the key physical processes that govern the heating and cooling of ISM. As the ISM acts both as a cradle for star formation and a reservoir for recycled stellar material, the proposed observations could be another step towards understanding not only aspects of the stellar cycle, but the formation and evolution of galaxies as well.

Speaking of galaxies, two of my colleagues in the Governing Council of Hel.A.S., Panos Patsis (KEAEM/Academy of Athens) and Emmanouil Xilouris, along with A. Alikakos (both of NOA) give a review of boxy galactic bulges, arguing that in reality these are the central part of the bars in the barred-spiral galaxies. In order to verify their arguments they used the 2.3 m Aristarchos Telescope to observe the galaxy NGC352, showing the diversity of the projects that can be performed with the particular instrument.

Looking back at the past year I would like to mention the many conferences and schools that were held in Greece. A special mention should be given to the EWASS 2016 that brought to Athens hundreds of astronomers from Europe and beyond. It was a very successful Conference organized by the European Astronomical Society in collaboration with Hel.A.S. and the Eugenides Foundation. It was not only the size, but also the quality of the talks that was impressive. I found the sessions to be very interesting and one had to make hard choices deciding which of the parallel session to attend. In the pages that follow one can find a report on EWASS 2016 along with reports from the other conferences organized all over Greece during the past year.

Last but not least I should note the 2nd Summer School of Hel.A.S., this time on the topic of Nuclear Activity in Galaxies. This was held in the Physics Department of the National and Kapodistrian University of Athens in July 2016 and it was attended by more than twenty, mostly graduate, students. As an eyewitness I can testify that the school was very topical and interesting, with excellent speakers and a very diversified syllabus, ranging from observations in various wavelengths to theory. I am pleased to see that our Society successfully sets the foundations for yet another tradition.

Closing this short message and trying to be in line with the past presidents, I have the feeling that, despite the turbulent times we have found ourselves into, our Society continues to grow and prosper. This is because the younger generations have embraced Hel.A.S. and there is gradually a shift of the members average age. Not only that but I also feel that there is a change in quality that pushes us onward and forward. This sets a challenge for everybody, but mainly for us in the Council, to keep the Society up to the growing expectations and to continue on a path that unites its members under common goals and rewards excellence – as is done, for example, with the Best Ph.D. Award. It is a simple recipe after all!

Apostolos Mastichiadis
President of Hel.A.S.

X-ray Tomography of Accreting Black Hole Sources and Its Implications

by Demosthenes Kazanas
NASA/Goddard Space Flight Center

Abstract:

X-ray spectroscopic observations of Active Galactic Nuclei and accreting Galactic black holes have established the ubiquitous presence of blue-shifted absorption features in their spectra. These are attributed to outflows, that is winds launched off the black hole accretion disks, ionized by the accretion disk X-rays. The physics of wind ionization that determines the position and velocity of each such absorption feature can then be employed to determine the density profile of the se winds along the observers' line of sight (LoS), e.g. to produce a tomography of these winds. Most interestingly, the inferred wind density profiles are not consistent with radiation driven winds, the simplest assumption given the intense radiation of the accretion powered sources; rather, they are consistent with winds driven by magnetic forces across the entire accretion disk domain. Furthermore, simple arguments based on the winds' ionization, indicate that the wind mass flux increases with distance from the black hole. This in turn provides a novel picture of the structure of AGN as magnetically dominated structures that span roughly 10^6 Schwarzschild radii. A recent application of a scaled-down version of the AGN disk wind models to the data of the Galactic accreting black hole GRO J1655-40, were found in excellent agreement with corresponding X-ray spectroscopic observations. This implies a universality of these models that extends across a dynamic range of $\sim 10^8$ in black hole mass, thereby providing a deeper understanding of the physics of accreting black holes.

1. Introduction

It is widely accepted that quasars and other types of Active Galactic Nuclei (AGN), as well as X-ray Galactic Black Hole Binary sources (XRB) are powered by accretion onto black holes that range in size from $\simeq 10$ to $\simeq 10^9$ solar masses. It is also widely accepted that accretion onto these black holes proceeds through the formation of an accretion disk whose basic properties were enunciated in the classic work of Shakura and Sunyaev [20]. While their viscosity is still a matter of debate, it is assumed on dimensional grounds that the viscous stresses are proportional to the local plasma pressure P, i.e. $t_{r\varphi} = aP$; once a viscosity prescription is adopted, the disk properties are rather well determined and their phenomenology rather well defined. Thus, because it is assumed (with some justification) that the accretion power is dissipated locally in black body form, one expects a maximum disk temperature. This is attained when the sources radiate at their Eddington rate (the luminosity at which the radiation pressure force overcomes that of gravity, thus presenting a maximum of accretion luminosity), from a disk area associated with its inner most stable circular orbit (ISCO) ($R_{ISCO} = 6M = 1.5\times10^6 (M/M_\odot)$ cm for a Schwarzschild black hole). This temperature is of order $T \sim 10^7 (M/M_\odot)^{1/4}$ K $= 10^5 (M/10^8\ M_\odot)^{1/4}$ K. Such quasi-thermal features have actually been observed at the appropriate temperatures both in XRBs (known as the multicolor disk – MCD) feature and in AGN (known as the Big Blue Bump – BBB).

These features generally (but not always) dominate the luminosity of these objects, in compliance with the theory demands. If that were the general rule, AGN research would have long ago been delegated to the astrophysics textbooks. However, the AGN and XRB phenomenology is much more diverse and quite often in disagreement with the basic theoretical predictions.

To begin with, besides the quasi-thermal component discussed above, accreting black holes exhibit invariably X-ray emission of power law form that extends to $E \simeq 50\text{-}100$ keV. The origin of this component is uncertain, however it has been thought that it represents emission of the disk photons comptonized by a hot corona overlying the accretion disk, much in the form of the solar corona. Unfortunately the flux of this component relative to that of the BBB (or the MCD) has a range of ~100, a quantity that it is not addressed by the theory, despite well defined systematics that have the X-ray component be the dominant one at states of lower bolometric source luminosity. This correlation is quite secure in galactic X-ray sources which exhibit well established sequences of varying luminosity states accompanied by changes in their corresponding spectral properties, with their MCD component being generally dominant at the higher bolometric luminosity states. By analogy, it is believed that AGN exhibit similar correlations, however, due to their very long variability time scales, and their wide mass range,

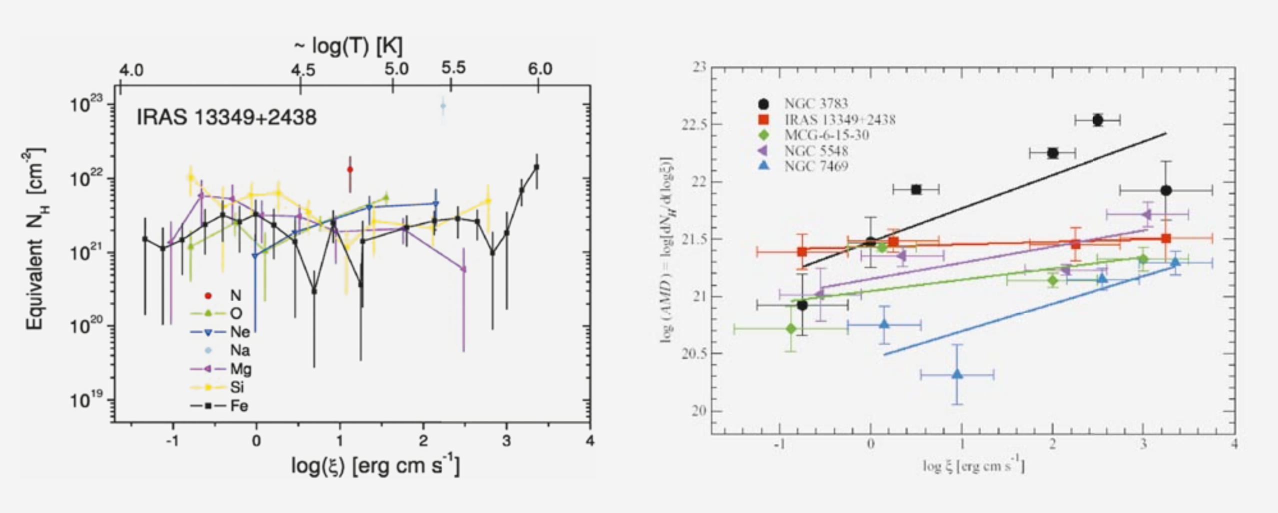

Figure 1: *(a-left) The Hydrogen equivalent column density as a function of the ionization parameter ξ (AMD) computed for the different elements shown in the figure. The distribution of N_H is independent of the specific element employed for its determination (Holczer et al. 2007). (b-right) The computation of the AMD from the X-ray absorption data of the AGN shown in the figure. The range of the values of the index p ranges between 0.02 < p < 0.3 (Behar 2009).*

such statements are supported only statistically.

A novel insight concerning the nature of X-ray emission by accreting black holes was introduced by Narayan & Yi [15]: These authors noted that for accretion rates (normalized to that of Eddington) sufficiently small, i.e. $\dot{m}<a^2$, the disk cooling time becomes longer than the viscous time scale $\tau_{vis}\sim\tau_K(1/a)(R/h)^2$ (τ_K is the Keplerian time scale); the protons attain their local virial value, the disk becomes geometrically thick, i.e. $h \simeq R$, and matter accretes on to the black hole before it has time to cool and radiate away its internal energy, reducing the disk's radiative efficiency. Because part of the viscously dissipated energy remains in the protons and it is advected into the black hole, these flows are known as ADAF (Advection Dominated Accretion Flows). With ADAF, the AGN X-ray emission became part of the dynamics of accretion and therefore far more constrained than it is in its coronal incarnation.

2. Winds

The launch of Chandra and XMM-Newton ushered a new era in X-ray astronomy of AGN with the discovery of blueshifted absorption lines in the X-ray spectra of ≃50% of all AGN. Their sensitivity and spectral resolution enabled for the first time accurate charge state and velocity measurements. The long observations of a number of AGNs revealed X-ray transitions of charge states as diverse as Fe_{i} through Fe_{xxvi}. This underscores the utility of X-ray spectroscopy which within ≃1.5 decades in photon energy encompasses transitions of ionic species that span ~5 decades in ionization parameter $\xi = L/n(r)r^2$ (L, n are respectively the source luminosity and local plasma density; r is the distance from the black hole). Similar progress was achieved in the UV study of AGN winds with the launch of HST, which showed that ~50% of AGN show evidence of outflow absorption in their UV spectra too. Apparently there is a relation between the X-ray and UV absorption feature properties, which however it is not quite as clear yet [6].

The large number and the broad range of their ionization parameter ξ of the X-ray transitions in the Chandra and XMM spectra allows for their statistical treatment. Thus, [10] and [1] assumed a continuous distribution of absorbers with ξ and using an error minimization procedure for the entire set of transitions, computed the distribution of their hydrogen-equivalent column N_H as a function of ξ; this way they produced what they called the absorption measure distribution (AMD), namely the differential hydrogen-equivalent column N_H of specific ions per decade of ξ, i.e. AMD = $dN_H/d\log\xi$. Most importantly, they found that the AMD has a rather weak dependence on ξ; in the small number of Seyferts for which the data quality allowed a quantitative analysis they found $dN_H/d\log\xi \propto \xi^p$, $0 \lesssim p \lesssim 0.3$ (see Figs 1a, 1b). The functional form of the AMD is significant as it provides the plasma column density at different radii along the observer's line of sight (LoS) and from that, under the reasonable assumption that $N_H \simeq n(r)r$, the radial distribution of the wind density, i.e. perform *a tomography of the AGN wind.*

One can easily see that

$$dN_H/d\log\xi \propto \xi^p \;\propto N_H \propto \xi^p$$

implies $n(r) \propto r^{-s}$, with $s = (2p+1)/(p+1)$; so the observed range in p, limits s to the range $1 \lesssim s \lesssim 1.2$. This finding is significant because the corresponding density profile is inconsistent with the $n(r) \propto r^{-2}$ density profile of radiation driven winds, the preferred means of launching winds in AGN and compact objects in general. This fact, along with the broad range of ξ and velocities of the wind plasma, implies that these winds are launched across the entire accretion disk; as such they must be driven by the action of magnetic fields, i.e. that they are the MHD outflows, as at large radii the local radiation field does not have sufficient momentum to launch these winds. Thus the X-ray absorber spectroscopy affords a global view of the structure of AGN along the observer's LoS, exclusive to this energy band.

The formal analysis of 2D MHD winds in relation to AGN was enunciated by [3]; they produced 2D solutions of the steady state, axisymmetric MHD equations involving a poloidal magnetic field threading a thin, rotating Keplerian accretion disk. These winds ex-

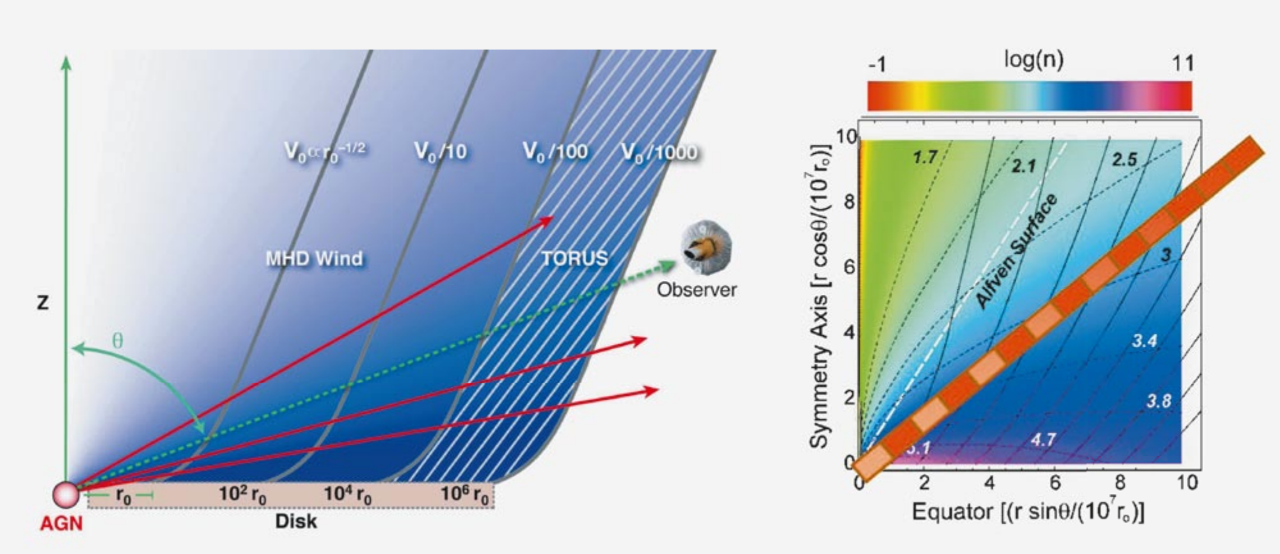

Figure 2: *(a-left) A wind schematic as a function of the logarithm of the distance along the disk. The thick lines represent the poloidal magnetic field lines, while the shaded region the wind section beyond the dust sublimation distance that acts as the "dusty AGN torus". (b-right) Poloidal distribution of the magnetic field (solid lines) and density (color, also dotted lines marked with the log of density). The brown diagonal box indicates the radiative transfer grid along the given line of sight (LoS) direction (Fukumura et al. 2017).*

tend over the entire radial range of the disk, from near the Schwarzschild radius R_S to its outer edge, believed to be at a distance of $10^6 R_S$ ~1-10 parsec in AGN. Their density profile is $n(r) \propto r^{-3/2}$, inconsistent with that inferred from the AMDs of Fig. 1. Generalized version of these winds that allow for a range of the exponent s consistent with observations were found and studied by [5]. Furthermore, winds similar to those of [5] with $n(r) \propto r^{-1}$ were invoked by [13] as the "torii" of AGN unification, as winds with this density profile provided, by reprocessing of the AGN UV radiation.

There is therefore evidence that the AGN central black holes are surrounded, over several decades in radius, by the plasma of MHD winds emanating from their accretion disks. While roughly axisymmetric, these winds have a rather unique density distribution, in that it drops like ≃1/r in the radial direction, while it has a sufficiently steep θ−dependence to provide the obscuration needed to account for the Seyfert 1 – Seyfert 2 unification on the basis of the observer's LoS direction (see fig. 1a). The specific radial density dependence is very important, as it implies roughly equal column per decade of radius, a fact that makes possible the detection of ionic species as diverse as Fe_{I} and Fe_{XXV} in the same object. Much steeper density profiles would make the low ionization ionic species all but impossible to detect, while much flatter than the above would lead to much higher columns for the low ξ ions than observed.

In two publications [7,8], Fukumura et al. computed the ionization of winds with density profile $n(r) \propto 1/r^s$ to examine their consistency with observation. This has been achieved by study of radiation transfer along the radial direction that represent the observer's LoS: The radial direction through the wind over, say, 6 decades in radius, is divided into 40 to 50 segments logarithmically in radius (Fig. 2b). The opacities at each such segment are computed invoking the photoionization code XSTAR and the continuum radiation is transferred through this segment. Its output is used as input in the next segment and the process is repeated to the edge of the wind.

With the density profile given, one can now compute the ionization structure of the wind. Details and examples of this procedure are given in [7,8]. Here we present only the scaling relations. The wind ionization is determined by the local ratio of photons to electrons, the ionization parameter $\xi = L/n(r)r^2$, (L is the source's ionizing luminosity, $n(r)$ the local density and r the distance from the ionizing source). This can also be expressed in dimensionless units: If η (≃10%) is the radiative efficiency of the accretion process, then the luminosity L can be written as $L \propto \eta \dot{m}_a M$ ($\dot{m}_a$ is the accretion rate that reaches the compact object to produce the luminosity L), or $L \propto \eta \dot{m}_a^2 M$ in the case of ADAF [15] [i.e for $\eta \dot{m}_a \lesssim a^2$ with a the disk viscosity parameter], yielding the for ξ an expression also independent of M, implying similarity in wind ionization, whether in AGN or XRB [7,12]

$$\xi(x) \simeq \frac{L}{n(r)r^2} \simeq \frac{\eta \dot{m}_a}{N_H(x)x} \simeq$$

$$\simeq \begin{cases} 10^8 \dfrac{\eta}{f_W} \dfrac{1}{x^{-s+2}} & \text{for } \dot{m}_a > a^2 \text{ (non-ADAF)} \\ 10^8 \dfrac{\eta}{f_W} \dfrac{\dot{m}_a}{x^{-s+2}} & \text{for } \dot{m}_a < a^2 \text{ (ADAF)} \end{cases} \quad (1)$$

where $f_W = \dot{m}_{w0}/\dot{m}_a$ (~1) is the ratio of mass flux in wind and accretion at the smallest radii,
p the parameter of $\dot{m}$ dependence on r,
and $x = r/R_S$, $R_S = 3 \cdot 10^5 (M/M_\odot)$ cm is the black hole Schwarzschild radius.

Writing Eq. (1) as $N_H(x) \propto \eta \dot{m}_a / \xi(x) x$ one can form the expression for AMD (HBK07), namely

$$\text{AMD} = \frac{dN_H(x)}{d\log \xi(x)} \simeq \frac{\eta \dot{m}_a}{\xi(x)x} \quad (2)$$

The fact that AMD is largely independent of $\xi(x)$ (HBK07) implies $\xi(x) \propto 1/x$ or $N_H(x) \propto \log(x)$, $n(x) \propto 1/x$ and $\dot{m} \propto x^{1/2}$, i.e. the wind mass flux increases with radius, as discussed above. Both the ionization parameter and the wind density decrease like 1/r while the column of the ions found at a given ξ remains roughly constant, in broad agreement with [1].

So, for sufficiently large accretion disks ($x \gg 1$), the wind launched at their largest radii will be beyond the dust sublimation distance to conform with the properties of the AGN unification "dusty torii" [13], including the angular distribution of the gas column along the observer's LoS (see fig. 2a). For face-on AGN ($\theta \simeq 0$) the winds are highly ionized and should exhibit little absorption (this is apparently the case with Mkn 509; see [11]), while for $\theta \gtrsim 80$ degrees, the wind would be Compton thick, as it is the case with Seyfert 2 AGN.

As indicated by Eq. (1) above, matter at small x is highly ionized, so the first transitions should occur at distances with $\xi \lesssim 10^4$, i.e. at distances $x \gtrsim 10^4$ or velocities $v \sim 10^{-2}\,c \sim 3{,}000$ km/s. However, the wind ionization depends in addition on the fraction of the ionizing radiation in the objects' spectral energy distribution (SED0; this is determined by the amount of X-ray photons per electron, a quantity measured by a_{OX}, the logarithmic slope of the X-ray to UV fluxes, that apparently varies with the luminosity of sources [22]. As a result, smaller (i.e. more negative) a_{OX}, implies transition to non-fully ionized plasma at much smaller radii and therefore higher velocities for the Fe_{xxvi}, Fe_{xxv} and generally all transitions.

The extreme objects in this category are the BAL QSOs with $a_{OX} \sim -2.0$. Indeed, in the BAL QSO APM 08279+5255 the Fe_{xxv} and C_{iv} absorption features were detected at velocities $v(Fe_{xxv}) \simeq 0.6c$ [4] and $v(C_{iv}) \simeq 0.1c$ respectively [21]. Fukumura et al. [8] employed the MHD wind models discussed herein to model the absorption properties of this object. The low X-ray contribution to the SED of this object, indicates that even very close to the continuum source, the plasma is not fully ionized, resulting in the observed high velocity of Fe_{xxv}. At the same time, the now opaque plasma, absorbs and reduces the continuum photons that produce the C_{iv} ion, so the latter also occurs at quite high velocity ($v(C_{iv}) \simeq 0.1c$). At the other end of X-ray spectral dominance, the galactic black hole candidate GRO 1655-40 has exhibited transitions similar to those of AGN at similar columns [14] but much lower velocities ($v \simeq 1{,}200$ km/s for Fe_{xxv}, and $v \simeq 200$-400 km/s for lower ionization species). This is consistent with the basic premise of our model, namely that all accreting black holes

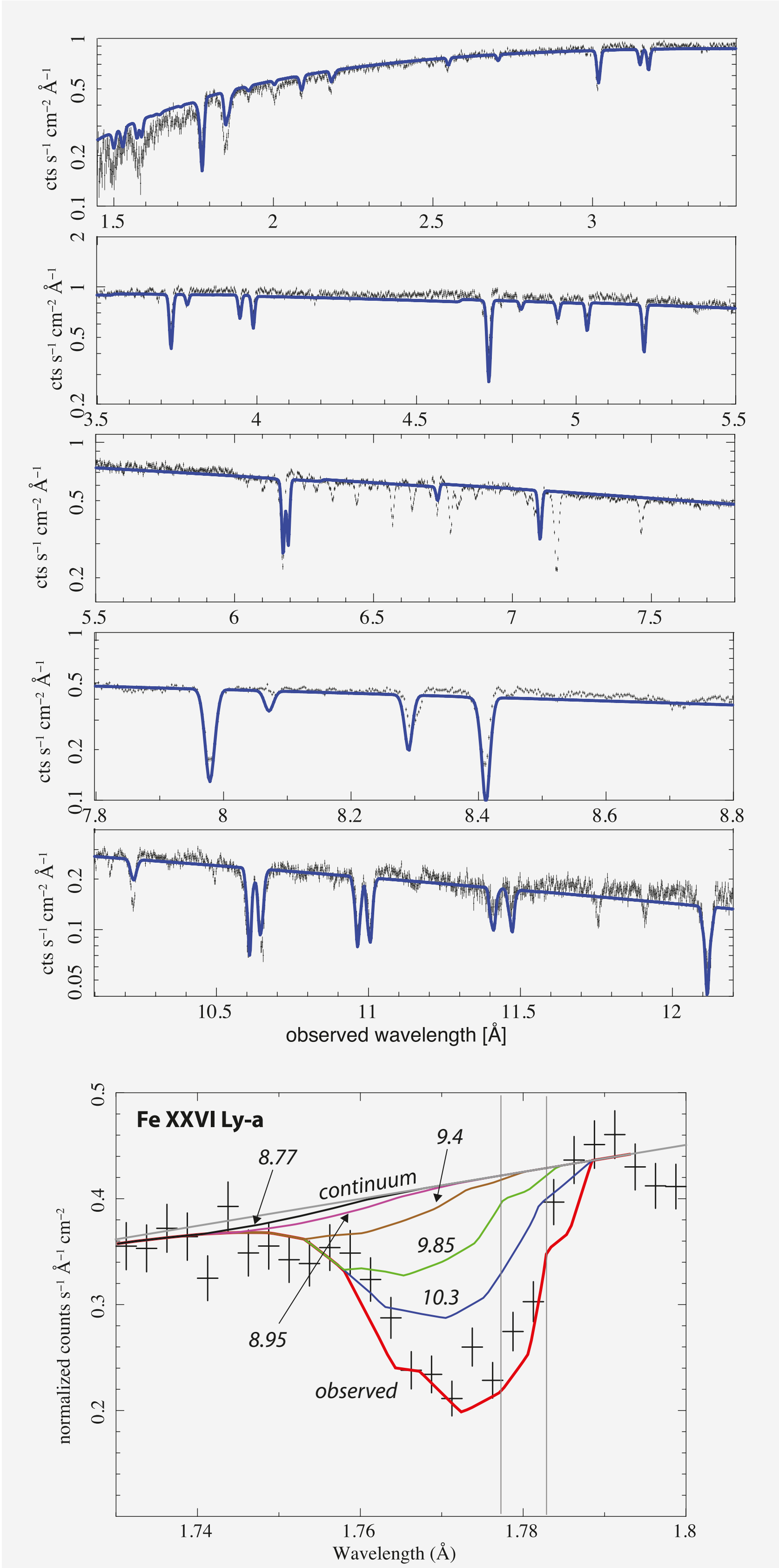

Figure 3: *(a) The **Chandra** data of GROJ1655-40 along with the model of [9] (thick blue line). (b) The development of the profile of the Fe_{xxvi} Lya ion as a function of distance along the observers' LoS. The numbers on each line represent the log of the distance from the black hole and the resulting profile to that point. The crosses are the data and red line is the profile observed at infinity. It is apparent that the model provides besides the correct column also the correct velocity structure of the absorbing medium (Fukumura et al. 2017).*

involve in essence the same accretion disk winds with velocities approaching c for radii close to the horizon and fully ionized plasma. However, their appearance (velocity of ions) depends on the distance from the black hole at which the wind plasma ceases to be fully ionized. This distance is larger the larger the X-ray content of the ionizing spectrum. The importance of the observations of [14] lies in their very high S/N ratio, requiring much more refined models for a good fit of the data. This has been the recent approach of Fukumura et al. [9], who produced models of the spectra of this source with variable density profile to determine the wind density profile. Fig. 3 shows the results of a model with density profile $n(r) \propto 1/r^{1.2}$ overlaid on the source's spectrum. It can be seen that the fit is more than satisfactory, providing besides the correct line depth, also the correct velocity structure of the absorption features, thus testifying to the strengths of this model.

In conclusion, the ubiquitous winds of accreting black holes provide us with several fundamental conclusions: (1) Their presence seems to be independent of the luminosity of the accreting black hole. This implies that processes other than radiation pressure are at work in launching them. (2) The dependence of their absorption features column on the ionization parameter ξ provides a means for probing their density dependence as a function of distance from the black hole. This is inconsistent with the $1/r^2$ dependence of a wind driven by a point-like radiation source and suggests wind launching across the entire disk domain, arguing strongly for their magnetic origin. (3) The specific wind density profiles obtained from the data analysis imply that the wind mass flux increases with radius. This is a feature crucial in uncovering the (most likely magnetic) nature of the accretion disk physics that give rise to such winds. Despite this progress, much observational and theoretical work are needed for a deeper comprehension of this phenomenon and its impact on the physics of AGN and XRB.

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Supernova 1987A

by Jason Spyromilio

European Southern Observatory, Directorate for Science, Project Science Department

On the 24th of February 1987 light from the first supernova discovered that year was seen at Las Campanas observatory in Chile by Ian Shelton and Oscar Duhalte. The supernova had been detected a few hours earlier on plates taken at Siding Spring observatory in New South Wales and was independently discovered by Albert Jones in New Zealand. This year marks the 30th anniversary of this remarkable object. I was privileged enough to see the supernova unaided by a telescope from Australia in one of the many observing runs during the early development and have been observing it with ever improved instrumentation over the past 3 decades. In this short article it is impossible to review all aspects of an object with more than 1000 publications to its name (in the title alone). I shall try to focus on a few recurring themes and the reader is pointed to the three review articles in ARA&A (Arnett et al. 1989, McCray 1993, McCray & Fransson 2017) for a more thorough coverage.

It is important to appreciate that at the time of the discovery astronomy was a very different environment to today both in the context of instrumentation and physics. The Hubble constant was tightly constrained to be both of 50 and 100 km/s/Mpc, space born observatories were limited to IUE and ground based facilities were limited to 4-m class telescopes. An eurocentric viewpoint would note that 1987A predates the approval of the VLT programme by the ESO Council. ESO was far from the powerhouse of ground based astronomy that it is today. Seeing limited observations with 1 arcsecond images were considered excellent and only recently had small (~0.2Mpix) CCD detectors been deployed on telescopes. The first infrared camera with 62x58 pixels had been deployed at UKIRT in 1986 but IR instrumentation on all other telescope whether southern or not was still based on single element detectors or a few pixels (e.g. 8 or 16) stuck close to one another.

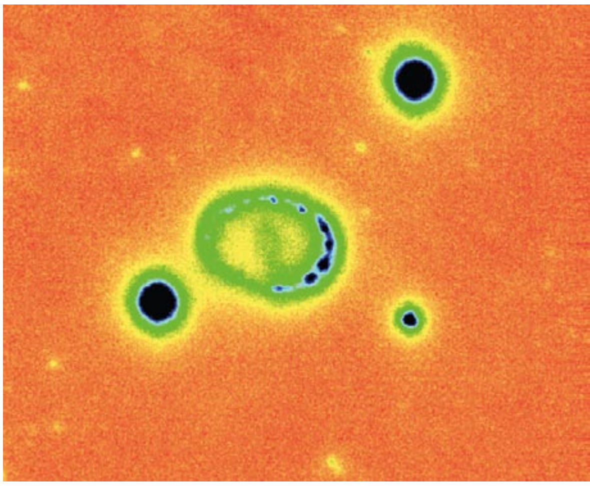

Figure 1: *Adaptive optics assisted observations of the supernova from the VLT (2.2 microns) using NACO. The ring is ~1 arcsecond along the short axis. The supernova ejecta are resolved. The emission is from Hydrogen Brackett gamma and molecular hydrogen. Credit: ESO / J. Spyromilio.*

SN 1987A is fortuitously located in the LMC. Even in 1987 the distance to the LMC was known to an accuracy of order 10%. This meant that the energetics of the supernova were understood. Moreover, the supernova progenitor was identified to be a blue supergiant Sanduleak -69 202 which posed a number of issues for the then established theory that core-collapse supernovae were the evolutionary end of red supergiant stars. The supernova was very kind to the observers and theorists by being located along a relatively unextinguished line of sight and furthermore expanded into a relatively empty environment that the progenitor evolution created for itself. Within a year narrow emission lines in the ultra-violet region revealed the presence of circumstellar material thrown off by the progenitor star before it exploded. Almost all the clues necessary for a deep understanding of the supernova were available to the community and as the supernova aged the development of new facilities has provided the necessary observations.

At 07:35 UT on the 23rd of February two neutrino detectors (Kamiokande in Japan and IMB in the USA) in the northern hemisphere detected a burst of antineutrinos (20 events). This "leptonisation" event is the confirmation of a core-collapse trigger for a supernova. While the Crab pulsar provided a colocation of an SNR and a neutron star, the temporal connection of the explosion to the leptonisation event was made in 1987A. The short time delay between the antineutrinos arriving on earth and the optical detection links the two and a large volume of work has used these detections to derive properties of neutrinos (now part of undergraduate courses on special relativity). For an electromagnetic observer, the neutrinos burst started the clock running. Knowing the time makes it possible to convert velocities observed in the expanding supernova ejecta into absolute distances. Absolute distances are of course the rulers that cannot be overridden. Supernova 1987A is an unforgiving target. Both energetically and in terms of spatial distributions, modeling is an exact discipline. There are few free parameters allowed. When 1987A provides a conundrum the answer will either reveal an error in the experiment or a new piece of physics.

For the astronomers that care little for the supernova itself, it is worth noting that in the distance ladder that ties the type Ia supernovae to the Cepheid variables (see Riess et al. 2016) the

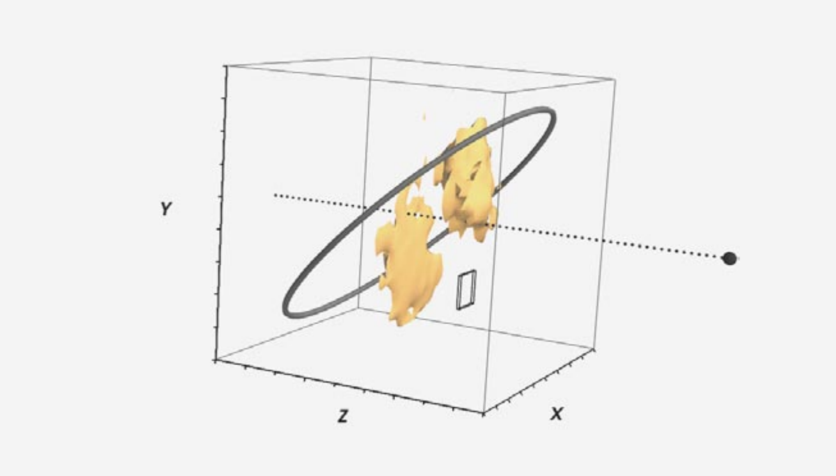

Figure 2: *Distribution of emission from the [SiI], [FeII] 1.64 micron feature in 2015. The emission is powered by theradioactive decay of ^{44}Ti. Adaptive optics assisted observations using SINFONI at the VLT. Credit ESO / Stockholm / J.Larsson.*

most accurate point is the distance to the LMC. This thanks to the HST observation of the circumstellar ring and the IUE observations of the narrow lines, provides a geometric distance to the LMC (a problem now set for high school students).

Over the past 30 years the supernova has provided us with a bedrock of quantitative information on the explosions of massive stars. The collapse of the core to a neutron star is halted at nuclear densities and a bounce results in a shock wave attempting to eject the envelope of the progenitor star. In numerical simulations this is unsuccessful and the shock is revitalized by coupling to the ample energy available in neutrinos radiated by the hot neutron star. As the shock propagates through the progenitor envelope the densities and temperatures are high enough that the material finds itself in nuclear statistical equilibrium with roughly equal numbers of protons and neutrons available. The doubly magic ^{56}Ni nucleus is the favoured product in this configuration although ^{57}Ni, ^{44}Ti and other species are also made. ^{56}Ni decays to ^{56}Co with a half life of 6 days which in turn decays to stable ^{56}Fe (77 days). The early energy from the radioactive decay is trapped in the still dense ejecta and without this input the supernova would rapidly fade. The distribution of the ^{56}Ni in the ejecta and the structure of the progenitor star dictate the shape of the lightcurve. In the first 100 days or so, the ejecta remain dense enough to have a diluted black body surface of last scattering (a photosphere of sorts) that gradually moves inwards in mass co-ordinates but for the first weeks physically grows in size making the supernova appear brighter. After that the ejecta thin out and the supernova becomes an emission nebula powered by the gamma rays and positrons of the radioactive decay that don't escape. Two years after the explosion the daughter products of ^{57}Ni provide much of the energy and 10 years after the explosion the radioactive decay of ^{44}Ti is powering the supernova. These longer lived isotopes will keep the ejecta warm for some time to come. This scenario has been confirmed by direct observations of gamma rays from ^{56}Co (Leising & Share 1991), ^{57}Co (Kurfess et al. 1992) and indirectly from the spectral lines in the near-infrared (Varani et al. 1990). The detection of ^{56}Co was a spectacular confirmation of the power source and our understanding of explosive nucleosynthesis (predicted by Colgate & McKee 1969). However, the gamma-rays escaped the ejecta much earlier than would be expected given the mass of the ejecta and the depth at which the ^{56}Ni was expected to be created. Additionally, the shape of the early light curve required that significant mixing of the ejecta had taken place. Spectroscopic evidence further strengthened this picture of a mixed ejecta. Rayleigh-Taylor instabilities during the early supernova evolution moved material from the core to the outer ejecta from where the gamma-rays had a smaller optical depth and could escape.

One of the most surprising early observations was the detection of molecular emission at an epoch of only 100 days after explosion. First overtone and the fundamental band of CO (Spyromilio et al. 1988, Meikle et al. 1989) and first overtone of SiO (Roche et al. 1991) were detected in the near and mid-infrared. Strikingly the expansion velocity of the emission was 2000 km/s locating the molecules deep in the core of the supernova which had iron moving at speeds of 3000 km/s and the hydrogen as fast as 1/10th of the speed of light. Moreover, and possibly less surprisingly, thanks to the immense cooling capacity of diatomic molecules (in comparison to atomic species) the CO and SiO were emitting at temperatures of order 2000 K. The chemistry required that the regions were the molecules were being made were shielded from the harsh UV radiation within the ejecta. Not only was the supernova mixed but it was also clumpy. Further evidence for a non-uniform distribution of the ejecta came from the forbidden lines of neutral oxygen at 6300 & 6363 Angstroms. Their line profiles (Stathakis et al. 1991) and the evolution of the line ratio of those lines (Spyromilio & Pinto 1991) show strong evidence for density enhancements in the ejecta.

Critically for our understanding of the powering mechanism and the distribution within the ejecta of these elements sophisticated radiative transfer calculations confirm that the observed spectrum cannot be reproduced without the presence of ^{44}Ti (Jerkstrand et al. 2011) later confirmed by direct detection of the emission from the radioactive decay of ^{44}Ti (Boggs et al. 2015). For the first few years of the supernova's evolution the timescales for the physical processes that create the nebular spectrum are rapid compared the evolution of the powering source and the dynamical timescales for the ejecta. However, 10 years after explosion the ejecta are thin enough that the recombination timescales are long and the cooling is dominated by the ground state transitions of the singly and doubly ionized species. Not only are we out of thermodynamic equilibrium, we are also out of ionization balance. The full time dependent non-LTE problem needs to be solved to simulate and understand the observations.

The supernova at first expanded into a rarefied medium as evidenced by the lack of significant radio emission which normally arises as the shock wave sweeps up the progenitor wind. Ultraviolet narrow emission lines were observed by IUE about 100 days after explosion and rose in brightness for approximately 1 year before fading away. In 1990 HST imaged the supernova producing the first of a series of spectacular images of the triple ring nebula surrounding it. The combination of the IUE light curves and the HST imaging yielded a geometric distance to the supernova (Panagia et al. 1991) which as mentioned above provides the firmest anchor of the extragalactic distance ladder.

The structure of the rings combined with revised opacities has almost extinguished any possibility that the progenitor of 1987A was a single star that travelled from the red supergiant branch to the blue just before exploding. The favoured scenario is of a binary merger (Morris & Podsiadlowski 2007).

Some of the most spectacular images were the deep observations during the first few years showing enormous (many arcminute sized) rings centered on the supernova. These are echoes, light from the supernova traveling in other directions that has been scattered by dust sheets along the line of sight into the line of sight. Some early work placed constraints on the structure of the ISM in front of the supernova but the most exciting results had to wait for the angles to be interesting and have come more recently (Sinnott et al. 2011) with spectroscopic observations of the echoes. We have direct visibility into the supernova from angles other than just the viewing angle of "Earth-LMC". An early remarkable observation by the 61-cm Bochum telescope on La Silla (Hanuschik & Dachs 1987) had shown a "glitch" on the Halpha profile. The Bochum event had perplexed theorists for some time. Was this a sign of asymmetric energy deposition (in which case we were at a preferred angle – always a doubtful proposition) or some part of the radiative transfer we did not understand. The 3D view that the echoes provide us confirms that the Bochum event has a preferred orientation in space and is most likely due to a finger of ^{56}Ni that protruded further in one direction.

The most photogenic part of the supernova is the circumstellar ring. SN1987A has been kind enough to provide us with a piece of the progenitor that we can analyse for composition and as discussed earlier a geometry that

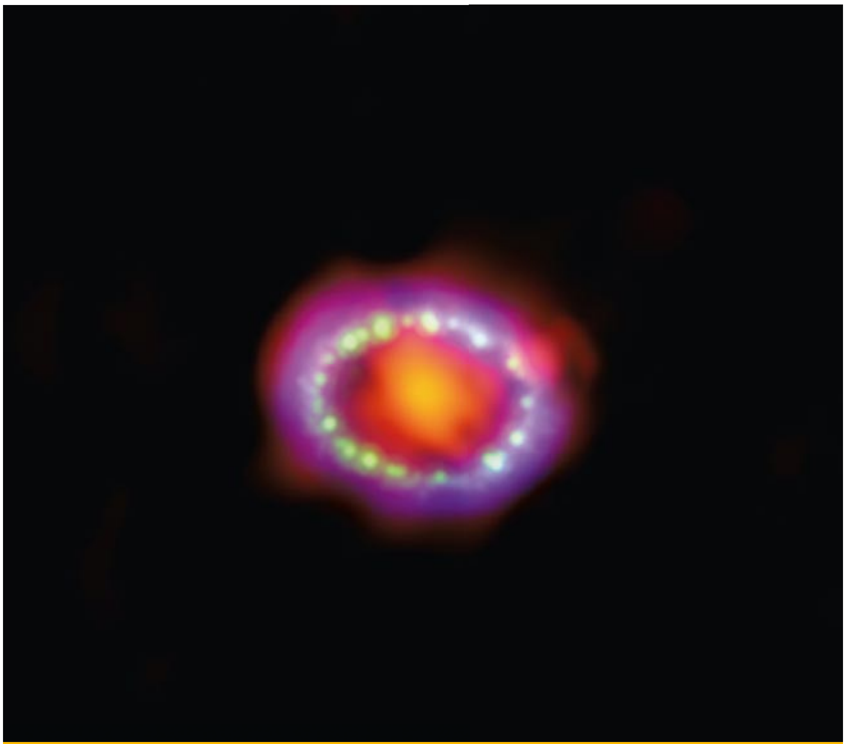

Figure 3: *Combined ALMA, Chandra and HST image of the suepernova. The red ALMA flux concentrated in the middle of the X-Ray and optically bright ring shows that the observed thermal emission associated with the massive cold reservoir of dust is located in the ejecta.*
Credit: ALMA: ESO/NAOJ/NRAO/A. Angelich
Hubble: NASA, ESA, R. Kirshner (Harvard-Smithsonian Center for Astrophysics and Gordon and Betty Moore Foundation) and P. Challis (Harvard-Smithsonian Center for Astrophysics)
Chandra: NASA/CXC/Penn State/K. Frank et al.

constrains the evolution of the progenitor. But this ring is also the location of the earliest fireworks coming from the transformation of the supernova into a supernova remnant. As the ejecta expand at a 10th of the speed of light they plow through the almost empty space between the progenitor and circumstellar ring and after approximately 10 years reach the ring. Under the influence of the strong shock the ring begins to emit in all bands from X-rays (Burrows et al. 2000) to optical (Sugerman et al. 2002) to radio (Manchester et al. 2002).

While the shock propagates through the knots the ring continues to glow brightly. Meanwhile, the ejecta are expected to fade following their radioactive power sources. Three interesting physical effects affect them. First: the ejecta cool predominantly through forbidden lines arising from low lying energy levels in first or second ionization levels (e.g. [FeII], [SiI]). When the electron gas temperature reaches a few 100 K the only transitions that can be excited are those within the ground states. Their cooling is constant as long as the temperature is above 100 K while the heating continues to decline exponentially. The supernova undergoes an "infrared catastrophe" whereby the bulk of the emission is in the mid-IR (Axelrod 1980) when the ground state has emission lines. Second: the supernova undergoes an "ionization freezeout" whence the recombination timescales become significant compared to the dynamical and heating timescales. The supernova starts storing energy in its ionization (Fransson & Kozma 1993). The time dependent nature of the radiative transfer in the ejecta complicates modelling and the interpretation of the spectrum. Third: the reverse shock from the interaction of the ejecta with the ring emits X-rays that illuminate the ejecta from the outside and depending on the energy of the X-rays penetrates to different depths within the ejecta (Fransson et al. 2013)

The supernova that we observe now is a complex beast, still in part powered by the material made during the explosion. Part of the illumination is that of a classical supernova remnant, the coupling of the enormous kinetic energy of the ejecta with the medium surrounding the progenitor. The spectrum of the supernova shows narrow (tens of km/s) lines arising from the unshocked ring, slightly broader (hundreds of km/s) lines arising from the shocked regions of the ring, ejecta lines at a couple of thousand km/s arising from material still heated from the radioactive decay of nuclei synthesized in the explosion and finally ten thousand km/s wide profiles of material at the reverse shock. A single element may exhibit all of these.

Given the close distance of the supernova we have been able since some time to spatially resolve the ejecta as they expand. This has given us a fascinating view into the structure of the explosion. Using integral field spectroscopy at the VLT Kjaer et al. (2010) showed that the inner ejecta are not aligned with what we would presume from the ring structures the rotational axis of the progenitor to be but lie much closer to the plane of the ring. Larsson et al. (2016) using HST and VLT have undertaken a detailed investigation of the ejecta structure to disentangle the location and powering sources for different lines.

Some of the most exciting recent results on SN 1987A have come from the Herschel space telescope and ALMA. Matsuura et al. (2011) reported the detection of the supernova with Herschel and concurrently, using the APEX telescope on Chanjantor, Lakicevic et al. (2012) observed emission at 350 and 870 μm. These results showed a large cold reservoir of dust (~0.5 solar mass at ~20 Kelvin). While dust had already been detected in the ejecta in the second year after explosion, the amount and temperature of the dust detected by Herschel and APEX is fascinating. If it survives the evolution into a supernova remnant then supernovae could be the providers of dust for the early universe. However, given the angular resolution of Herschel it was not possible to locate the dust in the ejecta rather than material swept up by the supernova. Better angular resolution ALMA observations (Indebetouw et al. 2014) clearly separated the emission from the dust from the ring synchrotron emission. The dust is within the ejecta. ALMA also recovered the molecular emission from CO and SiO within the ejecta of the supernova (Kamenetzky et al. 2013). The velocity distribution is 2000 km/s (in the homologously expanding ejecta velocity and location are exchangeable) same as that detected in the first year observations. In the near infrared we have been able to observe molecular hydrogen emission which ties down the chemistry and excitation for the molecular gas (Fransson et al. 2016). With the high angular resolution that ALMA provides in the extended configuration we are now able to resolve the ejecta of the supernova (Abellan et al. in preparation) in the cold gas to complement the observations with the VLT in the near-infrared and HST in the optical. The three dimensional structure of the explosion is being revealed.

At the same time the shock is overrunning the ring and its destruction is beginning to become visible (Fransson et al. 2015). However, no concrete detection of the remnant of the collapse has yet been made. Some hints are present (Zanardo et al. 2014) but no detection yet. The great supernova of 1987 remains one of the most exciting objects to observe and learn from.

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The Far-Infrared Spectroscopic Explorer:[1] tracing the lifecycle of the Interstellar Medium near and far

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Abstract:

The complex processes that initiate cloud collapse enabling the onset of star formation and subsequent stellar evolution leave their imprint on the Interstellar Medium (ISM) of our Galaxy and that of external galaxies. By studying the phase structure of the ISM we can begin to unravel the processes that control the heating and cooling of the clouds that eventually regulate star formation. Far infrared and submillimetre spectroscopy is essential in probing these processes since this regime contains important cooling lines of the different phases of the ISM. The Far InfraRed Spectroscopic EXplorer (FIRSPEX) is a novel concept for an astrophysics satellite mission that will revolutionize our understanding of the life cycle of the ISM starting from our own Galaxy out to distant galaxies. To achieve this goal we propose to obtain fully sampled velocity-resolved observations of carefully chosen key far infrared lines each probing a different component of the ISM. The spectral range selected contains important molecular, atomic and ionic species that cannot be observed from the ground. The FIRSPEX payload consists of a number of heterodyne detection bands targeting key molecular and atomic transitions in the terahertz (THz) and Supra-Terahertz (>1 THz) frequency range. The mission uses a heterodyne payload and a ~1.2m primary antenna to scan the entire sky in a number of discreet spectroscopic channels from the 2nd Lagrange Point (L2) some 1.5 million km from the Earth in the opposite direction to the Sun.

Introduction

Star formation and the ultimate destruction of molecular clouds are fundamental processes at the heart of the evolution of galaxies. The interstellar medium (ISM) of galaxies is the reservoir out of which star forming cores condense and, at the same time, it acts as the repository of gas ejected by stars at the end of their evolution (Figure 1). The cycling of baryonic matter between different reservoirs drives the evolution of galaxies. Understanding the coupling between the mass in stars and the various components of the interstellar medium (ISM) is essential for a complete model of the formation and evolution of galaxies. Typically, only about 10% of the mass of a galaxy is in its ISM, but through

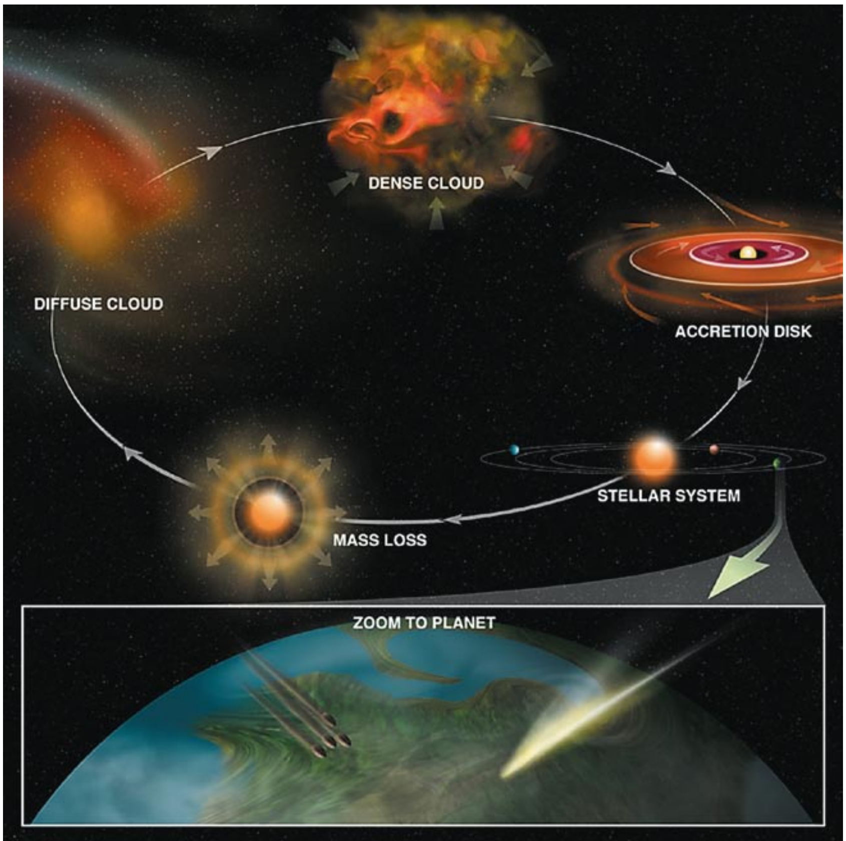

Figure 1: *The cycle of gas and dust in galaxies: from interstellar clouds to stars and planets (Credit: B. Saxton (NRAO/AUI/NSF)).*

1. FIRSPEX is a UK-led international consortium including contributions from academic institutions in France, Germany, Italy, Spain, Greece, Denmark, Ireland, USA, India, China as well as Industrial partners: Airbus-DS (Stevenage, UK), Airbus-DS (Marseille, France) and TICRA (Denmark). FIRSPEX was proposed to the European Space Agency (ESA) in response to the ESA-M5 call for proposals. Details on the mission can be found at http://futuremission.wixsite.com/firspex

the star formation it feeds, it is this material that drives the evolution of a galaxy. The feedback from young stars disrupts their natal clouds, limiting the efficiency of star formation and, together with material injected at the end of the life stars, maintains the warm and more diffuse ISM, producing a complex and dynamic multi-phase environment. Previous space Infrared (IR) missions (such as IRAS, ISO, Spitzer, AKARI, Herschel and Planck) have made great strides in elucidating the properties of the coldest and densest components of the ISM and, the mechanisms that lead to the formation of stars and planets, the building blocks of galaxies.

However, all of these missions have had limited ability to probe the other components of the ISM and especially its velocity structure which is key to unlocking its 3D structure. Far-infrared (FIR) continuum emission is widely used as a mass tracer of the ISM and since this emission is the result of the integrated contribution of the different ISM components along the line-of-sight it is impossible to study the various ISM components separately. Fortunately, the FIR regime is also rich in atomic, ionized, and molecular spectral lines, which can be detected and characterized via high-resolution spectroscopy. Carbon, Oxygen and Nitrogen are the most abundant elements in the Universe after Hydrogen and Helium. They are found everywhere: from the first massive stars that formed and died long ago to the carbon in our body and the oxygen we breathe. The ISM is host to these elements and by studying them we can begin to unravel their origin and the conditions under which they formed. Despite progress in the field key questions remain unanswered:

1) How do molecular clouds form and collapse to form stars and planets?
2) What is the life-cycle of matter across cosmic time?
3) What fraction of the baryonic matter is in CO-dark gas?
4) What regulates star formation in galaxies?

The Far Infrared Spectroscopic Explorer (FIRSPEX) is the first mission to target the properties of the multi-phase ISM through dedicated observations in our own Galaxy, nearby galaxies, all the way to the distant Universe.

The FIRSPEX mission

The interaction between stellar radiation and interstellar matter results in strong emission in the far infrared (FIR) to submillimetre (submm) wavelength range. Herschel's superb photometric capabilities afforded panoramic views of large areas of the Galaxy (e.g. Molinari et al. 2010;2016, Schneider et al. 2012) and deep regions of the extragalactic sky (e.g. Oliver et al. 2012, Lutz et al. 2014). But these deep FIR images of dust emission provide `static' snapshots of the complex processes that transform gas into stars. Without velocity resolved information it is impossible to fully understand the complex physics of the ISM and unravel the processes that turn gas into stars through cosmic time. The FIRSPEX mission has been designed to probe the multi-phase ISM by pursuing large-scale velocity resolved (3D) maps of key bright spectral lines (the dominant FIR gas coolants) in our Galaxy, nearby and distant galaxies.

The four FIRSPEX channels target fine structure (FS) lines that are fundamental probes of the physical conditions of the ISM. Ionized carbon, C+ or [CII] (158μm, 1.9 THz) is the strongest cooling line in the ISM at about 0.3% of the continuum infrared emission (COBE/FIRAS, Fixsen et al. 1999). Ionized nitrogen, N+ or [NII] (205μm, 1.46THz) is only produced in diffuse ionized gas and denser HII regions. The [NII] and [CII] lines have very similar excitation conditions with critical densities around 100 cm^{-3} and upper level temperatures of 70K and 91K, respectively, so that simultaneous observations of both lines allows subtraction of the contribution of the ionized medium to the [CII] emission. Neutral atomic carbon, [CI] (390μm, 809 GHz) occurs mainly in molecular gas where UV photons (with energies more than 11.1 eV) dissociate CO. Atomic oxygen [OI] (63μm, 4.7 THz) is an important line as it traces all phases of neutral gas but with a critical density of $5x10^5 cm^{-3}$ and upper level energy of 230K it strongly favours the warm dense gas in emission. Only a handful of [OI] measurements exist so far, therefore, spectrally resolved observations of the [OI] line with FIRSPEX open a previously unexplored scientific domain.

FIRSPEX Science

The primary scientific goal of FIRSPEX is to elucidate the mechanism by which clouds collapse to form stars. In order to grasp the complex physics involved in this process a clear understanding of the ISM on all scales from our Galaxy all the way to distant galaxies is necessary. FIRSPEX science focuses on three main areas: the physics of the ISM in the Galaxy through a wide area survey of the Galactic Plane, the physics of the ISM in Nearby Galaxies and, probing the ISM in the distant Universe. In what follows I will discuss how FIRSPEX will achieve its main objectives.

Our Galaxy

Overview and Scientific Objectives

The FIRSPEX Galactic Plane Survey (GPS) will map the velocity-resolved (3-D) distribution of the different phases of the interstellar medium (ISM). From this extensive measurement, the evolution, the transitions between each of the phases, and, finally, the impact of massive of star formation on the surrounding medium can all be gleaned. Since the Galaxy comprises multiple interstellar gas components and phases with distinct properties along any line of sight, the only way to distinguish among them is through the inherent line velocity information imprinted on the lines.

Spatially separated components can, usually, be distinguished by their different central velocity; related components are distinguishable by different velocity dispersions or other line broadening processes characteristic of the conditions of the line excitation. Figure 2 compares the [CII] line profile to molecular line profiles observed towards the same direction (Herschel GOTC+ project, Pineda et al. 2010). At least 13 velocity-separated components can be identified in the [CII] line, but only some of them have clear counterparts in the molecular or HI lines. Every component traces a different region with conditions overlapping along the same line of sight. Hence, the analysis of line-integrated line ratios can be highly misleading when trying to understand the nature of the gas. Figure 3 shows a typical example of line profiles that will be observed with FIRSPEX in [CII] and [OI] towards an individual bright source, observed with the GREAT receiver onboard SOFIA towards the massive star-forming region G5.89-0.39 (Leurini et al. 2015).

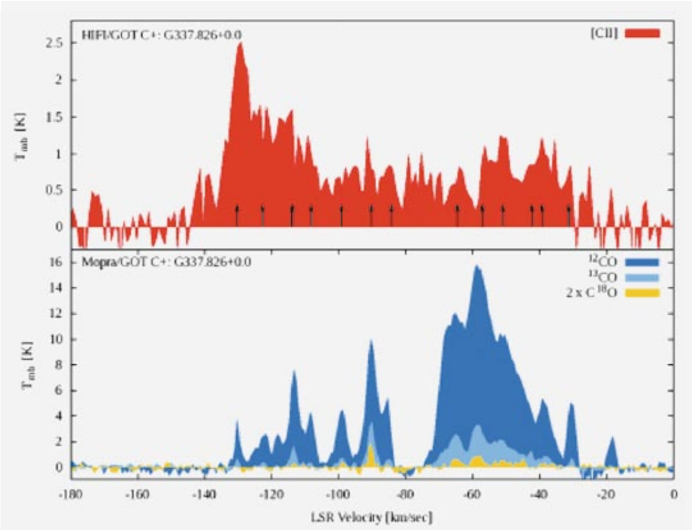

Figure 2: *Profiles of [CII], CO and isotopologues observed with HERSCHEL-HIFI towards G337.826+0.0 (from Pineda et al. 2010)*

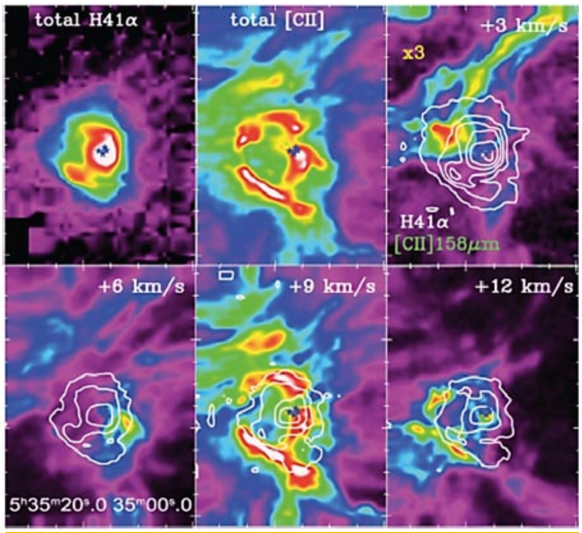

Figure 3: *[CII] and [OI] profiles observed with SOFIA-GREAT towards the massive star forming region G5.89-0.39 (from Leurini et al. 2015)*

The wings in both lines trace the emission from an outflow close to the central source while the centre of the line is blocked by cold foreground material with a narrow velocity distribution containing at least three different velocities. Therefore, the integrated line intensity measured by low resolution spectrometers cannot provide helpful information about the source. While such measurements provide important insight into the properties of individual sources only the full Galactic Plane survey with sufficient spectral and spatial resolution is able to trace the key structures of the ISM.

Mass assembly of molecular clouds

Theoretical studies (Goldbaum et al 2011) have suggested that molecular clouds are formed by large-scale accretion of new material onto existing dense clouds. Their findings are consistent with observations that suggest the global filamentary structure of molecular clouds is created by large scale flows of atomic material from earlier times (Wang et al 2010, Molinari 2010, Peretto 2012). Nonetheless, mass accretion has not been convincingly demonstrated observationally. The material may either be accreted as atomic hydrogen or, low-density molecular hydrogen. Atomic gas can be measured through the 21 cm atomic hydrogen line, but the emission is always highly confused by the warm neutral medium along the line of sight. Without the ability to separate the different ISM components, proper assessment of the atomic hydrogen emission is impossible. Unfortunately, molecular hydrogen is not detectable at low gas temperatures in the ISM since it has no dipole transitions. CO forms at much larger columns when the H_2 column density exceeds a few x $10^{21} cm^{-2}$, implying that the initial phases of the cloud formation process take place in the so-called "CO-dark" molecular gas. The best tracer of this phase is ionized carbon, C+ (Pineda et al. 2010). Goicoechea et al. (2015) directly observed such a filament of infalling gas in the largest so-far existing velocity-resolved [CII] map, obtained towards the Orion Molecular Cloud (OMC1, Figure 4). On smaller scales the infall through spurs has been observed in molecular lines (Schneider et al. 2010). To trace the accretion of material onto filaments and its effect on their structure evolution requires mapping surveys with reasonable angular resolution (< 1') together with large spatial coverage with adequate velocity resolution to detect the predicted velocity shifts of less than or equal to 1 km/s. Only by detailed imaging of a significant sample of those filaments, as planned through the FIRSPEX GPS along with their dense cores and associated young stars, can we determine the spatial scales at which accretion starts occurring and establish whether the accretion rates vary from the outskirts of molecular clouds to the dense cores with active star formation. This will help us to unravel the physics controlling the evolution of these structures and their role in the process of star formation.

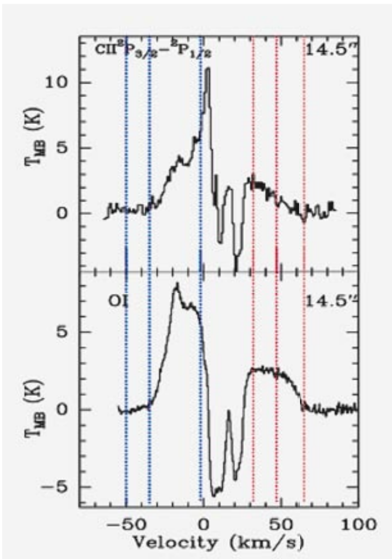

Figure 4: *[CII] map towards Orion measured in different velocity channels in comparison to the distribution of ionised gas. At v=3km/s a stream of infalling CO dark molecular gas is visible (from Goicoechea et al. 2015).*

CO-dark molecular gas

High spectral resolution observations of C+ will enable us to quantify the fraction of CO-dark gas, which is likely to contain a significant fraction of the baryonic matter in the Galaxy (as demonstrated by the Herschel GOTC+ team), but is invisible in most other tracers. Measuring the fraction of this CO-dark molecular gas in our Galaxy is crucial as it is likely to lead to a paradigm shift in our understanding of the molecular gas reservoir of galaxies. The derivation of the large scale distribution of the CO (1-0) and (2-1) lines from the Planck maps (Planck Consortium XIII, 2014) and complementary large scale mappings (e.g. Nishimura et al. 2015) showed a surprisingly low typical (2-1)/(1-0) ratio, typically ~ 0.5, that can only be explained by excitation temperatures well below the kinetic temperature of the gas, indicating gas densities below the critical density of about 1000 cm^{-3}. In such gas, the CO self-shielding is usually not strong enough to prevent dissociation over long time scales, i.e. most gas will be in a transitional phase with [CII] observations required to trace this material. Within the Galactic mid-plane the GOTC+ project provided a first inventory of the contributions of the different gas components to the [CII] emission, measuring the fraction of CO-dark molecular gas (Langer et al. 2010, 2013, 2014, Pineda et al. 2010, 2014). They found fractions between 20% and 75%. Following the fraction across the boundary of the Taurus cloud Xu et al. (2016) found values around 80% for visual extinctions below unity. So far all analyses are biased towards dense region of the Galactic midplane. As the fraction of more diffuse material is certainly higher than at higher Galactic latitudes we can expect that the fraction of CO dark molecular gas is also higher there. As a consequence, it is likely that the majority of the Milky Way interstellar gas is still unobserved. FIRSPEX will provide the full inventory.

Calibrating Far-Infrared lines as star formation tracers

Since C+ is mainly produced and excited by far- ultraviolet (FUV) radiation emanating from massive stars, most efficiently from B stars that are only short-lived, the [CII] line appears as a natural tracer for the star-formation. A strong correlation between the line intensity and the star-formation activity in galaxies has been found for many sources (see e.g. Rigopoulou et al., 2014, de Looze et al. 2014, Herrera-Camus et al. 2015) and also on Galactic scales (Pineda et al. 2014). In contrast, very luminous IR galaxies deviate strongly from this linear relation, showing a fine-structure-line deficit (e.g. Farrah et al. 2013). The explanation for this remains unclear, but it may be a combination of high optical depth, foreground absorption, and having regions that have exceptionally large total column densities. The "[CII] deficit" is seen, in effect in Orion, if one examines the fine structure line emission to

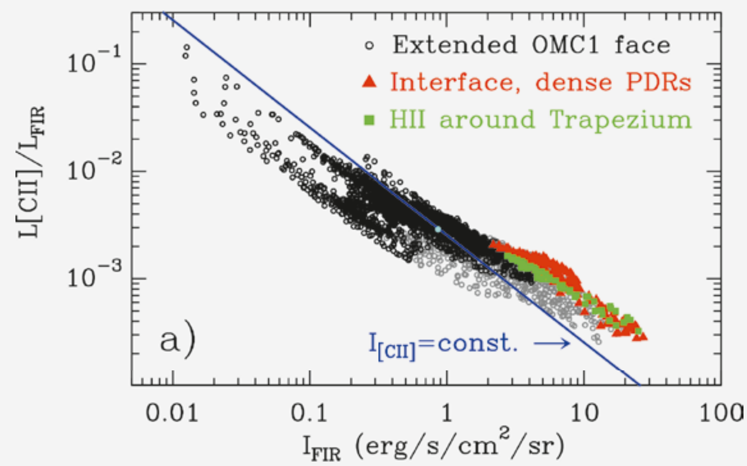

Figure 5: *C+/FIR luminosity ratio variation as a function of position in Orion (Goicoechea et al. 2015). This behavior is reminiscent of the "C+/FIR deficit" seen in local ULIRGs.*

total infrared emission ([CII]/TIR ratio) as a function of dust opacity (Figure 5). For "small" column densities this ratio is very large, but drops monotonically as a function of increasing column density (and opacity). This may reflect the simple fact that the dust throughout the cloud all emits in the IR, but the [CII] emission is confined to the layer with A_V < 2-3 mag. Thus, the emitting regions in ULIRGS may well have a "dust emission excess" rather than a [CII] deficit.

Measuring the actual fine-structure cooling line in the Milky Way through velocity-resolved spectra will provide a crucial step for calibration of the [CII]-intensity to star-formation-rate ratio in large regions of the Galaxy. This information will then be applicable to other galaxies, e.g. those observed with ALMA, and therefore represents a key science calibrator.

In the vicinity of a massive young star the surrounding gas will be ionized and in this region the [NII] fine structure line is a powerful probe of physical conditions. This has been exploited in a Milky Way Survey by Goldsmith et al. (2015), and in a sample of relatively nearby galaxies by Herrera-Camus et al. (2016) and (U)LIRGs by Zhang et al. (2016). The surprising result is that the electron density derived is typically ~30 cm^{-3}, far higher than expected for the warm ionized gas but, its extended nature makes its origin problematic. The FIRSPEX Galactic plane survey will measure the extent, smoothness, and mass of the ionized gas component and assess whether it originates in the proximity of massive stars.

Nearby Galaxies

Overview and Scientific Objectives

Physical conditions in nearby galaxies can be more extreme than in the Milky Way. Even within the Local Group, the massive star cluster R136, powering the 30 Doradus nebula in the Large Magellanic Cloud (LMC), is 10 times more massive than the most massive star cluster in our Galaxy. Beyond the Local Group, extraordinary star clusters in nearby dwarf galaxies (NGC 1569, NGC 1705) are more than 30 times more powerful than R136. To study the vast parameter space spanned by star formation in different environments (nuclei, arms, inter-arms, outer disks) and the detail of different physical and chemical conditions of the ISM (metallicity, mass, density, temperature, velocity, abundances) we need to go beyond the Milky Way and the Local Group of galaxies. The FIRSPEX Nearby Galaxy Survey (hereafter NGS) aims to map the velocity-resolved (3-D) distribution of the different ISM phases with a resolution ranging from 100pc to 1 kpc in ~200 nearby galaxies within 11 Mpc distance. The proposed survey will (i) trace star-formation rate (SFR) and the constituents of the ISM and their dependence on environment and metallicity; (ii) determine the contribution of CO-dark gas to the ISM; and (iii) assess the impact on the ISM of feedback from active galactic nuclei (AGN) and from massive stars and supernovae (SNe).

It is now well established that galaxies show large variations in the physical and chemical properties of their star forming gas, which in turn regulates their evolution. Existing atomic and molecular data, for at least the nearest galaxies, show a chemical diversity and complexity that cannot be explained by a one-component, steady-state chemical model, and indicates how relative abundances between atoms and molecules may be able to provide insights into the physical distribution of the gas and the energetics of these galaxies. Observations of the most abundant gas-phase atoms and molecules in nearby galaxies allow us to study the physical characteristics of galaxy environments and measure the amount of gas in each phase of the ISM.

FIRSPEX offers the unique opportunity to obtain for the first time, in a systematic way, velocity resolved maps of the major cooling lines of the ISM in galaxies. High spectral resolution is needed to disentangle the contributions of the various ISM phases along the same line of sight, i.e. the contributions from the dense, star forming molecular gas, photon dominated cloud interfaces, the diffuse molecular and atomic material, and the ionized gas. These observations will shed unprecedented light on the interplay of the ISM phases and their roles in the cycle of matter inside galaxies as well as their roles in the evolution of galaxies.

Probing Star Formation Rates and physical conditions

The use of [CII] and [NII] to trace the star formation rate in the Milky Way has already been discussed. These same arguments apply to nearby (and distant) galaxies, but without going beyond the Milky Way, we cannot explore the influence of environment and metallicity on Star Formation Rates. To truly explore the relation between star-formation activity and its tracers (including CO and dust), it is fundamental to examine a wide range of physical conditions. Observing C+, C, N+, and O simultaneously in galaxies sufficiently close to resolve regions within these galaxies spatially and kinematically will provide an unprecedented tool to understand some of the current enigmas, including the reasons behind the [CII] deficit in ULIRGs (e.g., Gracia-Carpio et al. 2012, Farrah et al. 2013); the superiority of [OI] at low metallicity to trace SFR (e.g., De Looze et al. 2014); and the viability of tracing SFR through [CI] (e.g., Glover et al. 2016). Although Herschel targeted [OI], [CII], and [NII] for a small number of galaxies, there was insufficient spectral resolution to assess kinematics and the effect of line absorption. With FIRSPEX and the NGS, we can start to assess how gas is converted into stars in galaxies with a detail that has been possible up to now only for the Milky Way and a few galaxies within the Local Group.

CO-Dark Molecular Gas

The [CII] line is in many cases the brightest cooling line of the ISM in galaxies and its intensity is known to be closely linked to their star formation rate. It probes dense and warm photon dominated regions (PDRs), but also the CO-dark molecular gas, warm and cold atomic clouds, and the diffuse ionised medium. Observations of line integrated intensities at high angular resolutions have been made possible with Herschel/PACS and SOFIA/FIFI-LS. However, disentangling the contributions of the various ISM phases to the [CII] emission is difficult in the absence of velocity information. Herschel/HIFI and SOFIA/GREAT observations of [CII] line profiles have started to shed light on its origin. HIFI observations of [CII] along various lines-of-sight in the Milky Way provided for the first time the necessary velocity resolution to address in particular the importance of the CO-dark molecular gas, the likely precursor of dense molecular clouds that will eventually form stars. These observations have shown that the dominant part of the molecular H_2 gas in the outer parts of the Milky Way is not detected in CO, but in [CII] (Pineda et al. (2013). These findings agree with high CO-to-H_2 conversion factors found in nearby, low metallicity dwarf galaxies (Schruba et al. 2012, Leroy et al. 2011). FIRSPEX measurements will, for the first time and in a systematic way quantify the fraction of CO-dark molecular gas as a function of environment and its impact on the total molecular gas reservoir in galaxies.

Assessing feedback from AGN and massive stars

One of the key Herschel results was the identification of AGN and starburst outflows through OH absorption lines (e.g., Sturm et al. 2011, Spoon et al., 2013, Veilleux et al. 2013). The FIRSPEX NGS has the potential to revolutionize the study of the impact of violent events on the surrounding ISM. The kinematics measured by the exquisite spectral resolution of FIRSPEX will probe the disruption of the ISM through massive star and AGN feedback; in fact modeling the kinematic information can establish whether the gas is tracing circular motion in a galaxy disk, or non-planar outflows.

The potential of this strategy has recently been demonstrated by SOFIA/GREAT observations of spectra of [CII] and [NII] 205 μm in the nuclear region of the nearby galaxy IC342 (Roellig et al. 2016). They find that the ionized gas emission shows a kinematic component with the signature of two bi-polar lobes of ionized gas expanding out of the galactic plane. Depending on position, 35-90% of the observed [CII] intensity stems from the ionized gas similar to the center of the Milky Way but considerably more than the lower fractions found in less violent regions in the disk (e.g., Pineda et al. 2014).

Similar studies of the effect of AGN feedback on atomic and fine-structure lines are still in their infancy (e.g., Debuhr et al. 2014, Hamer et al. 2014). However, high-velocity HI outflow signatures are common in powerful AGN (e.g. Morganti et al. 2005, Fabian 2012), and inevitably linked to outflows in other tracers including ionized gas (e.g., Liu et al. 2013) and CO (e.g., Cicone et al. 2014). The FIRSPEX NGS provides a potentially fundamental discovery space for understanding how violence in galaxies impacts the ISM and the consequent changes in the way a galaxy evolves.

Observations and velocity resolved PDR models

In recent years much effort has been invested in modelling [OI], [CI], [CII] observations from ISO and Herschel, (although only the [CI] at 609μm line can be observed from the ground) using PDR models (e.g. Rigopoulou et al 2013, Rosenberg et al. 2014, Pellegrini et al. 2013). Bisbas et al. (2014) modeled the photo-dissociation regions of NGC4038 using a 3D PDR code finding that the molecular and atomic emission lines trace different gas components, suggesting that single emission models

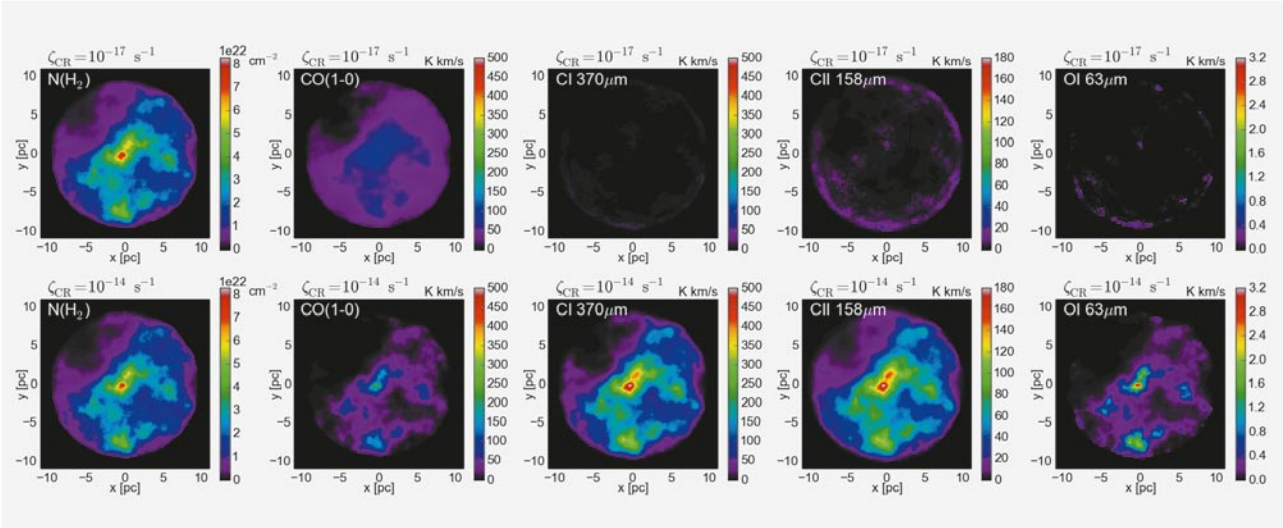

***Figure 6:** 3D-PDR simulations of a fractal cloud embedded in two cosmic ray ionization rates ($\zeta' = 1$ and 1000, where $\zeta' = \zeta_{cr}/10^{-17}$ s^{-1}). The cloud interacts with an isotropic FUV field of $x/x_0 = 1$ (Draine) at all times (FUV does not scale with ζ_{cr}). Leftmost columns shows the density of H_2 (cm^{-2}), which remains remarkably unaffected as ζ' increases (top left $\zeta' = 1$, bottom left $\zeta'=1000$). Values of $\zeta'=1000$ can be found in the Galactic Centre, in starbursts and ULIRGs. The emission of CO (1-0), [CI] (370μm), [CII] (158 μm) and [OI] (63 μm) (in units of K km/s) are shown in the subsequent panels (from left to right). It can be seen that in environments where cosmic rays are expected to be much higher (e.g. >500) from the mean Galactic value, H_2-rich clouds/whole disks are much better observed in lines captured by FIRSPEX and which could be used to trace molecular regions that are hard-to-impossible using the standard CO-to-H_2 technique (Bisbas et al. 2015).*

are insufficient to reproduce the observed values. The analysis of the Bisbas et al. (2014) models shows that PDRs are not uniformly distributed and that without knowing the amount of gas enclosed in PDRs it is not possible to provide quantitative estimates. The lack of a 3D cloud structure together with the different spatial resolution of the observations of the various emission lines makes it impossible to determine how much material is located in the different phases of the ISM. In fact, to date, there are no homogeneous maps of the three tracers at the same spatial and spectral resolution. A high spectral resolution map of nearby galaxies in C, C+, and O would yield the determination of their 3D structure which, when compared to photo-ionisation and PDR models (such as TORUS-3D PDR, Bisbas et al. 2015) coupled with hydrodynamic simulations of turbulent, star-forming clouds (e.g. Offner et al. 2013), would lead to the determination of the physical characteristics (density and temperature) and energetics (UV, cosmic and X ray fluxes) of the galaxy. shows an example of the models at hand and the type of 3D synthetic maps (computed with the ORION hydrodynamical code and post-processed with the 3DPDR from Bisbas et al.) that we can use to interpret the observations.

Distant Universe

Overview and Scientific Objectives

Understanding how the ISM in galaxies evolves with redshift and luminosity is crucial for determining how galaxies –and star formation within galaxies– evolve, from their birth to the galaxies we observe today in the local Universe. Far-IR lines, such as [O I], [O III], [N II] and [C II] are the best tracers of the ISM conditions, also controlling star formation by providing the cooling needed by the clouds to collapse and initiate star formation. The different lines originate in different regions and probe the different physical conditions of the ionized or neutral ISM (i.e., density, ionization potential of the power source, temperature).

With the availability of ALMA a surge in detections of the [CII] line from high-z galaxies (z>3) has taken place. However, such detections come only from sparse observations of specific targets, each with different characteristics (i.e., redshift, luminosity), and observed at different wavelength, sensitivity, spectral and spatial resolution. Therefore, a systematic study of the evolution of the ISM in galaxies has, so far, not been possible. FIRSPEX will provide line observations of unbiased samples of galaxies at different redshifts, between 0<z<3 bridging the local Universe to the high redshift Universe covered by ground facilities (observing in the mm/sub-mm range, where far-IR lines are redshifted at z>3).

FIRSPEX Deep Surveys

FIRSPEX will be able to observe statistically significant samples of sources in different far-IR lines at different redshifts, providing the first line luminosity functions of galaxies at 0<z<4. In particular, considering a survey using two of the four FIRSPEX bands, centered at [N II] 205μm and [CI] 370μm, it will be possible to carry out "blind" surveys of the [C II] line emitters at z~0.3 and z~1.35, of [N II]122 at z~0.7 and z~2, of [OIII]88 at z~1.35 and z~3.2. Such surveys will allow for the first time to perform a statistical study of how lines and the ISM conditions change across different epochs. In particular, given the two channels providing surveys of [O III] and [C II] at z~1.3, it will also be possible to study how the ratio between the two line intensities and their properties (therefore the ISM conditions) vary with redshift, from the peak of the star-formation rate density in the Universe (SFRD, peaking at z~1-3) to the local Universe. This will allow us to understand what stopped star-formation, causing the dramatic decrease observed in the galaxy

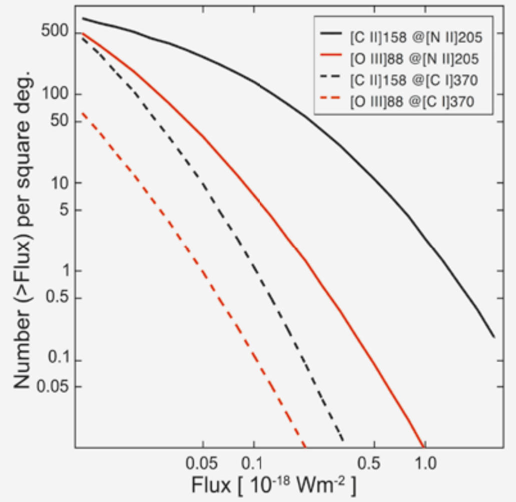

***Figure 7:** Number counts expected from FIRSPEX 'blind surveys' in [NII]205 and [CI]370 channels.*

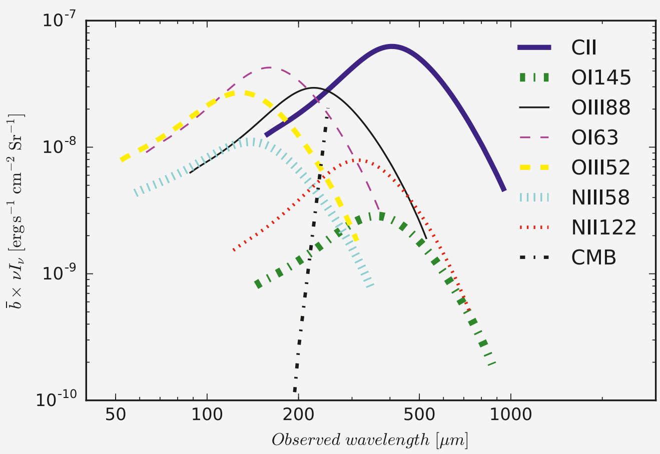

***Figure 8:** Intensity of the far-IR fine-structure lines as a function of the observed wavelength. FIRSPEX allows observations at 370 and 205 microns and will probe primarily [CII] 158 μm at z = 0.3 & 1.3 and [OIII] 88μm at z = 1.3 and [OI] 63 μm at z = 2.2.*

SFRD from the SFR peak to nowadays (e.g., Madau & Dickinson 2014).
Based on the Herschel luminosity function of Gruppioni et al. (2013), providing the number of galaxies per volume density and total IR luminosity at different redshifts (to z~4) and the local line-to-total IR luminosity ratios of Spinoglio et al. (2012), under the assumption that the latter do not change with z, we have estimated the number counts of sources expected to be detected in the different far-IR lines within the FIRSPEX filters (Figure 7). Given the nominal sensitivities of FIRSPEX, we estimate we will be able to detect hundreds of sources per square degree in [C II] at z~0.3 and few tens in [O III] at z~1.3 (considering bandwidth of 32 GHz). The number counts are shown in Figure 7. By observing an area of the sky of a few 100 deg^2 (~400 deg^2), we will construct a significantly sizable sample of sources of different luminosities (for [C II] at z~0.3 beyond the knee of the luminosity function, while for [OIII]88 at z~1.3 only around/above the knee), allowing us to study in detail the properties of the ISM, of the cooling lines and their evolution in different kind of galaxies.

Intensity Mapping

The FIRSPEX deep extragalactic survey over ~400 sq. degrees at high Galactic latitudes is an ideal data set for full 3-dimensional tomographic intensity mapping of large-scale structure. The primary science goal of the deep survey is detection and physical characterization of z=0.3, 1.3 [CII], z=1.3 [OIII], and z=2.2 [OI] line emitting galaxies, among rare sources that may also be detectable in several other lines. The redshift intervals (that correspond to the frequency coverage of each of the FIRSPEX bands) are such that these are the line tracers and their corresponding redshift intervals that will be present in the two lower frequency bands centered at [NII] 205 μm and [CI] 370 μm (rest frame).

Beyond individually detected galaxies, above the usual threshold of ~4 for the line flux, the same deep field data can be used to map out the integrated line emission from the galaxies though fluctuations in the integrated emission of spectral lines. Previously, such fluctuation studies leading to statistical measurement of the ensemble star-forming galaxy properties as well as the cosmic star-formation rate density and cosmic dust abundance were limited to broad-band continuum imaging data. At far-IR/sub-mm wavelengths such studies have been successful with wide surveys of Herschel/SPIRE (Amblard et al. 2011; Viero et al. 2013; Thacker et al. 2015).

However, mapping the statistics of line intensities in a narrow waveband but with significant spectral resolution increases the power of the data by providing information in the third dimension, permitting an understanding of spectral line emission as a function of redshift. The width in the radial direction is based on the spectral resolution of FIRSPEX 32 GHz bandwidth in each of the [CI] and [NII] bands; this corresponds to redshift intervals Δz~0.1 at z=1.3 increasing to Δz~0.3 at z=0.3 (Figure 8). The proposed study is similar in spirit to intensity mapping now pursued by the cosmological community using a variety of emission lines as tracer of the large-scale structure. The 21-cm spin-flip line of neutral hydrogen is the most common example, with a variety of low-frequency interferometers pursuing the signal as a probe of reionization. Low-redshift studies have mostly concentrated on rest-frame optical and UV lines, including H_α and Ly_α. FIRSPEX provides avenues for intensity mapping in the far-infrared using atomic fine structure lines (Gong et al. 2012; Uzgil et al. 2014).

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Boxy bulges and the 3D morphology of galactic bars

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Abstract:

Nearly half of the bulges of edge-on disk galaxies in the local universe have a characteristic boxy- or peanut-shaped structure. A typical example of a galaxy belonging to this class is the MilkyWay, which apart from the characteristic boxy central morphology has also similar bulge kinematics and similar stellar populations of the central component with the other galaxies of this type. Studies of the last ten years established the picture of the boxy bulges being the central thick part of the bars in barred-spiral galaxies. We review the numerical and observational arguments that demonstrate this relation and we present the 3D morphology of these objects by means of deep observations of NGC 352 obtained with the 2.3m Aristarchos telescope of Helmos Observatory.

1. Models and Observations

Galactic disks observed inclined at an angle close to 90° with respect to the plane of the sky (edge-on), have in many cases a boxy central morphology. This boxy component can be peanut-shaped or even harboring an "X" feature. Because of its location in the central region of the disk it is called "bulge", despite the fact that it is not elliptical, as are the classical bulges. In this case we speak about a boxy/peanut bulge (B/P). Lütticke et al. (2000) analyzed a sample of 1350 disk galaxies viewed nearly edge-on and concluded that about 45% of their bulges were B/P shaped.

Since we cannot observe directly one galaxy from different viewpoints and get a complete view of its morphology, we can only understand the origin of B/Ps through theoretical models. *N*-body simulations, where a bar is formed have shown that the B/Ps are actually part of bars seen edge-on (Combes & Sanders 1981; Combes et al. 1990; Pfenniger & Friedli 1991, Raha et al. 1991; Athanassoula & Misiriotis 2002, Athanassoula 2003, Athanassoula 2005, O'Neil & Dubinski 2003; Debattista et al. 2004; Martinez-Valpuesta & Shlosman 2004; Debattista et al. 2006; Martinez-Valpuesta, Shlosman & Heller 2006, Saha et al., 2013, Portail et al. 2015).

An example of an *N*-body B/P is given in Fig. 1. The peanut appears in the stellar component as soon as a bar is formed in simulations of stellar disks (Fig. 1a) or in simulations including both stars and gas (Fig. 1b and c). In Fig. 1a a disk of 10^6 stars and dark matter particles evolves self-consistently and builds a bar that appears peanut-shaped when viewed side-on (the major axis of the bar is almost along the x-axis of the system). A similar simulation that includes also gas which forms stars, is presented in Fig. 1b and c. The stars coloured green have been born after the beginning of the simulation from the available gas that initially constitutes 10% of the stellar mass. Clearly

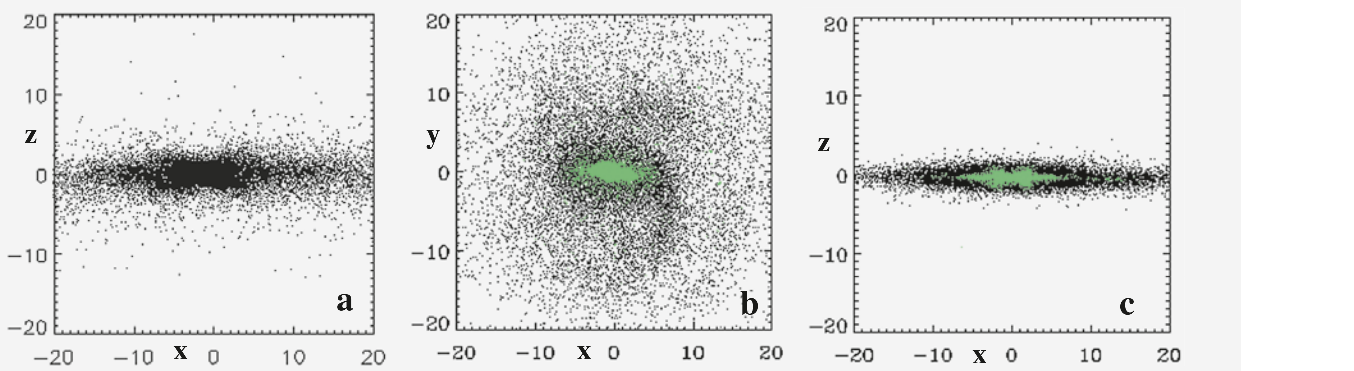

Figure 1: *B/Ps structures formed in an N-body model with the GADGET code. (a) The side on view of the bar of a pure stellar disk. (b) and (c) A bar formed in a disk with stars and gas (in (b) we give the face-on and in (c) the side-on view of this model). The light green particles indicate stars born from the available gas. The major axis of the bar is almost along the x-axis. Both in (a) and in (c) we observe a conspicuous peanut structure. The units on the axes are in kpc.*

these rather young stars form a bar, the inner part of which is peanut-shaped when viewed from the side (cf. panels b and c in Fig. 1). The simulations run in the RZG Computing Center in Garching, Germany, with the GADGET-2 code (Patsis & Naab in preparation).

While the connection between bars and B/Ps has been established through the numerical *N*-body simulations, the dynamical mechanisms that act for shaping the peanuts have been described by the orbital theory (Binney 1981; Pfenniger 1984; Skokos et al. 2002; Patsis et al. 2002). They are related with the presence of vertical resonances experienced by stars moving in rotating barred potentials and more precisely with the vertical 2:1 resonance. This phenomenon can be described briefly as follows: If we consider successive elliptical periodic orbits on the equatorial plane of the galaxy belonging to the main family of periodic orbits which support the bar, the so called x_1 family (Contopoulos & Grosbol 1989), their energies increase as we move from the center of the system outwards. At a certain distance from the center they reach a critical energy at which these planar elliptical periodic orbits become unstable when perturbed vertically. They remain vertically unstable (*U*) in a narrow energy range ΔE and then become again stable (*S*). In other words they experience a double change of their vertical stability ($S \rightarrow U \rightarrow S$). According to the orbital theory, at the transitions from one kind of stability to the other, new families of periodic orbits are born (Contopoulos & Magnenat 1985). The most important of these double transitions happens at the vertical 2:1 resonance, which in most cases is the closest to the center vertical resonance. Since we have a double stability transition, two new families of periodic orbits are introduced in the system, bifurcated from the planar ellipses. The stars following the orbits of the new families perform two vertical oscillations by completing one revolution around the galactic center and can reinforce the B/Ps. The standard mechanism is the trapping of quasi-periodic orbits around stable three dimensional periodic orbits, which bring in the right place the right morphological structure with the right size (Patsis et al 2002). Nevertheless, recently Patsis & Katsanikas (2014a,b) have shown how the peanut-shaped and the "X" structures can be supported also by sticky (Contopoulos & Harsoula 2008) orbits in the vertical 2:1 resonance region as well as by a bretzel-type family (Portail et al. 2015) that exist in the same region. They have also emphasized the role of the quasi-periodic orbits that are trapped on the tori of the planar x_1 family. In Fig. 2 we give an orbital profile built by a combination of quasi-periodic orbits around the stable orbits of the vertical 2:1 family and by sticky chaotic orbits. The model used is a rotating 3D Ferrers bar model (Patsis & Katsanikas 2014a). These orbits support a conspicuous "X"-shape structure in the side-on profile of the model (the major axis of the bar is along the x-axis).

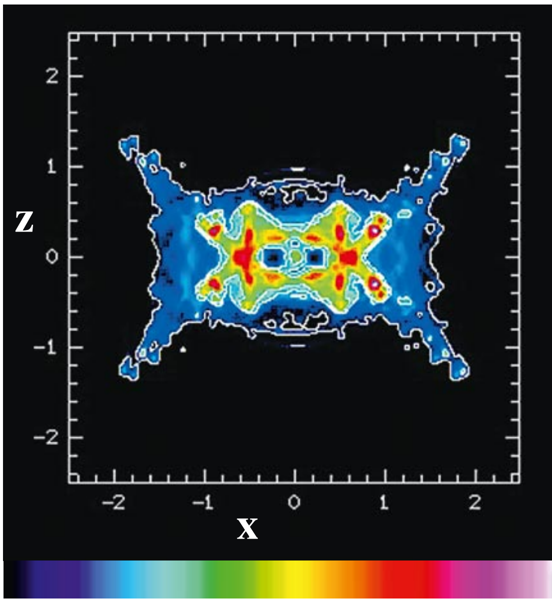

Figure 2: *An orbital "X"-shaped side-on profile, built by superposition of quasi-periodic and sticky orbits associated with the stable family of periodic orbits bifurcated at the vertical 2:1 resonance in a rotating 3D Ferrers bar potential. The colors represent the local numerical density of the profile, which increases from left to right according to the colored band at the bottom of the figure. The units on the axes are in kpc.*

By applying one or the other orbital scenario, one can build in the model the box, the peanut and the "X". The "X" comes in two types, depending on whether or not the wings of the "X" pass through the center of the galaxy (Bureau et al 2006). A crucial result is that in all cases the B/Ps are shorter than the bars. This is in agreement with what is found in *N*-body models as well as in real galaxies (Lütticke, Dettmar & Pohlen 2000; Athanassoula 2005, Athanassoula & Beaton 2006, Patsis & Xilouris 2006). In Patsis & Xilouris (2006) the non-axisymmetric component of the disk, i.e. the bar, of edge-on galaxies has been revealed by subtracting from their I-band images an axisymmetric model developed by Xilouris et al. (1997) to describe the smooth distribution of stars and dust in these objects. The result for NGC 4013 is given in Fig. 3.

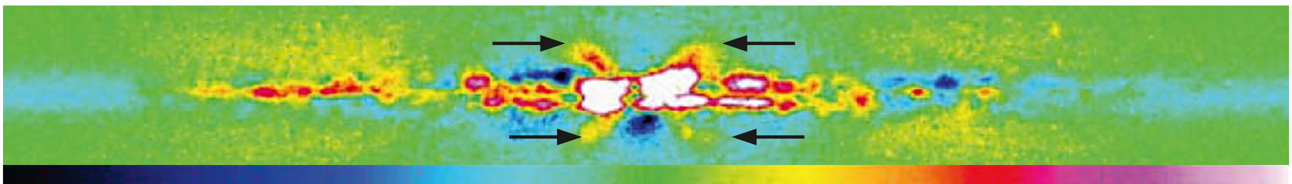

Figure 3: *The non-axisymmetric component of the edge-on disk galaxy NGC 4013 as the result of the subtraction of the Xilouris et al. (1997) model from the image of the galaxy. A conspicuous "X"-shaped feature is revealed in this residual image. The arrows point to its four extremities away of the equatorial plane of the disk. The pseudo-colors (colored band at the bottom of the figure) indicate pixel's intensity, which increases along the band from left to right. (Patsis & Xilouris 2006)*

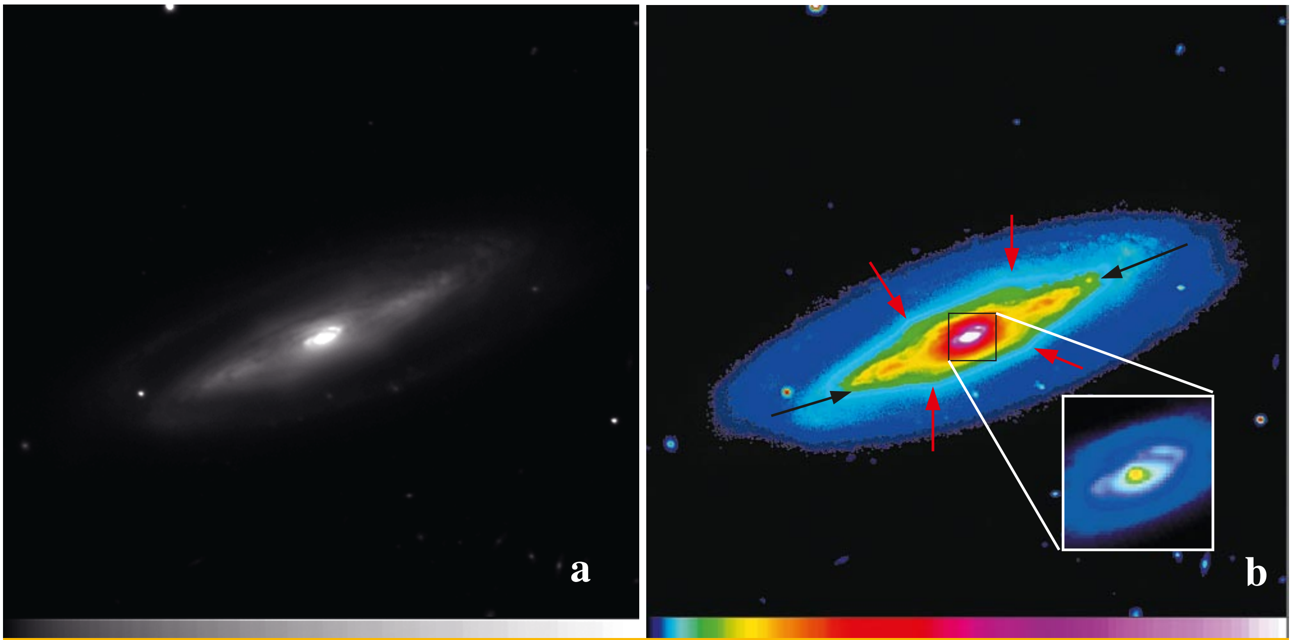

Figure 4: *The barred-spiral galaxy NGC 352, observed with the 2.3m Aristarchos telescope in R filter. (a) A greyscale representation. (b) A pseudo-color image of the galaxy. Black arrows indicate the radial extent of the thin and red arrows the vertical extent of the thick part of the bar. In both cases we use logarithmic scales for the pixels' intensity (increasing from left to right in the bands at the bottom of the images). In the embedded frame it is presented in enlarged scale the nuclear spiral of the bar.*

2. A 3D view

Both *N*-body and orbital models agree that bars have a thick inner and a thin outer part. It is not easy however to reproduce in details the three-dimensional mass distribution of a barred galaxy.

In images of edge-on disk-galaxies, the presence of the bar is inferred by an analysis based on photometric profiles of strips parallel to the projected equatorial plane. The fingerprint of a bar in such a plot is a rather horizontal part of the intensity profile along the major axis (on the equatorial plane), followed by a sharp drop, that designates the end of the bar component. By taking intensity profiles parallel to the major axis at a given height away of the equatorial plane and applying the same technique, we can estimate the length of the peanut at that height in a similar way (see e.g. D' Onofrio et al. 1999). This is an indirect method to estimate the relative extent of the peanut with respect to the length of the bar from images of edge-on disk galaxies.

In snapshots of *N*-body models this is easier, since we can rotate the model and inspect the extent of each part of the bar. A recent work by Athanassoula et al. (2015) has shown that the B/P feature as seen edge-on, corresponds to an oval structure (in many cases being more boxy in the central parts) in the nearly face-on views of the models. This inner part is called a "barlens" (Laurikainen & Salo 2016). All these observational and numerical studies support the idea that the "barlenses" of the face-on bars correspond to the component build by the dynamical phenomena that take place at the vertical 2:1 resonance, i.e. it is the B/P or "X"-shaped bulge itself.

A direct view of all these structural components in a single image of a galaxy, has been observed recently with the 2.3m Aristarchos telescope of the Helmos Observatory, by the authors. The image, taken in R filter, is given in Fig. 4. It is an excellent example of a galactic disk with an ideal inclination to allow a direct inspection of each of the parts that build the system. In Fig. 4a we present the image in greyscale. Black arrows in the pseudo-colour image of the galaxy in Fig. 4b indicate the ends of the bar, out of which emerge the spiral arms. The "X"-shaped peanut structure occupies the central region of the galaxy. Radially it extends about half the distance from the center to the ends of the bar, while it swells out of the equatorial plane. The red arrows indicate the four extremities of the "X" feature away from the galactic plane.

An additional interesting feature discovered due to the long exposure times used, is a nuclear spiral that is located close to the center of the galaxy. It can be better observed in Fig. 4b and is also given in an enlarged frame. The magnified image reveals a grand design barred-spiral morphology. Adopting the 63.8 Mpc distance of the object given in NED, the whole nuclear structure seems to be confined within 1-1.5 kpc. Having a classical bar existing in the disk of the galaxy, the inner spiral structure gives a nice example of bar-induced nuclear spiral arms. Bars are an efficient mechanism to transport interstellar gas towards the galactic centers. The interplay between the amount of gas accumulated in this way in the central part of the galaxy, the star formation taking place in the region, the morphology of the central structure and the possible presence of Super Massive Black Holes (SMBH) in the galactic centers are subjects of great interest in contemporary galactic astronomy. All these phenomena are directly related with the secular evolution of barred galaxies (for a review see Kormendy 2013). Recently, Combes et al. (2014), associated a possible trailing character of the nuclear arms with the presence of a SMBH. This is also a morphological feature existing in the very central parts of NGC 352 making it an ideal object for the study of the dynamical phenomena and their interconnections taking place in barred-spiral galaxies.

The study of the formation and longevity of boxy bulges is a key issue for tracing the correct scenario of disk galaxy formation and evolution. They can be proven the Rosetta stone for understanding how the Milky Way and other galaxies of similar size work.

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Astronomical conferences and schools in Greece during 2016

Every year take place in Greece several astronomical conferences and schools. As a matter of fact the members of the scientific organizing committees decide about the organization of a workshop, or a conference, in order to present new, important results and summarize the state of the art in a particular topic. Thus, since the organizers of astronomical scientific meetings in Greece are in the vast majority of the cases Greek astronomers, the conferences trace to a certain degree the progress in research fields in which Greek astronomers actively participate. On the other hand, the schools reflect the potential interest existing for a specific astronomical subject and their organization aims to the transfer of knowledge to the next generation of researchers. The necessity for their organization reflects also the interest of new researchers and PhD students to deeper understanding the particular field.

We thought that a brief presentation of the results of these events could be a useful reference for the broader Greek, astronomical community. So, we asked the organizers of scientific meetings that took place in Greece during 2016 to present in short these events for the readers of Hipparchos.

On the following pages you can find the contributions we received, which refer to the following meetings:

- Supernova Remnants: An Odyssey in Space after Stellar death, 6-11 June 2016, Chania, Crete
- Hot spots in the XMM sky: Cosmology from X-ray to Radio, 15-18 June 2016, Mykonos
- NEON 2016 Observing School, 19 June – 2 July 2016, Heraklion, Crete
- European Week of Astronomy and Space Science (EWASS), 4 – 8 July 2016, Athens
- Computational perturbative methods for Hamiltonian systems - Applications in Physics and Astronomy, 11-13 July 2016, Athens
- The 2nd Summer School of the Hellenic Astronomical Society, 11-15 July 2016, Athens
- The ISM-SPP Olympian School of Astrophysics 2016, 3-7October 2016, Paralia Katerini
- Space Radiation Modelling and Data Analysis Workshop 2016, 5-7 October 2016, Sykia, Peloponnese

Supernova Remnants: An Odyssey in Space after Stellar death

6-11 June 2016, Chania, Crete

The international conference titled **"Supernova Remnants: An Odyssey in Space after Stellar Death"** explored the exciting recent observational and theoretical progress in the structure, evolution and physics of SNRs. The Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing of the National Observatory of Athens (NOA), organized this meeting between June 6-11, 2016, at the «Minoa Palace Hotel», in Crete, Greece, with great success. The 151 distinguished scientists from 30 countries who participated in the conference truly exceeded our expectations, as they contributed presentations of a very high level and motivated many valuable scientific discussions. The goals of the meeting were understanding the evolution of SNRs and their interaction with interstellar gas, elucidating the physical processes that govern shock waves and relativistic plasmas, and inferring characteristics of supernova explosions from SNR observations. New understanding of the nature of supernova remnants and processes that occur there offers new insights into the role of SNRs in the structure and evolution of galaxies and the nature of supernova explosions.

Many new important results were presented such as the new ALMA observations of supernova 1987A mixing, nucleosynthesis and dynamics of the ejecta (by Matsuura et al., now accepted by MNRAS) where they detected the CO, SiO, HCO+ and SO molecular lines from the ejecta (Fig. 1). Those molecules can probe three different aspects of the SN 1987A ejecta: (a) Footprints of mixing and dynamics in the early days after the supernova explosion, (b) Molecular chemistry in the last twenty-five years, (c) Explosive nuclear synthesis, using isotopologues, hence isotope ratios.

Information about the scientific results can be found on the conference website:

http://snr2016.astro.noa.gr

Panos Boumis (SOC & LOC)
& Alceste Bonanos (LOC)
Co-chairs

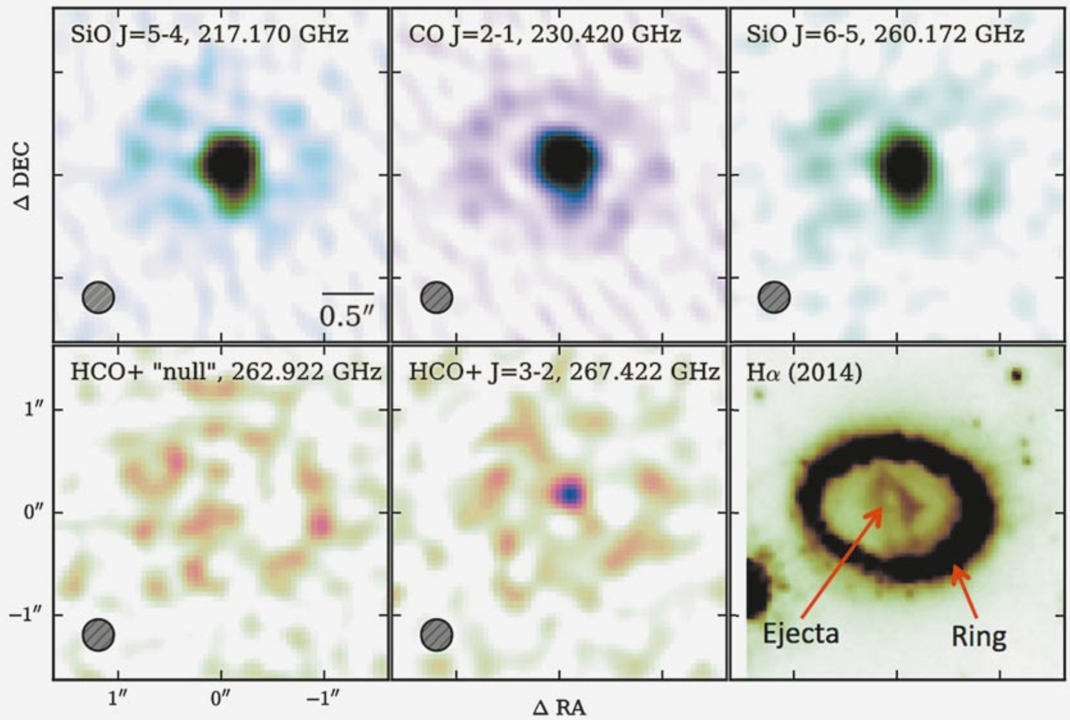

***Figure 1:** Molecular emissions are from the ejecta (Matsuura M., et al., 2017, MNRAS, in press, astro-ph:170402324).*

Hot spots in the XMM sky: Cosmology from X-ray to Radio

15-18 June 2016, Mykonos

The Astrophysics, Astronomy & Mechanics sector of the Physics Department of the Aristotle University of Thessaloniki organized the international conference "Hot spots in the XMM sky: Cosmology from X-ray to Radio", which took place in Mykonos island between the 15th and the 18th of June 2016. About 80 scientists and students participated and almost all presented either talks or posters. The scientific organizing committee included prominent colleagues from all over the world: C. Adami (LAM/Pytheas, France), M. Birkinshaw (Univ. Bristol, UK), A. Evrard (Univ. Michigan, USA), C. Horellou (Obs. Onsala, Sweden), A. Iovino (INAF-OAB, Italy), C. Lidman (AAO, Australia), S. Maurogordato (Obs. Nice, France), L. Moscardini (Univ. Bologna, Italy), S. Paltani (Univ. Geneva, Switzerland), M. Pierre (CEA Saclay, France), M. Plionis (Univ. Thessaloniki, Greece), H. Rottgering (Obs. Leiden, Holland), V. Smolcic (Zagreb Univ., Croatia), J. Surdej (Univ. Liege, Belgium), C. Vignali (Univ. Bologna, Italy), J. Willis (Univ. Victoria, Canada).

The topics spanned a large range of extragalactic high-energy astrophysics and observational cosmology themes, based mostly on galaxy clusters and AGN, namely: Cluster of Galaxies selection from X-ray to Radio, the physical evolution of galaxy clusters, Galaxy clusters as a cosmological probe, Galaxy clusters at z>1: the emergence of massive virialised structures from the cosmic web, the impact of cosmological simulations, Cosmology and Large-Scale Structure with AGN, AGN demography, evolution and triggering mechanisms, AGN obscuration, coordinating XMM observations with other large-survey instruments, legacy data sets for the EUCLID, eRosita and Athena missions.

The power-point presentations of most talks and the reviews, as well as photos from the event, can be found in the following address:

http://www.astro.auth.gr/~xmmcosmo16/

Finally, we would like to note that the meeting was supported by the Culture Sector of the Regional Government of South Aegean and the Municipality of Mykonos.

NEON 2016 Observing School

19 June – 2 July , 2016, Heraklion, Crete

The NEON (Network of European Observatories in the North) 2016 Observing School took place at Skinakas Observatory and the Physics Department of the University of Crete, in the period between June 19 to July 2, 2016. The school focused on observations, for a period of 5 nights, at the 1.3 m telescope at the Observatory, followed by data reduction and presentation of the scientific results at the Physics Department. The school was attended by over 25 PhD students and early post-docs from all over the world. Professional astronomers from the Physics Departments of the University of Crete and the University of Thessaloniki, as well as colleagues from other European Institutes, gave lectures on current Astrophysical tipics, and on topics related to telescope optics, optical spectroscopy and photometry. The school gave the opportunity for high quality transfer of knowledge from the experienced researchers in the filed to the young students and postdocs. The participants had the opportunity to listen to world class presentations on the most active research topics, currently, in Astrophysics, world-wide. They had the opportunity to use the 1.3 m telescope at Skinakas observatory to perform photometric and spectroscopic observations of stars and galaxies, as part of their projects, which resulted in impressive results, and high quality presentations. Overall, the school was highly successful, and the feedback of the participants, and of the instructors, regarding the Observatory infrastructure was very positive and enthusiastic.

I. Papadakis (Physics Department, UoC) & P. Reig (IESL, FORTH)

The dome of the 1.3 m telescope at Skinakas Observatory where the observing activities of the NEON 2016 school took place.

European Week of Astronomy and Space Science (EWASS)

4-8 July 2016, Athens

PRESS RELEASE
Wednesday, 6 July 2016
European Week of Astronomy and Space Science (EWASS)

On Monday, 4 July 2016, the international conference "European Week of Astronomy and Space Science 2016 – EWASS 2016" started in Athens. EWASS was organized by the European Astronomical Society, in collaboration with the Hellenic Astronomical Society, and was the largest astronomical conference in Europe. Each year it is organized in a different European country. Almost 900 participants from all over the world presented, at the Eugenides Foundation and the adjacent Metropolitan Hotel, their latest research results in 10 parallel sessions. In total, 17 Symposia and 12 Special Sessions took place. The topics covered many areas of modern Astrophysics: from the Sun and its planets, to stars, to extra-solar planets, to distant galaxies and cosmology.

Tuesday 5 July, was a special day, because a lecture was given at the crowded Digital Planetarium of the Eugenides Foundation by Dr. Jason Spyromilio, distinguished Astronomer of the European Southern Observatory, entitled "The accelerating Universe". The lecture was given in Greek and it was open to the general public of Athens.

During the conference, eight honorary awards of the European Astronomical Society were bestowed. The first one, the Lodewijk Woltjer Lecture, was awarded on Monday (July, 4) to Thibault Damour, Professor at the Institute des Hautes Etudes Scientifiques of France. Professor Damour had a major contribution in the development of basic and quite complicated theoretical calculations, that enabled the solution of Einstein's equations of gravity, that led to the theoretical computation of the expected gravitational waves. These waves are emitted during the coalescence of two black holes and were measured experimentally for the first time only recently. Joachim Truemper, Emeritus Professor at the University of Munich and former Max-Planck-Institute Director, received the Tycho Brache award for his life-long contributions to X-ray Astrophysics. Finally, three young scientists, Yingjie Peng, Oliver Pfuhl, and Maria Petropoulou received awards for the quality of their research, which was performed for their PhD in a European University. In particular, Dr. Petropoulou did her PhD in Theoretical Astrophysics in the Department of Physics of the University of Athens and she is currently an Einstein Postdoctoral Fellow at Purdue University in the USA.

A large number of very interesting scientific results were presented during EWASS. Here, only three of them are described.

Observing a supermassive black hole swallowing a star

European Week of Astronomy and Space Science (EWASS), 4-8 July 2016, Athens

Astronomers have used a radio telescope network extending over the whole surface of the Earth in order to obtain such a great resolution that would allow them to distinguish a 2-euro coin on the Moon as seen from Earth. Such a resolution would allow them to observe a rare phenomenon happening in a remote galaxy. A jet, a narrow beam of particles, shoots out of the nucleus of a galaxy as the supermassive black hole at its center consumes a star.

The international team of scientists led by Jun Yang from Chalmers University, Sweden, followed for a the time interval of three years the activity in a galaxy named Swift J1644+57 using the European network of radio telescopes known as the "European VLBI Network". Their results have been presented in the EWASS conference in Athens and have been published in the journal "Monthly Notices of the Royal Astronomical Society". Based on their measurements it became apparent that as the star starts being disrupted in the process to be swallowed by the black hole at the center of the specific galaxy, part of its material radiates bright light in X-rays. However, in parallel, another part escapes from the strong gravitational field of the black hole and is ejected from it in the form of a jet.

It is the first time that the continuously developing technology makes possible such an observation. In the near future, new more advanced gigantic radio telescopes that are currently built (like the Five Square Kilometer Array, FAST, in China and the Square Kilometer Array, SKA, in South Africa) will give us even more information about what happens in the enigmatic black holes.

Information:
Robert Cumming, communications officer, Onsala Space Observatory, Chalmers University of Technology, Sweden, email: robert.cumming@chalmers.se

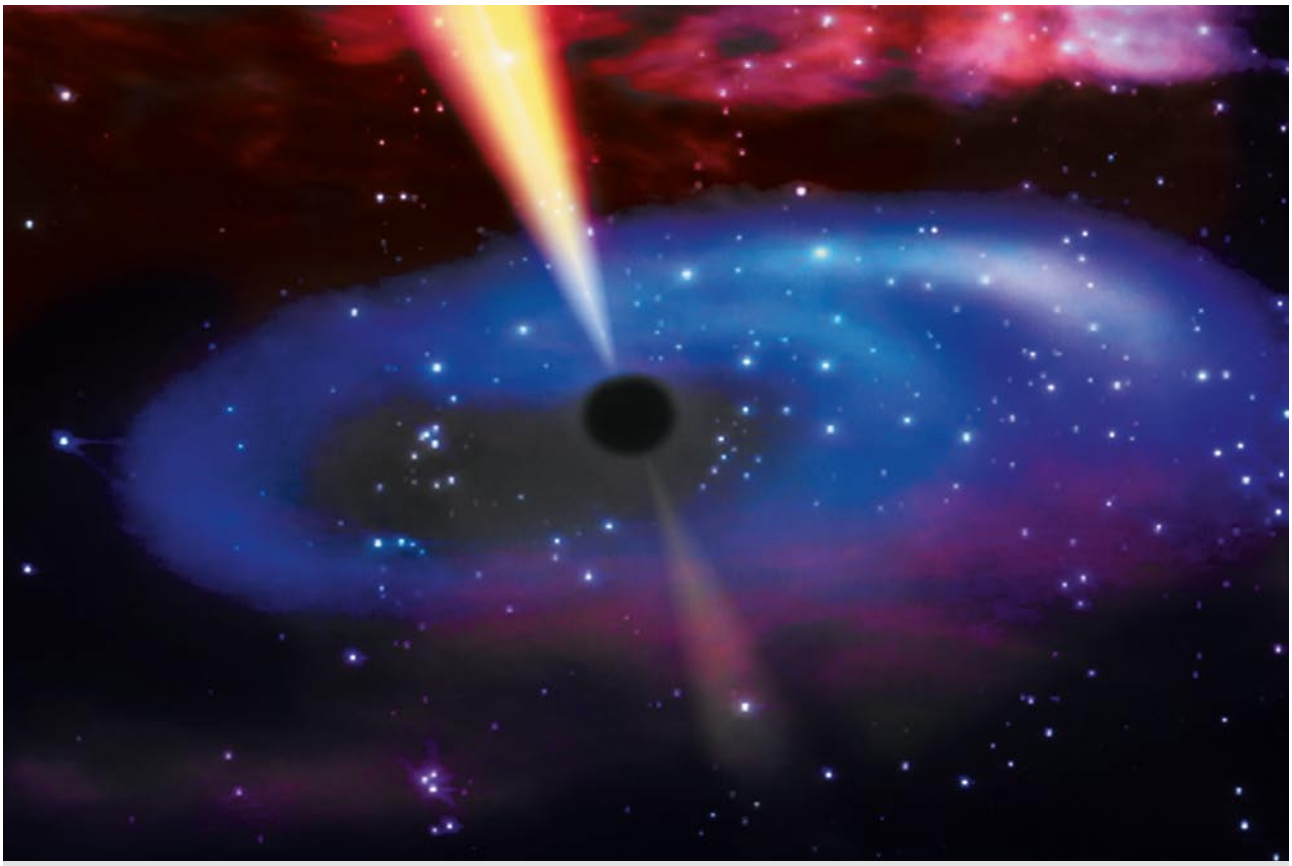

Image description: *An artist's impression of a jet of particles (in yellow) that is ejected from a black hole (dark disk at the center) as a star has been swallowed by it.*

Can stellar eruptions influence exoplanet habitability?

European Week of Astronomy and Space Science (EWASS), 4-8 July 2016, Athens

Researchers from the University of Ioannina and the RCAAM of the Academy of Athens have developed a novel technique to estimate the magnetic field magnitude of solar and stellar magnetic eruptions. This study can potentially rewrite the exoplanet habitability criteria, contingent to stellar magnetic activity.

Contemporary astronomy and astrophysics have been rocked by the discovery of thousands of exoplanets revolving around their mother stars in the not-too-distant universe. A fraction of these exoplanets can be found in the so-called "habitability zone" of stars, with the term loosely referring to an appropriate astrocentric distance at which planetary atmospheric pressure and temperature allows for the existence of liquid water in a planet's otherwise rocky surface. Existence of liquid water is imperative for the development of lifeforms compatible to human cognition. However, this rather "flat" assessment of habitability may prove insufficient and oversimplified, the reason being the magnetic activity of stars hosting planetary systems. Extreme stellar superflares and corresponding mass ejecta may act to even strip planets off from their atmosphere, rendering the existence of liquid water untenable even in case other habitability conditions are fulfilled. We may be encountering such a dramatic occurrence in our own solar system, namely in planet Mars: atmospheric erosion due to solar eruptions is, in fact, the most credible justification for the lack of Martian atmosphere, as suggested by results of NASA's MAVEN mission to the red planet.

A novel, computationally inexpensive method has been developed to constrain the magnetic field of gigantic solar and stellar coronal expulsions, known as coronal mass ejections (CMEs). The CME magnetic field is estimated in different locations within the solar and stellar planetary systems, including habitability zones and the vicinity of possible exoplanets. Besides Sun and Sun-like stars, analysis extends also to M-type stars (red dwarfs) that are known to be fully or partially convective and hence generate variable, potentially eruptive, coronal magnetic fields. Solar CMEs are known to javelin about 10 billion tons of solar coronal plasma toward the heliosphere with speeds often exceeding 1000 km/s. Such massive, rapidly propagating blobs of plasma and magnetic flux can strongly compress the terrestrial magnetosphere, causing geomagnetic storms and impacting our technological civilization, that is strongly dependent on space-technology applications. This variability at timescales of hours to days has been termed space weather.

Using the fundamental principle of magnetic helicity conservation in highly conducting plasmas, strong accumulations of which lead to helical and potentially catastrophically unstable stellar magnetic fields, researchers first estimate the near-Sun (or near-star) CME magnetic field strength and then extrapolate it to planetary distances or at Earth's vicinity. The decisive step of extending the method to Sun-like stars and red dwarfs was first presented during the 2016 European Week of Astronomy and Space Science (EWASS) in Athens. A successful method extension may lead to improved exoplanet habitability conditions, even on a case-by-case basis, using minimal information pertaining to observed stellar flare energies, habitability-zone distance and a planet's assumed equatorial magnetic field.

Results described in Patsourakos, S. and Georgoulis, M. K.: A Helicity-Based Method to Infer the CME Magnetic Field Magnitude in Sun and Geospace: Generalization and Extension to Sun-Like / M-Dwarf Stars and Implications for Exoplanet Habitability, 2017, *Solar Physics*, in press.

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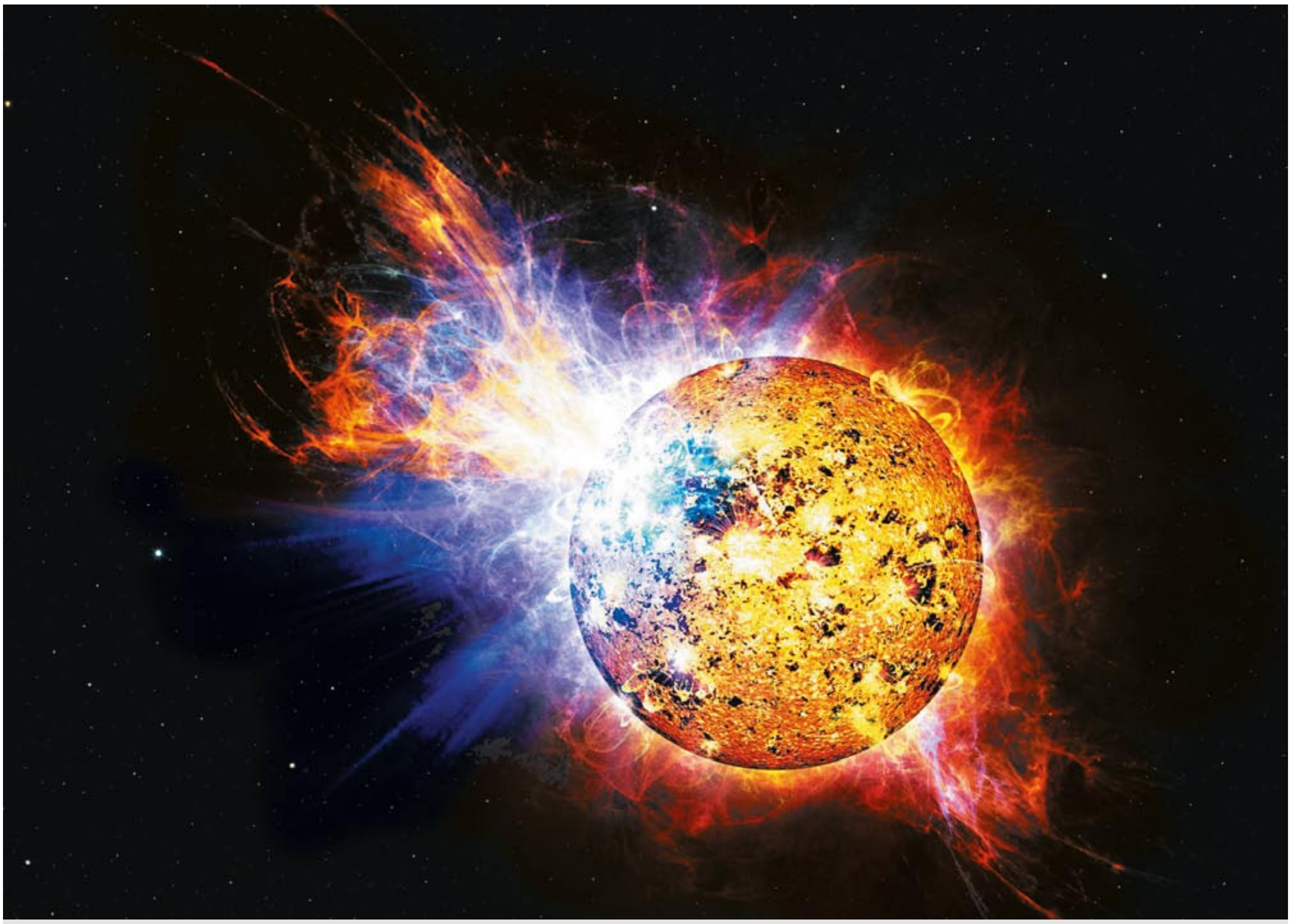

Image description: *artist's conception of a stellar eruption in red dwarf EV LaCerta, some 16.5 light years from Earth. The new method described here uses the estimated energy of stellar flares observed in X- and γ-rays to assess the magnetic field strength of such colossal eruptions, both in the star's vicinity and around its possible exoplanets. Source: NASA*

PASIPHAE: Clearing the path to the Big Bang

European Week of Astronomy and Space Science (EWASS), 4-8 July 2016, Athens

Preparations have started for the implementation of a unique Astrophysics experiment, set to take place at Skinakas Observatory and at the South African Astronomical Observatory, located near the city of Sutherland in South Africa. The experiment's goal is to pave the way towards the detection of the imprint of the first moments of the creation of the Universe on the primordial light.

Called PASIPHAE (Polar-Areas Stellar-Imaging in Polarization High-Accuracy Experiment), the experiment will map, with unprecedented accuracy, the polarization of millions of stars at areas of the sky away from the Galactic plane, in both the Northern and the Southern hemispheres, and use this information to locate the best regions of the sky where astronomers can look for information from the early Universe.

PASIPHAE (named after the Minoan Queen) is a collaborative effort of the Astrophysics Group in Crete (the joint Astrophysics group at the Institute of Plasma Physics, the University of Crete, the Foundation for Research and Technolohy-Hellas, and the Skinakas Observatory) with the Inter-University Center for Astronomy and Astrophysics (IUCAA) in Pune, India (the greatest laboratory of optopolarimeter design and development in the world), the California Institute of Technology (Caltech in the US, including the Caltech Optical Observatories and the Owens Valley Radio Observatory), the South African Astronomical Observatory, and the University of Oslo in Norway.

PASIPHAE is led by Konstantinos Tassis, Assistant Professor of Theoretical Astrophysics at the University of Crete, and it is made possible by a grant by the Stavros Niarchos Foundation. It is additionally sponsored by Infosys, India, the South African National Equipment Program, and the US National Science Foundation.

PASIPHAE will use unique, innovative polarimeters (the Wide Area Linear Optical Polarimeters, WALOPs) that are designed specifically for this purpose. The development of the WALOPs is led by Professor A. N. Ramaprakash at IUCAA, and is currently underway.

A very large amount of observing time has been generously committed to the PASIPHAE survey by the Skinakas Observatory at its 1.3 m telescope, and the South African Astronomical Observatory at its 1.0 m telescope.

The PASIPHAE polarimetric map will be used to perform magnetic tomography of the Galaxy: it will allow to deduce the 3-dimensional structure of the magnetic field and the dust that resides in our own Galaxy. This dust acts as a "veil" preventing scientists to get vital data that will allow us to probe the first instants of the Universe, as well as the, yet-unknown, physics of Gravity at unprecedentedly high densities and temperatures.

PASIPHAE will open an invaluable and vastly under-explored window to the Universe, through the study of starlight polarization. Beyond studies of the early Universe, the survey will lead to leaps forward in some of the most actively pursued areas in Astrophysics. For Astrophysics of the highest energies, PASIPHAE will reveal the optical counterparts (which are highly polarized) for nature's highest-energy yet-unidentified sources. At the same time, the tomographic mapping of the Galactic magnetic field of PASIPHAE will enable us to back-track the paths of ultra-high—energy cosmic rays (the highest-energy particles ever observed in the Universe) to identify their sources. Finally, PASIPHAE will allow us to better understand how stars themselves –the lighthouses of the Universe– are formed out of cold interstellar gas. For interstellar Astrophysics, the role of the magnetic field as a moderator for the rate of formation of interstellar clouds and stars is currently hotly debated.

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Computational perturbative methods for Hamiltonian systems - Applications in Physics and Astronomy

11-13 July 2016, Athens

In July 2016, the Research Center for Astronomy and Applied Mathematics, in collaboration with the Università degli Studi di Roma "Tor Vergata" (under the DEXTEROUS project), organized a workshop focusing on applications of perturbation theory in Celestial Mechanics and Galactic dynamics. The meeting gathered 40 international experts and a number of young researchers, and discussed innovative aspects of Hamiltonian perturbation theory and nonlinear dynamical systems as applied to systems of astronomical interest, mainly our Solar System, extrasolar planetary systems and galaxies.

One of the key motives for organizing this meeting was the recognition that there has been since long a number of groups developing diverse symbolic tools or computer-algebraic methods for implementing Hamiltonian perturbation theory in various contexts of mathematical or physical interest. These methods have already reached a state of maturity, and their implementation has yielded a number of results of particular importance both in the theory and in the applications of Hamiltonian systems. The meeting discussed also future prospects in this promising field of research.

Sub-topics included: Analytical and semi-analytical methods - Study of convergence – accumulation of small divisors in series of perturbation theory, Computer-algebraic techniques, special manipulators and computational environments, Computations of quasi-integrals of motion, Invariant manifolds – Reduction to the center manifold, Weak-ly chaotic diffusion, dynamics of multiple resonances. Several speakers presented applications in Celestial Mechanics (restricted three-body problem, multi-body problems, space manifold dynamics, satellite dynamics, extrasolar planetary systems), Galactic dynamics (periodic orbits, spiral structure, triaxial potentials), but also in other applications of nonlinear dynamical systems (atoms and molecules, dynamics on non-linear lattices, etc.).

More details as well as uploaded versions of the talks can be found in the workshop's webpage:
https://hamiltonian2016.wordpress.com/

C. Efthymiopoulos, RCAAM,
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The 2nd Summer School of the Hellenic Astronomical Society

11-15 July 2016, Athens

The Hellenic Astronomical Society (Hel.A.S.), in collaboration with the National Observatory of Athens (NOA) and the National and Kapodistrian University of Athens (UoA), under the initiative to offer knowledge and scientific training to the younger members, graduate students and young postdoctoral researchers of the Society, has organized the 2nd Summer School titled: "Nuclear activity in galaxies" in Athens, from the 11th until the 15th of July 2016.

The 32 participants, mostly graduate students in the master and PhD level, but also a few undergraduate students, and the tutors, spent five days together and had the chance to interact and discuss on various topics related to Active Galactic Nuclei (AGN).

Each day was devoted to an area of AGN physics, with talks in the morning sessions and laboratory exercises prepared by the tutors in the afternoon sessions. The four topics covered were "Infrared Emission from Dust and Gas in Galaxies", "X-ray surveys - Black hole evolution across cosmic times", "X-ray emission from AGN", and "Jets from AGN". Some of the students also gave talks during the last day of the school. A detailed program as well as the slides of the presentations can be found on the web page

http://www.helas.gr/school/2016/index.php

The students expressed positive opinions in the questionnaire that anonymously filled after the end of the school.

The expenses of the school were covered by the Hel.A.S. (for the coffee breaks and light meals), the NOA (for the dinner at the gardens of its historic building at Thissio), and UoA (for the room and internet connection).

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The ISM-SPP Olympian School of Astrophysics 2016

3-7 October 2016, Paralia Katerini

The "ISM-SPP Olympian School of Astrophysics 2016" took place the week of 3-7 October 2016 in Paralia Katerini, Pieria prefecture. It was organized by the non-profit organization Olympian Centre for Astrophysics (OCfA, http://olympiancfa.org/), in collaboration with the Max Planck Institute at Garching (Munich, Germany) and a generous sponsorship by the ISM-SPP Priority Program 1573 of the German Foundation of Research (Deutsche Forschungsgemeinschaft).

A total of about twenty lectures focused on topics of the dynamical and chemical evolution of the interstellar medium (ISM) with particular emphasis on Galactic and extragalactic environments. Several aspects on dynamics (instabilities, turbulence, and magnetic fields) and the astrochemistry of photoionization, photodissociation and molecular regions were extensively discussed. The lectures further focused on the star formation processes from low-mass to high-mass stars, triggered versus non-triggered star formation, as well as the importance of hydrodynamical simulations and the comparison with observations.

About thirty graduate students, young PhD students and early career scientists, coming from twelve different countries attended the school with particular emphasis given by the organisers on the participation of young Greek graduate and postgraduate students (five in total). Financial support was granted for fourteen attendees. Participants attended lectures by six distinguished scientists of the field: Robi Banerjee (University of Hamburg, Germany), Friedrich Wyrowski (Max-Planck-Institut für Radioastronomie Bonn, Germany), Kalliopi Dasyra (National and Kapodistrian University of Athens, Greece), Simon Glover (University of Heidelberg, Germany), Matthias Gritschneder (Ludwig-Maximilians Universität München, Germany), and Konstantinos Tassis (University of Crete, Greece). Furthermore, they were given the opportunity to work hands-on on basic hydrodynamical simulations prepared and supervised by Philipp Girichidis (MPA, Germany) and to present their own work by posters and short oral presentations.

The school opened on Sunday October 2, 2016 with a public outreach lecture, entitled "Είμαστε Αστρόσκονη (We are stardust)", given by Dionisios Simopoulos (Director Emeritus of the Eugenides Planetarium) and attended by more than 250 people. Students enjoyed during the week a social program comprising a welcome reception, a conference dinner and a guided tour in the archaeological site of Dion and a traditional village of the Pieria prefecture. Further information about the school is available at the ISM-SPP Olympian School of Astrophysics 2016 website:

http://school2016.olympiancfa.org/

Space Radiation Modelling and Data Analysis Workshop 2016

5-7 October 2016, Sykia, Peloponnese

The Space Radiation Modelling and Data Analysis Workshop 2016 was held in Sykia, Peloponnese, Greece, during the first week of October 2016. The workshop was convened by Piers Jiggens (ESA/ESTEC, The Netherlands), Ioannis A. Daglis (University of Athens, Greece), Paul O'Brien (Aerospace, USA) and Ingmar Sandberg (IASA, Greece) and was organized under the auspices of:

- ESA HERMES project, Institute for Accelerating Systems & Applications (IASA), Greece
- AE-9/AP-9/SPM Technical Team, USA
- European Space Agency

The sessions of the meeting included the following topics:

- Data calibration & cross-calibration procedures
- Data processing
- Radiation belt environment modelling
- Solar Energetic Particle (SEP) environment modelling
- Statistics and Worst-cases
- Combined modelling of different radiation environment

Experts in space radiation data analysis and modeling of space radiation particle environment presented recent developments in the field, while representatives from ESA identified the current needs of spacecraft operators and addressed the open issues with respect to the characterization of space environment. The participants prioritized their activities in the framework of current and future international collaboration schemes and agreed to reconvene in the near future.

Back issues of Hipparchos

Hipparchos is the official newsletter of the Hellenic Astronomical Society. It is distributed by post to the members of the society. You can download back issues from: **http://www.helas.gr/news.php**