OGLE – IV

The Largest Sky Variability Survey

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OGLE: The Optical Gravitational Lensing Experiment (1992 - ….)
Four Phases of the OGLE Project

- OGLE-I (1992-1995). 1 m Swope telescope at LCO. ~2 million stars observed. Microlensing
- OGLE-II (1997-2000). 1.3 m Warsaw telescope. ~40 million stars observed. Variable and non-Variable Stars in GB, MC
- OGLE-III (2001– 2009). 8k x 8k mosaic CCD. ~200 million stars observed (GB, GD, MC). Extrasolar Planets, Microlensing
- OGLE-IV (2010– ….). 32-chip 256 Mpixel mosaic CCD. Billion stars regularly monitored

http://ogle.astrouw.edu.pl

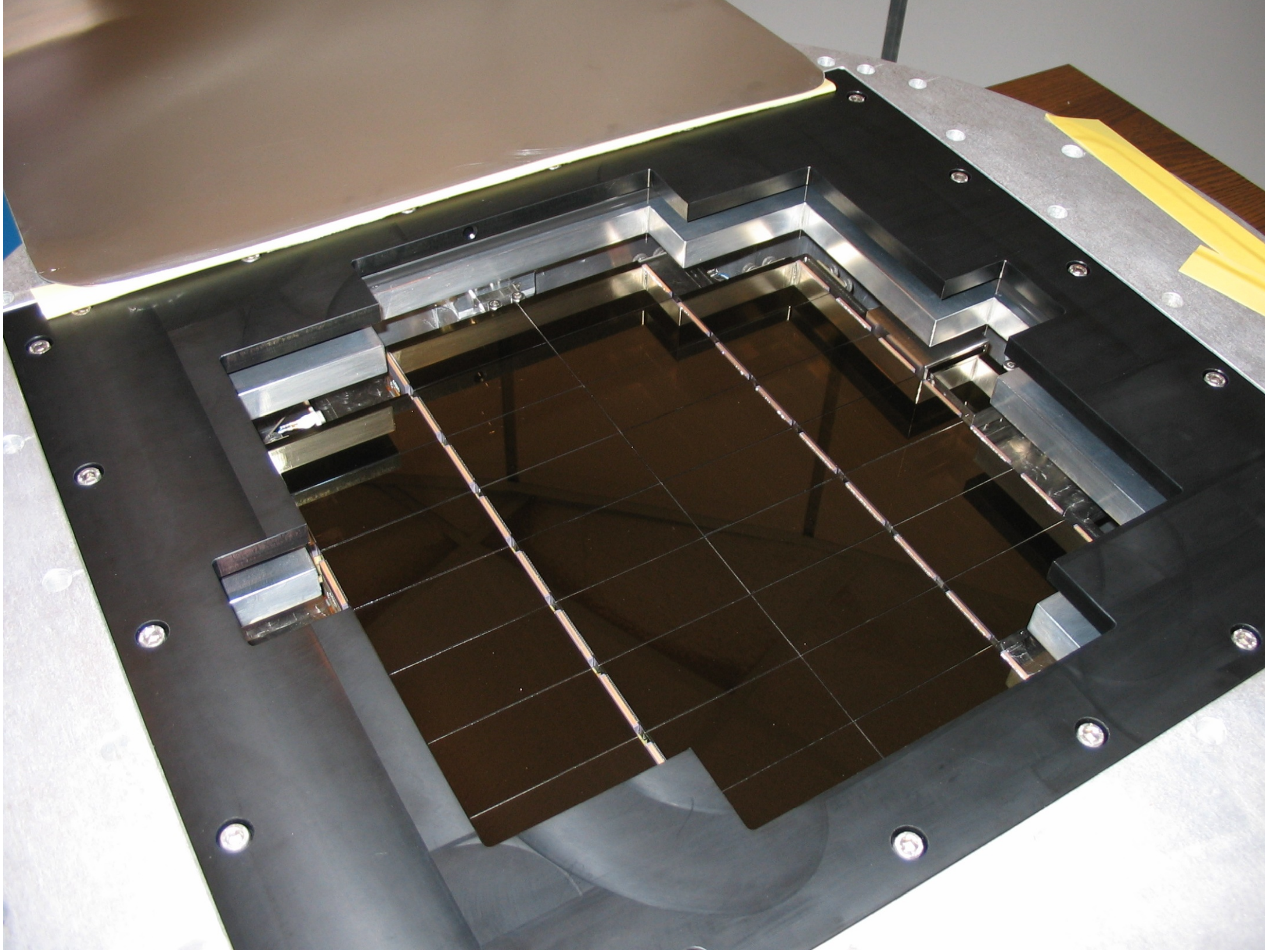
Las Campanas Observatory, Chile

Las Campanas – Warsaw Telescope – Magellanic Clouds

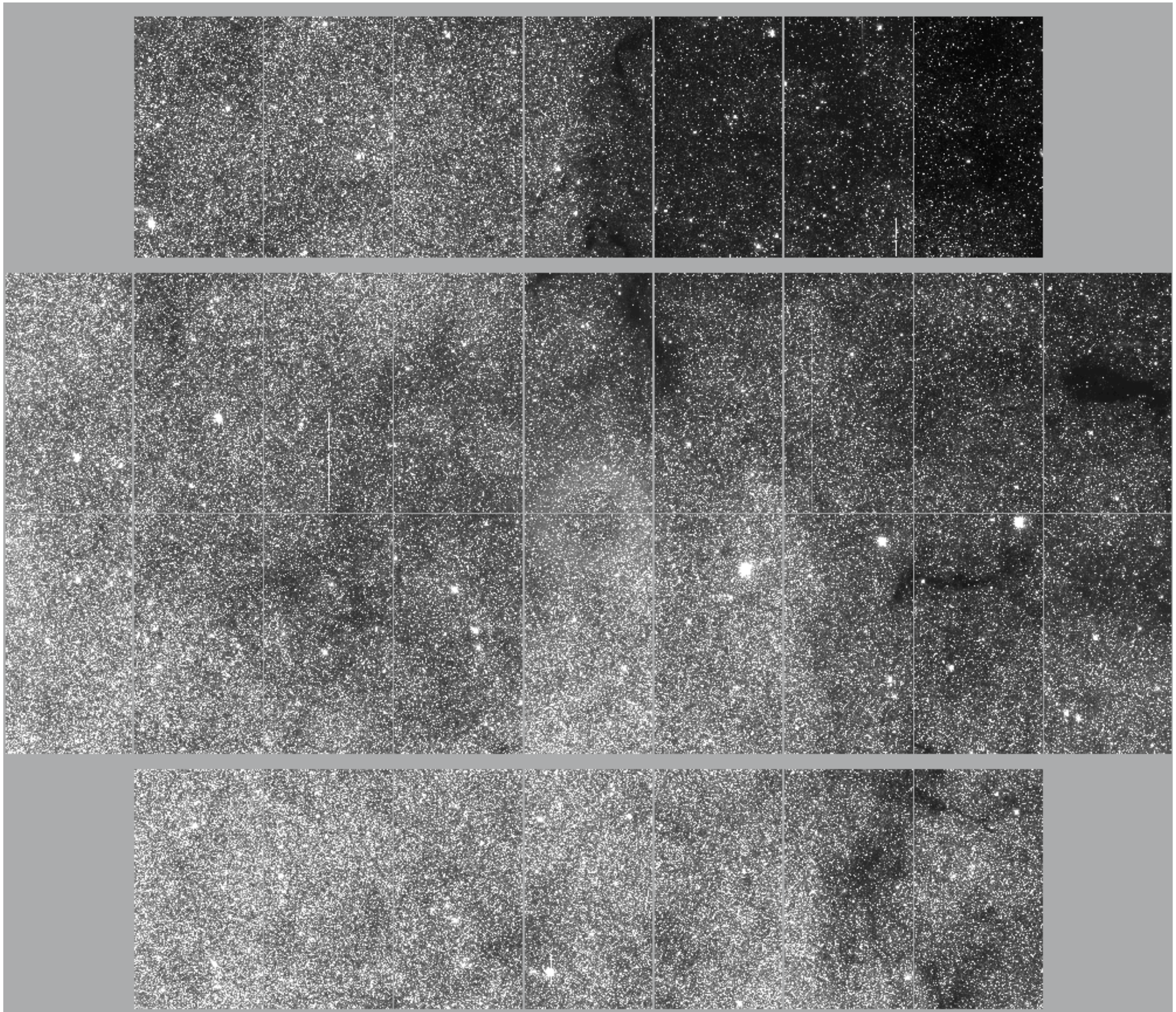
OGLE-IV: 2010 – ….

- 32 chip 256 Mpixel mosaic CCD camera (+ 2 chips for guiding)
- 2048 x 4102 pixel E2V 44-82 DD CCD detectors (15 μm).
- 1.4 square degrees field (~7 Moon disks), scale – 0.26”/pixel
- 20 sec. reading time
- First light September 7, 2009
- Regular observations since March 4/5, 2010
- 30-50 TB of raw data per year
- ~3 mmag accuracy (DIA photometry since 2001)


REMOVE BEFORE OPERATION

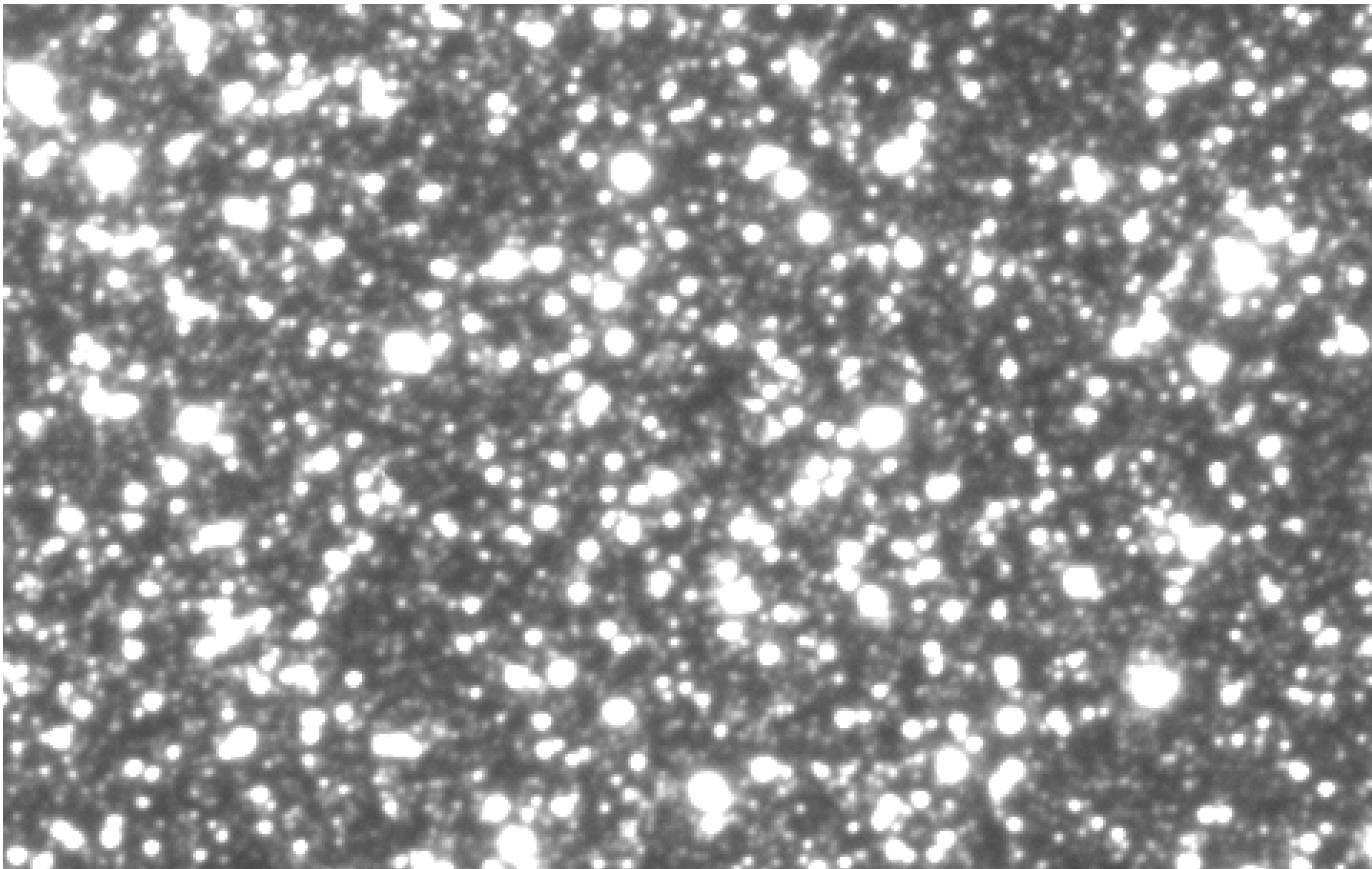


OGLE-IV SKY: 1.4 deg^2 FOV, I~21mag

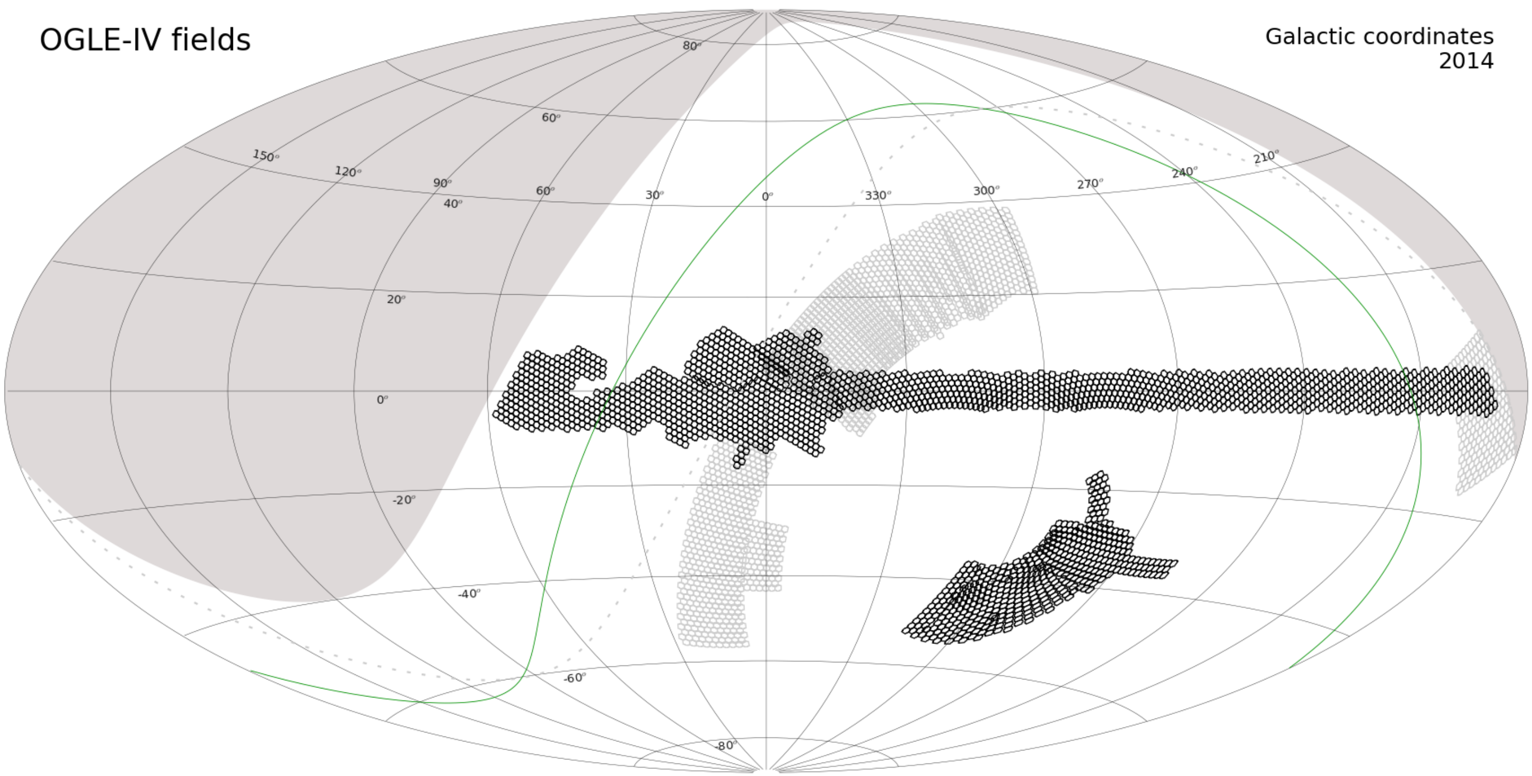


~6 million stars in this picture!

OGLE Speciality



OGLE-IV Sky


OGLE-IV fields
Galactic coordinates
2014
80°
60°
150°
120°
90°
60°
30°
0°
330°
300°
270°
240°
210°
40°
20°
0°
-20°
-40°
-60°
-80°

OGLE-IV 2014 BLG SKY

~130 square degrees

Cadence:

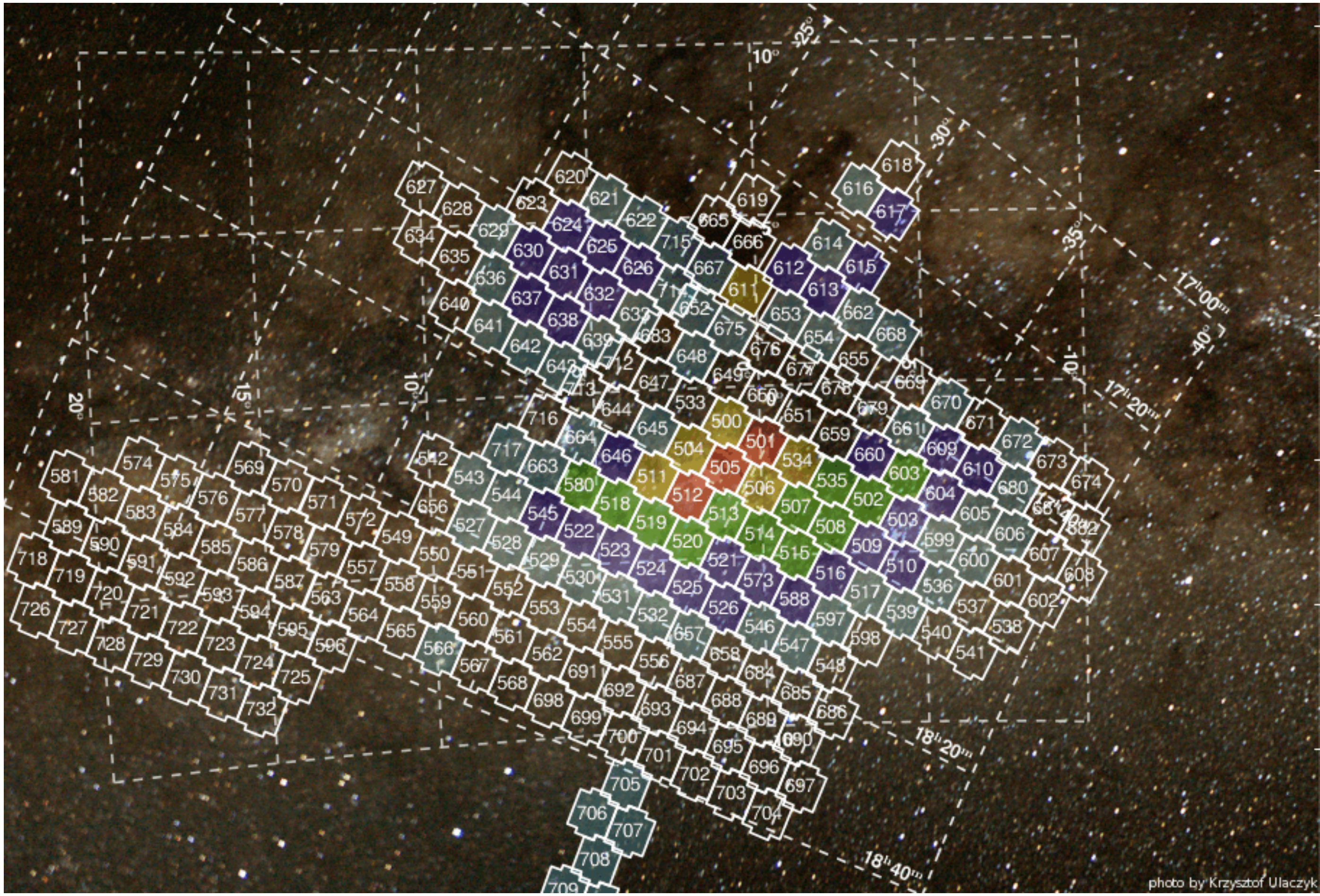
red – ~30 epochs/night

yellow – ~10 epochs/night

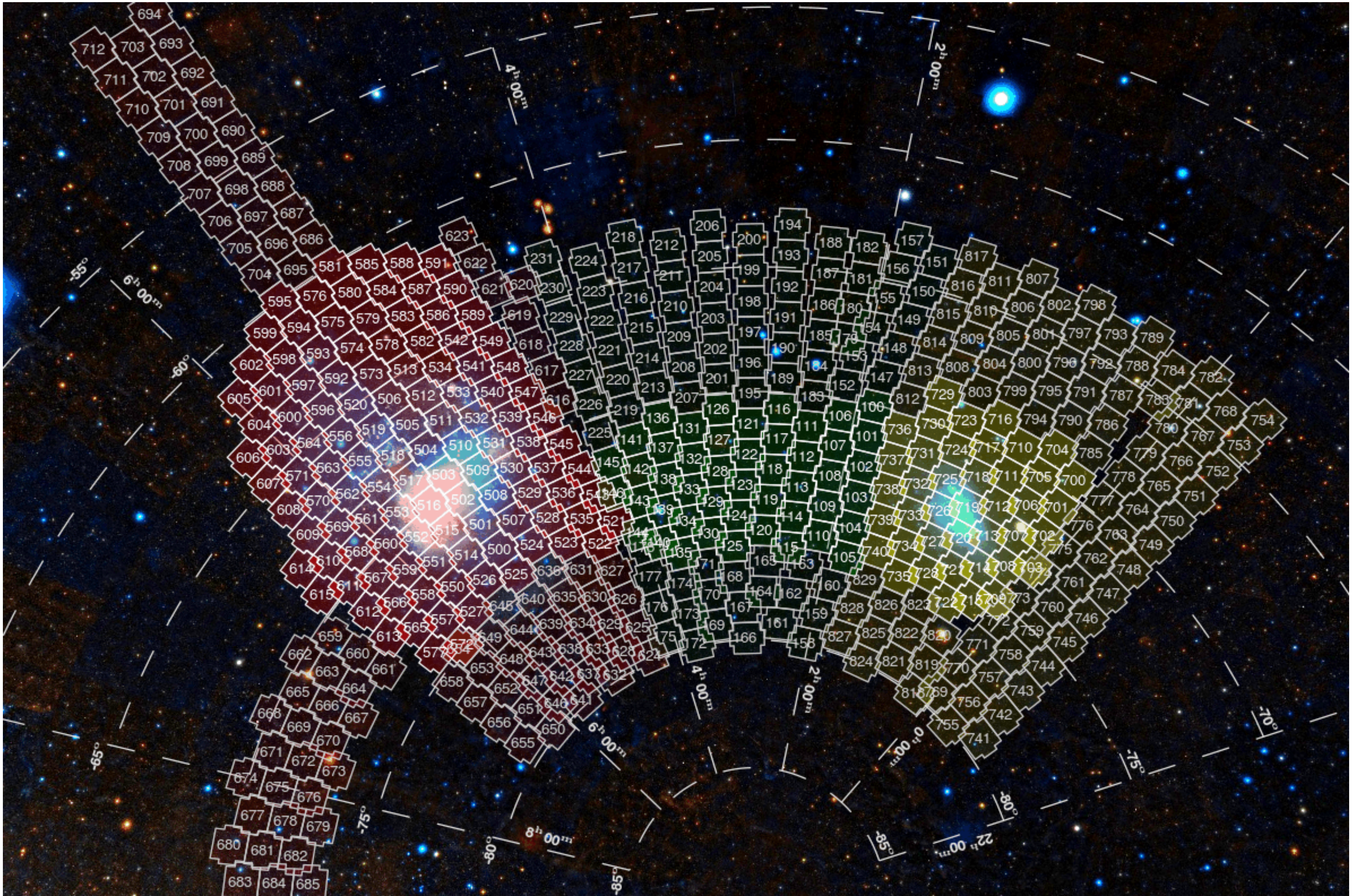
green – ~3 epochs/night

blue – ~1 epoch/night

cyan – ~1 epoch /2 nights



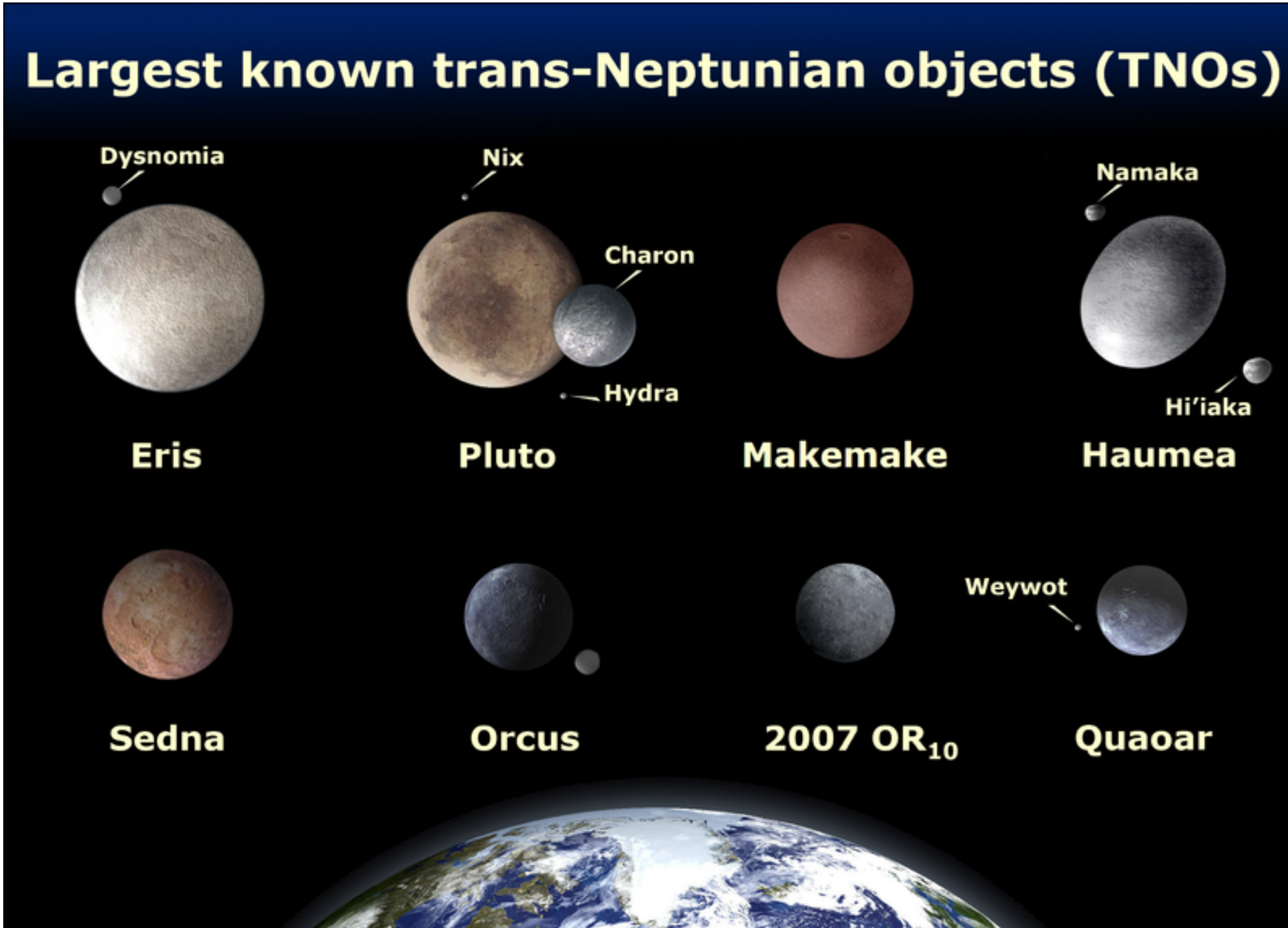
Current O-IV MC Survey – 670 square degrees



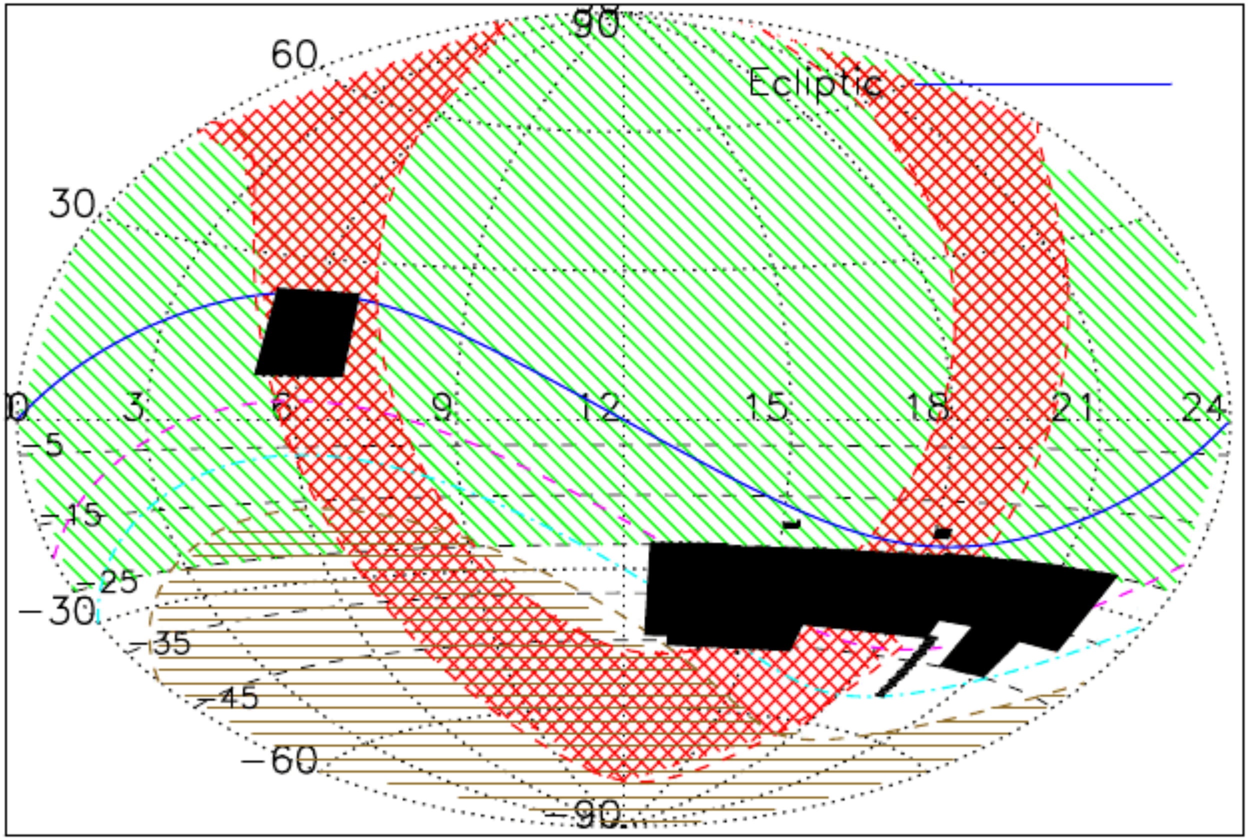
OGLE-IV Galaxy Variability Survey

(~1700 square degrees)

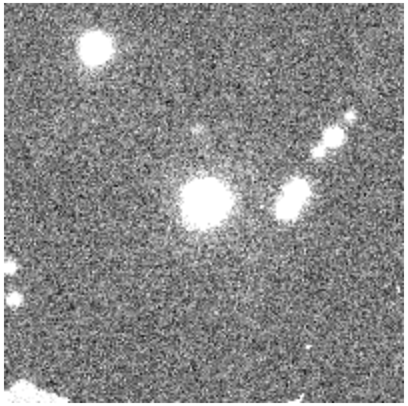
Trans-Neptunian Objects



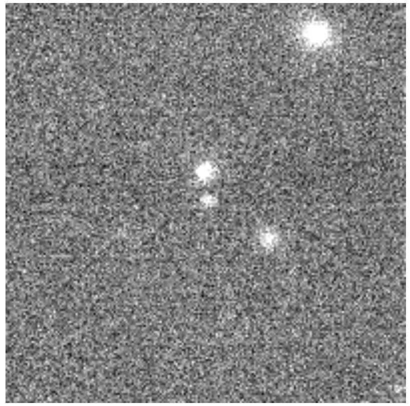
Ogle-Carnegie Kuiper belt Survey – OCKS



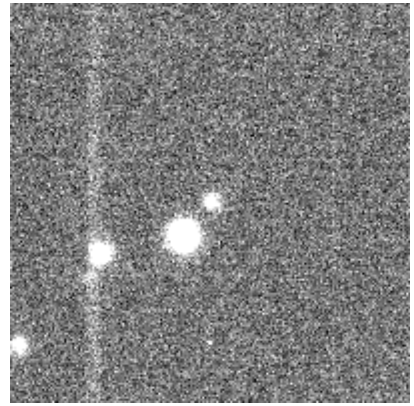
OCKS – Results



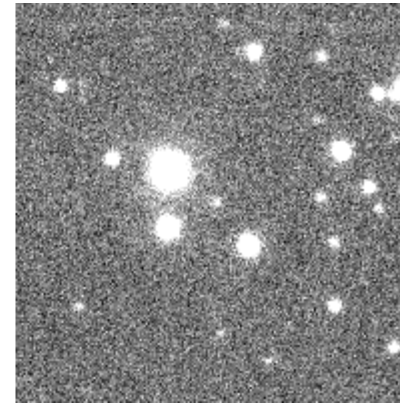
2010 FX86
H=4.3 mag



2010 EL139
H=5.3 mag

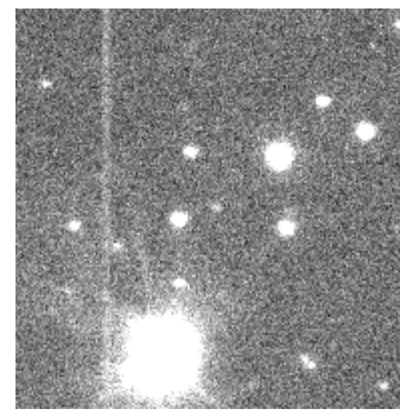


2010 EK139
H=3.8 mag



2010 KZ79
H=3.9 mag

- 1700 (1500+200) fields – ~2400 square degs
- Discovery of 14 new TNOs
- Largest (brightest) solar system objects in the last 6 years
- Dwarf planet candidates
- Diameters of: 300–1100 km (unknown albedo); 2010 EK139 D~500 km (*Herschel*)



2010 JK124
H=5.4 mag

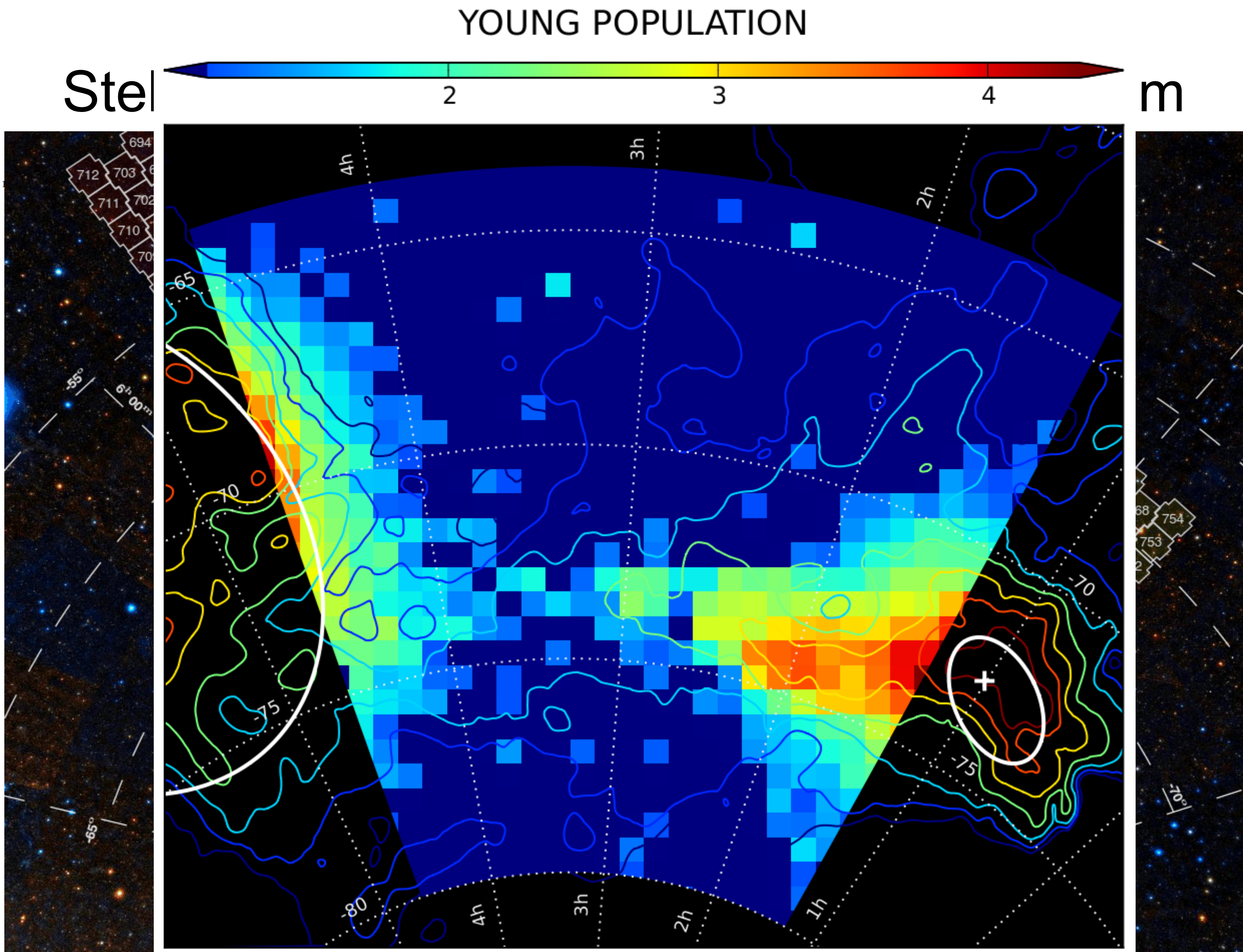
Non-Variable Stars

- ~billion stars monitored – *VI* CMDs
- O-III Photometric Maps:

LMC – 35 million stars, SMC – 6.2 million stars, GB – 380 million stars, GD – 9 million stars

- Structure studies (Magellanic System, Galactic Center – X bar structure)
- Reddening maps (Magellanic Clouds, Galactic Bulge)

Stel m


YOUNG POPULATION
2
3
4
4h
3h
2h
1h
-65
-70
-75
-80
694
712
703
711
702
710
-55°
6h 00m
-65°
754
753
-70°

OGLE Variable Sky

- Gravitational Microlensing
- Largest Collection of Variable Stars
- Transients
- Extragalactic Sources

Gravitational Microlensing

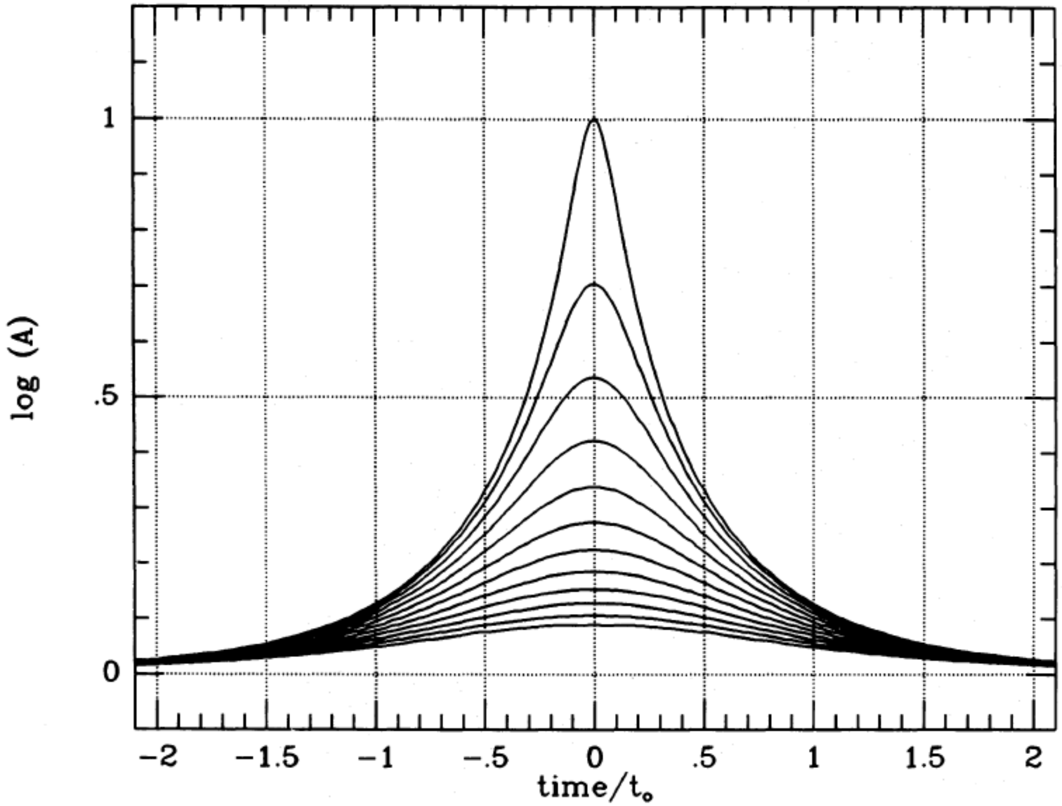
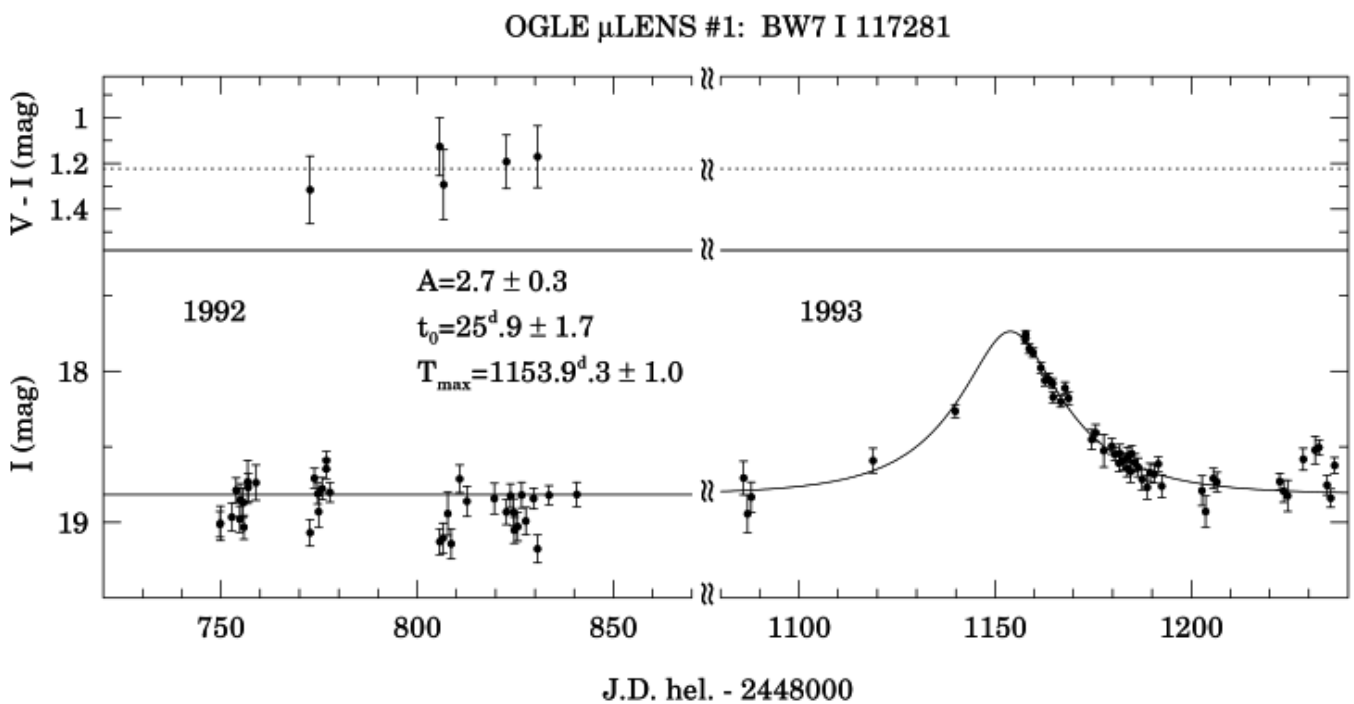
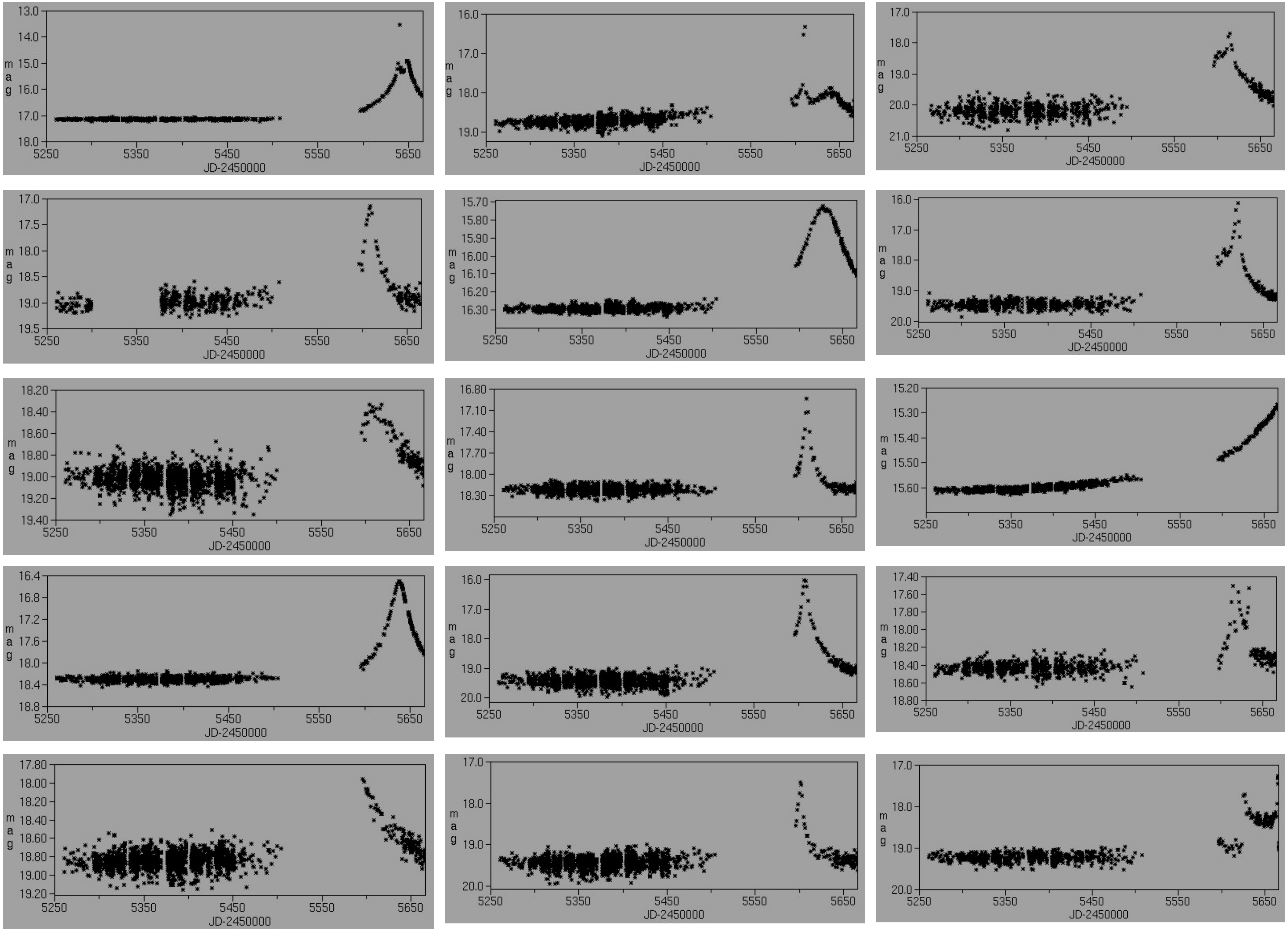


FIG. 2.—Time variation of the amplification due to gravitational microlensing for events with the impact parameter d/R_0 equal 0.1, 0.2, ..., 1.1, 1.2. The largest amplitude corresponds to the smallest impact parameter. The unit of time is given as $t_0 \equiv R_0/v$, where R_0 is the radius of ringlike image formed when the source, the lensing mass, and the observer are perfectly aligned (see eq. [2] and [16]) and v is the relative tangential velocity of the lensing object.

OGLE-I #1



Microlenses: Discovery of the first events toward the GB (1993).


13.0 14.0 15.0 16.0 17.0 18.0
mag
5250 5350 5450 5550 5650
JD-2450000
16.0 17.0 18.0 19.0
mag
5250 5350 5450 5550 5650
JD-2450000
17.0 18.0 19.0 20.0 21.0
mag
5250 5350 5450 5550 5650
JD-2450000
17.0 17.5 18.0 18.5 19.0 19.5
mag
5250 5350 5450 5550 5650
JD-2450000
15.70 15.80 15.90 16.00 16.10 16.20 16.30
mag
5250 5350 5450 5550 5650
JD-2450000
16.0 17.0 18.0 19.0 20.0
mag
5250 5350 5450 5550 5650
JD-2450000
18.20 18.40 18.60 18.80 19.00 19.20 19.40
mag
5250 5350 5450 5550 5650
JD-2450000
16.80 17.10 17.40 17.70 18.00 18.30
mag
5250 5350 5450 5550 5650
JD-2450000
15.20 15.30 15.40 15.50 15.60
mag
5250 5350 5450 5550 5650
JD-2450000
16.4 16.8 17.2 17.6 18.0 18.4 18.8
mag
5250 5350 5450 5550 5650
JD-2450000
16.0 17.0 18.0 19.0 20.0
mag
5250 5350 5450 5550 5650
JD-2450000
17.40 17.60 17.80 18.00 18.20 18.40 18.60 18.80
mag
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17.0 18.0 19.0 20.0
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5250 5350 5450 5550 5650
JD-2450000

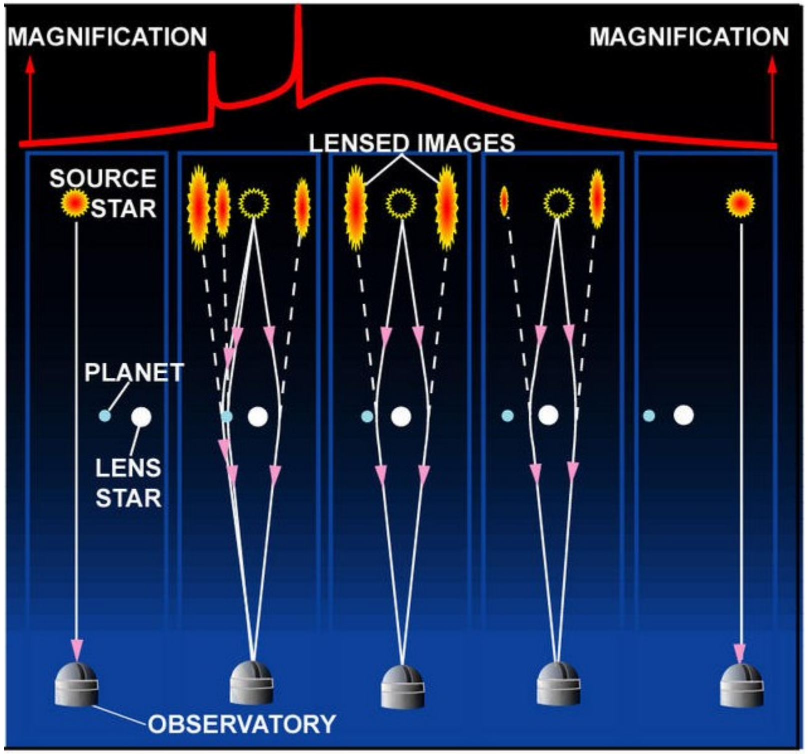
>20 Years Perspective: Three Main Scientific Contributions

- Search for Dark Matter
- Galactic Structure Studies
- Extrasolar Planets – Planetary Microlensing

Planetary Microlensing (in Theory)

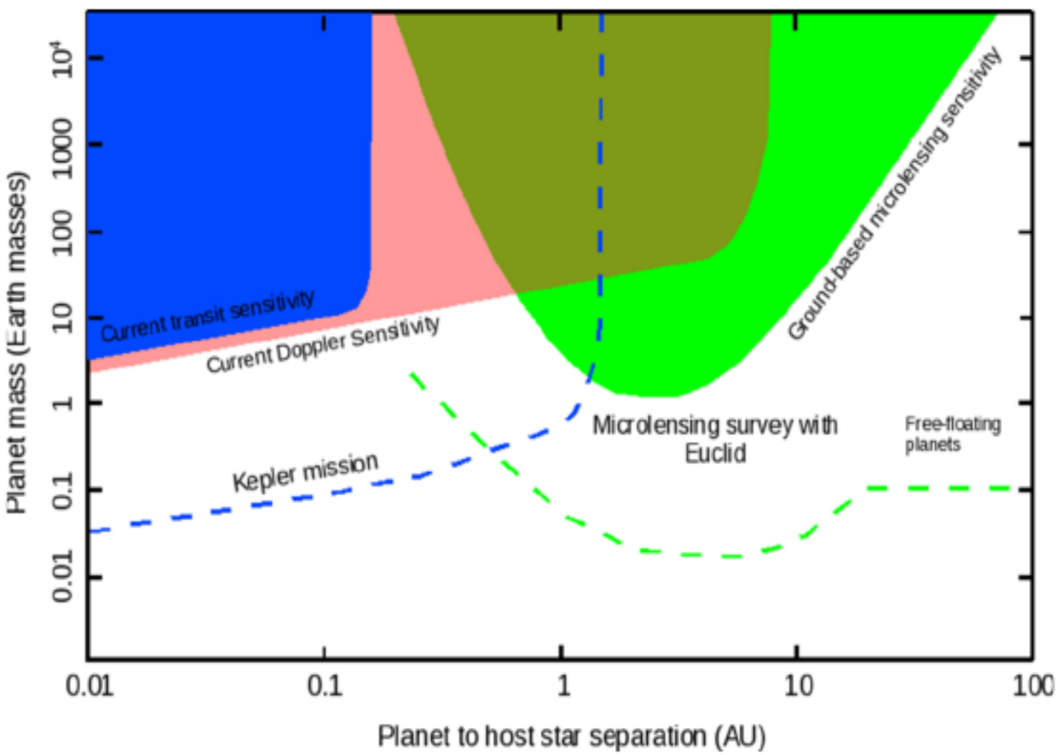
- Short-lived anomaly in the light curve of a typical single mass microlensing event.
- O-III ~600 microlensing events per year in real time (2002-2009)
- O-IV ~2000 microlensing events per year in real time (2010-…)

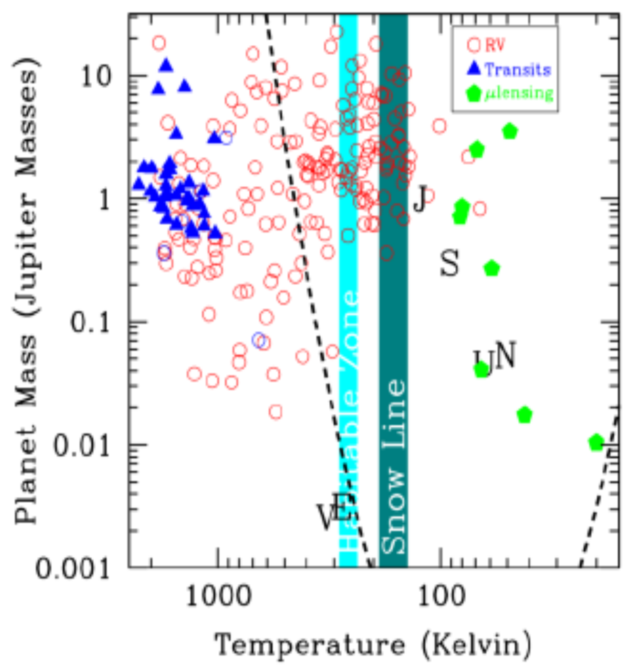
- Original Observing Strategy: Surveys (OGLE, MOA) + Follow up Monitoring (uFun, PLANET)
- 2nd Generation Survey: Large Field + High Cadence Monitoring: MOA+Wise+OGLE-IV



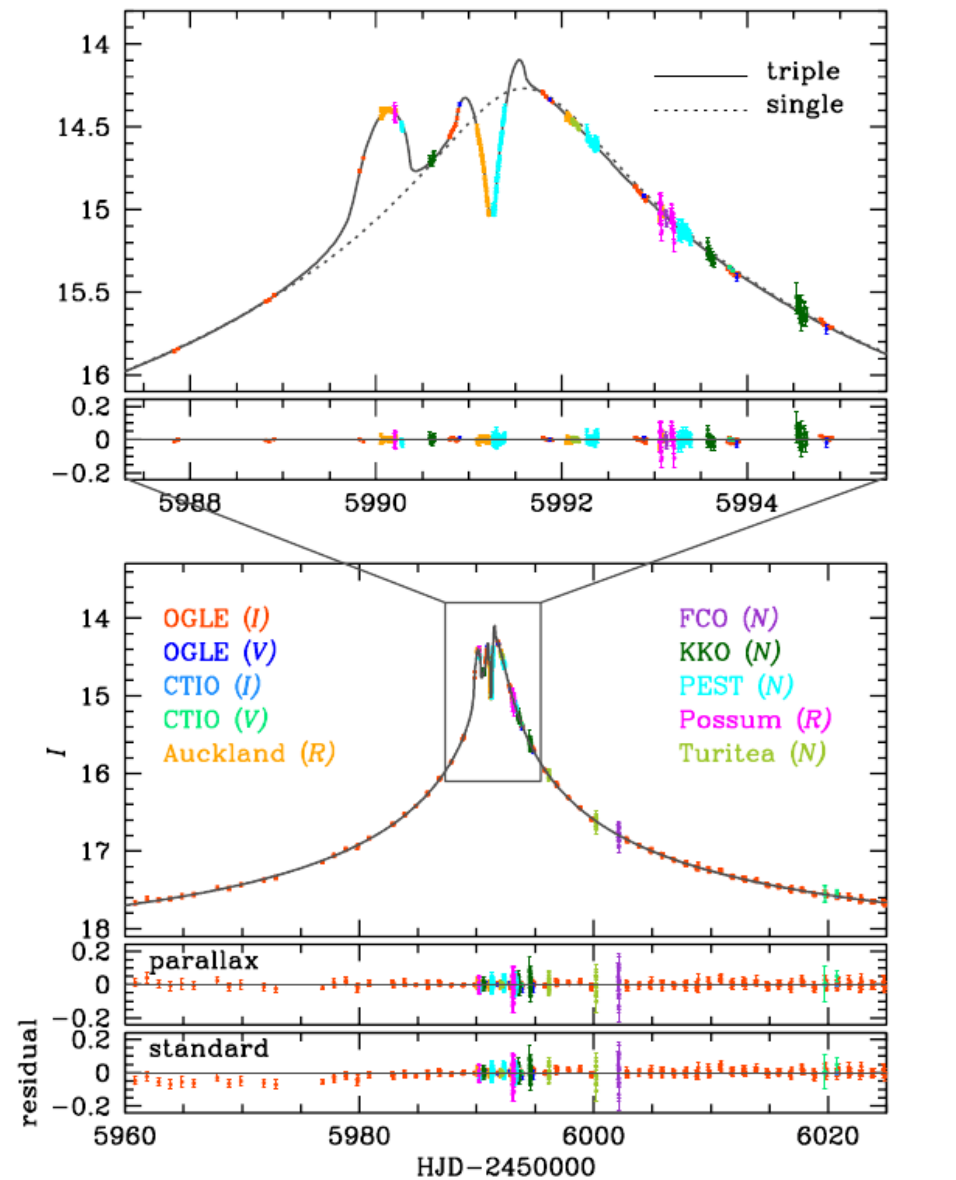
Main Potential of Microlensing

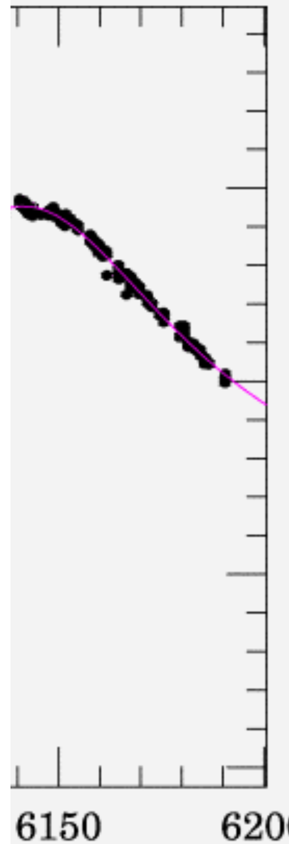
- Full status and characterization of exoplanets in regions located 0.5—10 AU from Host Stars (the regions at and

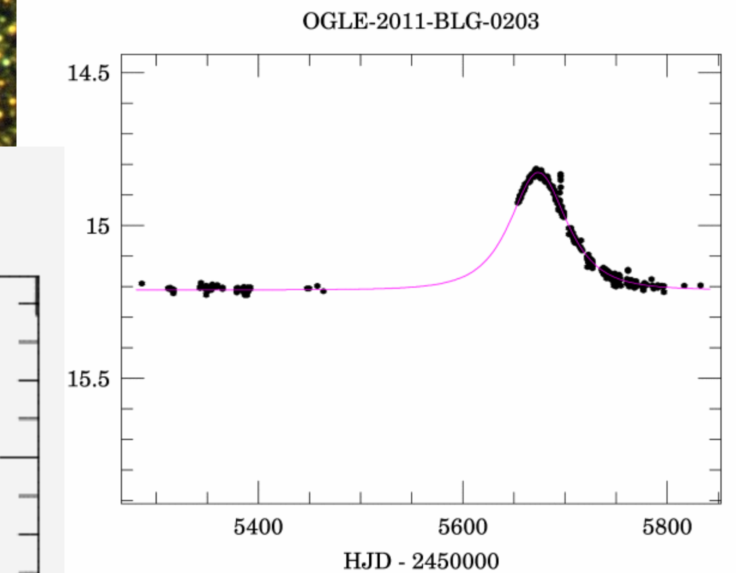


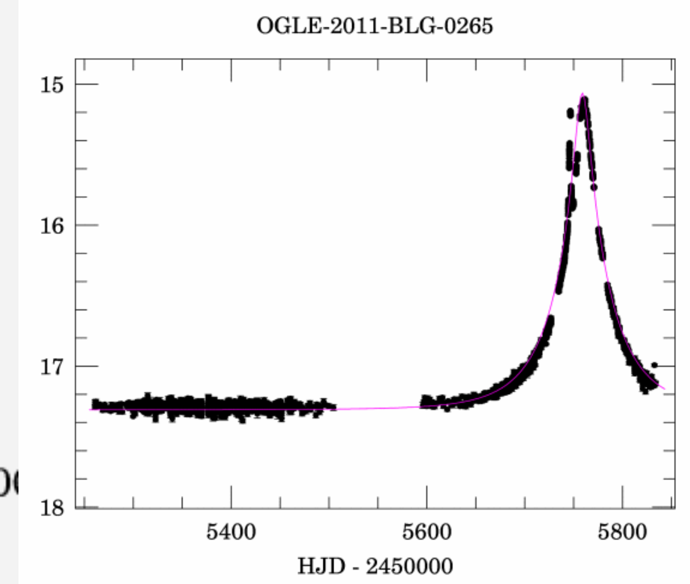


Planetary Microlensing in Practice

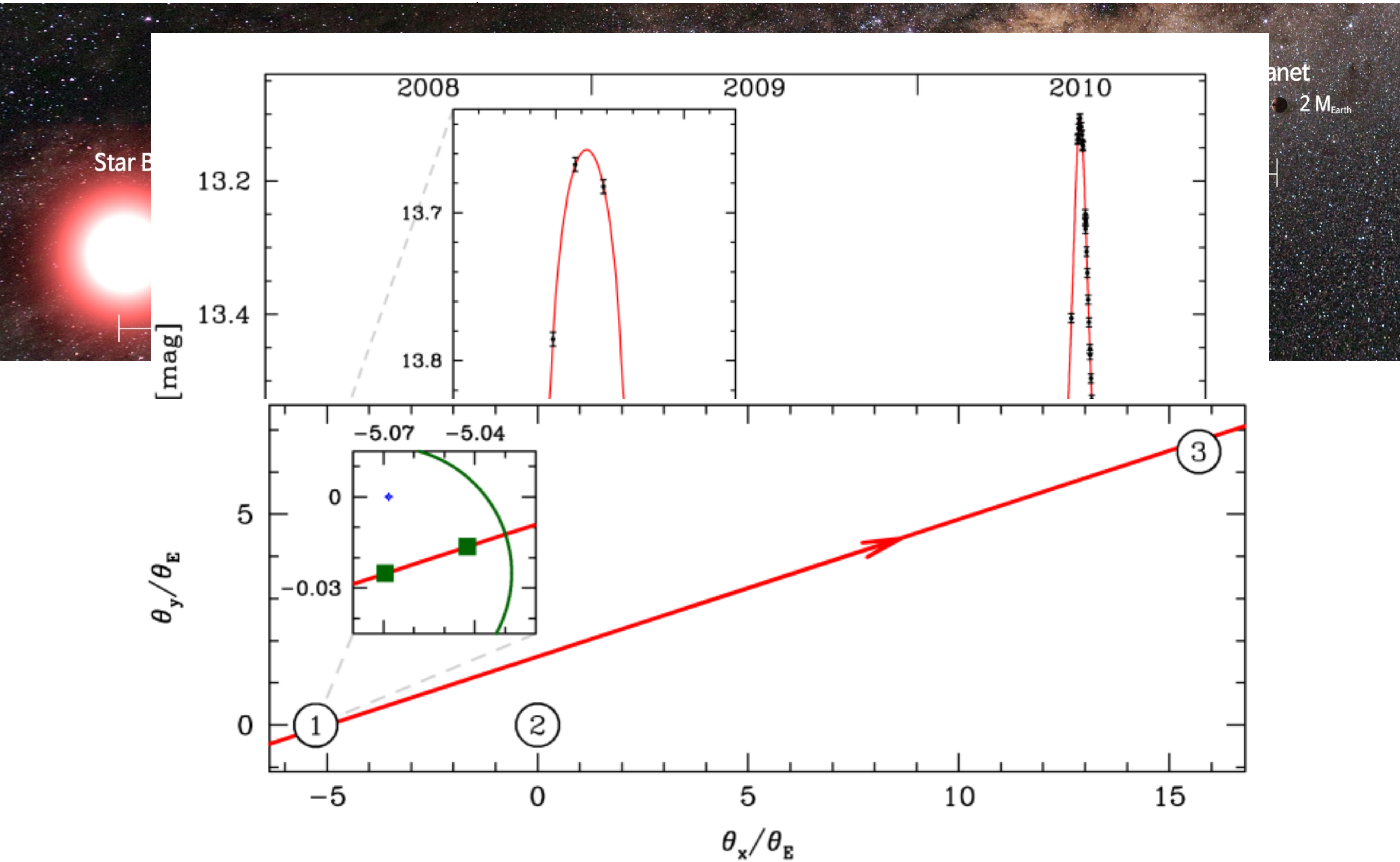






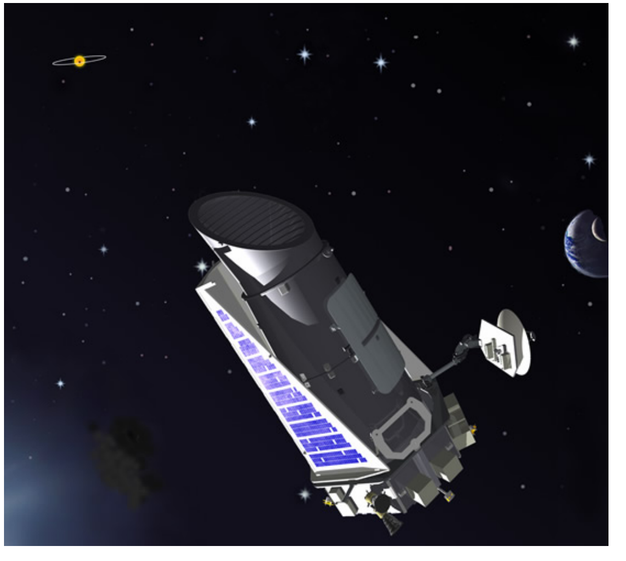


New Microlensing Discoveries

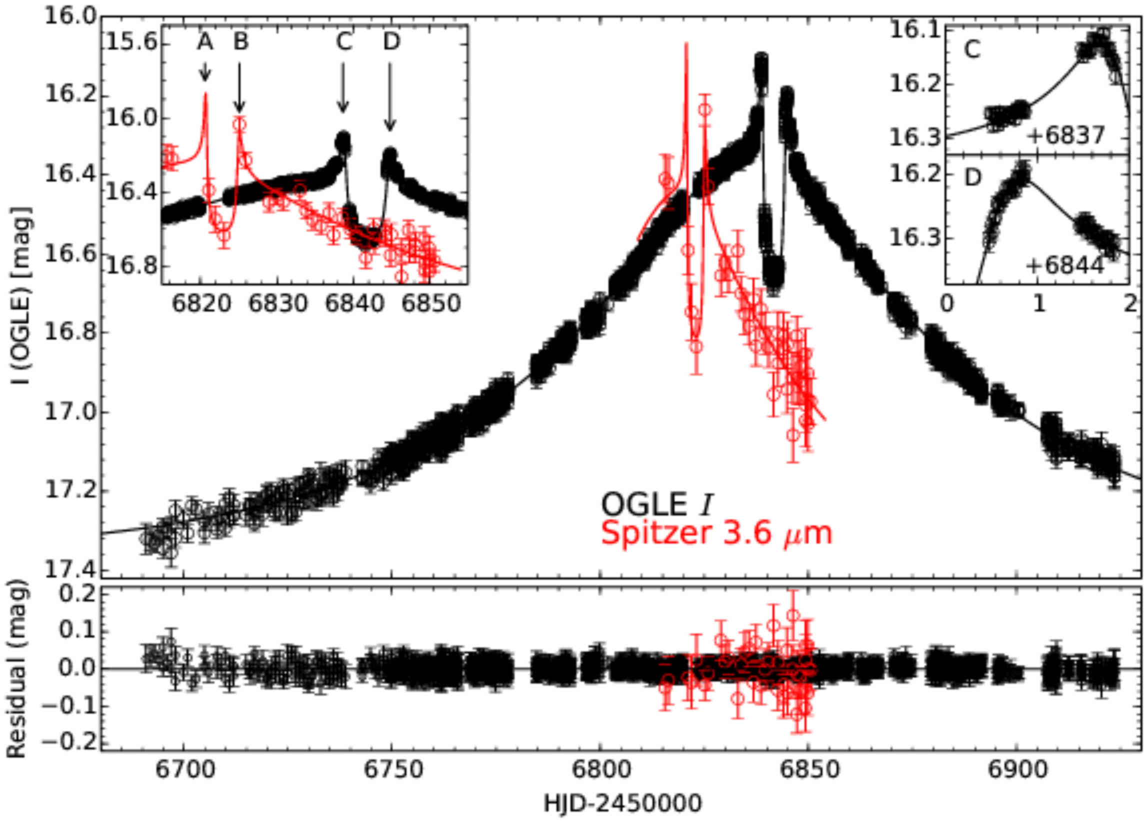


Prospects for Planetary Microlensing: Very Bright

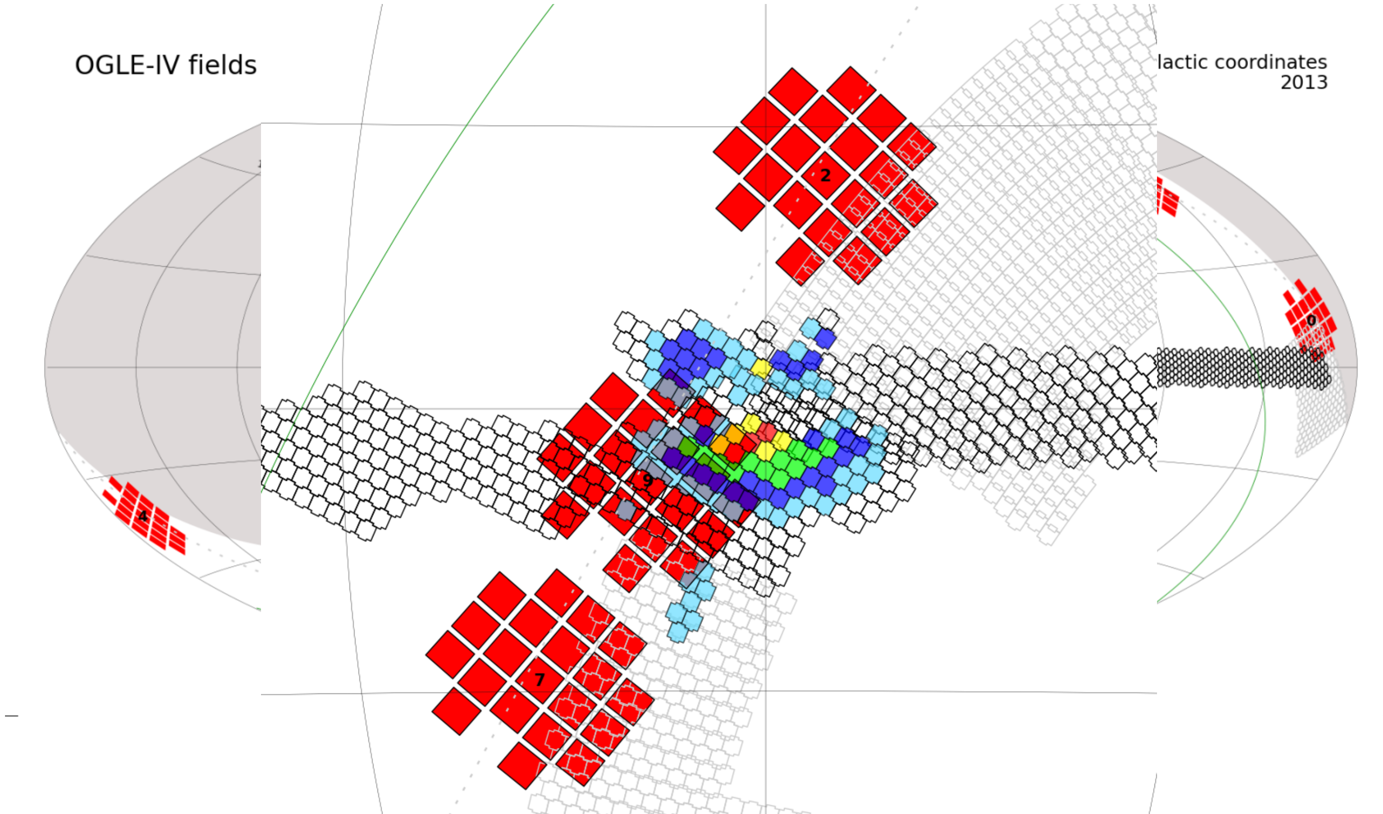
- Many New Discoveries every season
- New facilities: Bisdee Tier Tasmania, LCOGT Network, KMNet
- Spitzer, Kepler K2, Gaia
- Space Dark Energy Missions: WFIRST



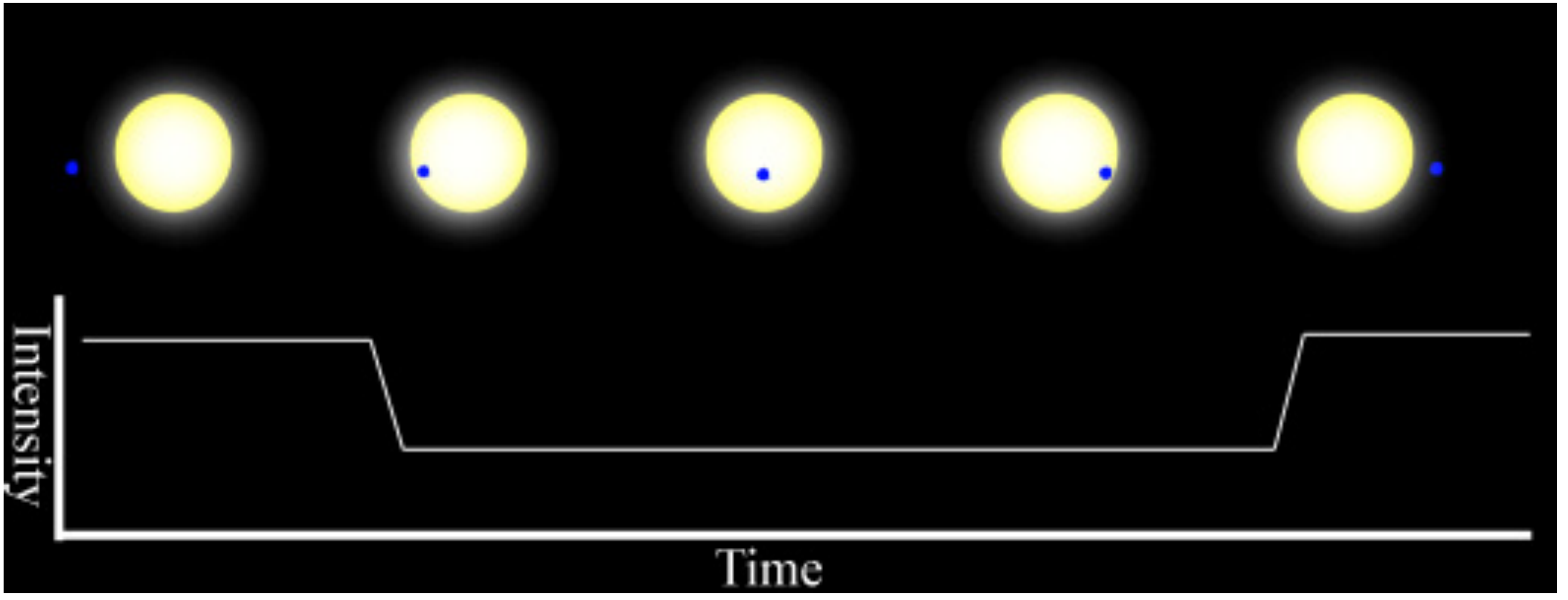
Spitzer Pilot Program



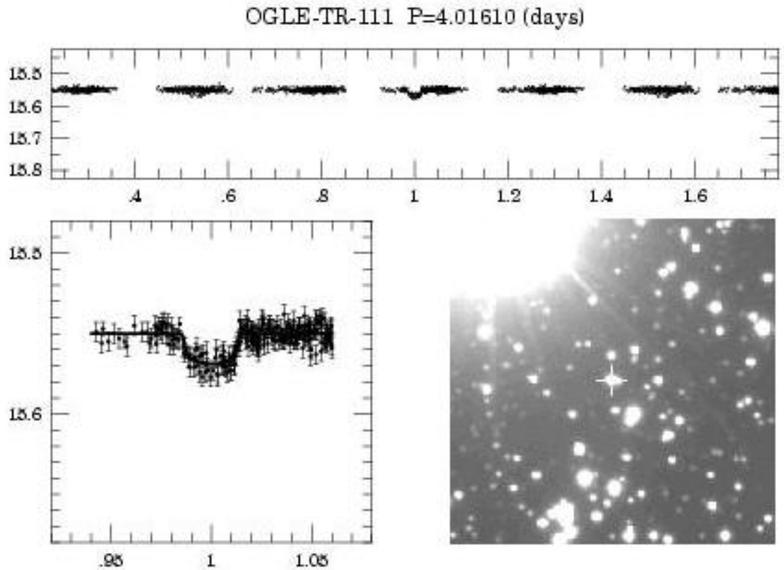
Kepler – K2

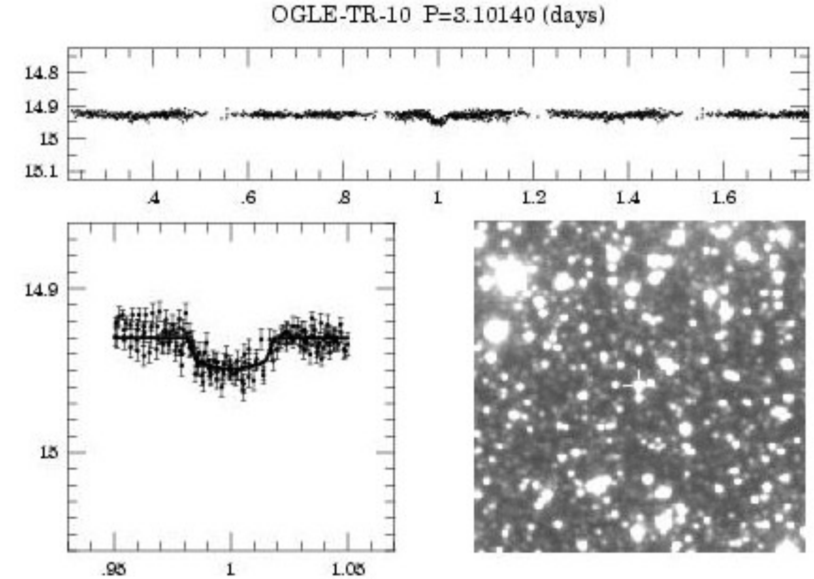


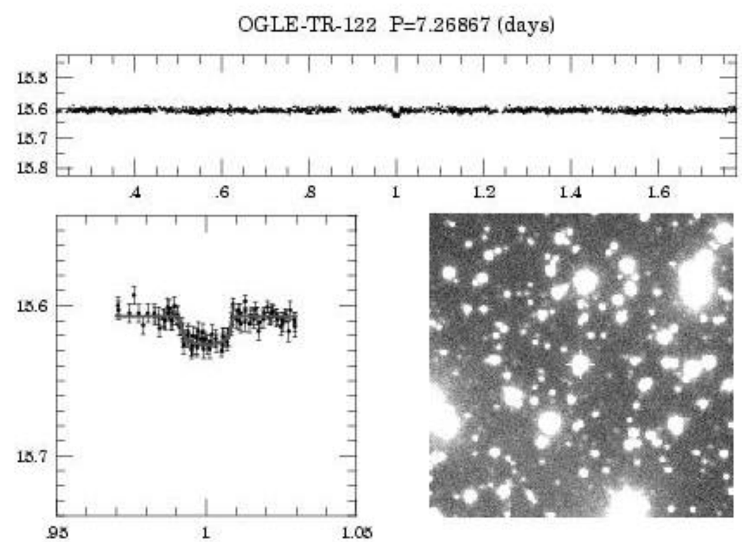
Transiting Planets



Transiting OGLE Exoplanets (2001– 2004)







OGLE Variable Star Collection

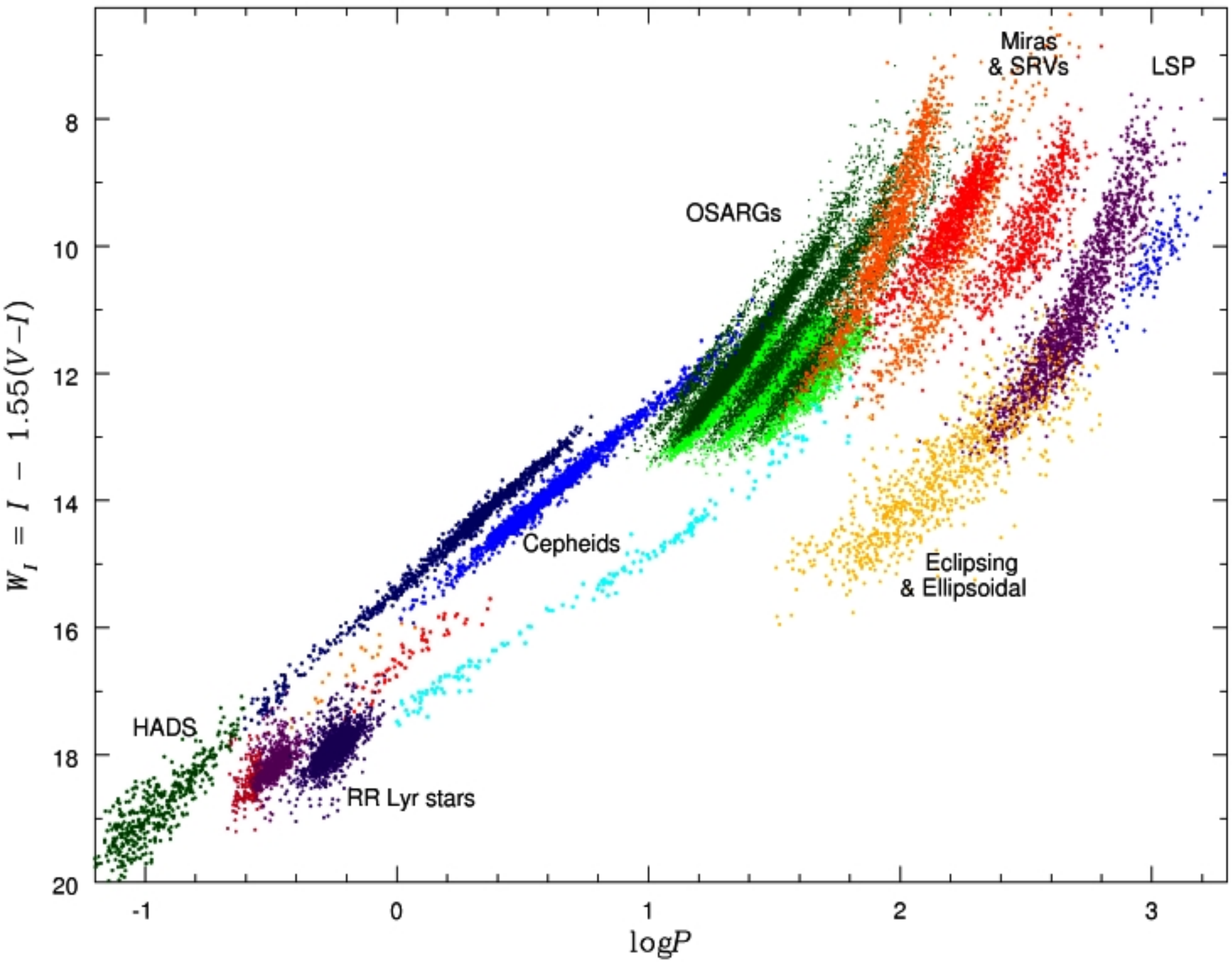
OIII-CVS: OGLE-III Catalog of Variable Stars

(Soszyński *et al*. 2013, *Acta Astronomica* 63, 21; Part XV)

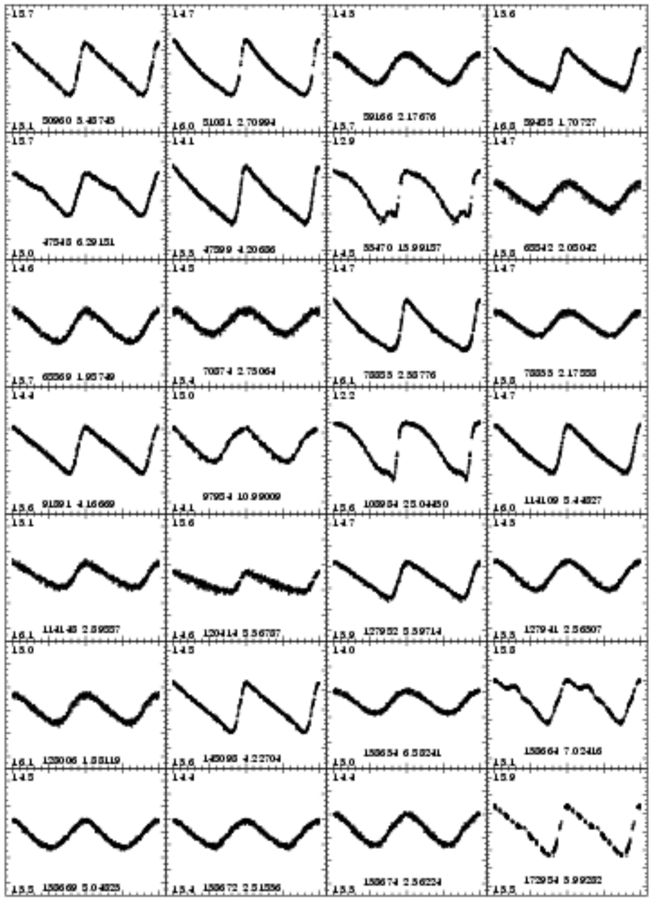
- LMC: 3361 Classical Cepheids, 280 Pop. II Cepheids, 24906 RR Lyrae stars, 2786 Delta Scuti, 91995 LPVs, 26121 Eclipsing Binaries
- SMC: 4630 Classical Cepheids, 43 Pop II Cepheids, 2475 RR Lyrae stars, 19384 LPVs
- Galactic Bulge: 16836 RR Lyrae (~400 from SGR Dwarf Galaxy), 32 Classical Cepheids, 357 Pop II Cepheids, 232406 LPVs
- Galactic Disk: ~30000
- Total > 450000

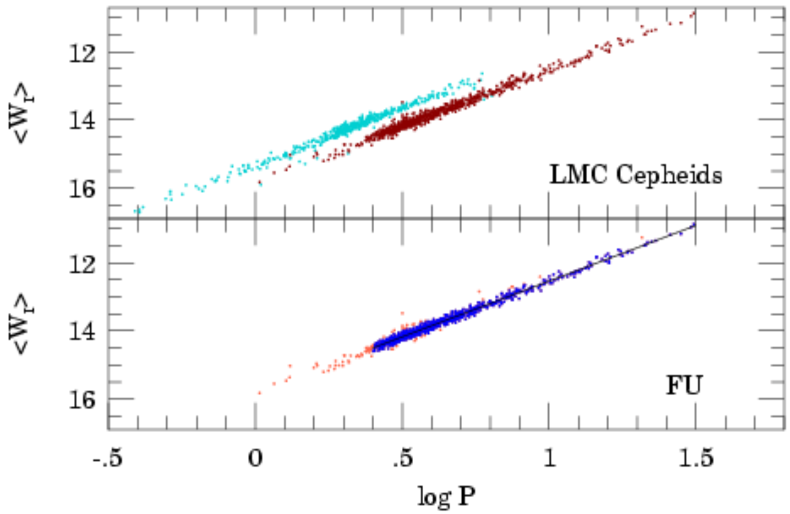
OGLE-IV: Many more. E.g. MS: ~9500 Cepheids, ~46000 RR Lyrae. GB: >38000 RR Lyrae. Time range of variability: minutes to decades

OGLE Pulsating Stars



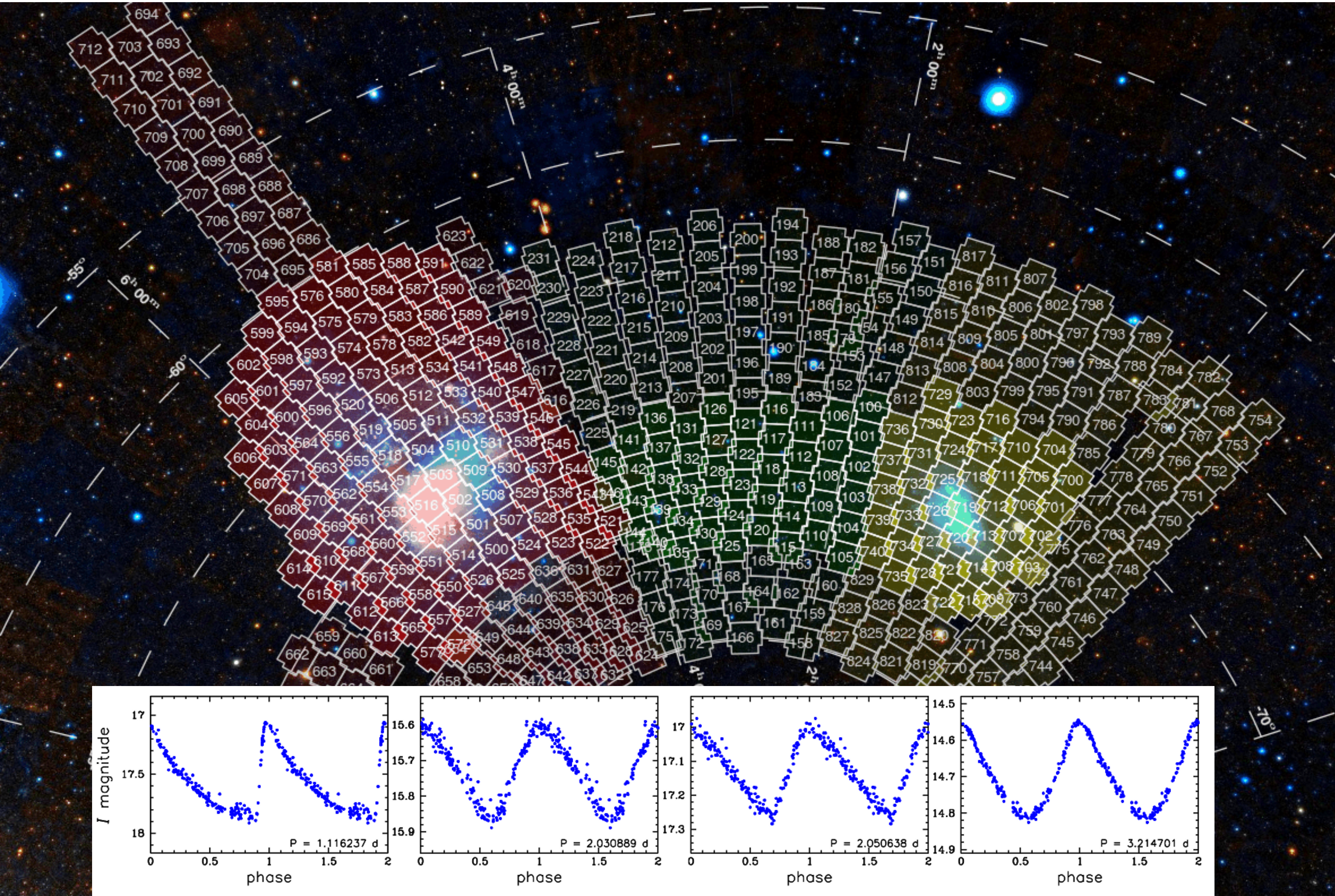
Cepheids in the MCs



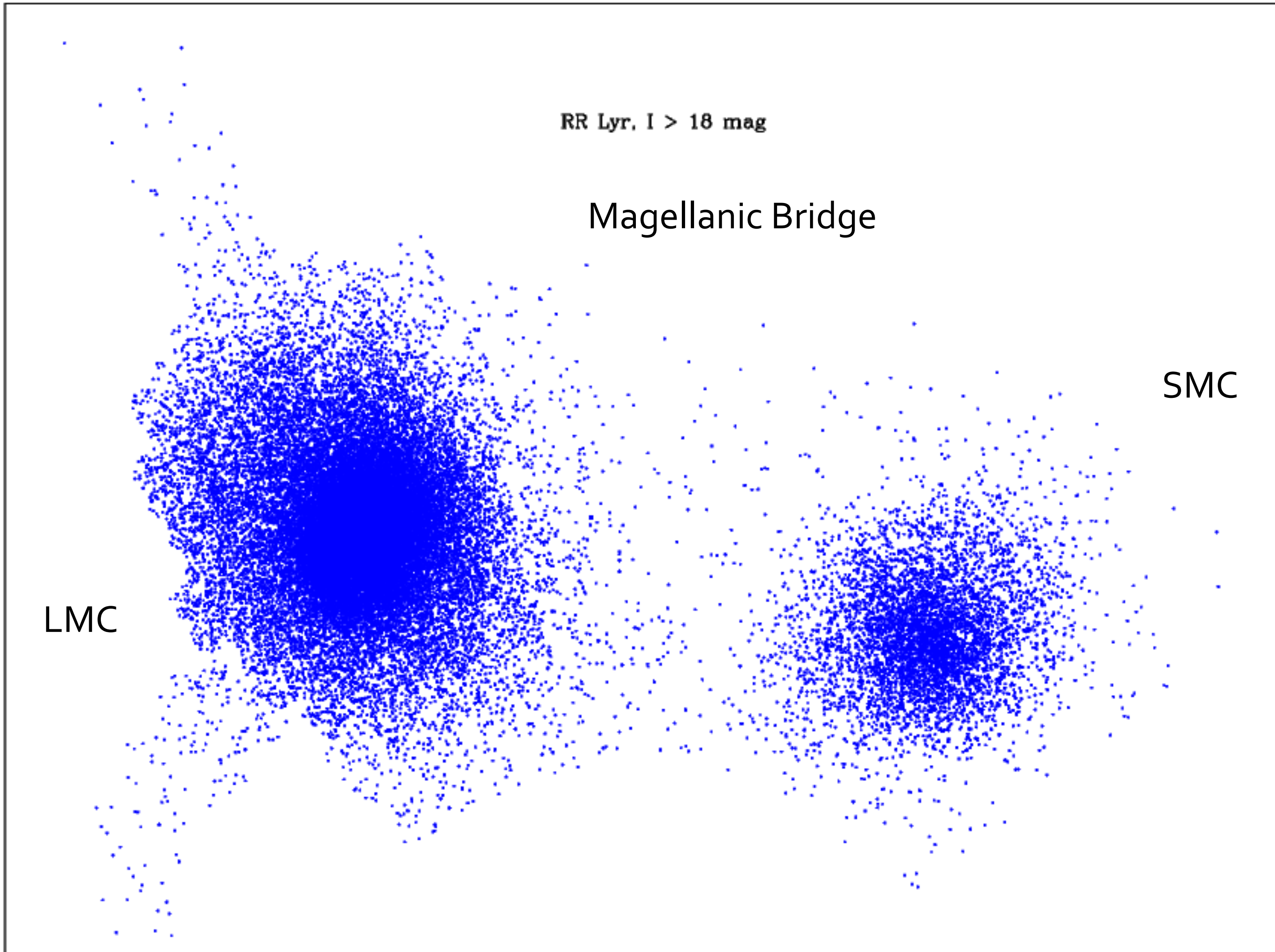


Hubble constant determination is based on OGLE PL relations

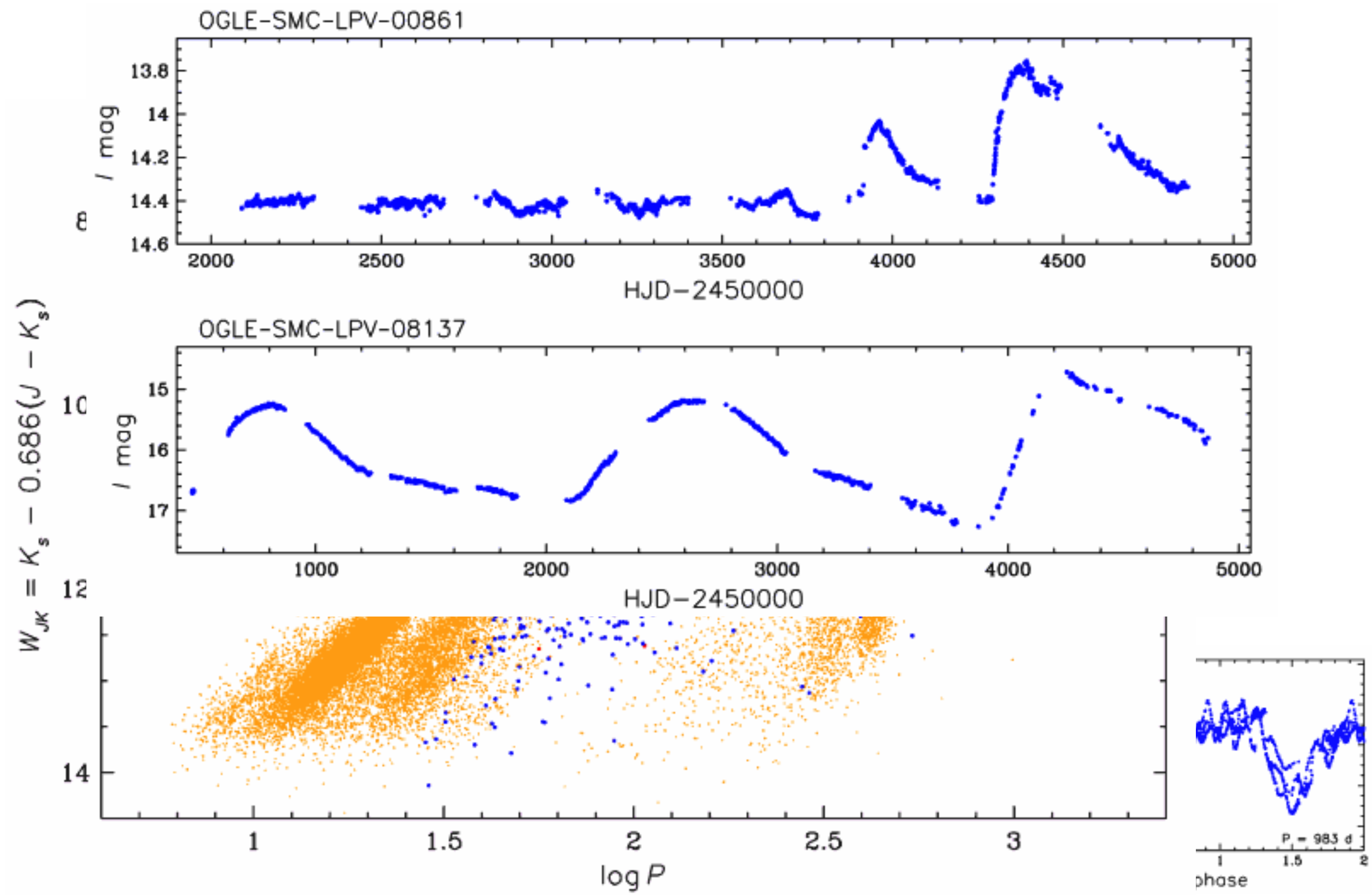
Classical Cepheids in the Magellanic Clouds



RR Lyrae Stars in the Magellanic Clouds

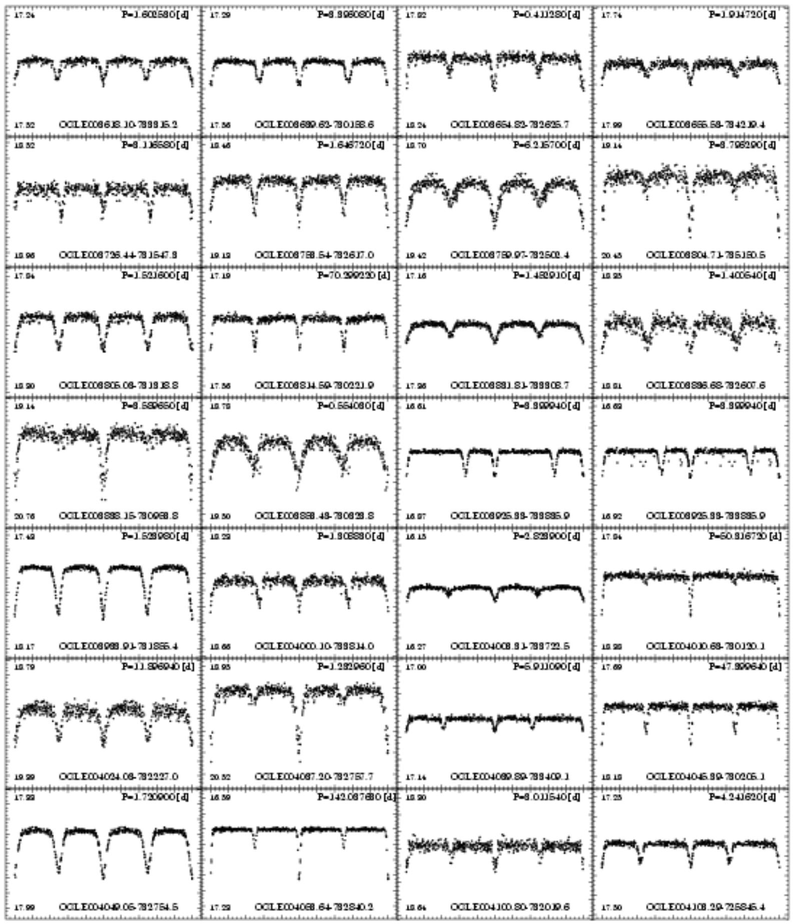


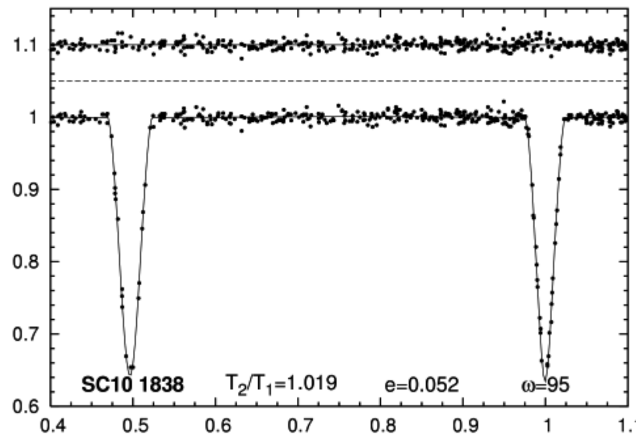
MC: LPVs

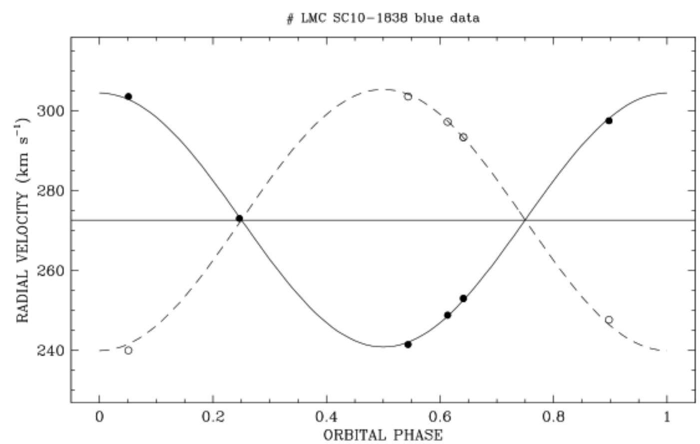


OGLE-SMC-LPV-00861
I mag
HJD−2450000
OGLE-SMC-LPV-08137
I mag
HJD−2450000
$W_{JK} = K_s - 0.686(J - K_s)$
log P
phase
P = 983 d

Eclipsing Stars
(Great distance indicators)







Distance to the LMC

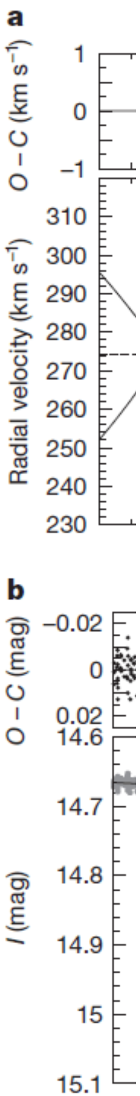


Figure 1 | C
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LETTER

doi:10.1038/nature11878

An eclipsing-binary distance to the Large Magellanic Cloud accurate to two per cent

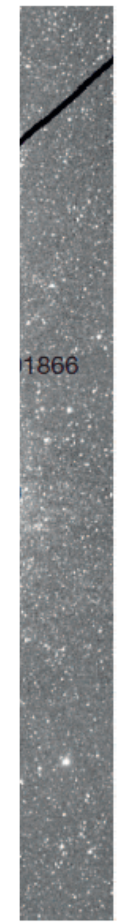
G. Pietrzyński[1,2], D. Graczyk[1], W. Gieren[1], I. B. Thompson[3], B. Pilecki[1,2], A. Udalski[2], I. Soszyński[2], S. Koz½owski[2], P. Konorski[2], K. Suchomska[2], G. Bono[4,5], P. G. Prada Moroni[6,7], S. Villanova[1], N. Nardetto[8], F. Bresolin[9], R. P. Kudritzki[9], J. Storm[10], A. Gallenne[1], R. Smolec[11], D. Minniti[12,13], M. Kubiak[2], M. Szymański[2], R. Poleski[2], Ł. Wyrzykowski[2], K. Ulaczyk[2], P. Pietrukowicz[2], M. Górski[2] & P. Karczmarek[2]

In the era of precision cosmology, it is essential to determine the Hubble constant to an accuracy of three per cent or better[1,2]. At present, its uncertainty is dominated by the uncertainty in the distance to the Large Magellanic Cloud (LMC), which, being our nearest galaxy, serves as the best anchor point for the cosmic distance scale[2,3]. Observations of eclipsing binaries offer a unique opportunity to measure stellar parameters and distances precisely and accurately[4,5]. The eclipsing-binary method was previously applied to the LMC[6,7], but the accuracy of the distance results was lessened by the need to model the bright, early-type systems used in those studies. Here we report determinations of the distances to eight long-period, late-type eclipsing systems in the LMC, composed of cool, giant stars. For these systems, we can accurately measure both the linear and the angular sizes of their components and avoid the most important problems related to the hot, early-type systems. The LMC distance that we derive from these systems (49.97 ± 0.19 (statistical) ± 1.11 (systematic) kiloparsecs) is accurate to 2.2 per cent and provides a firm base for a 3-per-cent determination of the Hubble constant, with prospects for improvement to 2 per cent in the future.

Silla, together with near-infrared photometry obtained with the 3.5-m New Technology Telescope located on La Silla.

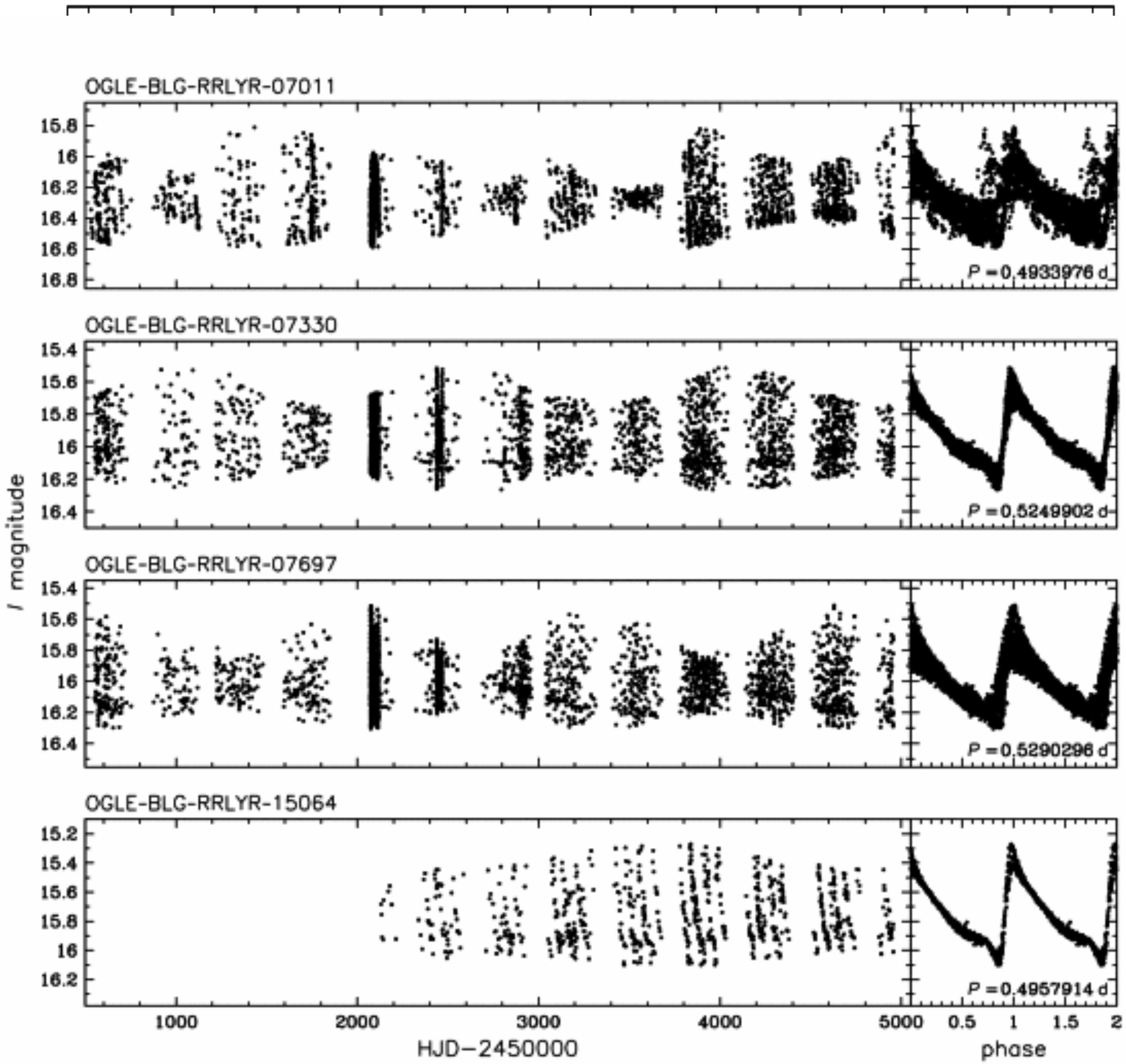
The spectroscopic and OGLE V- and I-band photometric observations of the binary systems were then analysed using the 2007 version of the standard Wilson–Devinney code[14,15], in the same way as in our recent work on a similar system in the Small Magellanic Cloud[9]. Realistic errors in the derived parameters of our systems were obtained from extensive Monte Carlo simulations (Fig. 2). The astrophysical parameters all the observed eclipsing binaries were determined with an accuracy of a few per cent (Supplementary Tables 2–9).

For late-type stars, we can use the very accurately calibrated (2%) relation between their surface brightness and $V-K$ colour to determine their angular sizes from optical (V) and near-infrared (K) photometry[16]. From this surface-brightness/colour relation (SBCR), we can derive angular sizes of the components of our binary systems directly from the definition of the surface brightness. Therefore, the distance can be measured by combining the angular diameters of the binary components derived in this way with their corresponding linear dimensions obtained from the analysis of the spectroscopic and photometric data. The distances measured with this very simple but accur-



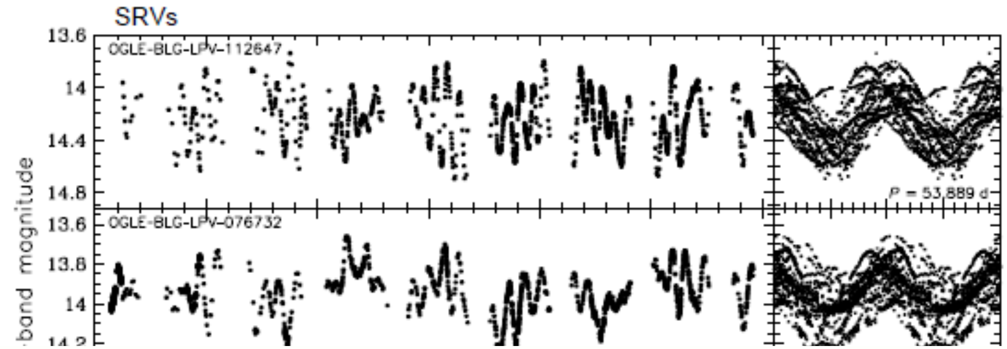
Most of

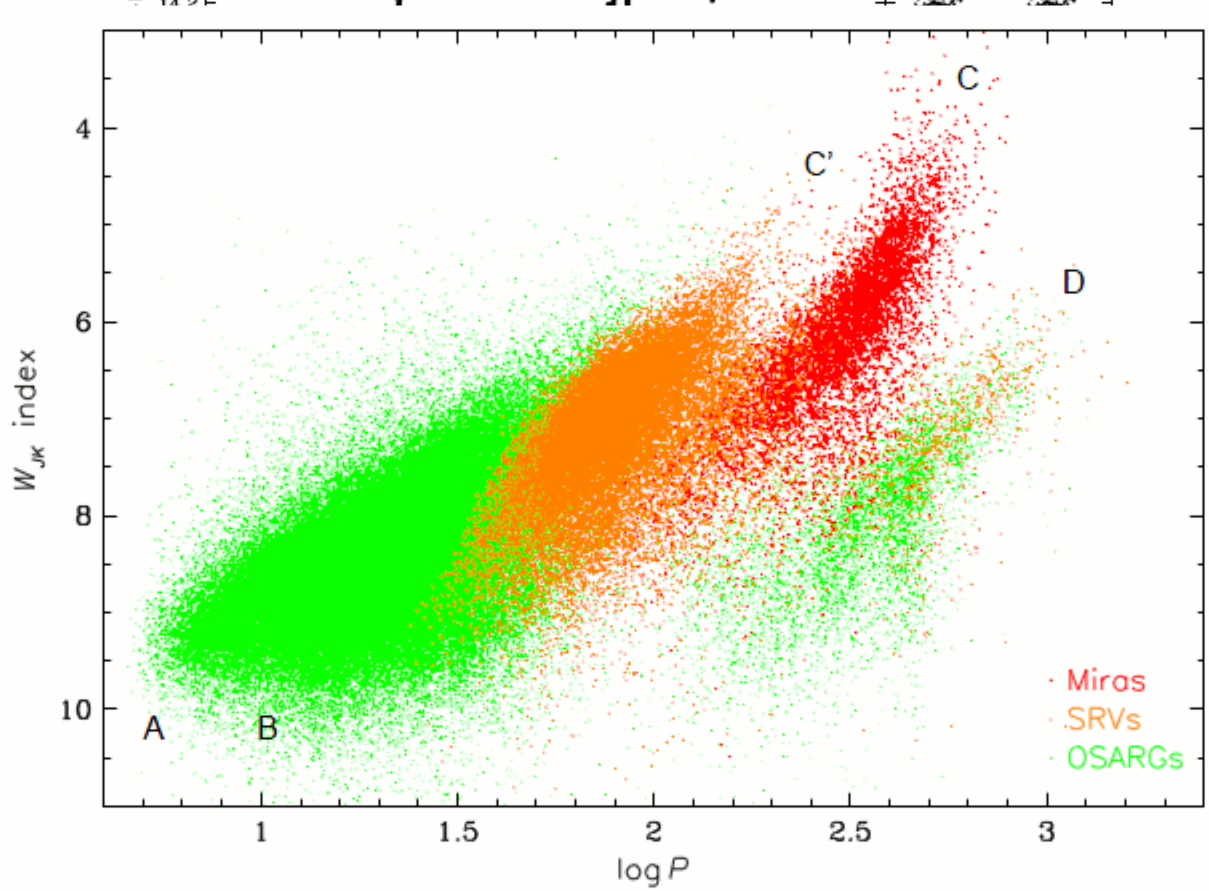
GB RR Lyrae



OGLE-BLG-RRLYR-07011
P = 0.4933976 d
OGLE-BLG-RRLYR-07330
P = 0.5249902 d
OGLE-BLG-RRLYR-07697
P = 0.5290296 d
OGLE-BLG-RRLYR-15064
P = 0.4957914 d
I magnitude
HJD−2450000
phase

GB LPVs

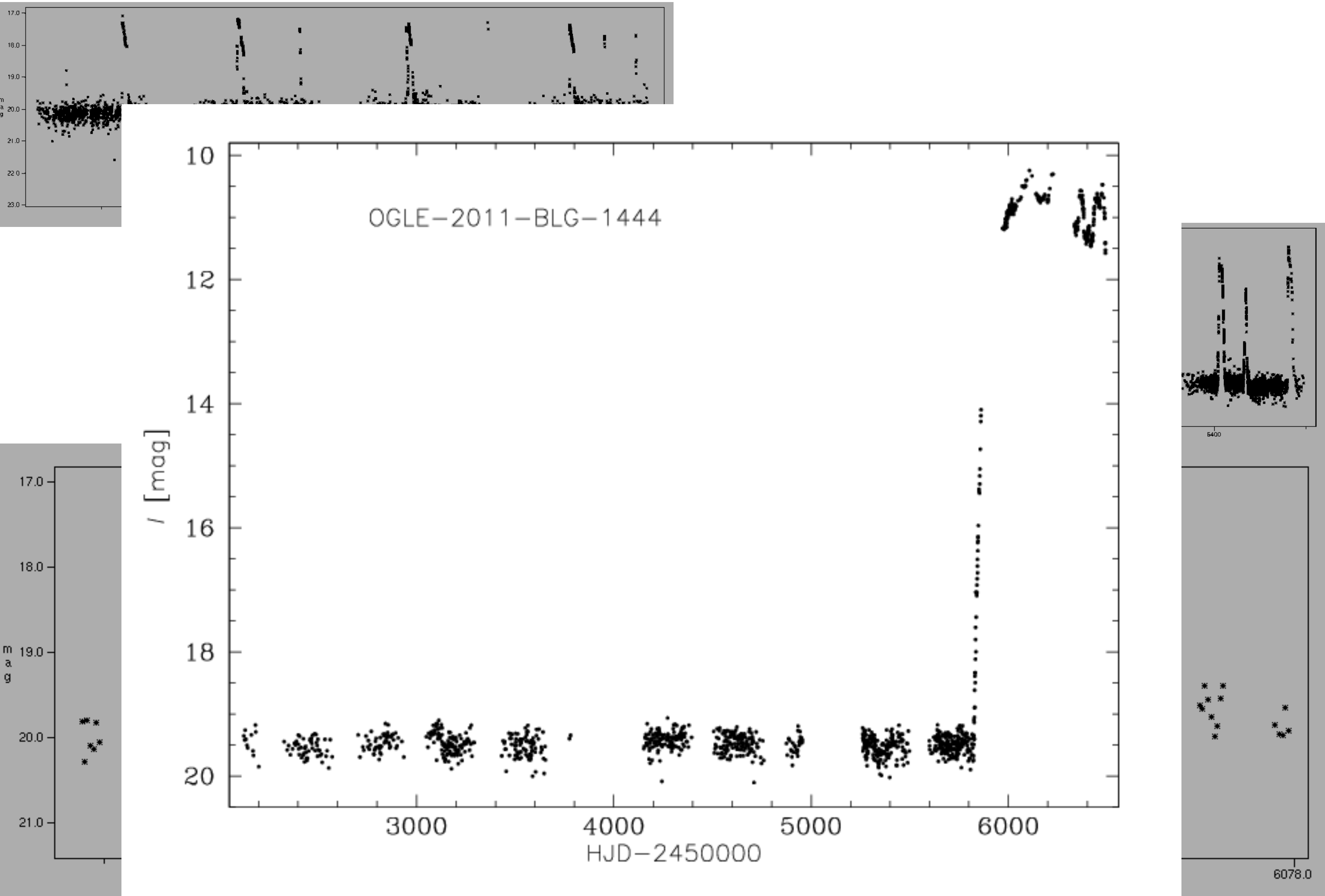

SRVs
OGLE-BLG-LPV-112647
OGLE-BLG-LPV-076732
P = 53.889 d
band magnitude
13.6
14
14.4
14.8
13.6
13.8
14


C
C'
D
A
B
Miras
SRVs
OSARGs
W_{JK} index
log P
4
6
8
10
1
1.5
2
2.5
3

2014 Transient Inventory

- ~2000 Microlensing Events
- ~150 SNe
- Three Novae
- Symbiotic Nova (archive data)
- Hundreds of other type CVs

Cataclysmic Variables

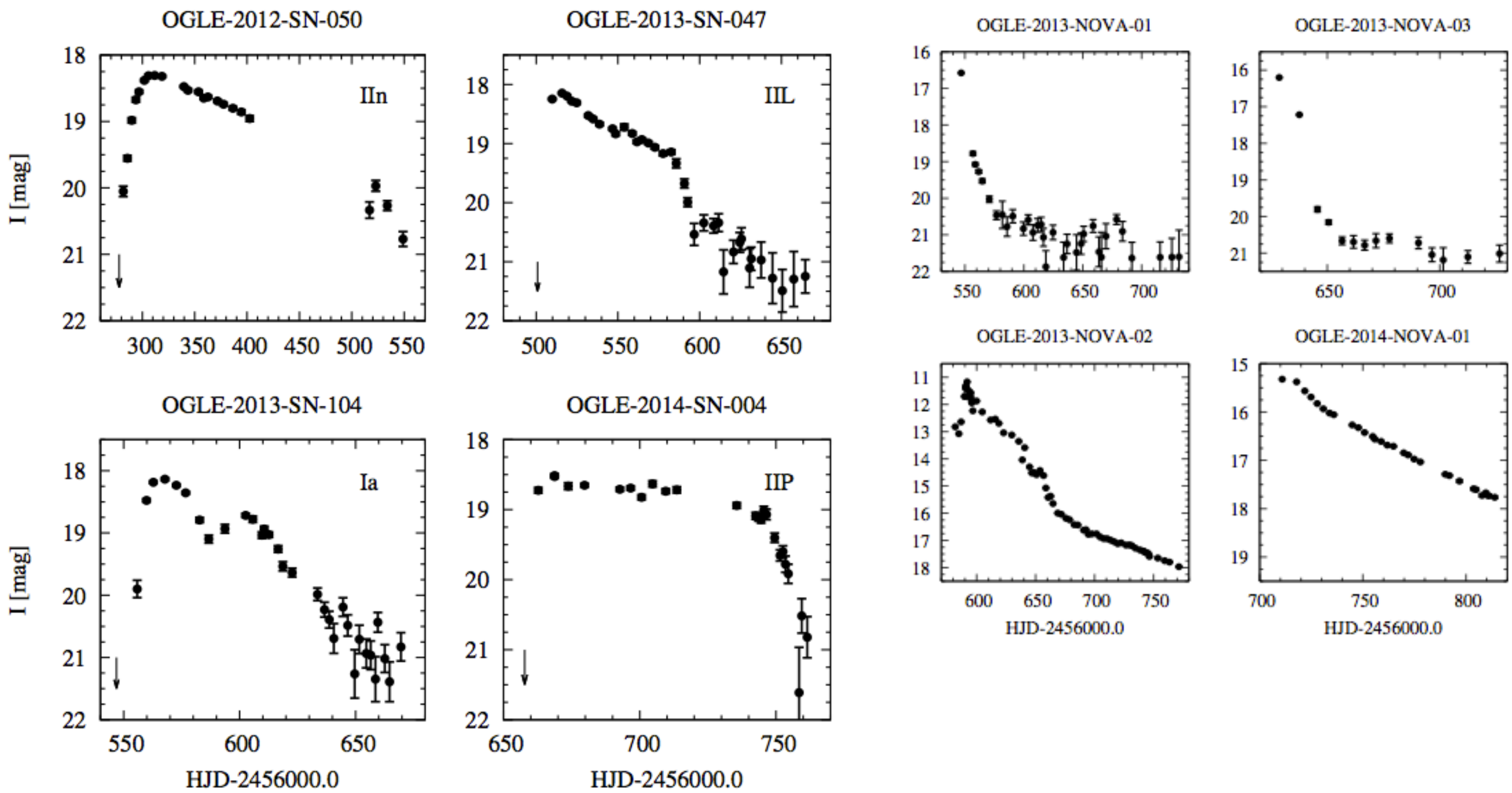


SUPERNOVAE IN OGLE

since 2012

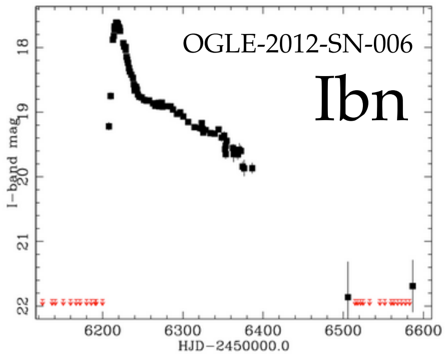
150/year in 650 sq.deg.

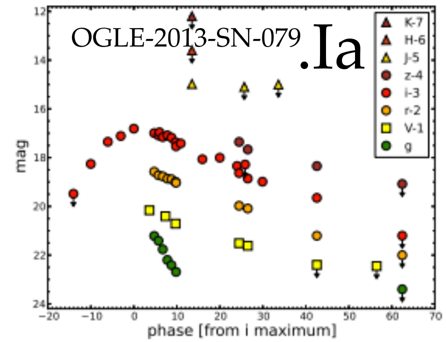
4 days mean sampling



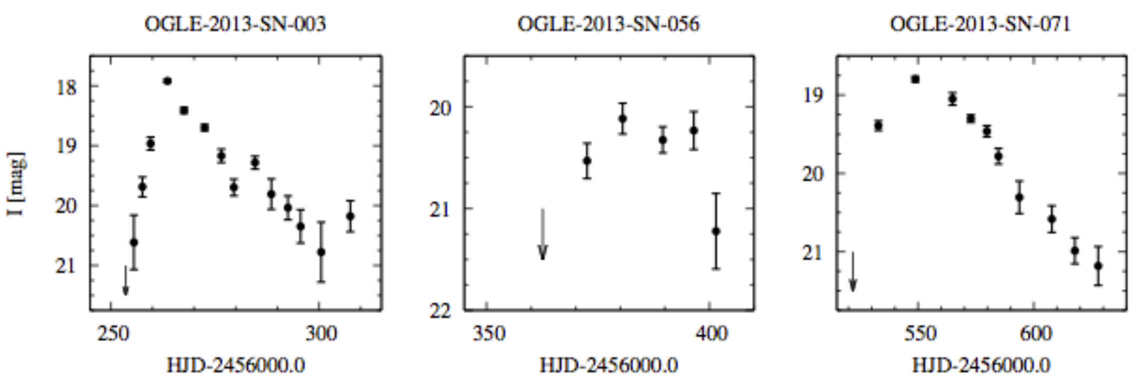
http://ogle.astrouw.edu.pl/ogle4/transients/

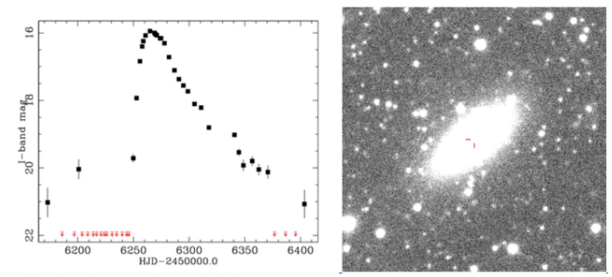
SUPERNOVAE IN OGLE





Spectral follow-up:
PESSTO
Carnegie SN Project
AAT



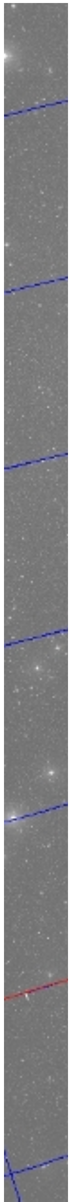


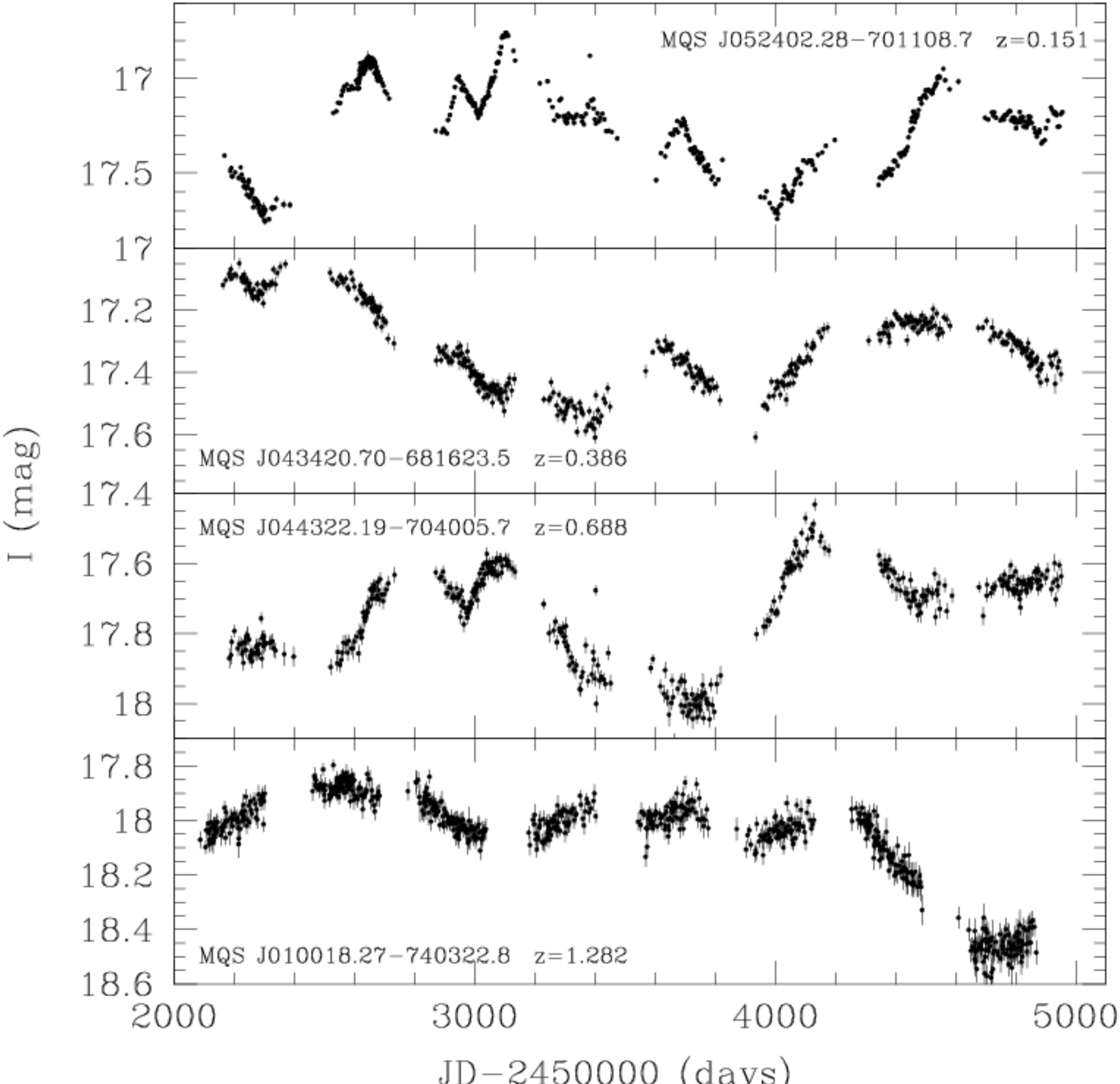
OGLE-2012-SN-040 Ra,Dec= 6:07:01.59 -69:21:17.1 HJD_max= 6264.81780 2012-12-03.318 LMC568.14.15N

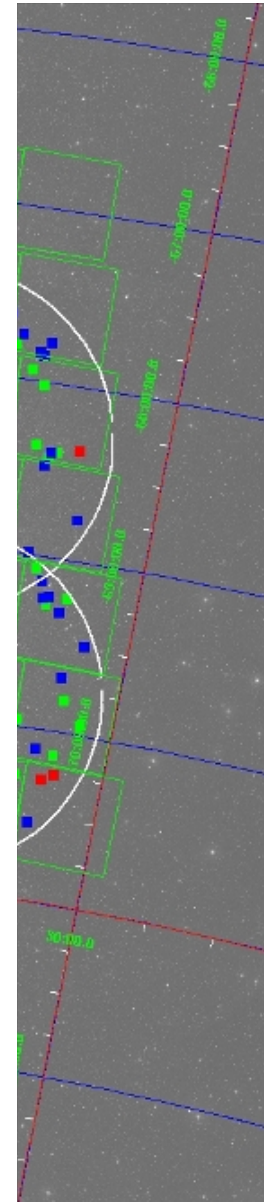
http://ogle.astrouw.edu.pl/ogle4/transients/

SiIV [OIII]

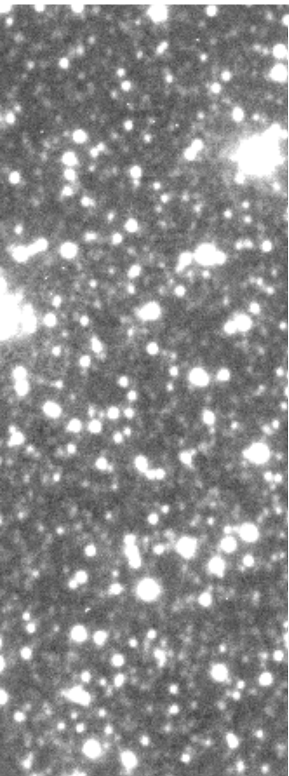
uds

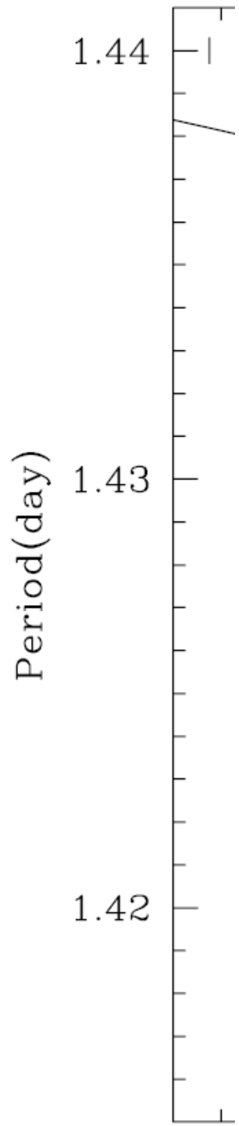


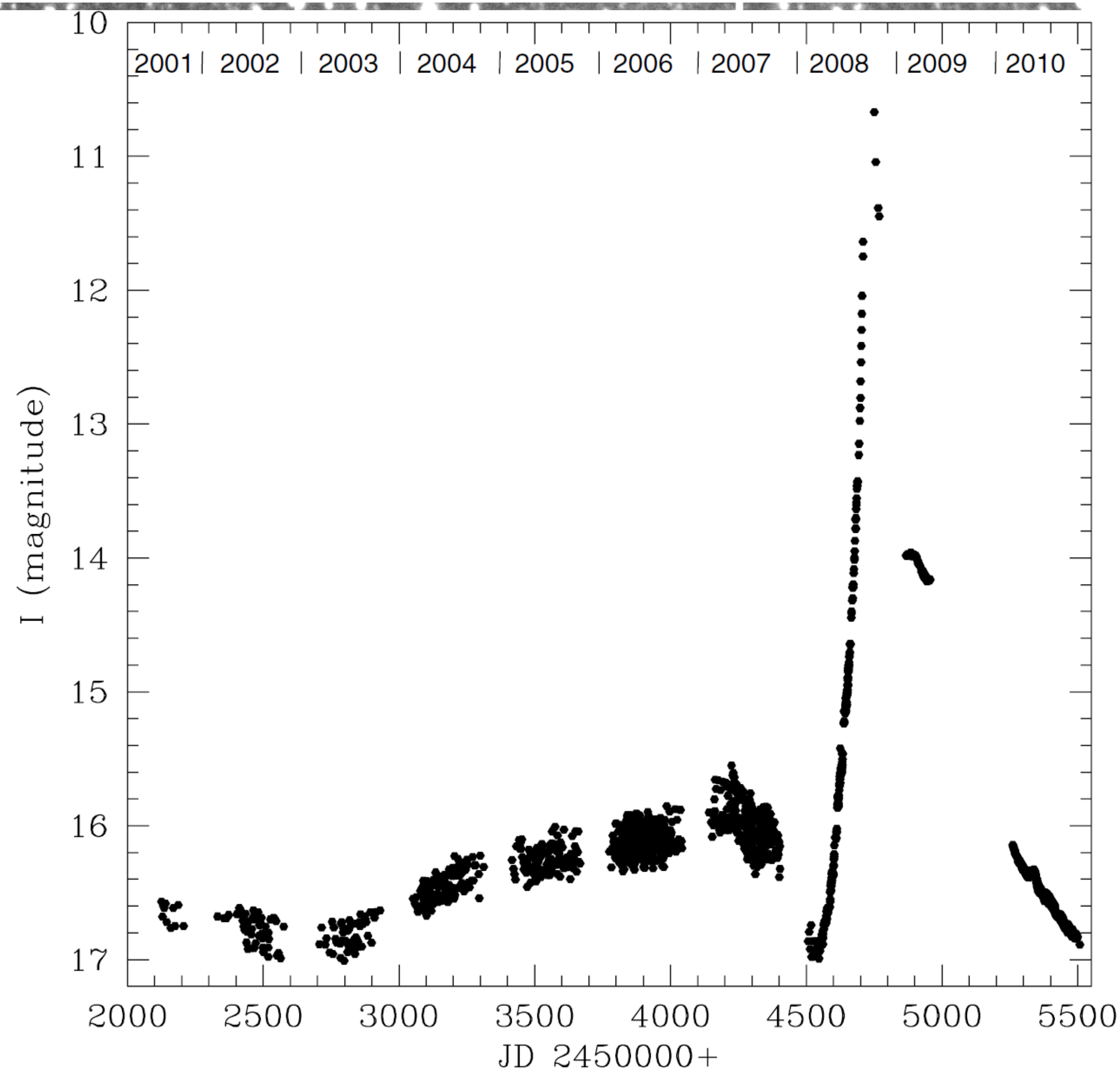


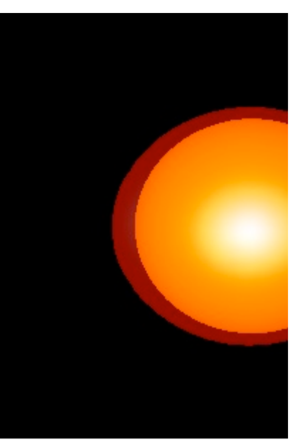


Nova Scorpii 2008 (V1309 SCO) – OGLE









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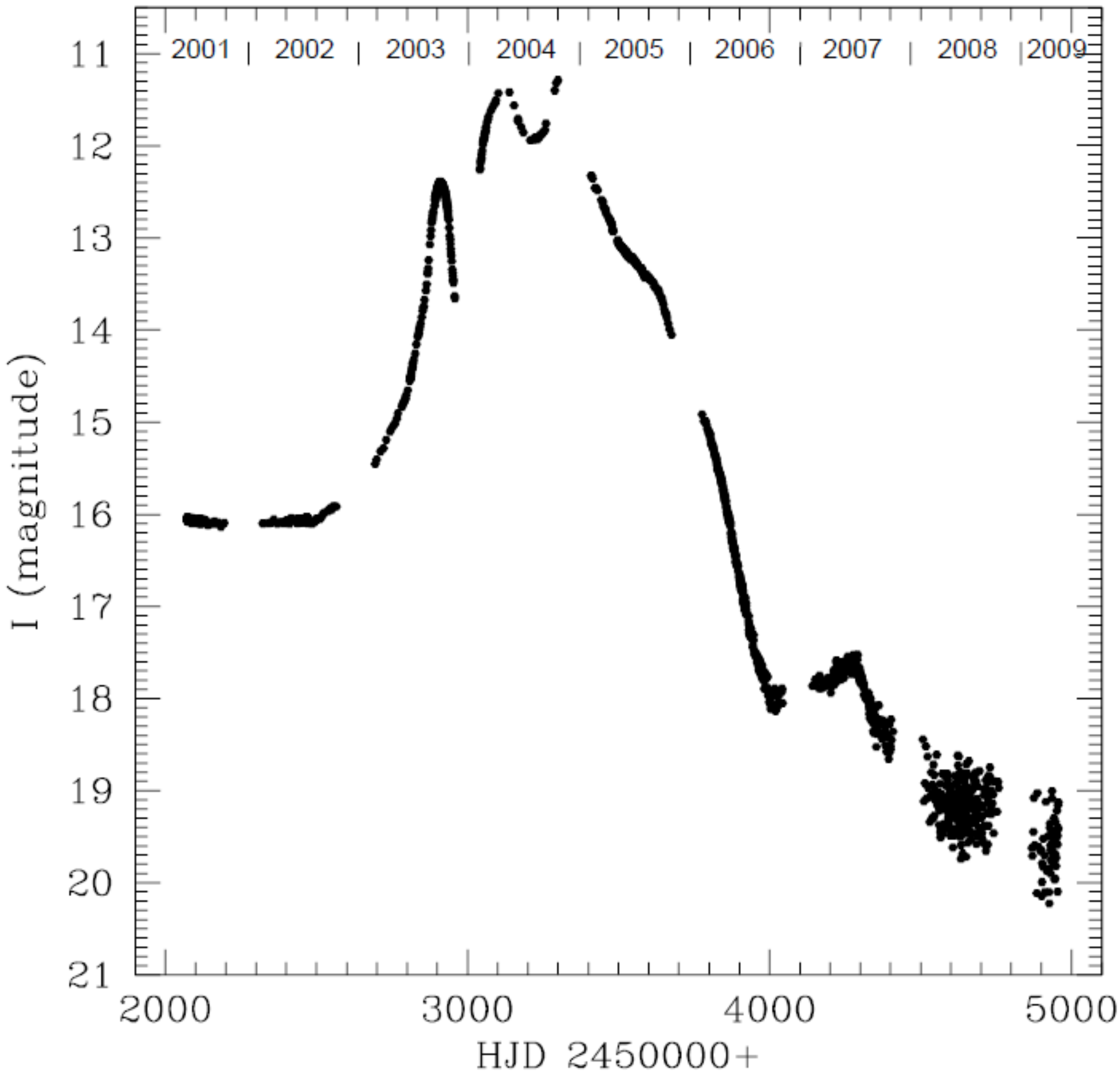

2001
2002
2003
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2005
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2007
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2009
I (magnitude)
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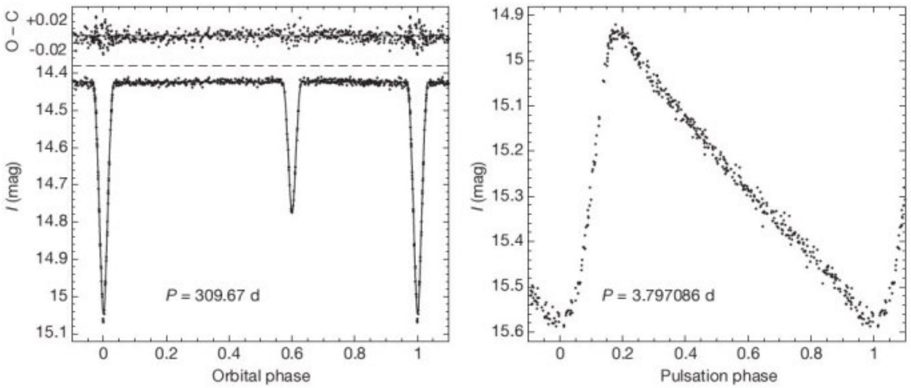
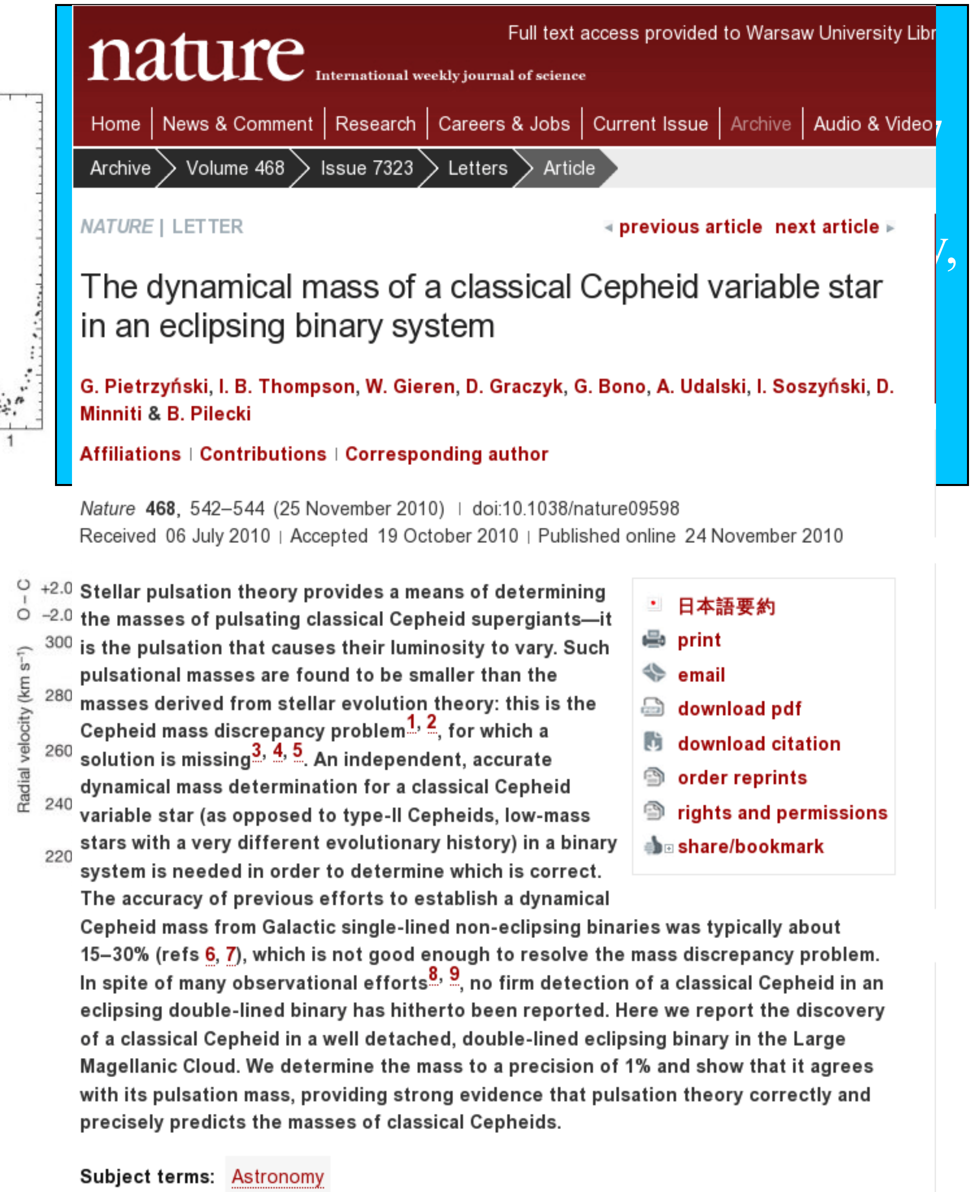
21
2000
3000
4000
5000
HJD 2450000+

OGLE-CEP-0227





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NATURE | LETTER

previous article next article

The dynamical mass of a classical Cepheid variable star in an eclipsing binary system

G. Pietrzyński, I. B. Thompson, W. Gieren, D. Graczyk, G. Bono, A. Udalski, I. Soszyński, D. Minniti & B. Pilecki

Affiliations | Contributions | Corresponding author

Nature **468**, 542–544 (25 November 2010) | doi:10.1038/nature09598
Received 06 July 2010 | Accepted 19 October 2010 | Published online 24 November 2010

Stellar pulsation theory provides a means of determining the masses of pulsating classical Cepheid supergiants—it is the pulsation that causes their luminosity to vary. Such pulsational masses are found to be smaller than the masses derived from stellar evolution theory: this is the Cepheid mass discrepancy problem[1, 2], for which a solution is missing[3, 4, 5]. An independent, accurate dynamical mass determination for a classical Cepheid variable star (as opposed to type-II Cepheids, low-mass stars with a very different evolutionary history) in a binary system is needed in order to determine which is correct. The accuracy of previous efforts to establish a dynamical Cepheid mass from Galactic single-lined non-eclipsing binaries was typically about 15–30% (refs 6, 7), which is not good enough to resolve the mass discrepancy problem. In spite of many observational efforts[8, 9], no firm detection of a classical Cepheid in an eclipsing double-lined binary has hitherto been reported. Here we report the discovery of a classical Cepheid in a well detached, double-lined eclipsing binary in the Large Magellanic Cloud. We determine the mass to a precision of 1% and show that it agrees with its pulsation mass, providing strong evidence that pulsation theory correctly and precisely predicts the masses of classical Cepheids.

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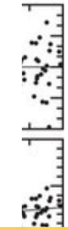
Subject terms: Astronomy

$M^{Ceph} = 4.14 \pm 0.05\ M_\odot$

$M^{Pul} = 3.98 \pm 0.29\ M_\odot$

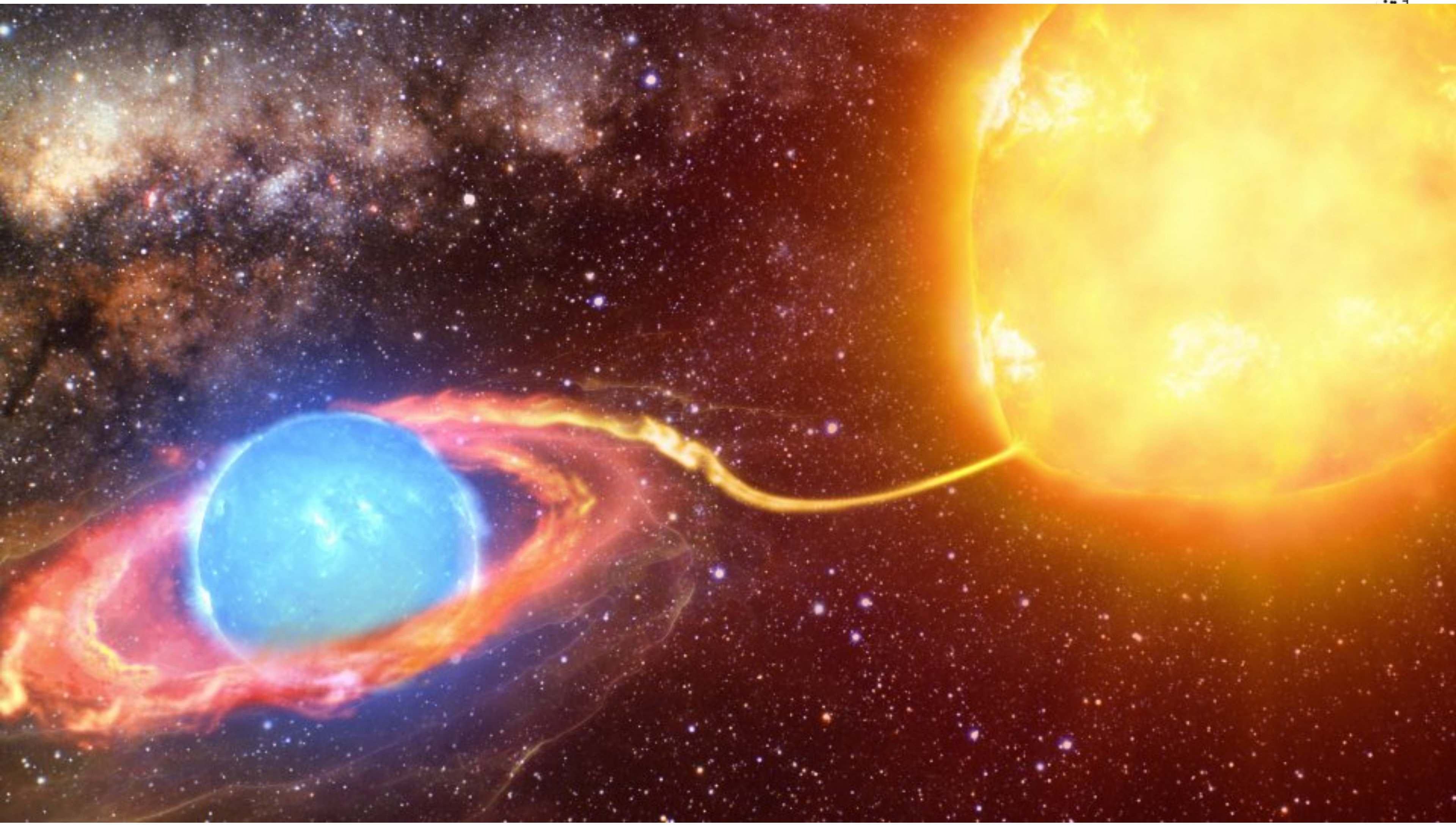
Cepheid pulsation mass in agreement with measured dynamical mass a

a

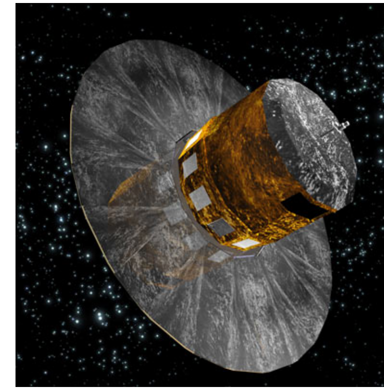


LETTER

doi:10.1038/nature10966

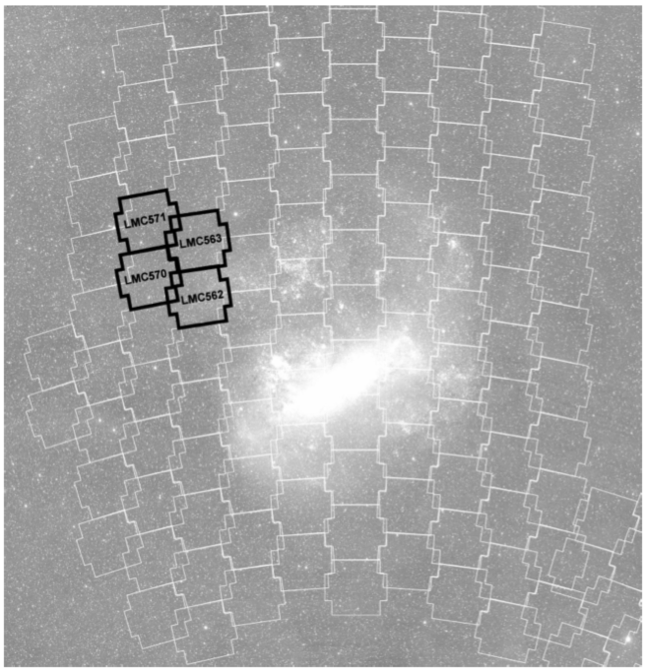


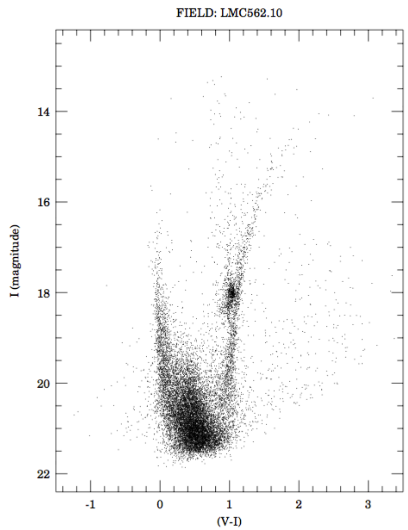
ACTA ASTRONOMICA
Vol. **62** (2012) pp. 0–0

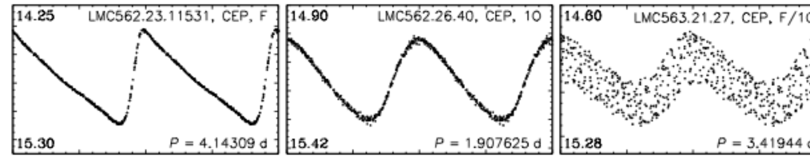


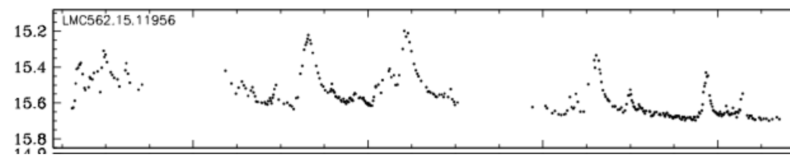
The Optical Gravitational Lensing Experiment. Gaia South Ecliptic Pole Field as Seen by OGLE-IV*

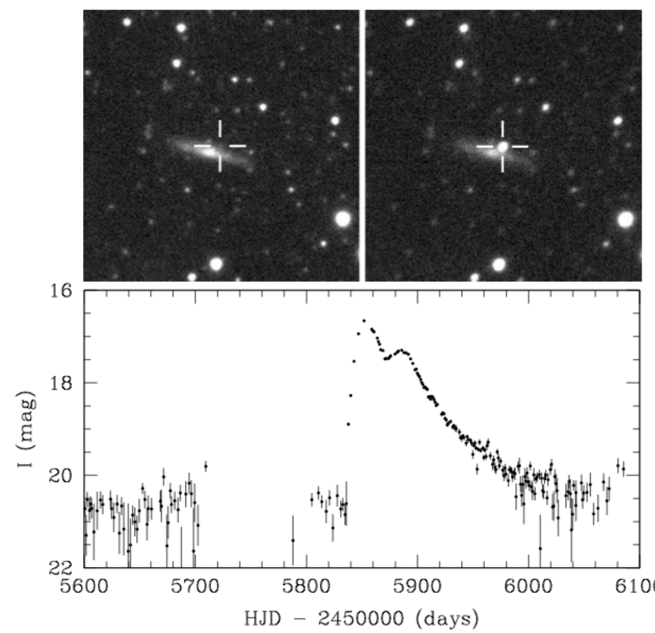
I. Soszyński[1], A. Udalski[1], R. Poleski[1], S. Kozłowski[1], Ł. Wyrzykowski[1,2], P. Pietrukowicz[1], M.K. Szymański[1], M. Kubiak[1], G. Pietrzyński[1,3], K. Ulaczyk[1], and J. Skowron[4,1]

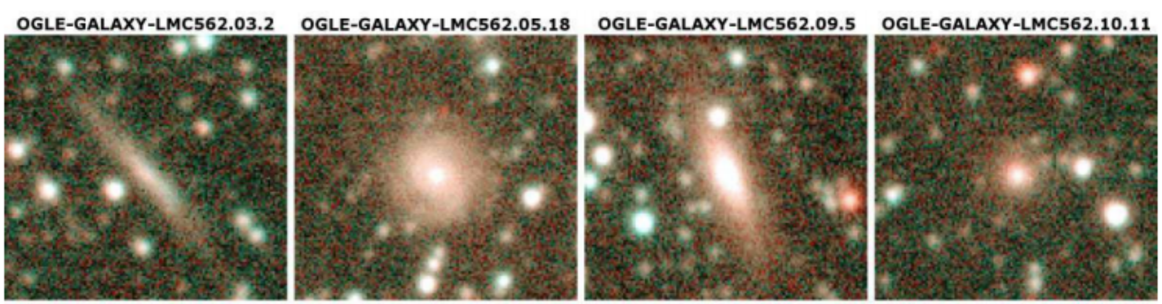


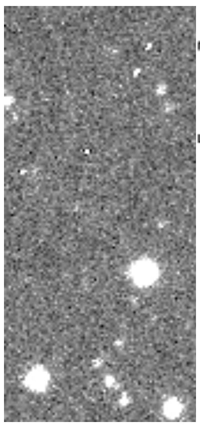


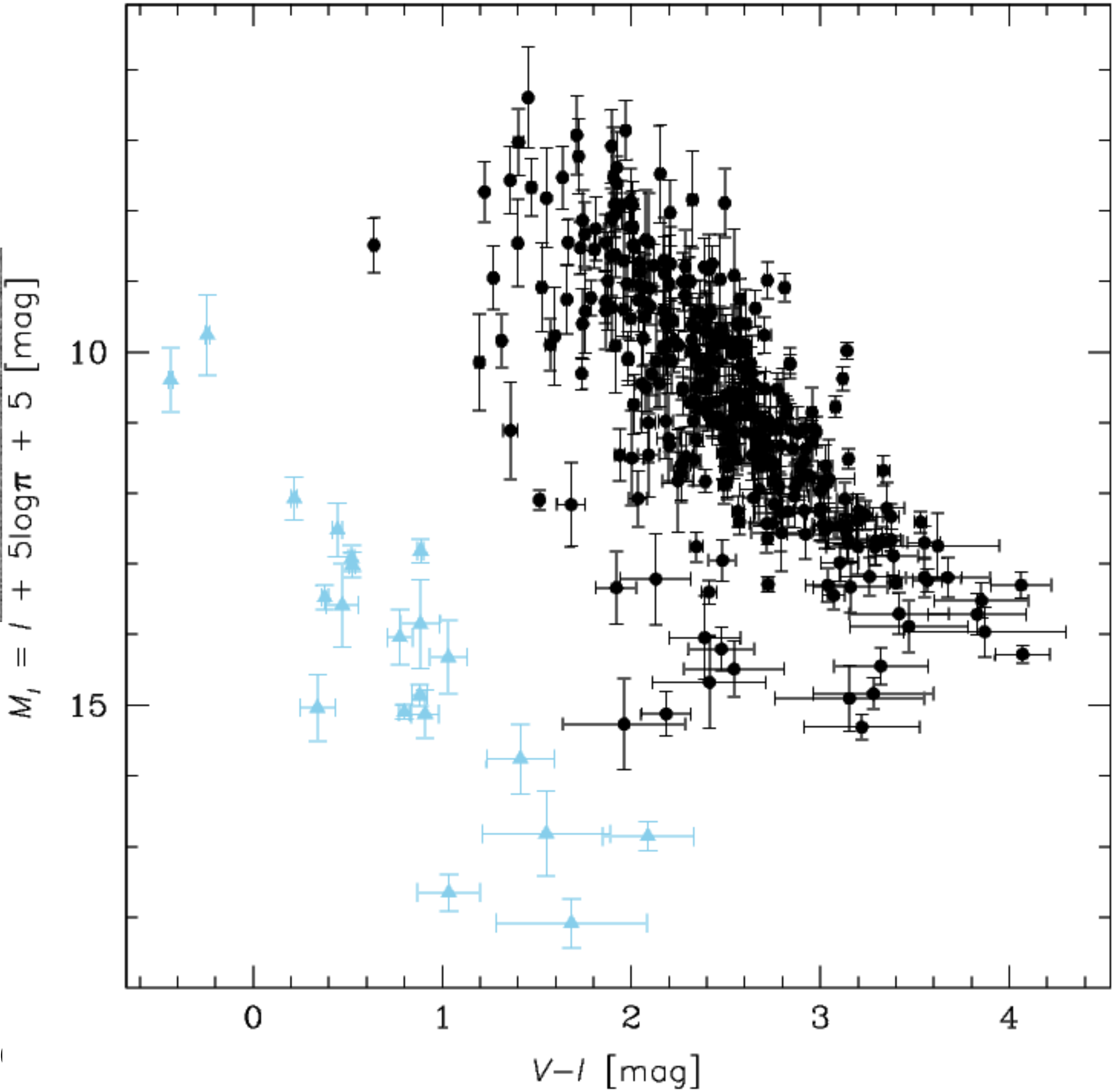


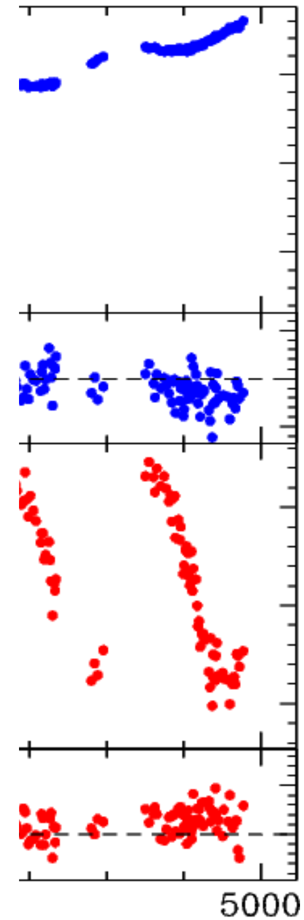












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