A complete census of mid-infrared spectral features in active galaxies

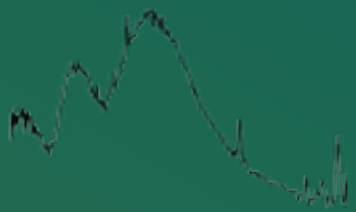
Evanthia Hatziminaoglou
ESO-Garching

Antonio Hernán-Caballero, Anna Feltre

Conference, Thessaloniki, 28.06.15 - 02.07.15

AGN in the MIR

MIR emission in AGN is (believed to be) UV light reprocessed by the hot dust surrounding the AGN.



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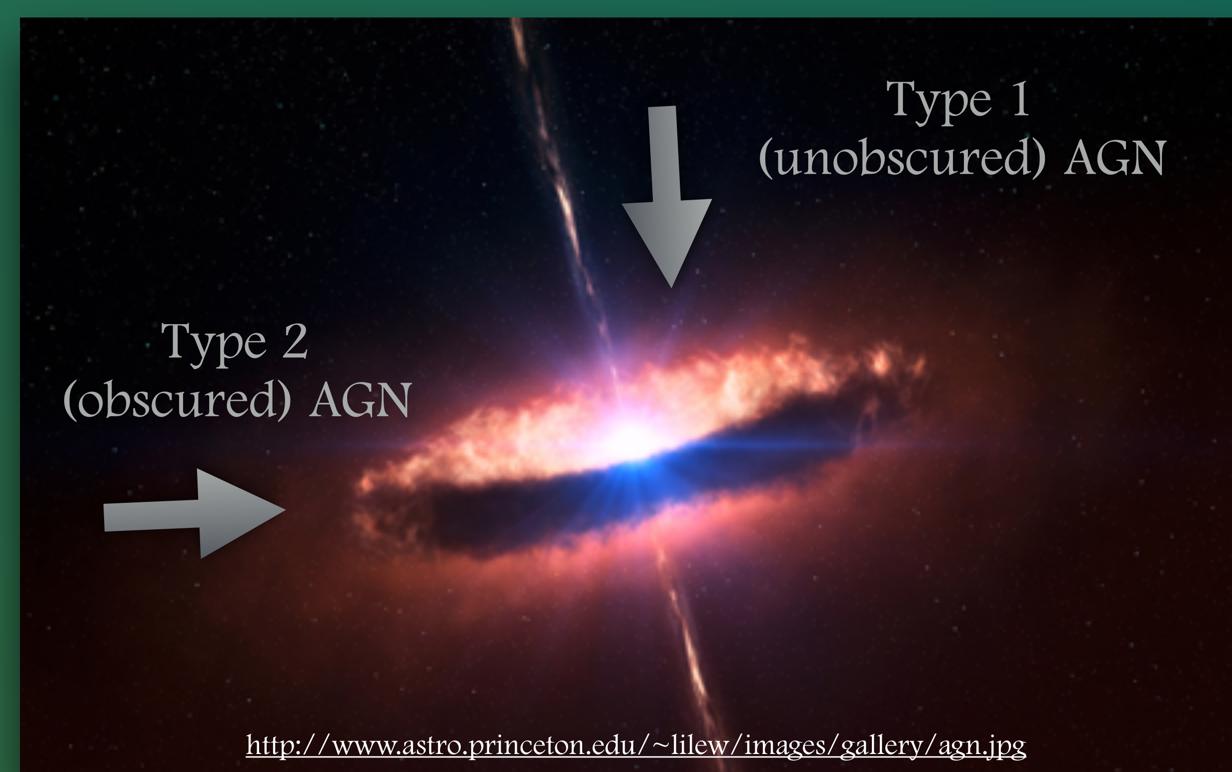
Dust, the cornerstone of AGN unification, often assumed to form a toroidal structure in pc scales around the nucleus, is considered to be distributed either smoothly (e.g. Pier & Krolik 1992; Granato & Danese 1994; Fritz et al. 2006) or in clumps (e.g. Hönig et al. 2006; Nenkova et al. 2008).

Dust (aka 'torus') is invoked in order to explain the diversity of AGN types and properties.



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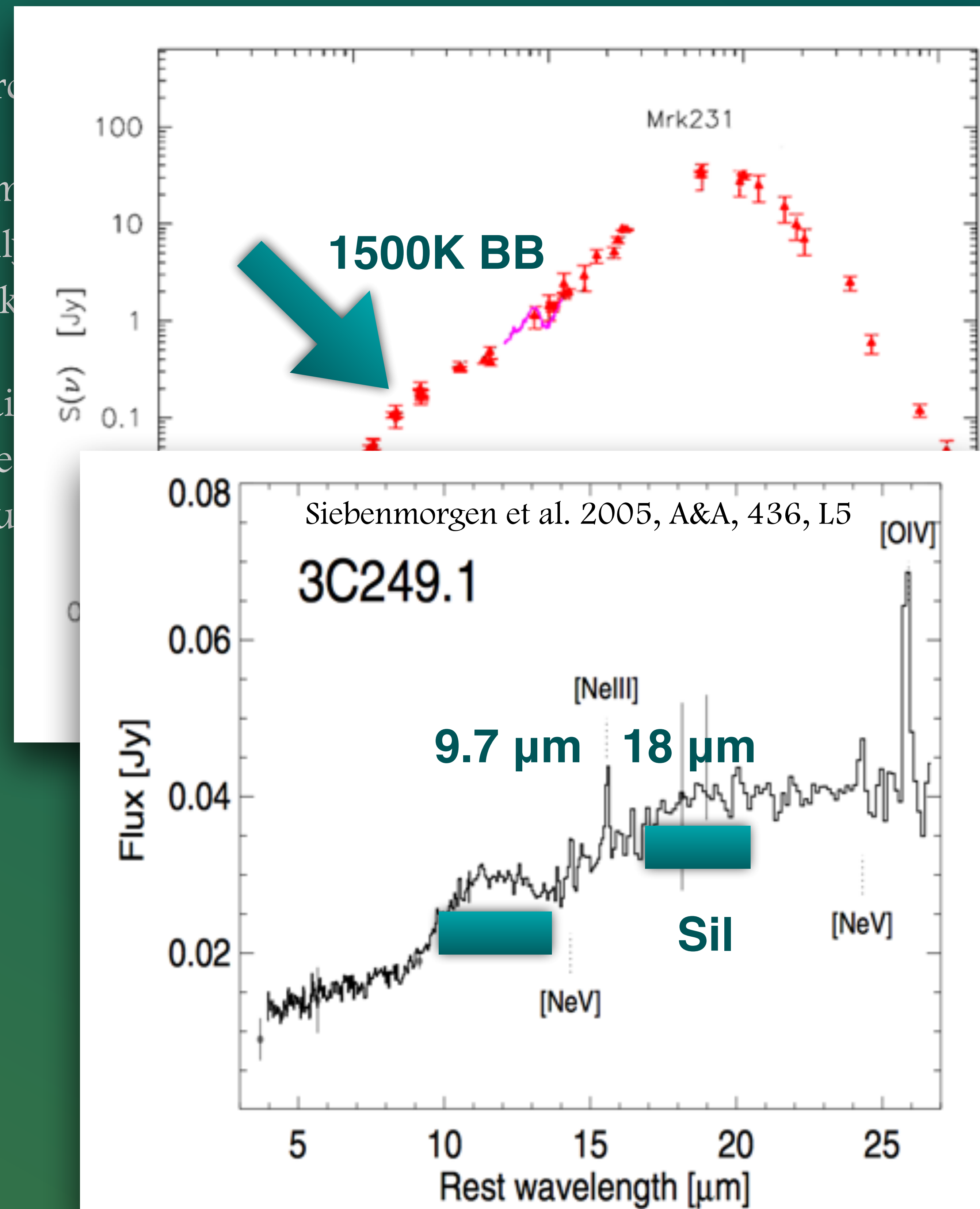

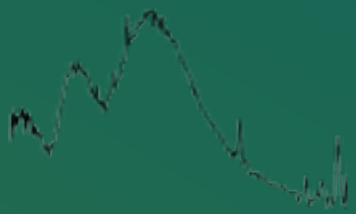

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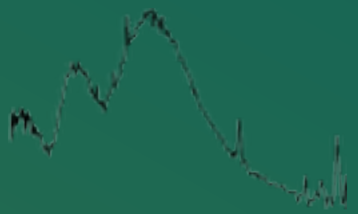
Dust is believed to consist of graphite and silicate grains, each leaving their unmistakable signature in the SED of AGN, namely the 1500K black-body like rise of the MIR continuum of type 1 AGN (e.g. Hatziminaoglou et al. 2005) corresponding to the sublimation temperature of graphites, and a feature (in emission or absorption) centred at 9.7 μm (and at 18 μm).

Star formation most commonly manifests itself in the MIR in the form of prominent emission bands at 3.3, 6.2, 7.7, 8.6, and 11.2 μm, attributed to PAH, altering the MIR spectral characteristics of AGNs.

MIR spectroscopy crucial for studying both the AGN torus and the occurrence of star formation in AGN



AGN IRS spectroscopy

Silicates were unambiguously observed in emission in the MIR spectra of type 1 AGN with Spitzer/IRS (Siebenmorgen et al. 2005; Sturm et al. 2005; Hao et al. 2005; Buchanan et al. 2006; Shi et al. 2006).

The first works studying silicates in AGN, based on a few tens of AGN (e.g. Spoon et al. 2007; Hao et al. 2007; Wu et al. 2009), showed the silicate feature to show a wide diversity but to vary, on average spectra, with AGN type, ranging from moderate emission in bright quasars to almost no emission or slight absorption in Seyfert 1 galaxies to stronger absorption in Seyfert 2 galaxies.

In parallel, diagnostics were sought for in order to quantify the relative contribution of nuclear and starburst activity when they occur concomitantly (e.g., Genzel 1998; Peeters et al. 2004; Spoon et al. 2007; Hernán-Caballero et al. 2009; Hernán-Caballero & Hatziminaoglou 2011) while trying to relate the properties of the silicates to the geometry and opacity of the hot dust (e.g. Levenson et al. 2007; Maiolino et al. 2007; Schweitzer et al. 2008).

We compiled the largest AGN sample with uniform MIR spectroscopy ever

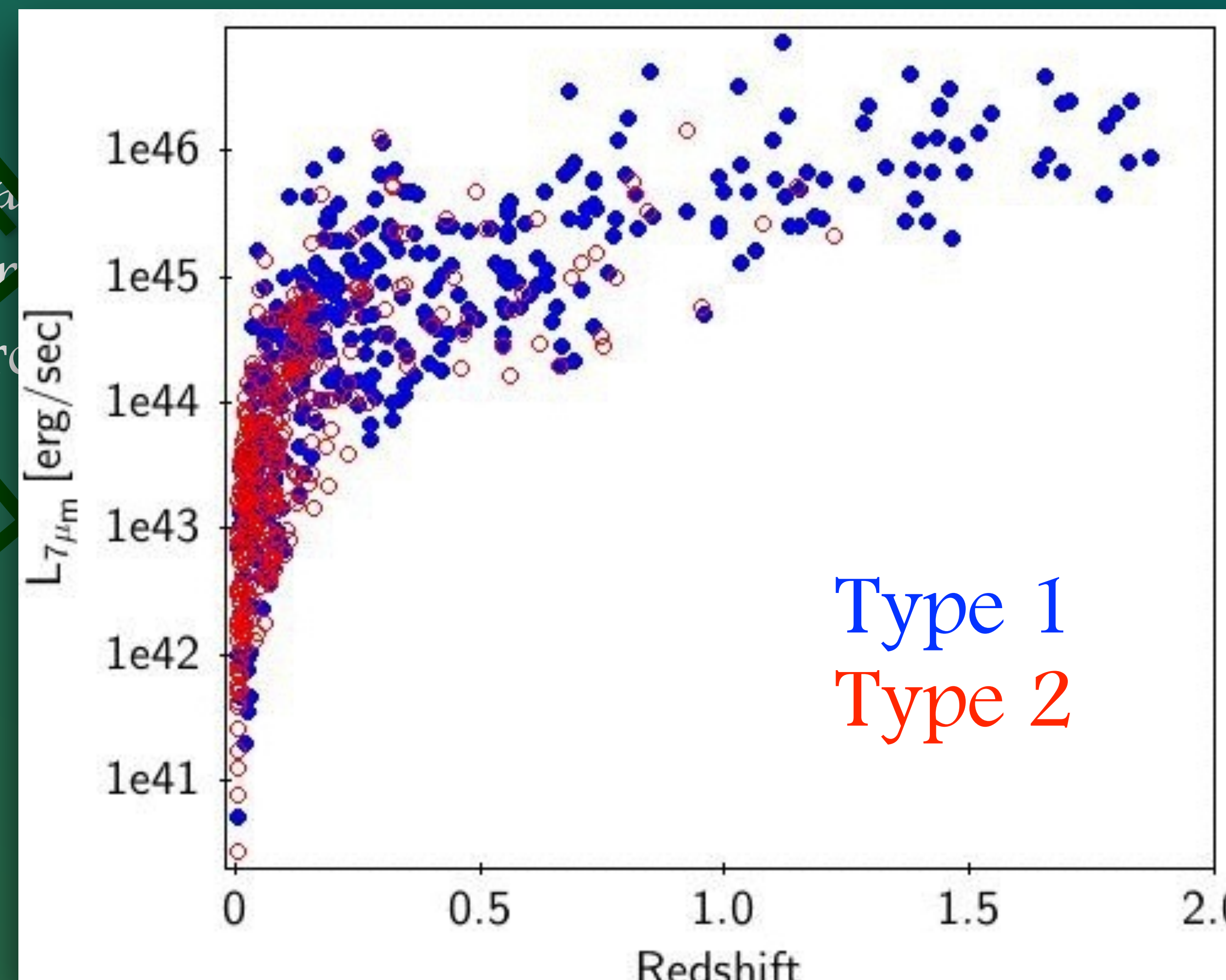
CASSIS AGN

All CASSIS[1] objects with NED[2] identification a
classification, a robust redshift[3], an IRS spectr
the wavelength range between 6 and 15 micro

Type	Nobj
Type 1 AGN (SDSS quasars)	375 (141)
Type 2 AGN	329

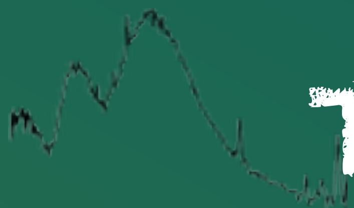
Relying on NED classification

Not a statistical sample!



Representative of the MIR AGN population

[1]Cornell Atlas of *Spitzer*/IRS Sources; http://cassis.astro.cornell.edu/atlas/
[2]NASA/IPAC Extragalactic Database; http://ned.ipac.caltech.edu
[3]Optical or mid-infrared

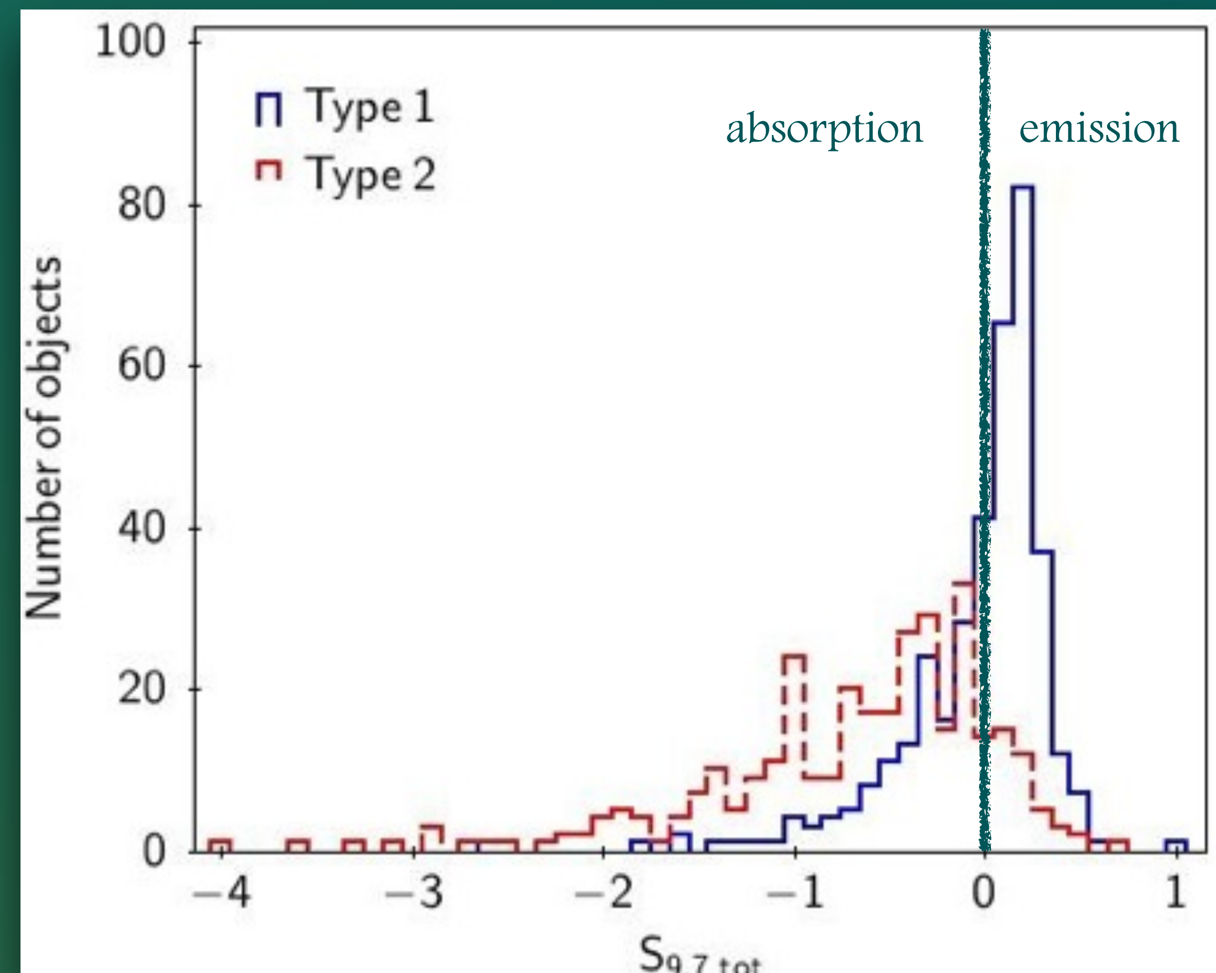


The silicate feature at 9.7μm

$S_{sil} = \ln F(\lambda_{peak}) / F_C(\lambda_{peak})$
e.g. Pier & Krolik (1992)

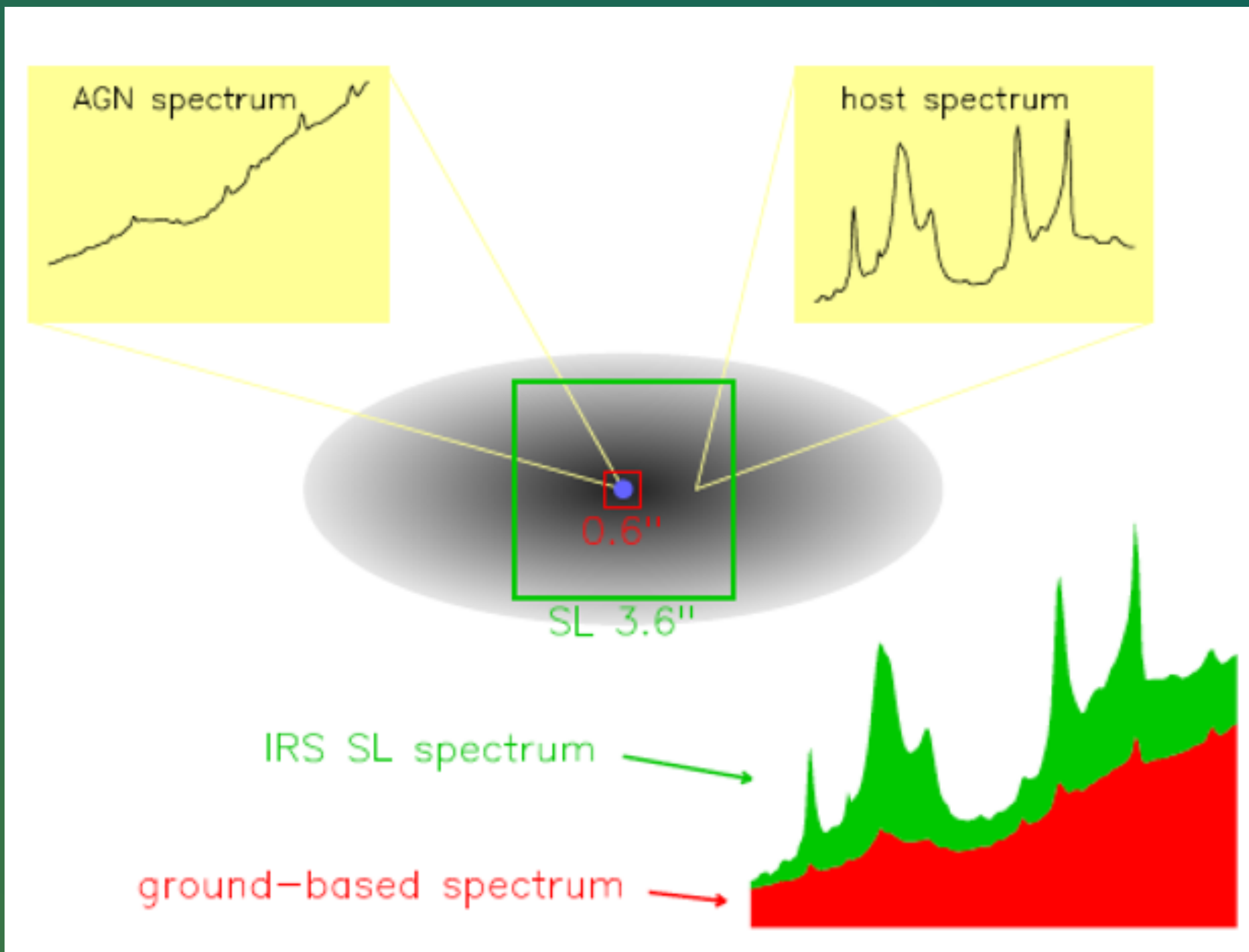
On average, type 1 (2) AGN exhibit the feature in emission (absorption) but:

35% of type 1 AGN have $S_{9.7\ tot} < 0.0$
15% of type 2 AGN have $S_{9.7\ tot} > 0.0$

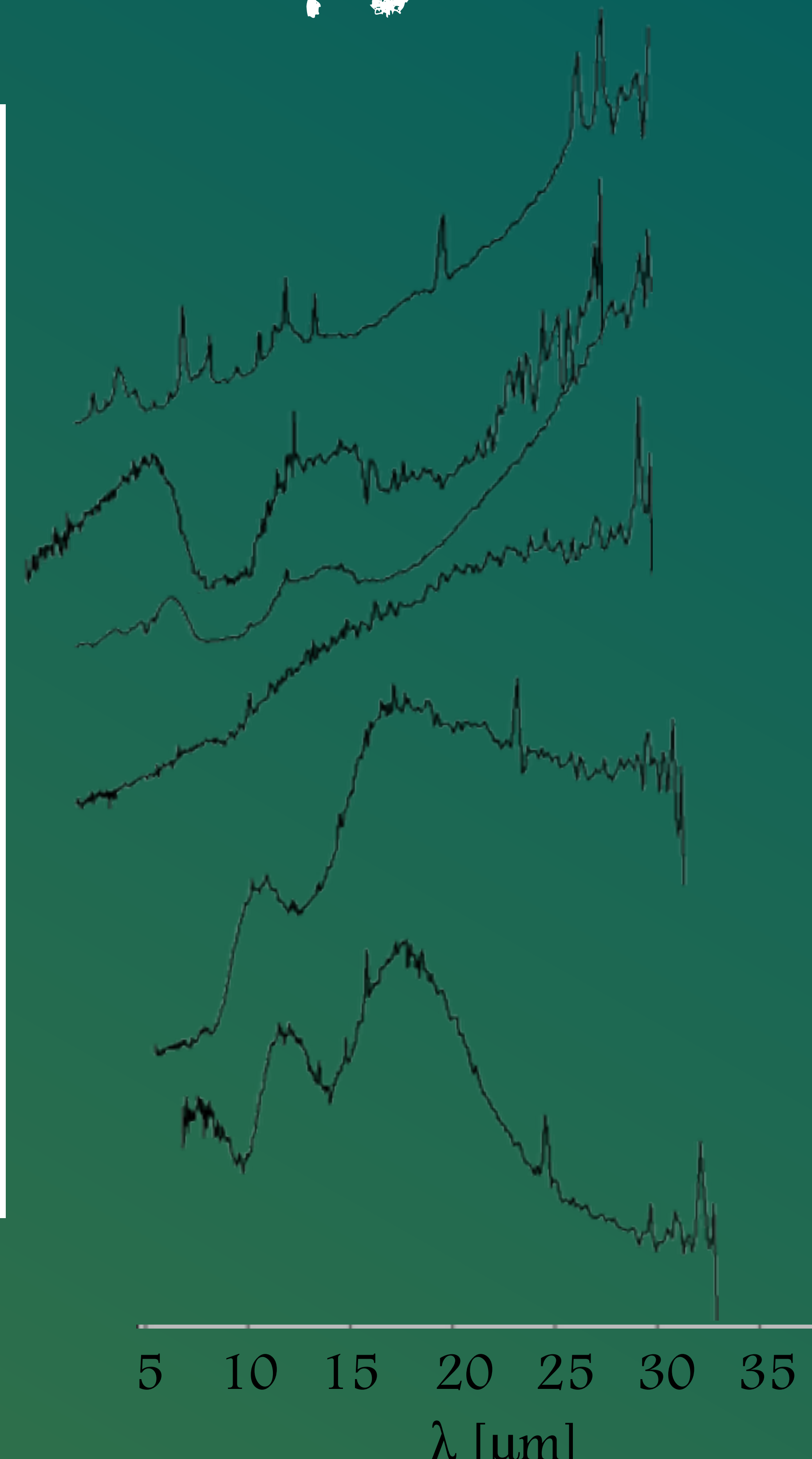


Hatziminaoglou et al. 2015, ApJ, 803, 110

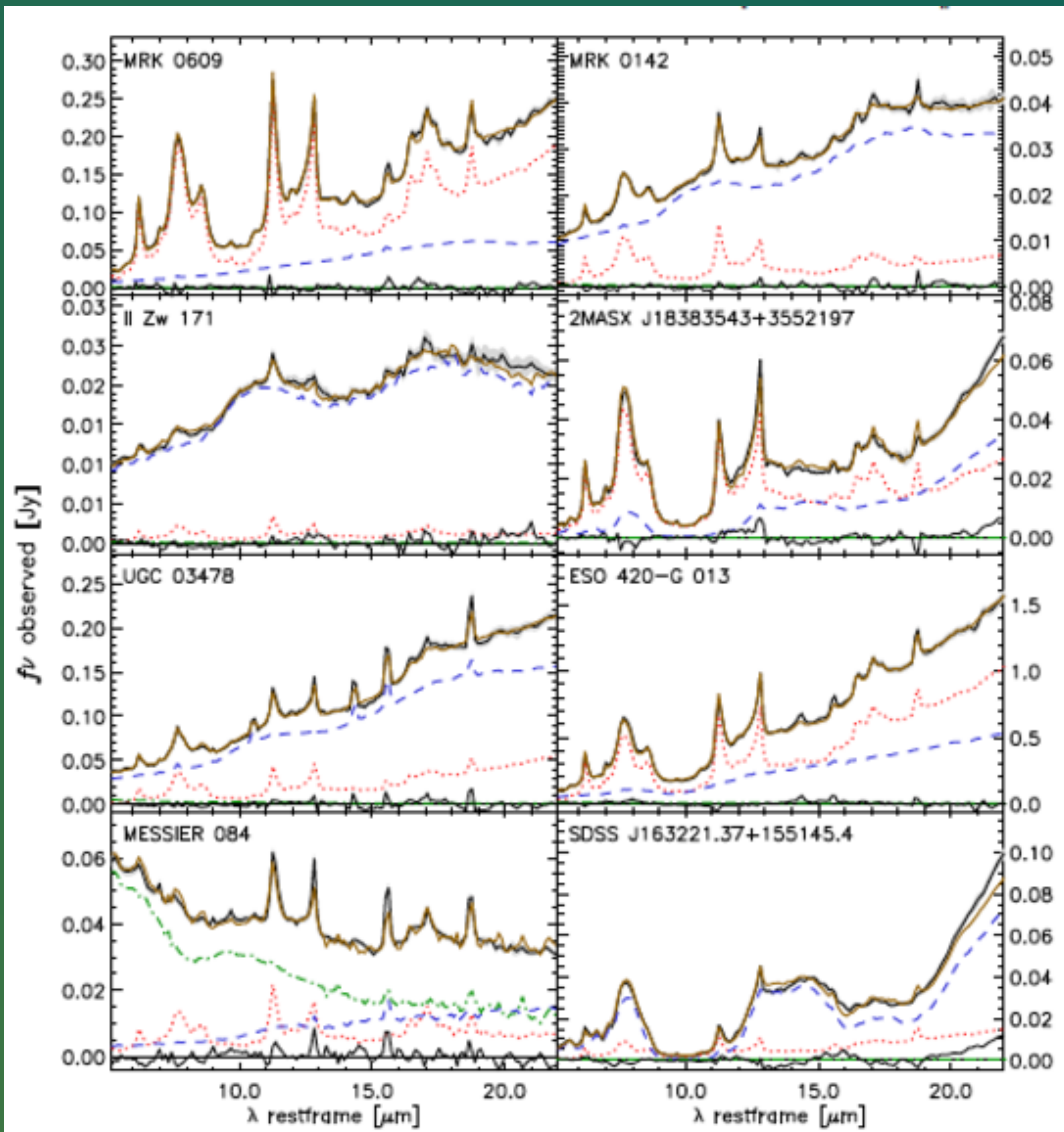
MIR (IRS) spectroscopy



Hernán-Caballero et al. 2015, ApJ, 803, 109



Spectral decomposition



Templates:

- AGN: negligible or no PAH emission, classified as AGN (NED)
- Starburst: strong PAH emission, weak continuum at 5 μm, not classified as AGN (NED)
- Stellar: local ellipticals and S0s, with negligible PAH emission; blue star-like continuum and not classified as AGN (NED)

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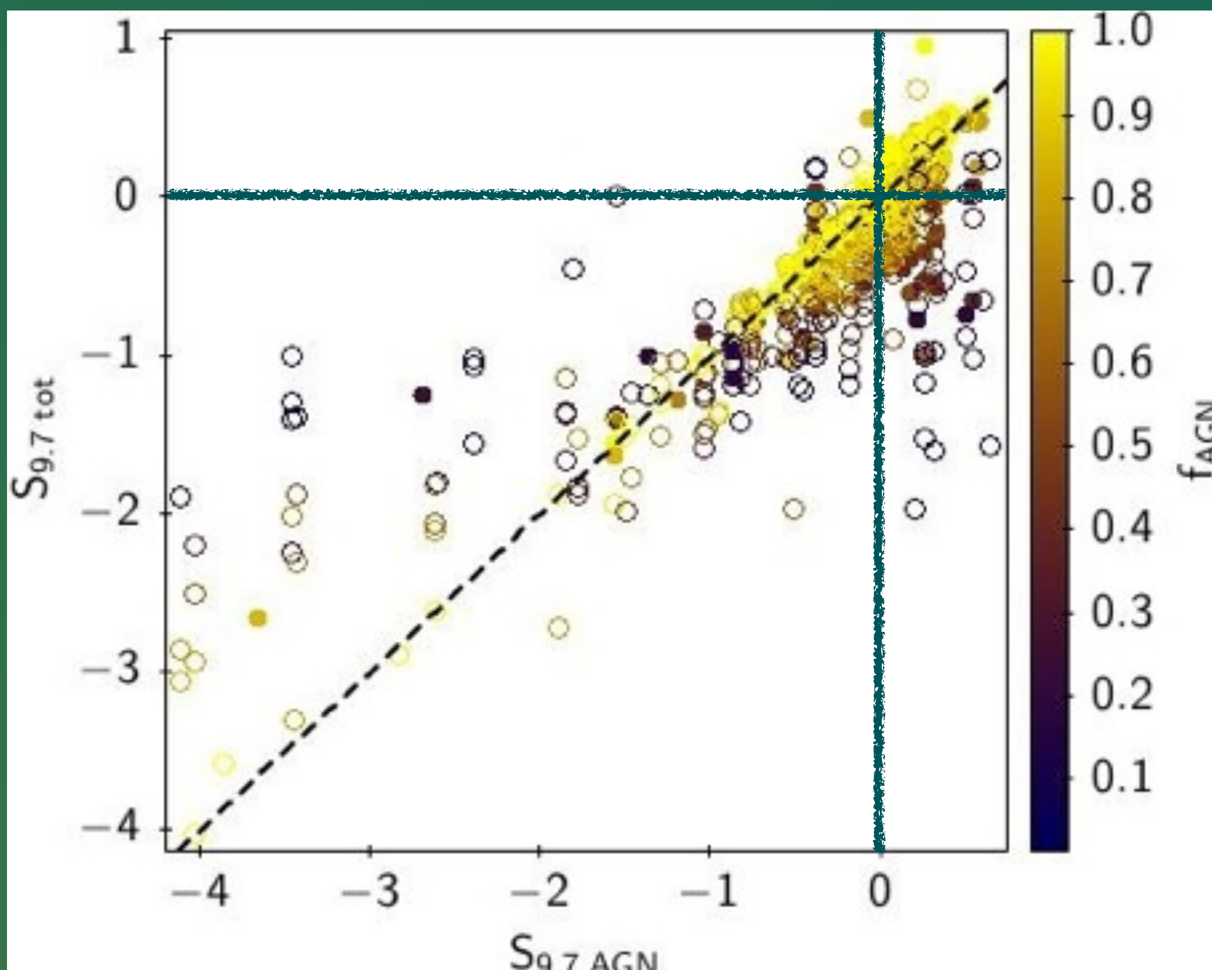
Measure S_{sil} closer to the AGN

$$f_{AGN} = L_{AGN}/L_{5-15\mu m}$$

Removing the effect of the host



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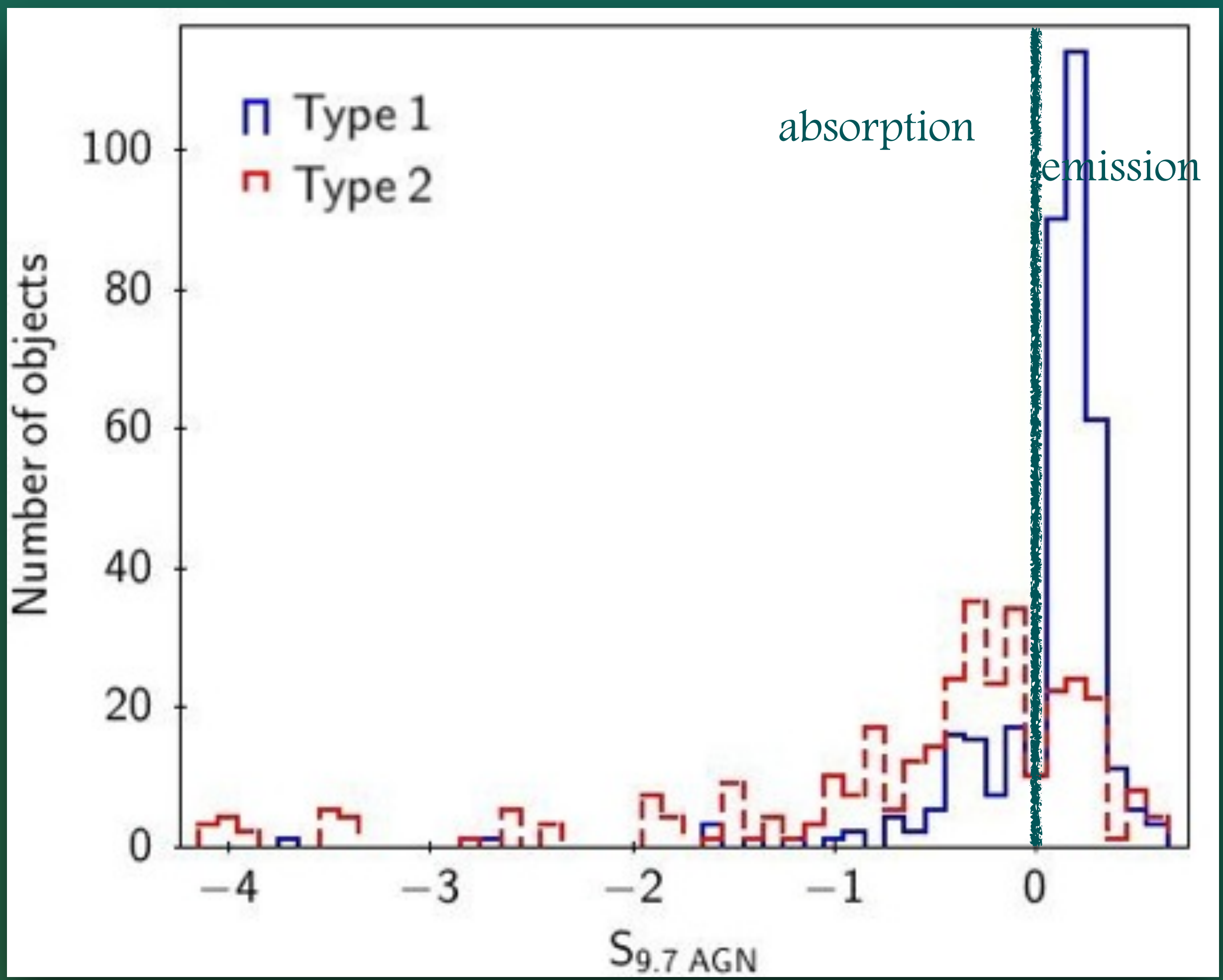


20% of type 1 AGN have $S_{9.7\,AGN}<0.0$

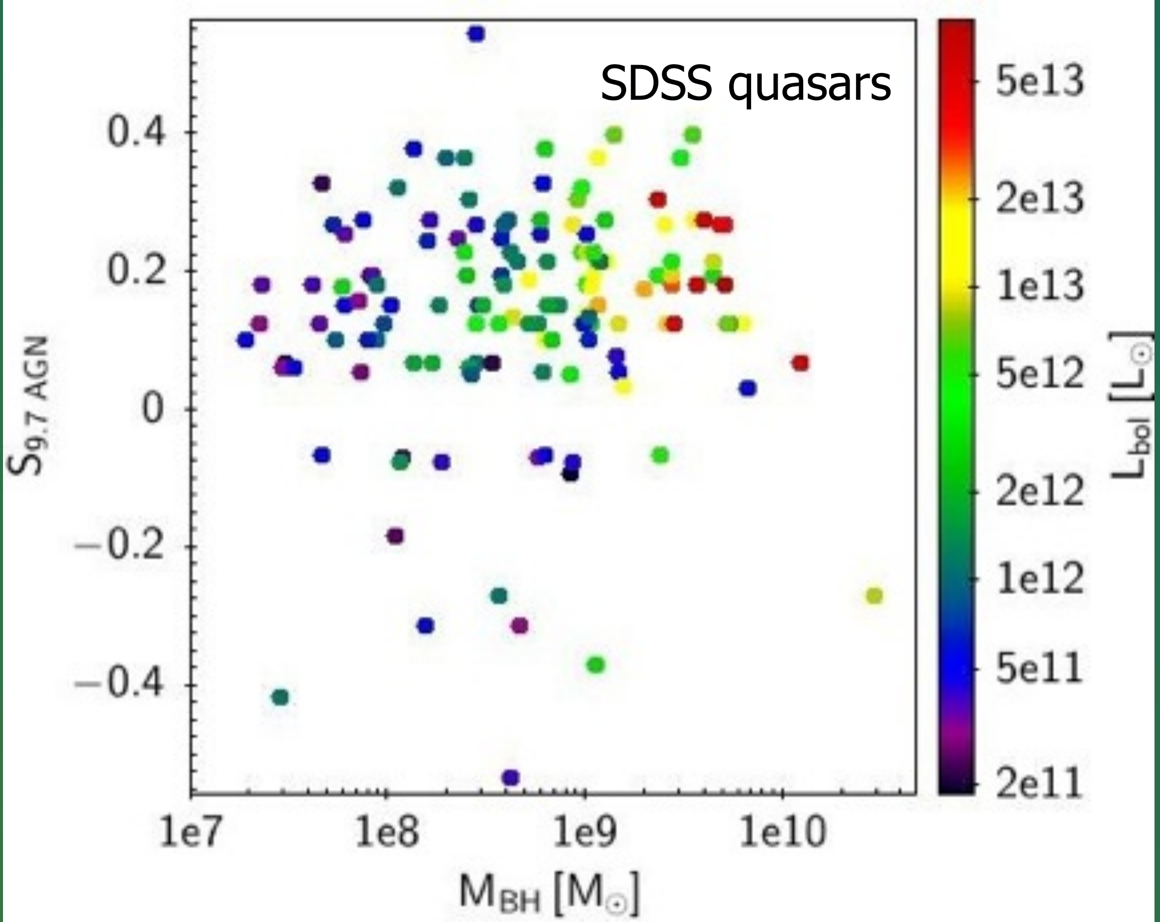
20% of type 2 AGN have $S_{9.7\,AGN}>0.0$

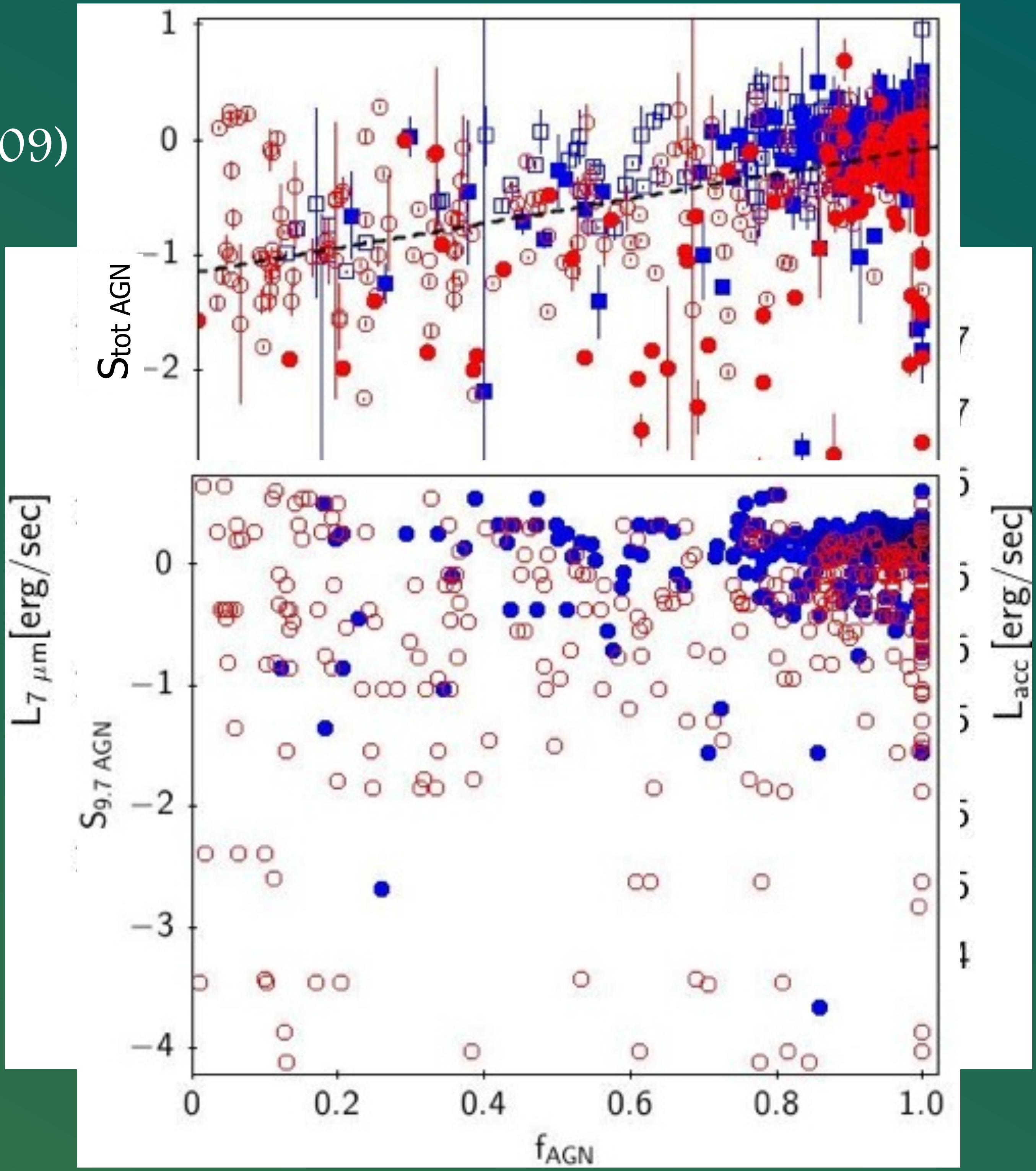
Silicates as a function of AGN properties

$S_{sil} \nearrow M_{BH}$ (Maiolino et al. 2007)

S_{sil} does not depend on L_{bol} (Thompson et al. 2009)

or does it?





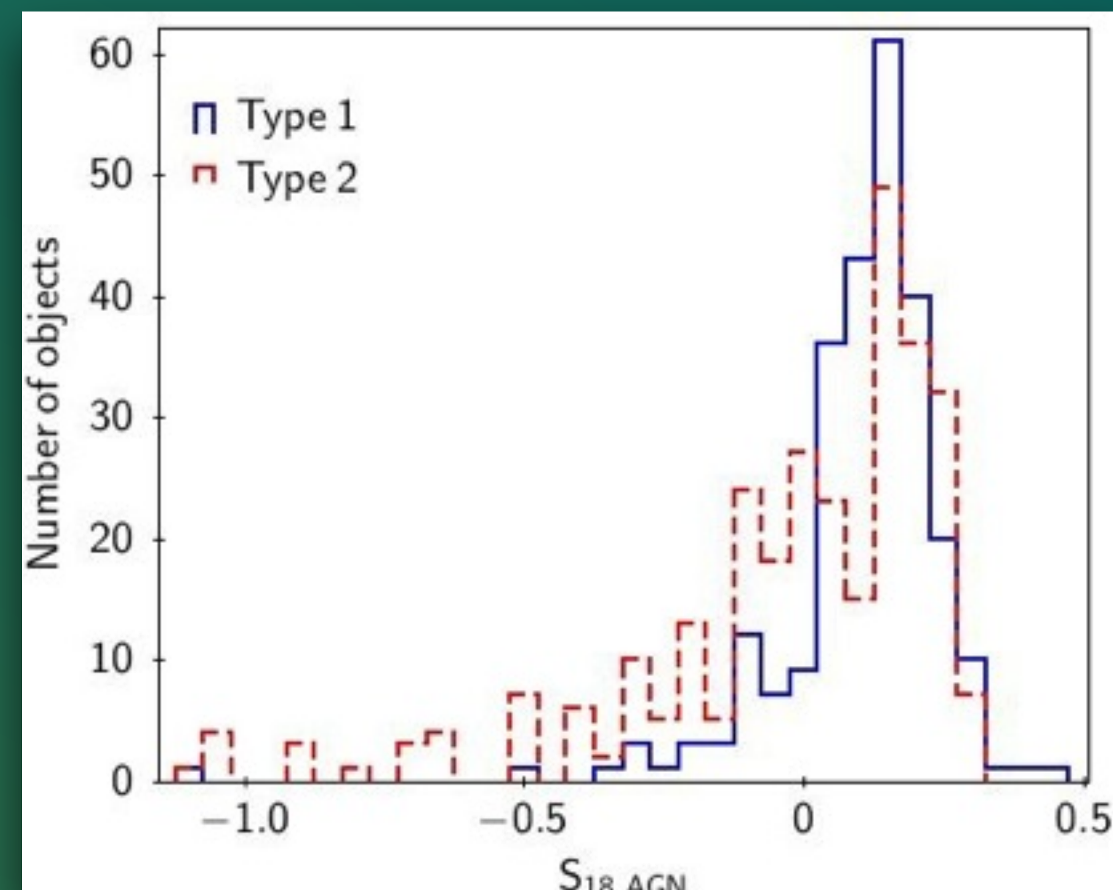
➪ decomposition does a good job

The silicate feature at 18µm

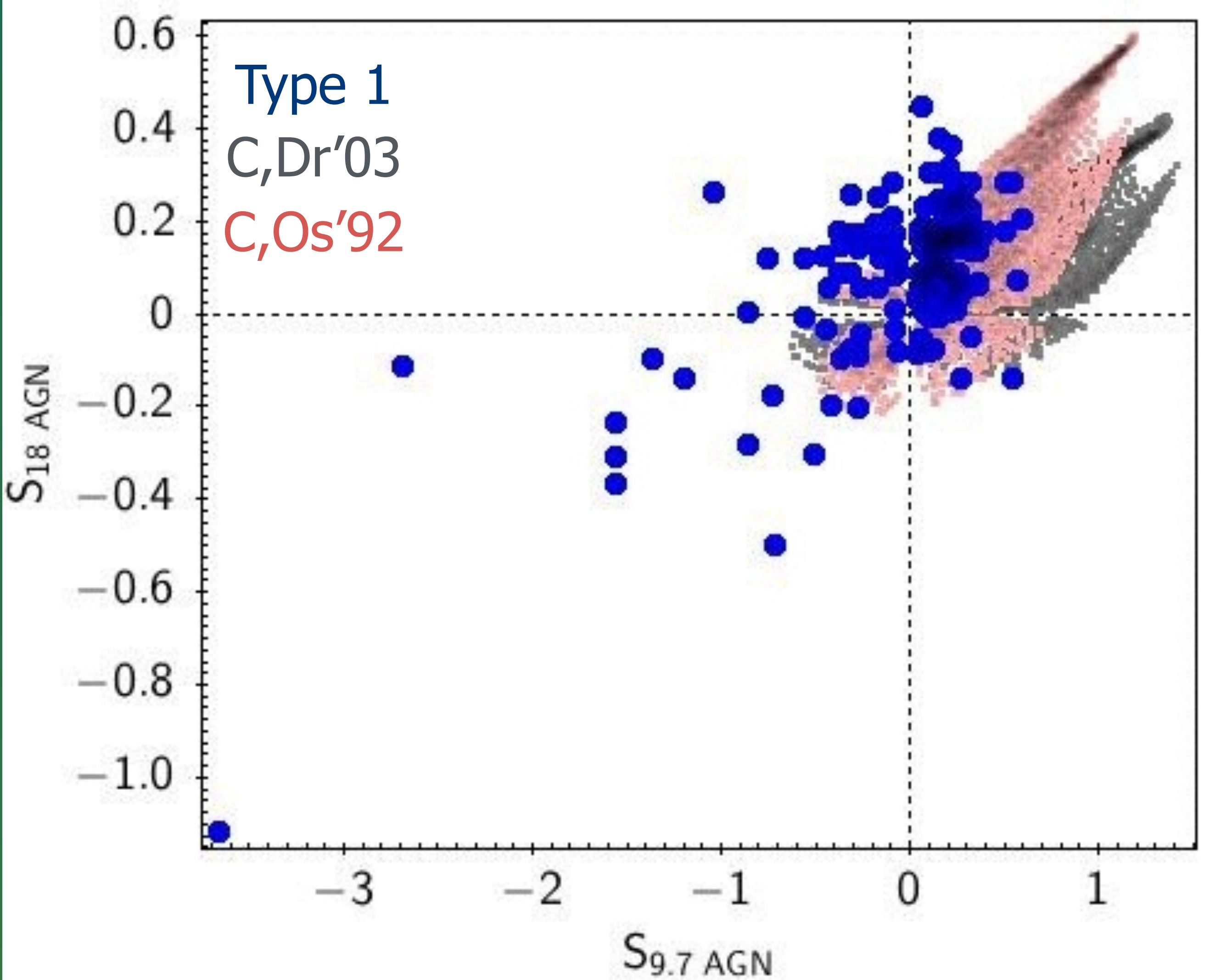
AGN MIR bump

Steep mid–to–far infrared emission from the host

At least as prominent in emission as its 9.7 µm counterpart, only appears in moderate absorption



Observations and models: type 1 AGN



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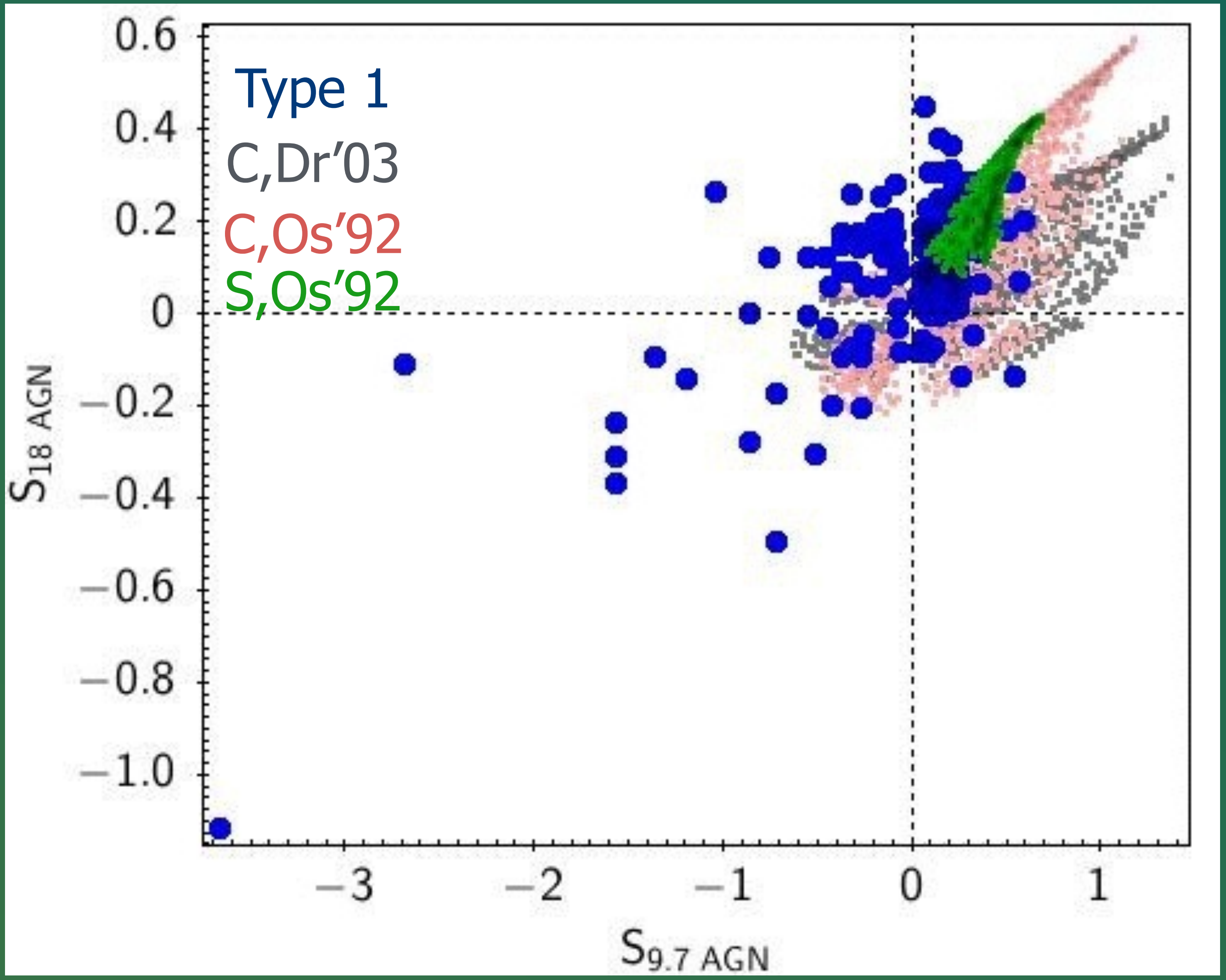
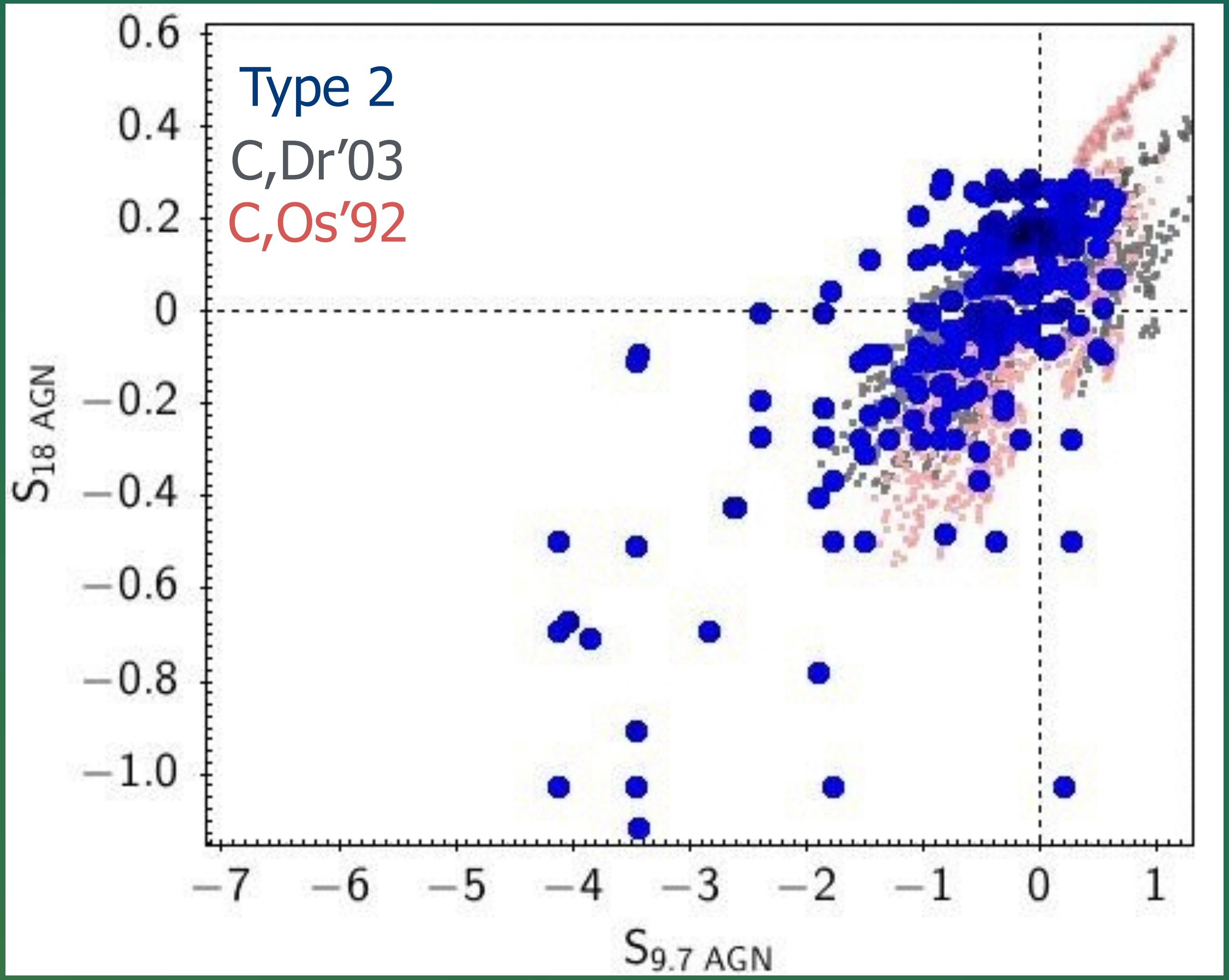


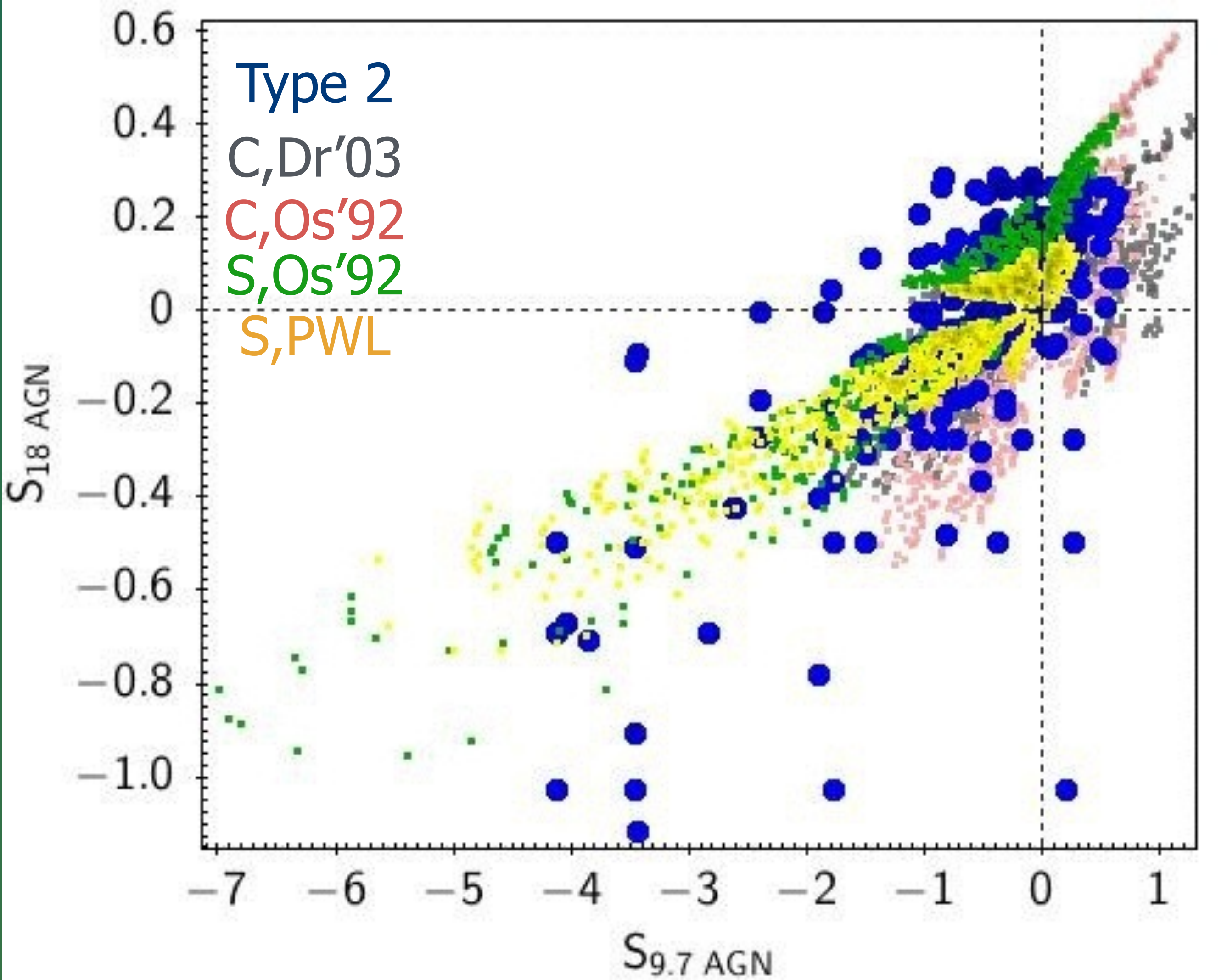
Type 1:

- Ossenkof '92 produce weaker silicates in emission at 9.7μm and a slope closer to that observed
- Smooth models only reproduce a limited number of points and cannot reproduce the features in absorption
- Strong absorption features are not produced by any configuration

Observations and models: type 2 AGN



Observations and models: type 2 AGN



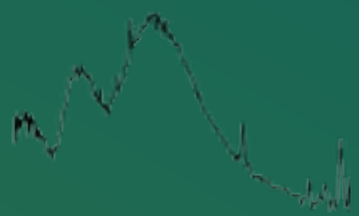
Type 2:

- Emission spectrum of the input source (largely unconstrained) as important as other parameters

- Only smooth models can produce silicates in very deep absorption BUT:
- Visual inspection of all AGN with $S_{9.7\ AGN} < \sim 1.5$ showed their hosts to be dusty or interactive

⇓

In favour of a foreground absorber

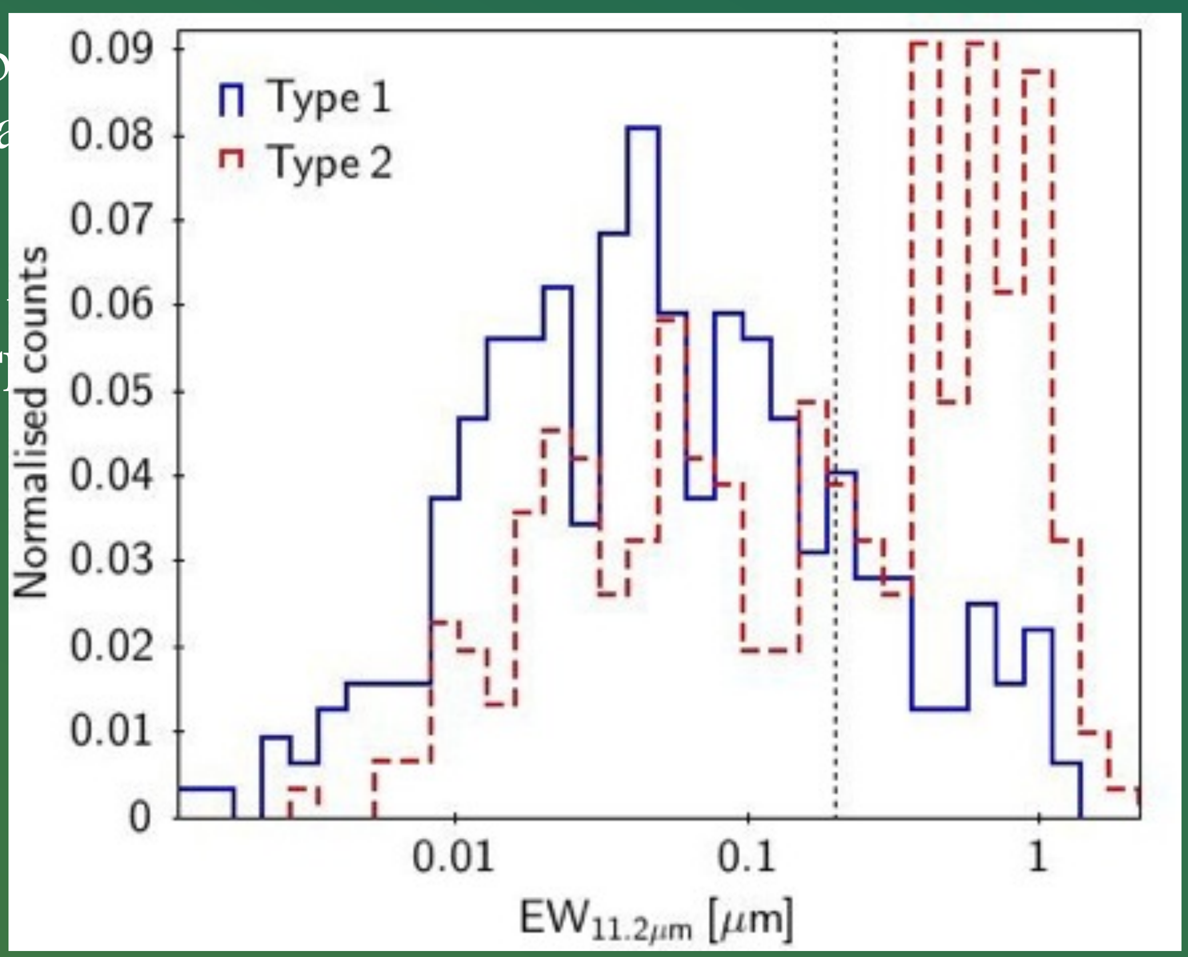


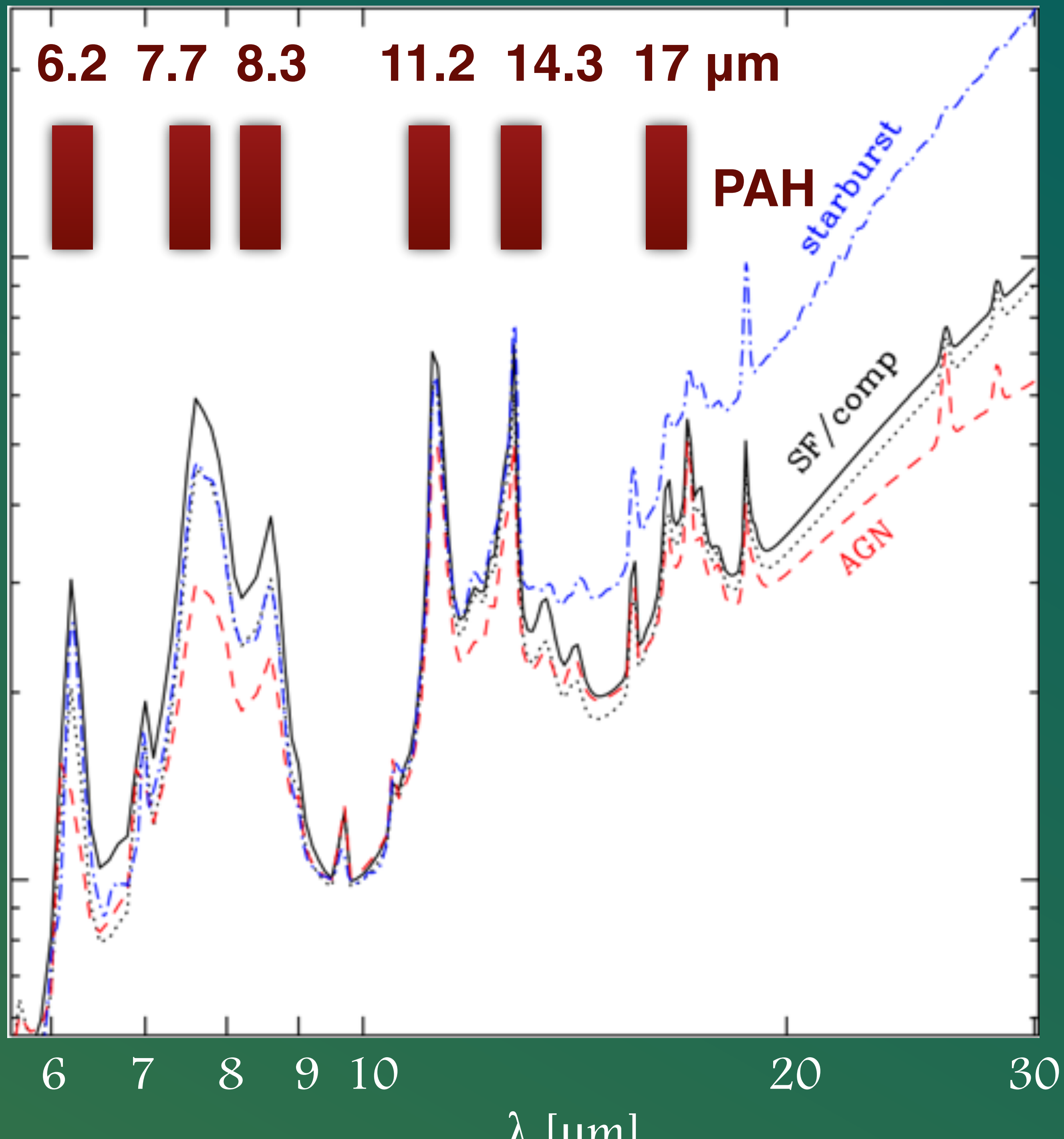
PAH features

Hydrocarbons —organic compounds containing only carbon and hydrogen—that are composed of multiple aromatic rings (organic rings in which the electrons are delocalised) — Wikipedia

Fo
sta

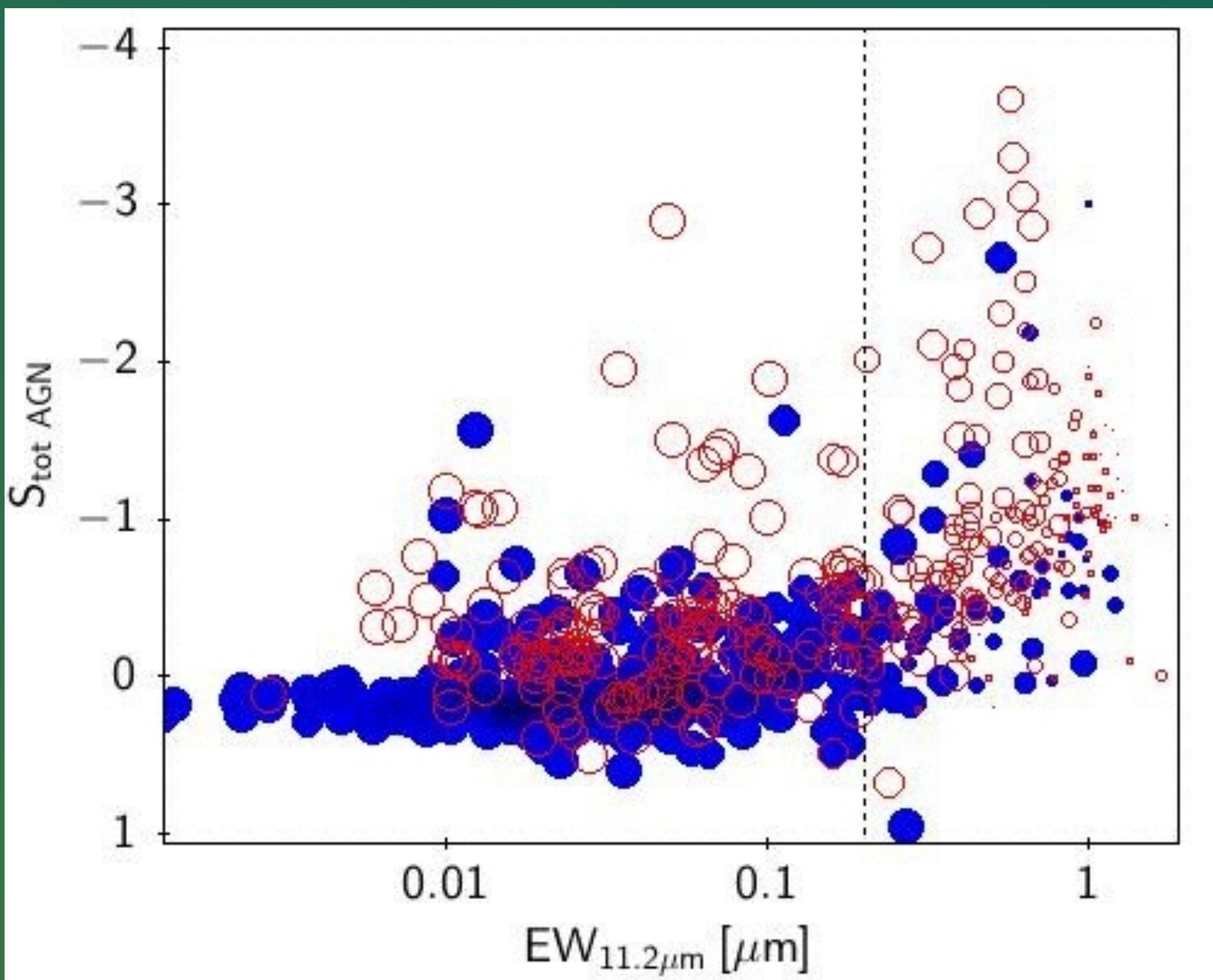
➪
SF





Treyer et al. 2010, ApJ, 719, 1191

MIR diagnostics



á la Spoon et al. 2007, ApJ, 654, L49

Intense star formation in AGN-dominated systems, including SDSS quasars

Type 2 AGN have lower f_{AGN} and higher $EW_{11.2\mu m}$

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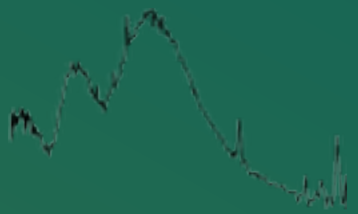
SF more common in type 2 AGN



To take away

For the first time, intrinsic S_{sil} measured, and on such a large sample.

Silicates in emission (and absorption) can appear in AGN with luminosities spanning several orders of magnitude; S_{sil} does not depend on L_{acc} (or M_{BH}) or f_{AGN}.

$S_{18}/S_{9.7}$ constrains the morphology but also shows the importance of 'hidden' parameters, such as the Si absorption and scattering coefficients and the input spectrum. Ossenkopf et al. 1992 ("Cosmic") silicates closer to observations. Input spectrum needs further studying.

The deepest absorption features appear in dusty systems. PAH features present in the MIR spectra of AGN of all types and luminosities, including SDSS quasars, but are stronger in the spectra of type 2 AGN. Fraction of objects with strong contamination from the host ($f_{AGN}<0.7$) is much higher among type 2 AGN (43%) than among type 1 AGN (12%).

This suggests a foreground absorber. Not in disagreement with unified scheme, but implies that AGN might be absorbed (type 2) even if the torus did not intercept the line of sight.