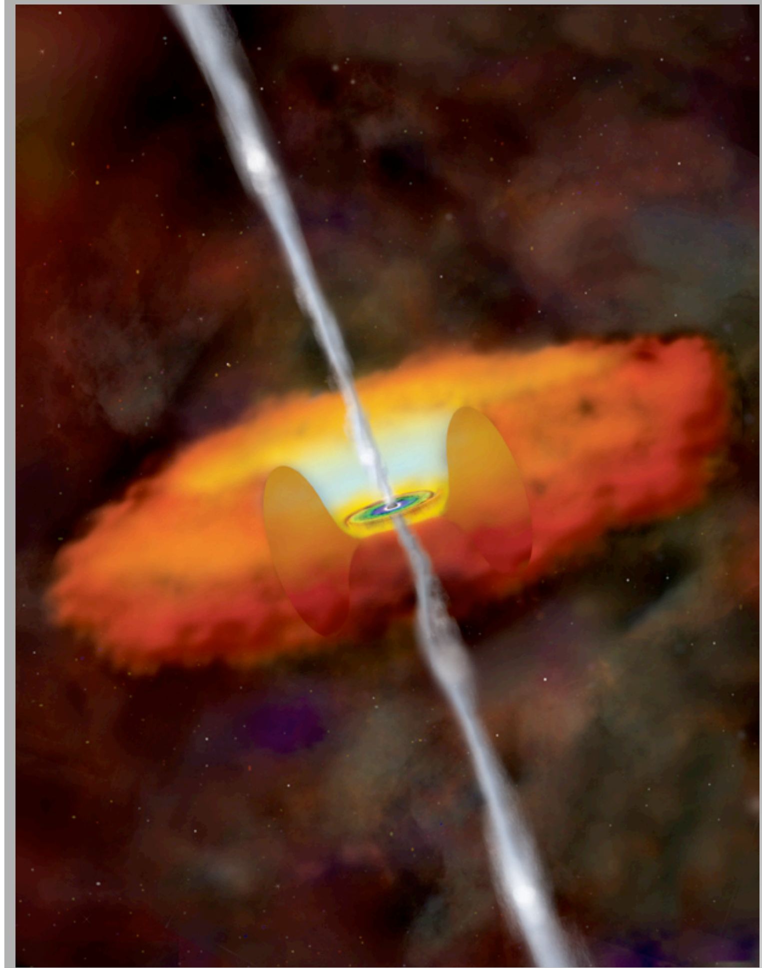

Challenges in AGN science: the VLTI in a broader context (from an infrared perspective)

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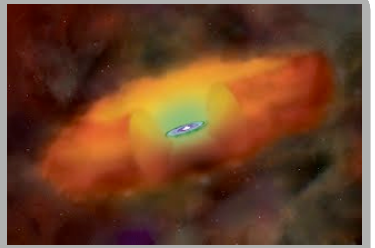
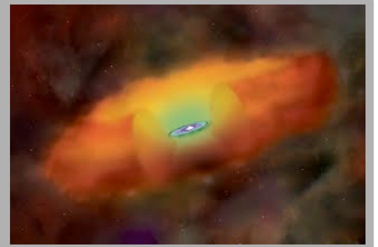
CANTABRIA CAMPUS INTERNACIONAL

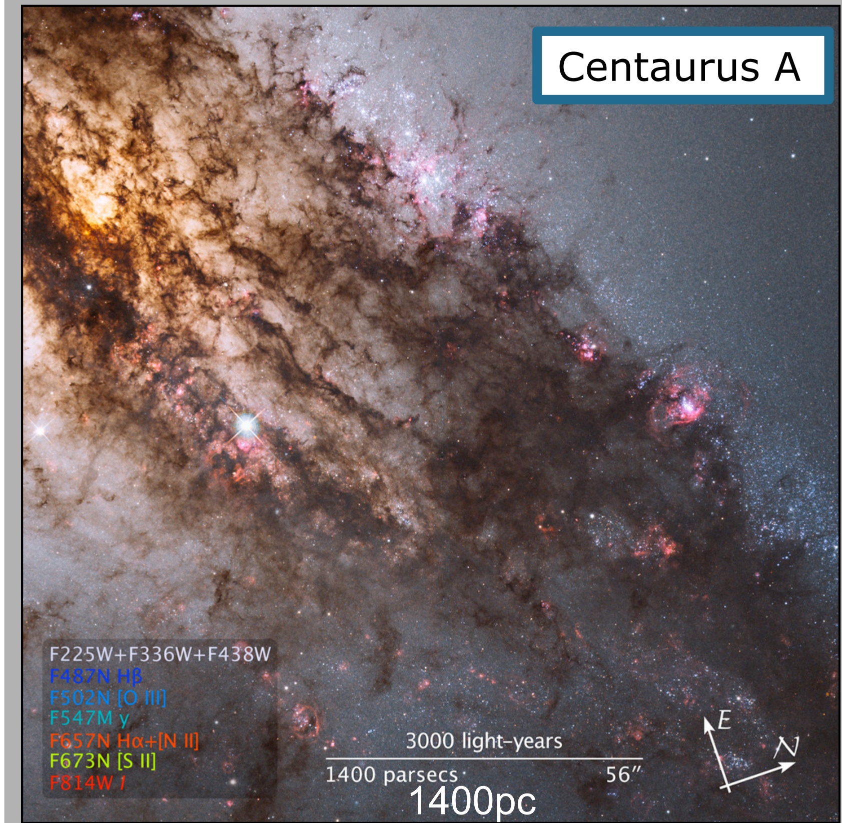
Open questions about the torus and its environment

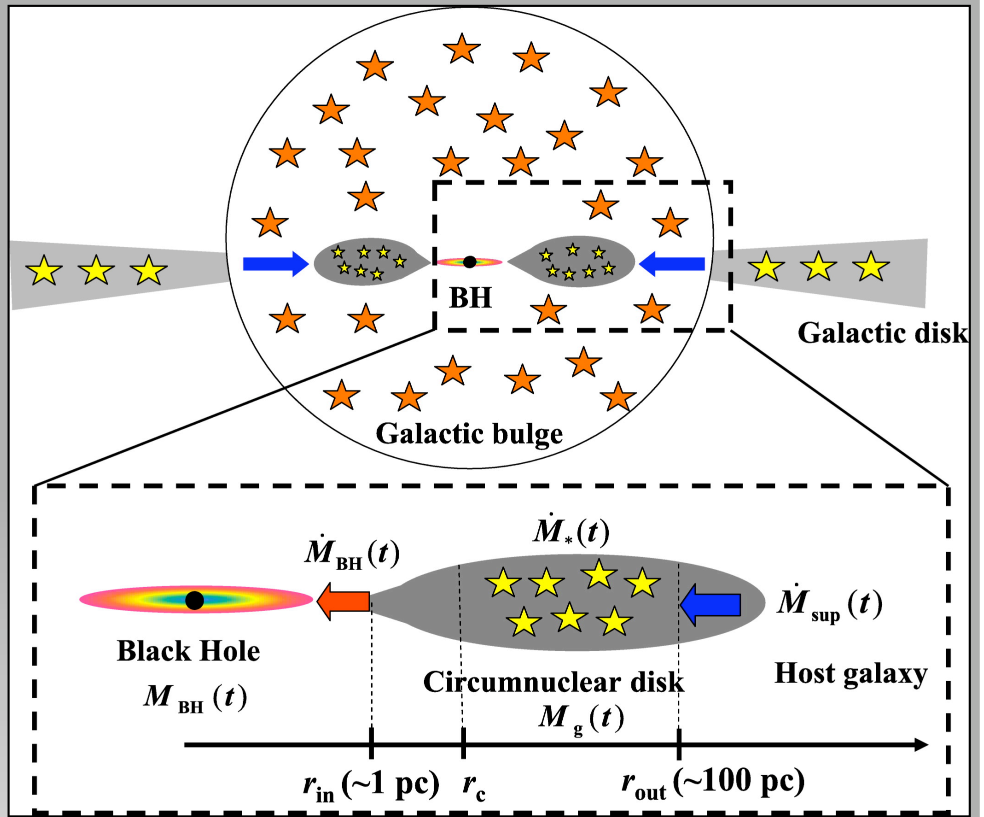


- **Naked tori?** The role of “other” dust components
- **One torus rules it all?** Unification of type 1 and type 2 AGN
- **Whas is the torus?**
- **The winner takes all?** Nuclear (<100pc) star formation vs. black hole accretion
- **How about the wimpy ones?** Low luminosity AGN and the origin of the torus

The dusty torus is not an isolated structure

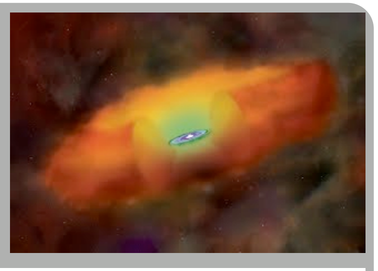


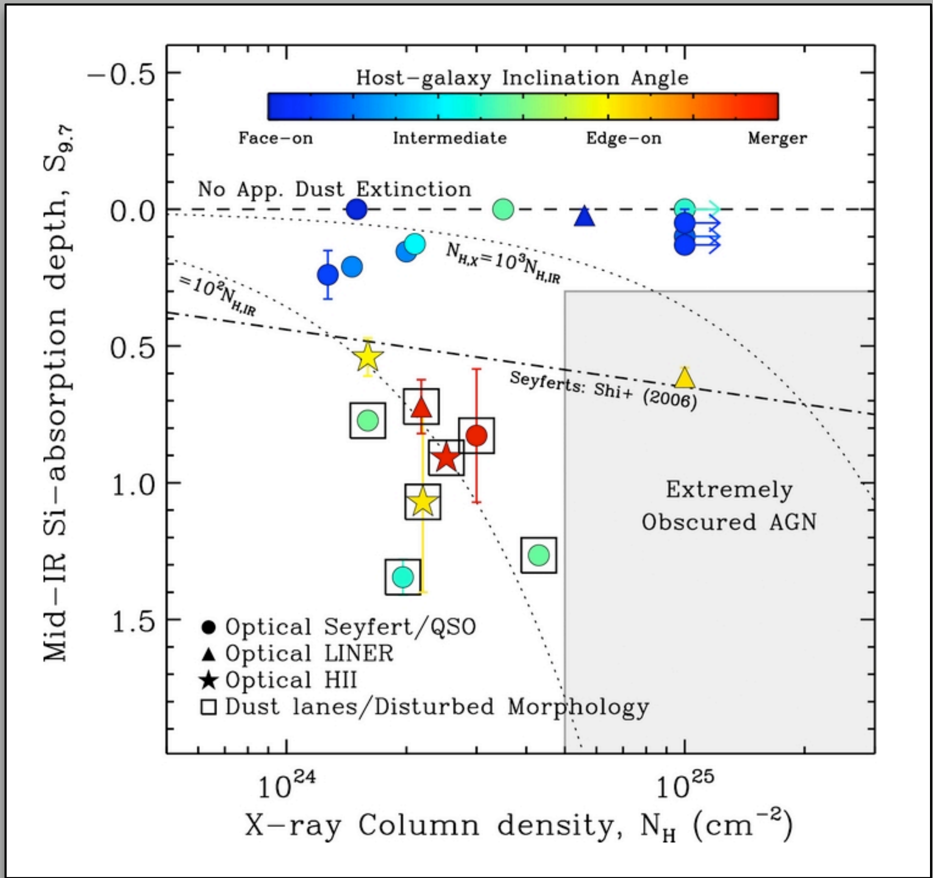




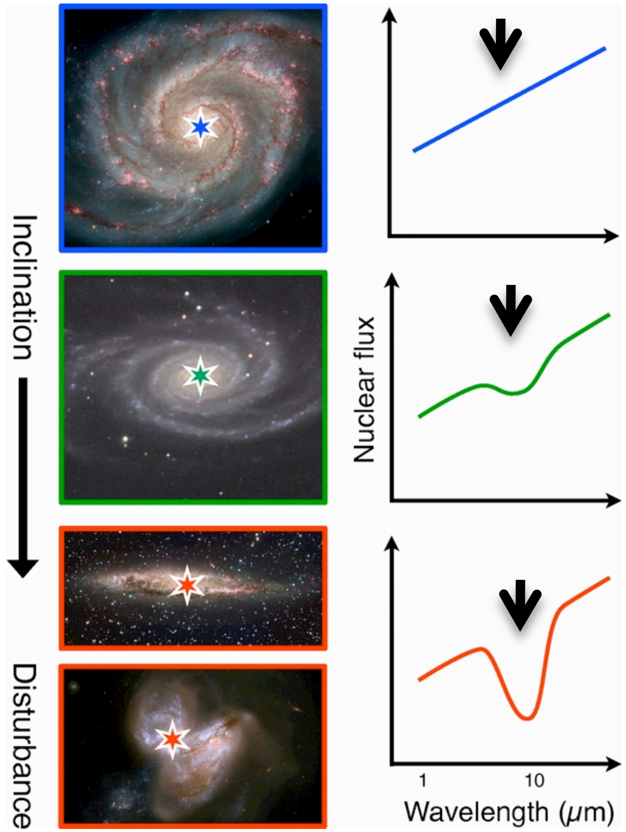
Kawakatu & Wada 2008

Host galaxy: kpc scale obscuration





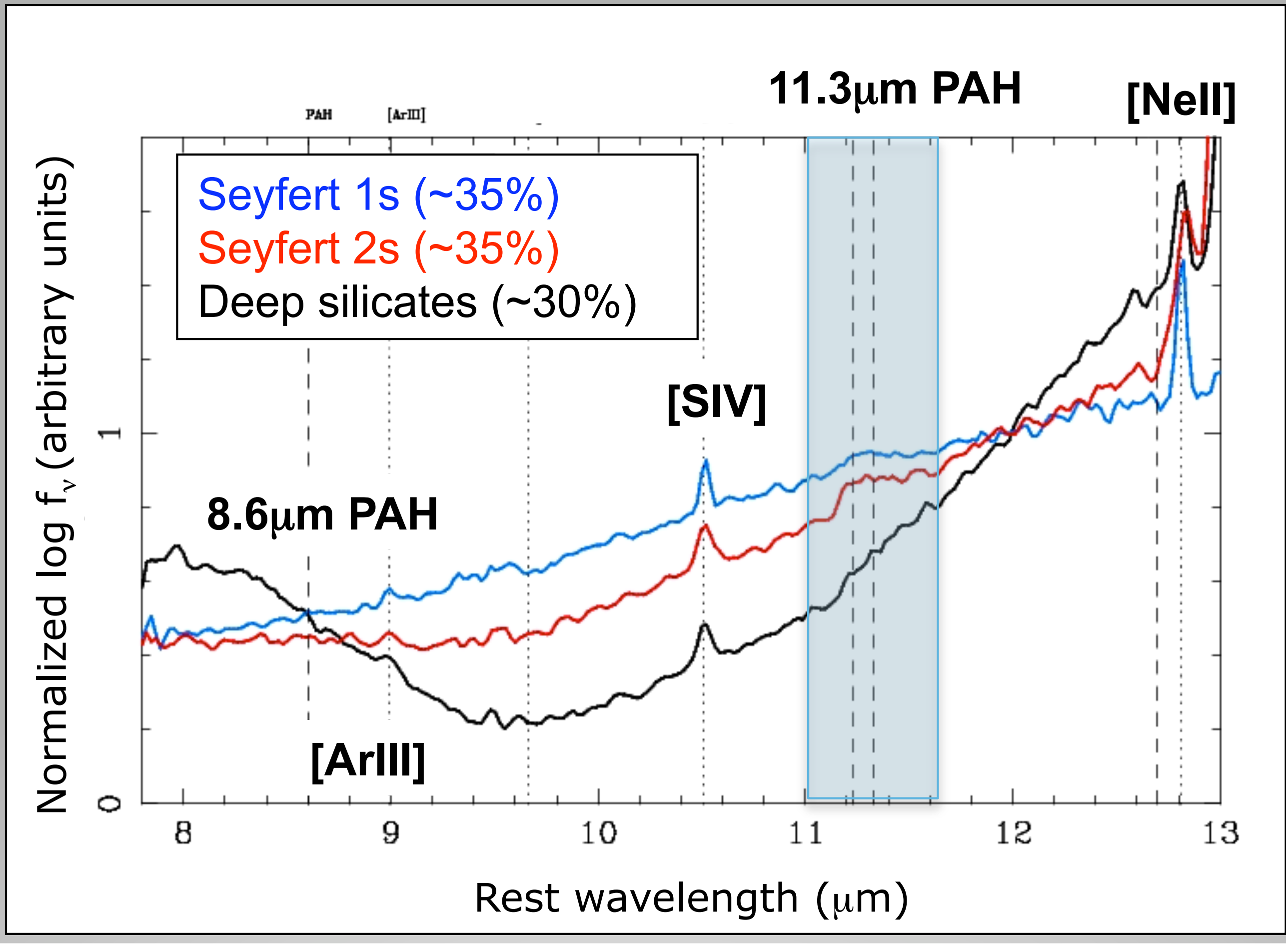
9.7μm silicate feature



Effects of extinction on kpc scales: IR using Spitzer/IRS: Goulding et al. 2012
Using X-rays and HST images: Guainazzi et al. 2005

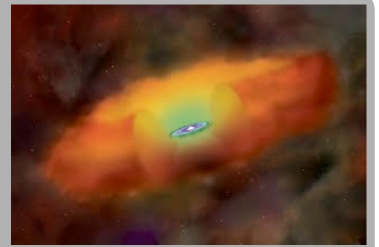
Nuclear (<100pc) spectra of RSA Seyferts

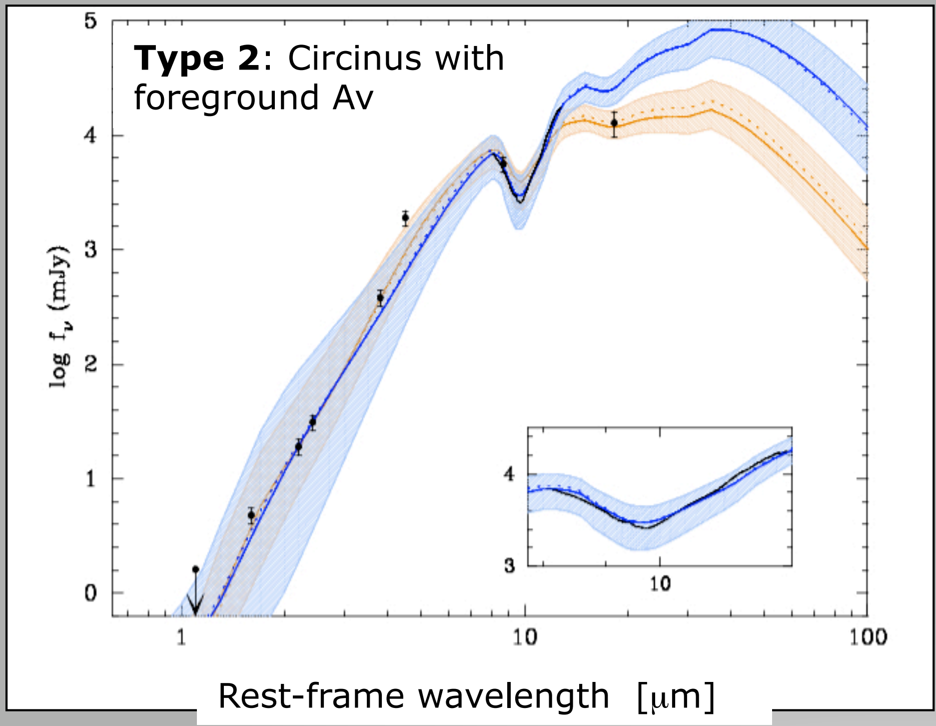
Ground-based observations (0.3-0.5″ resolution) with T-ReCS, VISIR, and Michelle of 30 Seyferts in RSA sample.

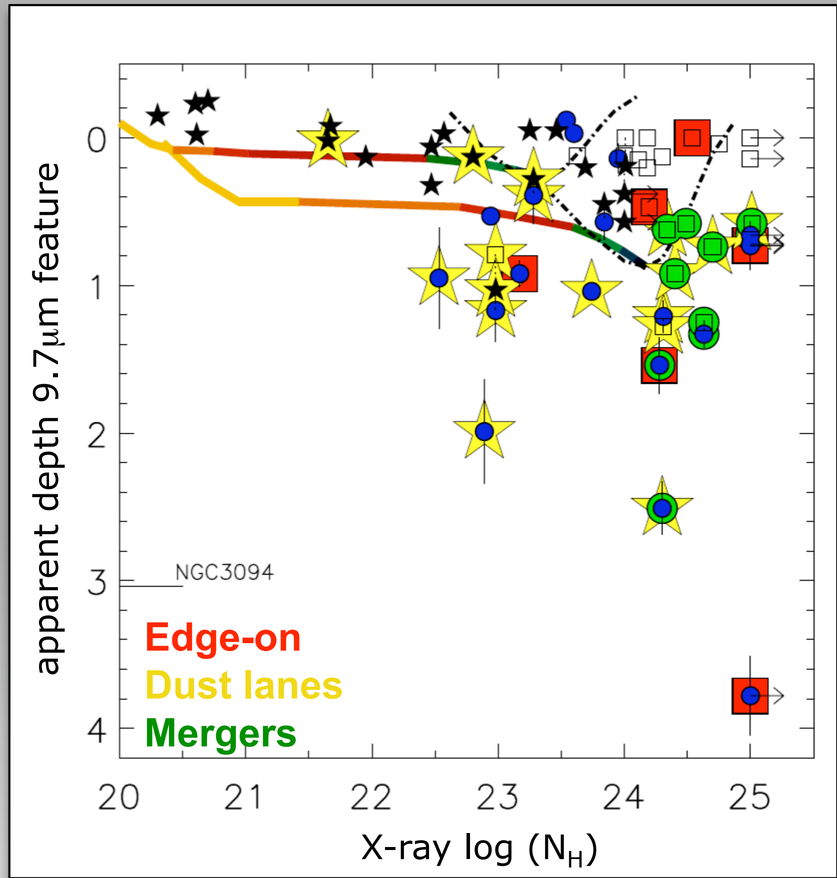


Average nuclear (central 60pc) spectra:
data compiled by Esquej et al. 2014

Importance of host galaxy obscuration on 100pc scales





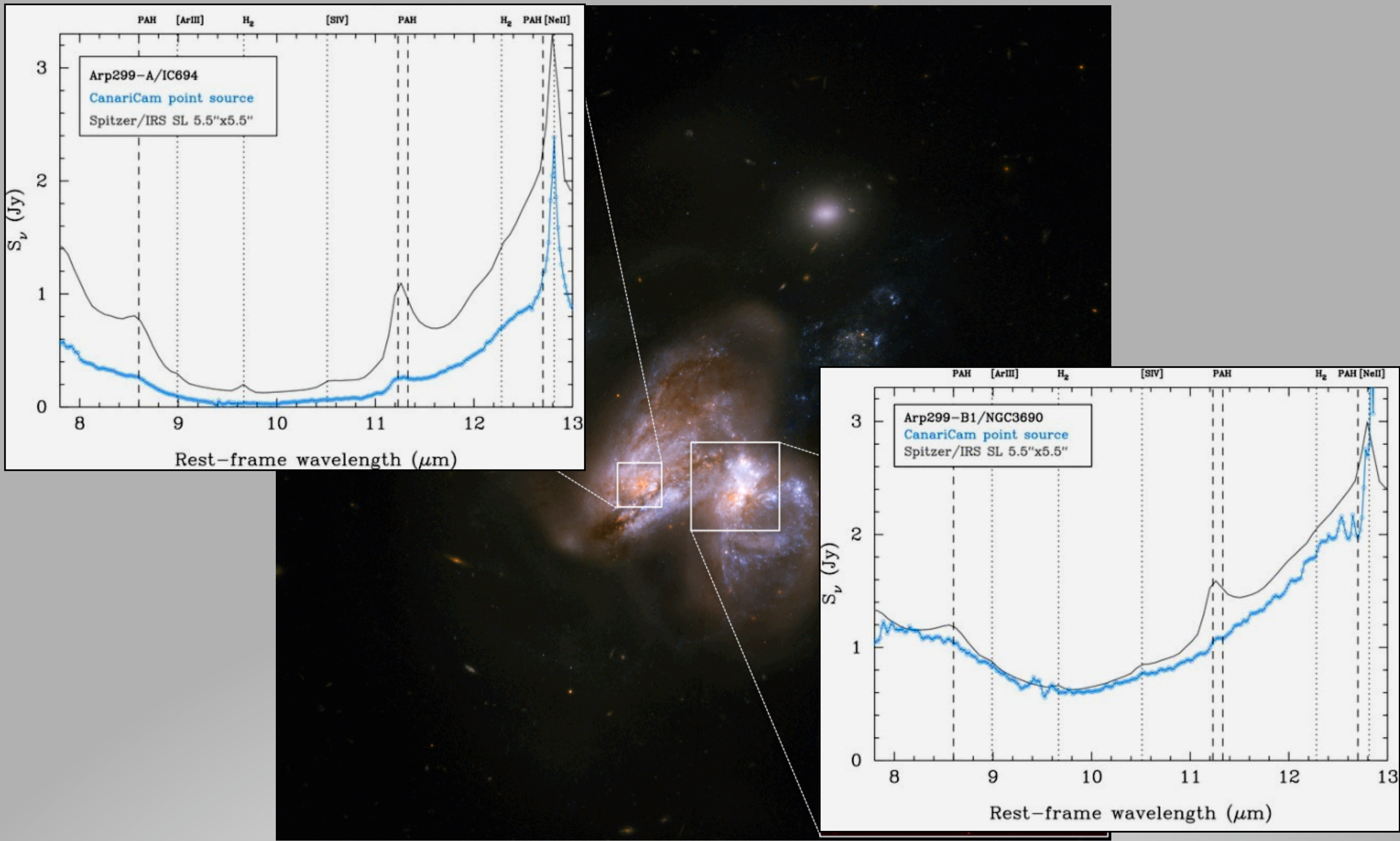


Consistent with presence of 100pc dust lanes in galaxies

Fits: Alonso-Herrero et al. 2011

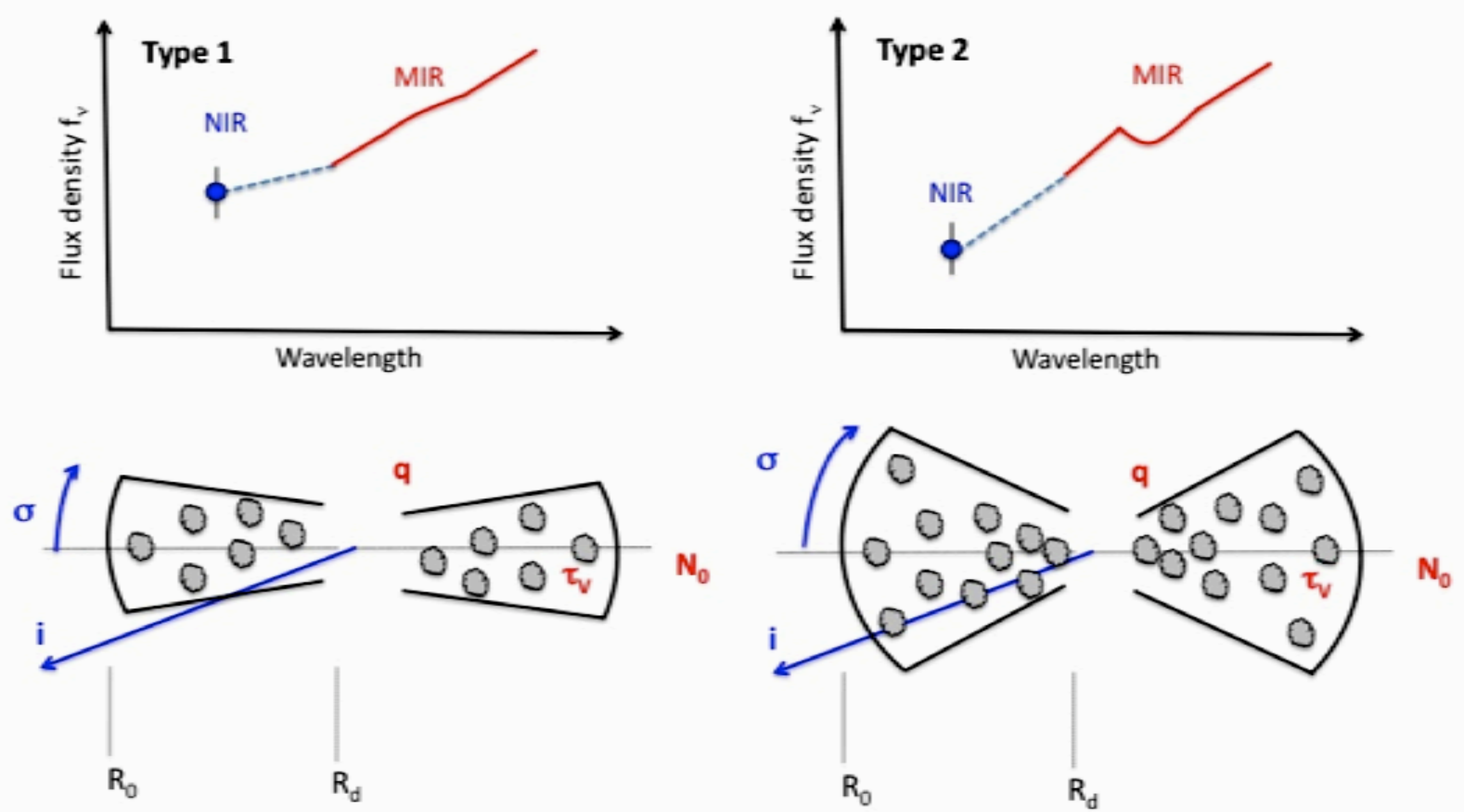
100 pc scales (Gemini/T-RecS, VLT/VISIR): González Martín et al. 2013

Two deeply embedded AGN in Arp299



First GTC/CanariCam observations of AGN survey:
Alonso-Herrero et al. 2013

Do the torus properties change with AGN type, luminosity, etc?

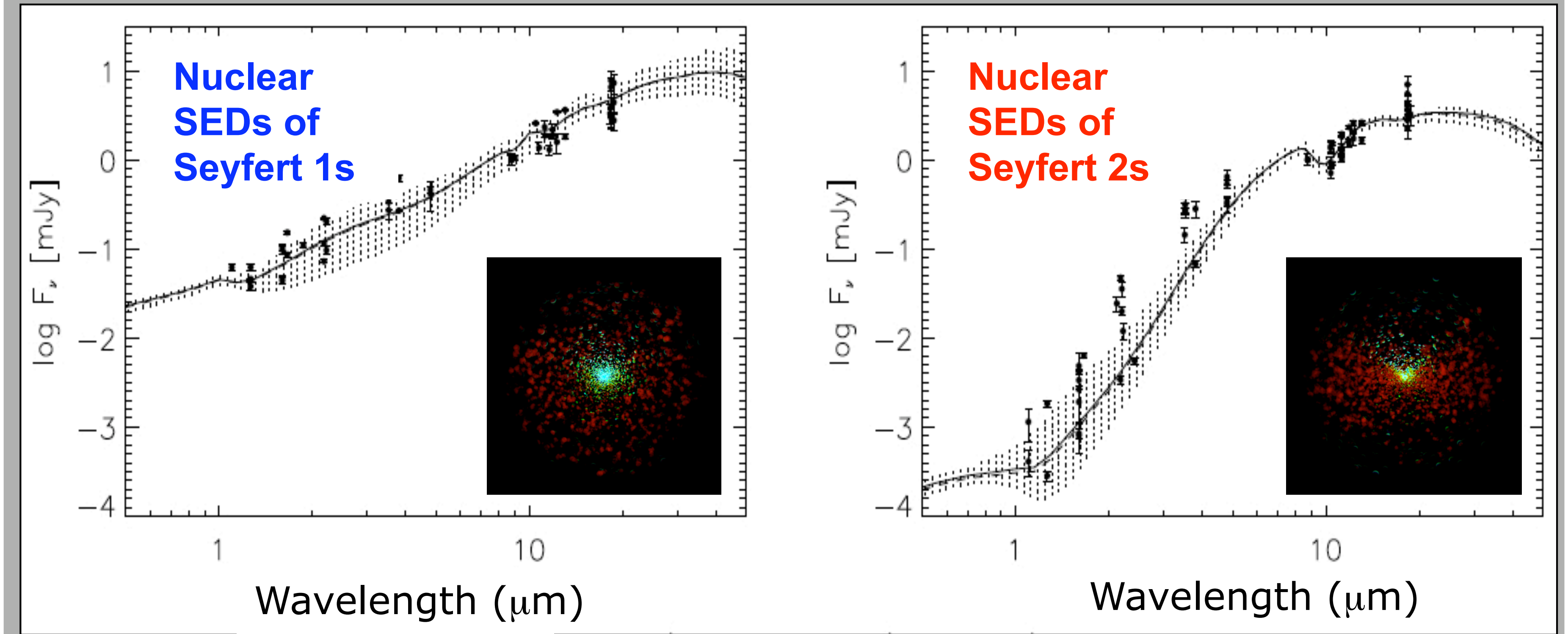


Nenkova et al. (2008) clumpy torus models

Ramos Almeida et al. 2009, 2011, 2014 and Alonso-Herrero et al. 2011

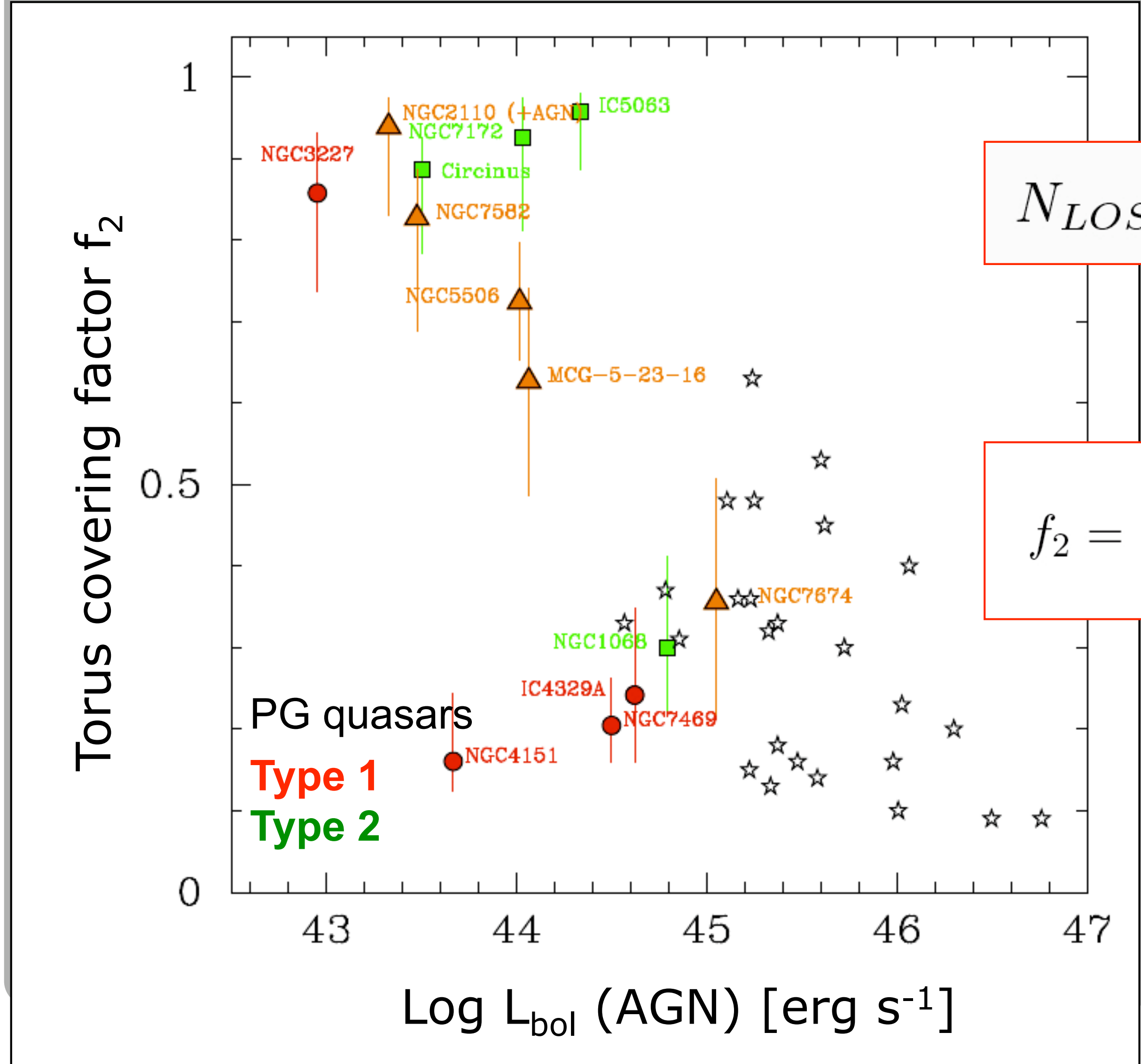
Torus emission peaks in the mid-IR

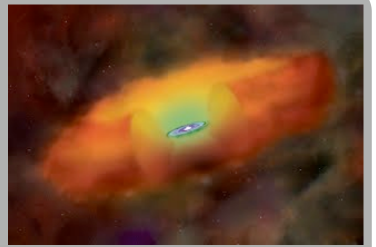
High angular resolution IR observations are needed to minimize contamination from host galaxy
Modeling with Nenkova et al. (2008) clumpy torus models



Ramos Almeida et al. 2009, 2011, 2012, 2014, Alonso-Herrero et al. 2003, 2011, 2013

Receding torus?





$$N_{LOS}(i) = N_0 \ e^{-(90-i)^2/\sigma^2_{\rm torus}}$$

$$P_{\rm esc} \simeq e^{(-N_{\rm LOS})}$$

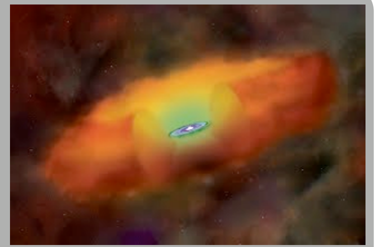
$$f_2 = 1 - \int_0^{\pi/2} P_{\rm esc}(\beta)\cos(\beta)d\beta.$$

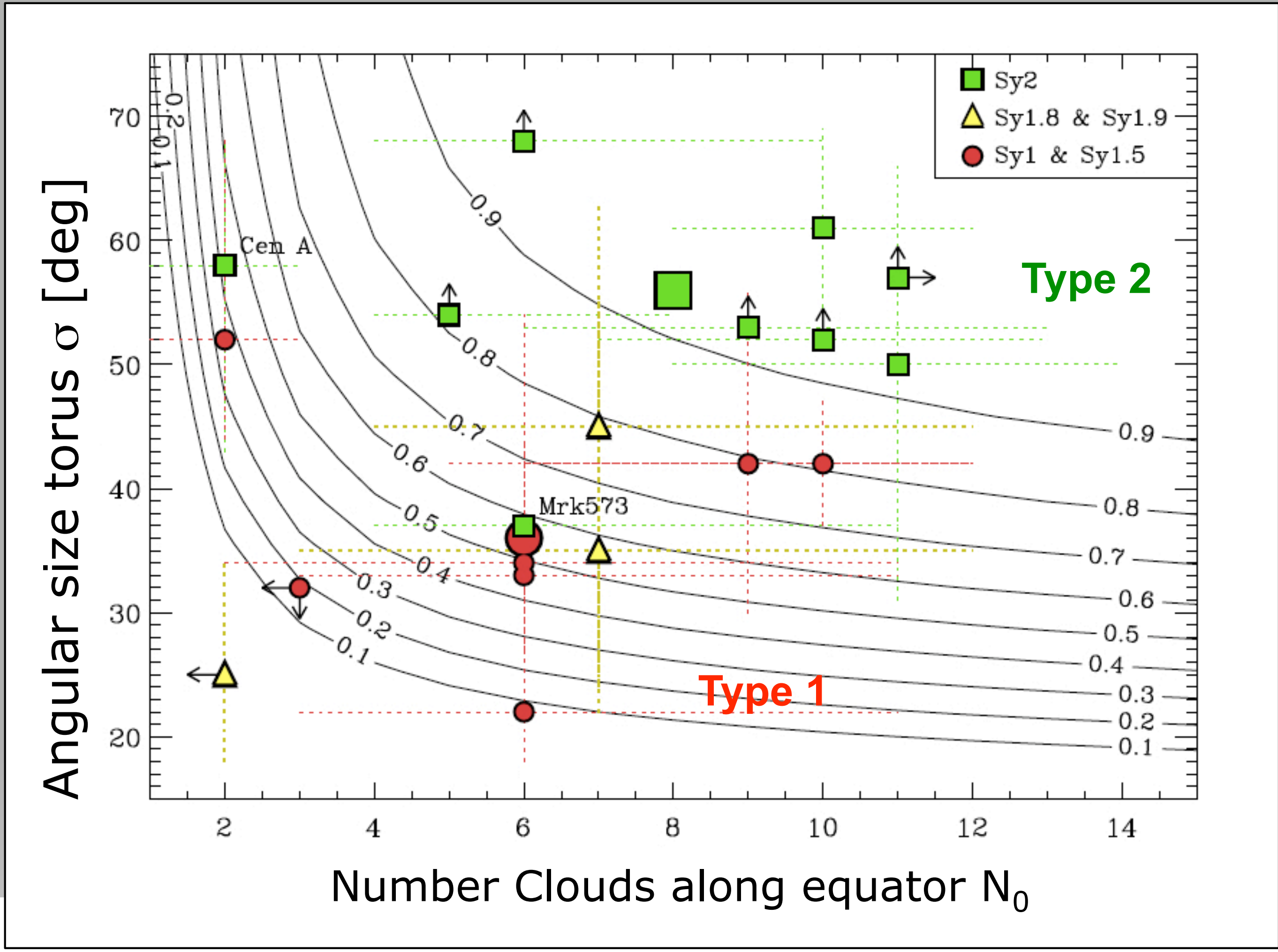
Covering factor f_2 is the ratio of type 2 to type1 AGN

Observationally f_2 decreases at high L_{AGN}

Alonso-Herrero et al. 2011, also Mor et al. 2009 for PG quasars

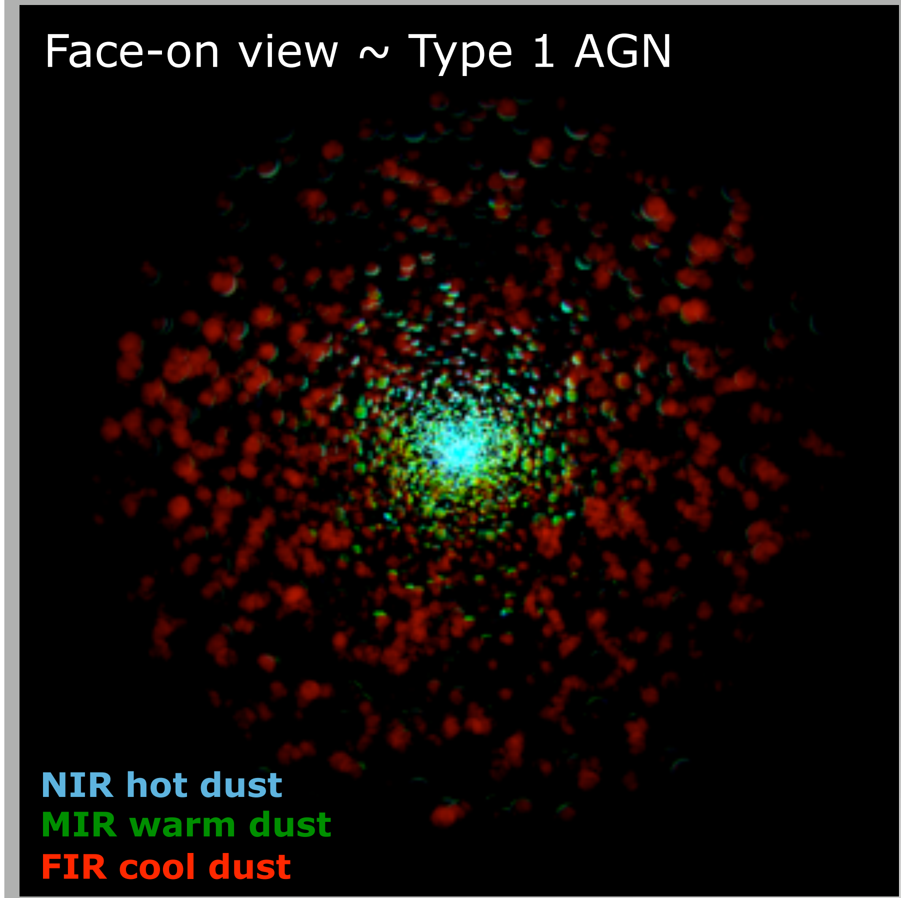
Different Covering Factors

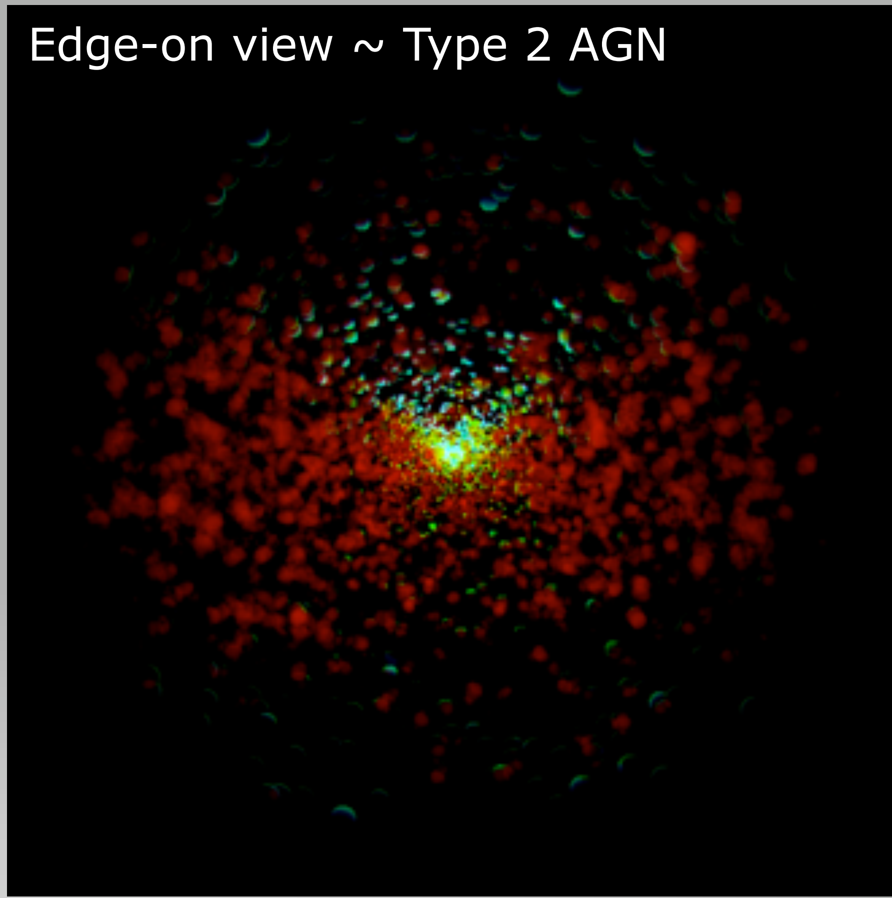




Ramos Almeida et al. 2011

The extent of the dusty torus

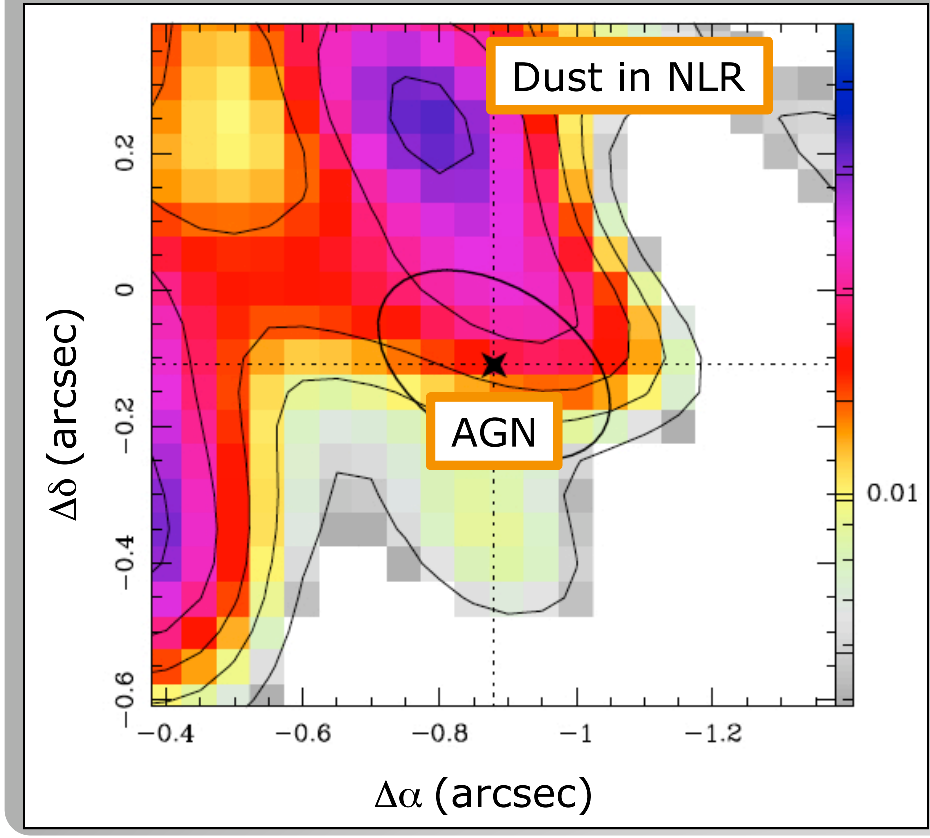




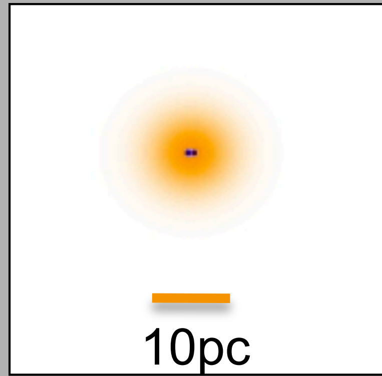
Torus models from Hönig & Kishimoto 2010
http://www.sungrazer.org/CAT3D.html and review Hönig 2013

The dusty torus of NGC1068

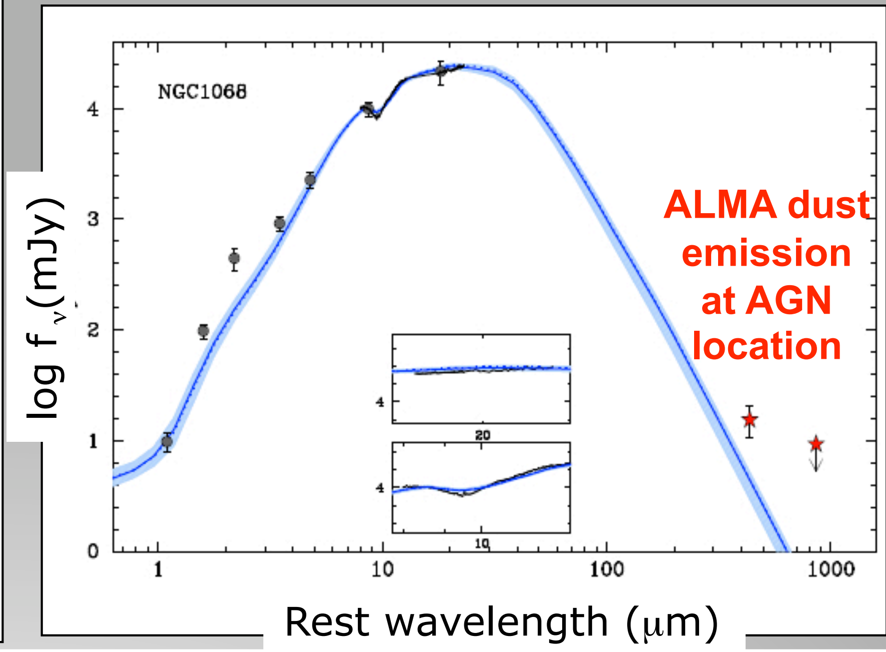
ALMA continuum emission at 435μm at 0.2”x0.4” angular resolution, no AGN point source FWHM<32-16pc



MIDI model image at 12μm



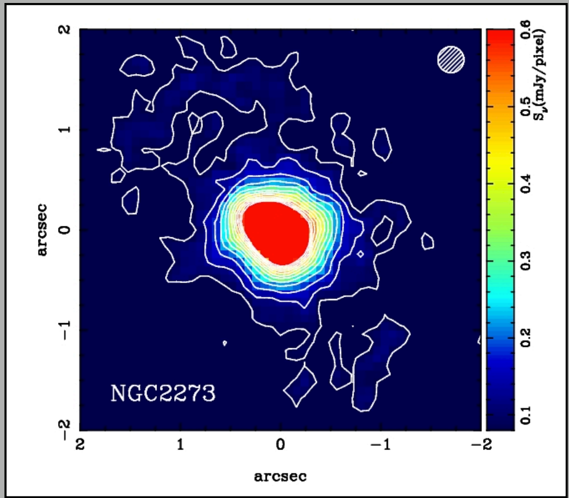
Burtscher et al. 2013



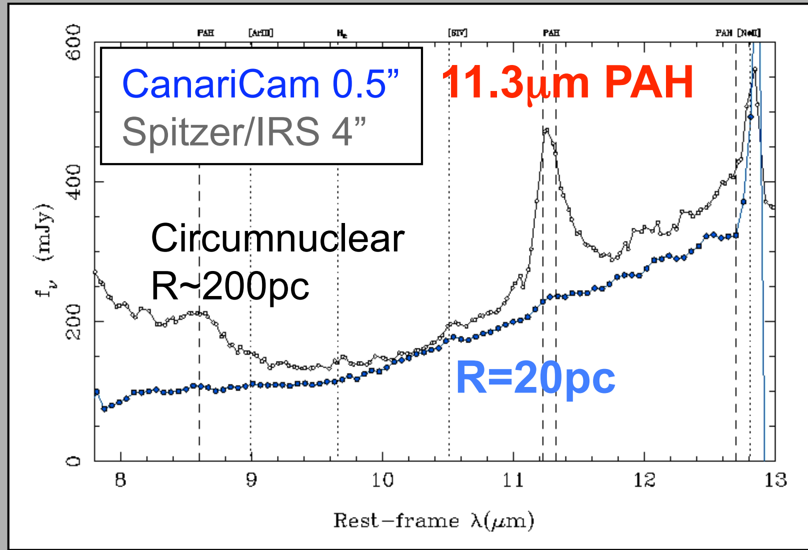
ALMA data: García Burillo et al. 2014 (about to be submitted)

SED + spectroscopy fit: Alonso-Herrero et al. 2011

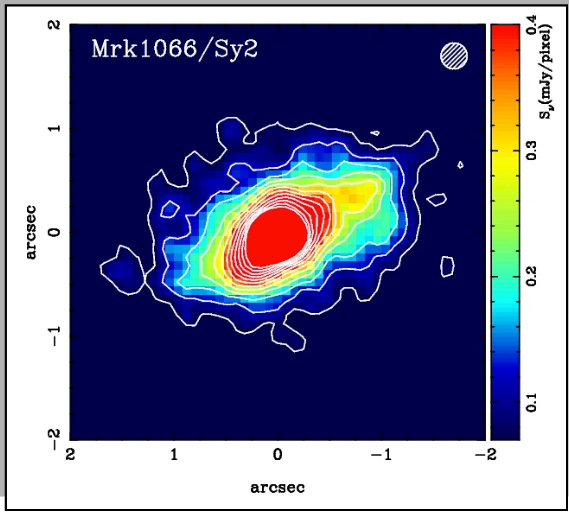
Nuclear and Circumnuclear SF in AGN



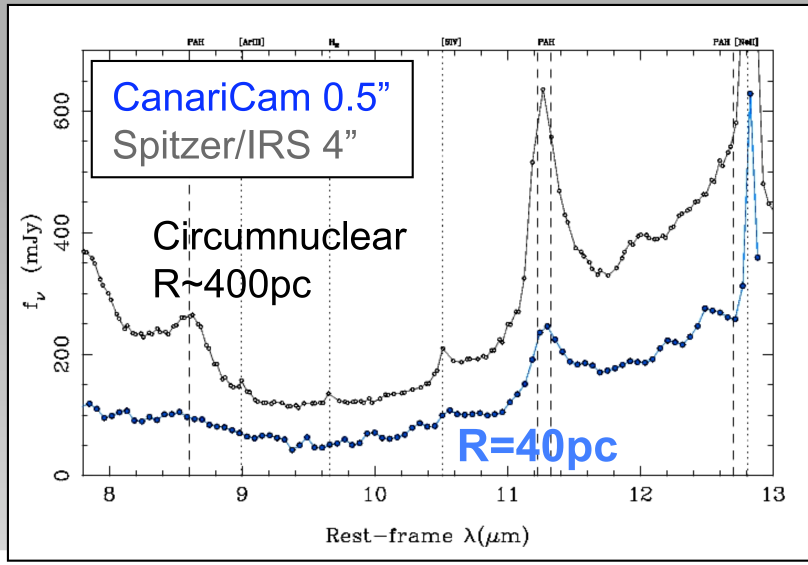
NGC2273



GTC/CanariCam 8.7μm



Mrk1066



Alonso-Herrero et al. 2014 in preparation, see also e.g., Siebenmorgen et al. 2004, Hönig et al. 2010, Esquej et al. 2014

Nuclear PAH molecules shielded by torus

Siebenmorgen et al. 2004 predict PAH evaporate at D_{AGN}< 10pc but will survive at D_{AGN}>100pc
PAHs will survive if rate of reaccretion of carbon onto PAHs higher than evaporation rate due to harsh AGN radiation field

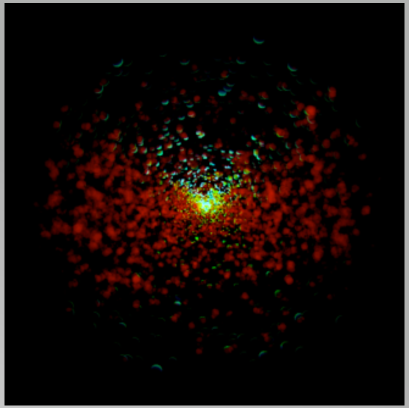
$$\tau \approx 700\,\mathrm{yr} \left(\frac{N_\mathrm{H}(\mathrm{tot})}{10^{22}\,\mathrm{cm}^{-2}}\right)^{1.5} \left(\frac{D_\mathrm{agn}}{\mathrm{kpc}}\right)^{2} \left(\frac{10^{44}\,\mathrm{erg\,s}^{-1}}{L_\mathrm{X}}\right)$$

3000yr

Voit 1991, 1992, Miles 1994

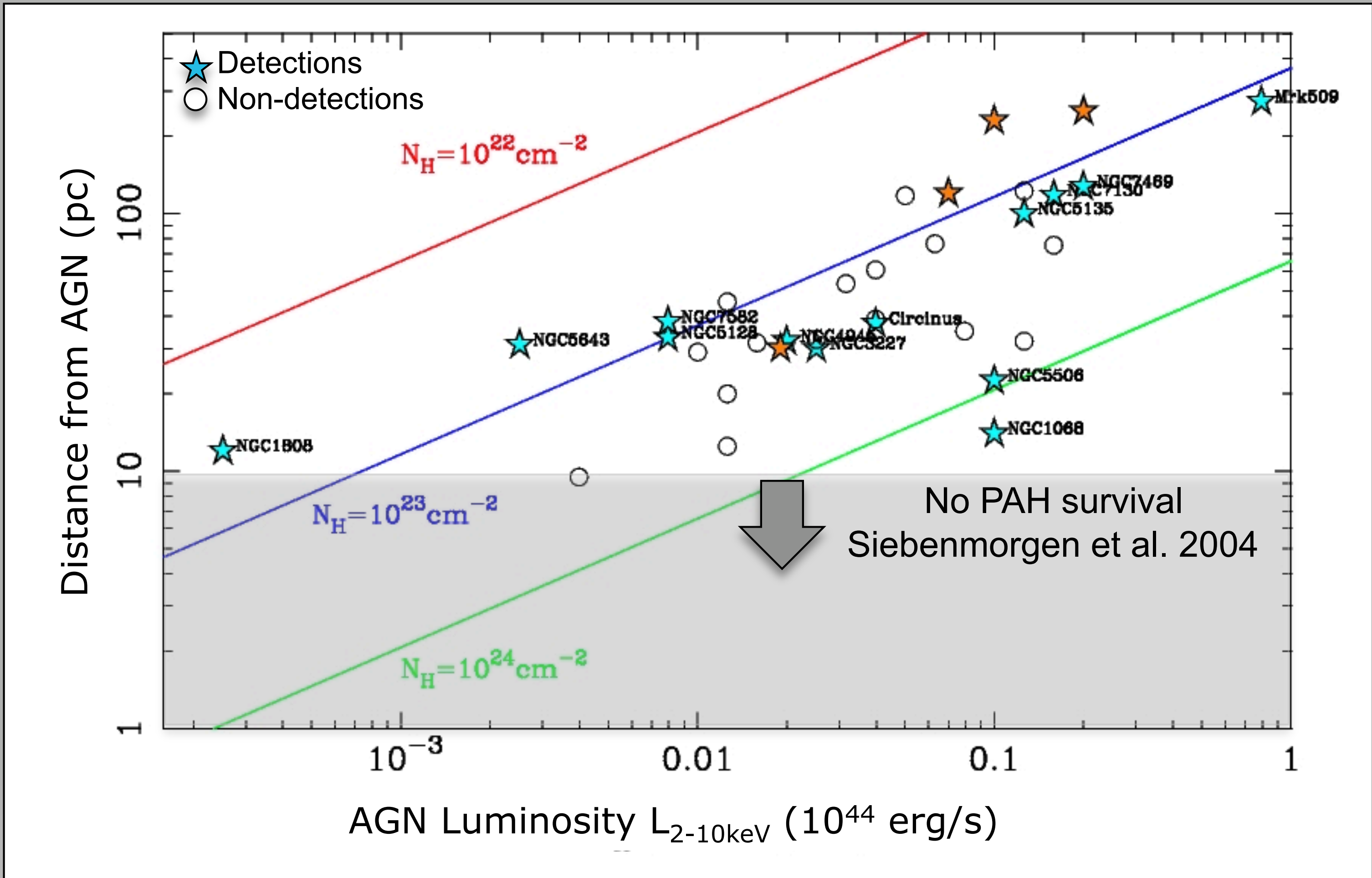
Torus and/or material in host galaxy provides sufficient material to shield the PAH molecules for RSA Seyferts:

L_X(AGN)~10^{41}-10^{44} erg/s
Distances to AGN D_{AGN} ~12-250pc
N_H~a few 10^{23} to 10^{24}cm^{-2}



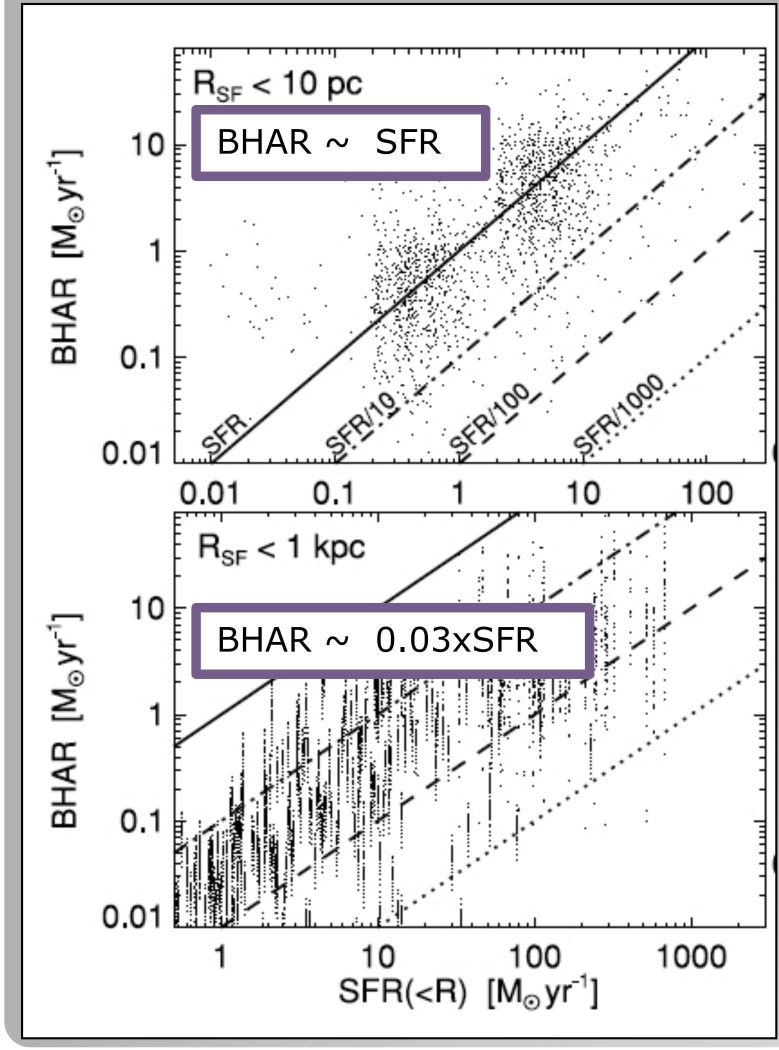
Ramos Almeida et al. 2009, 2011, Alonso-Herrero et al. 2011, González-Martín et al. 2013, Esquej et al. 2014

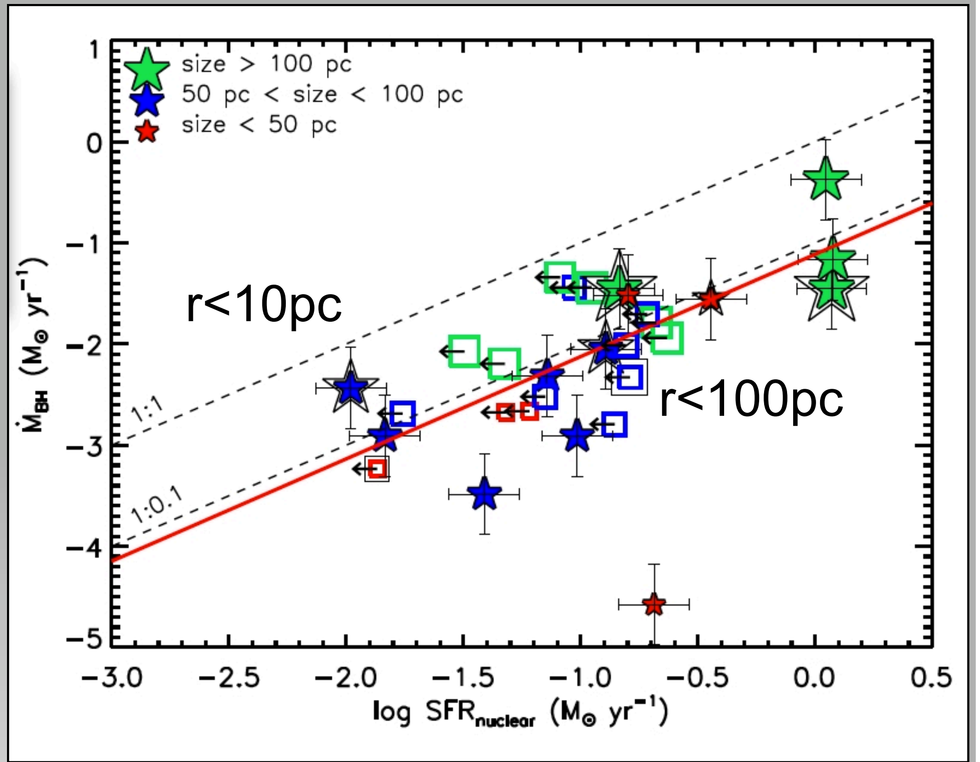
11.3μm PAH carriers do not get destroyed near AGN to distances >10pc



RSA galaxies: data compiled by Esquej et al. 2014
New GTC/CanariCam observations: Alonso-Herrero et al. 2014 in prep.

Black Hole Accretion Rate vs. Nuclear SFR

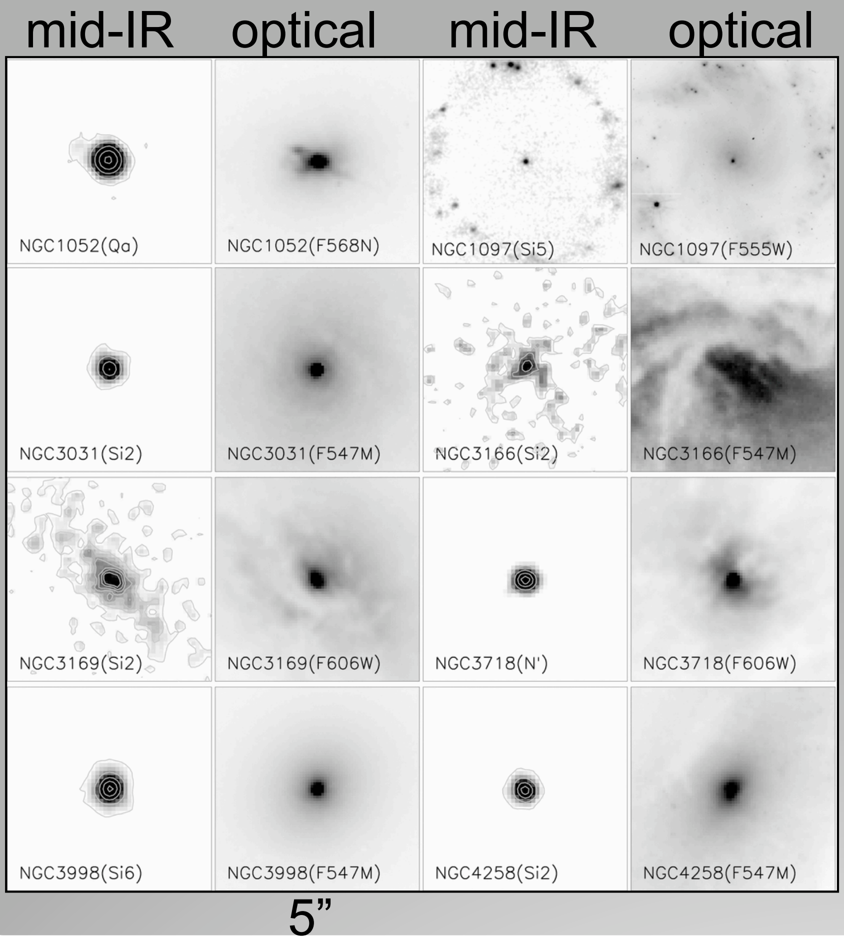




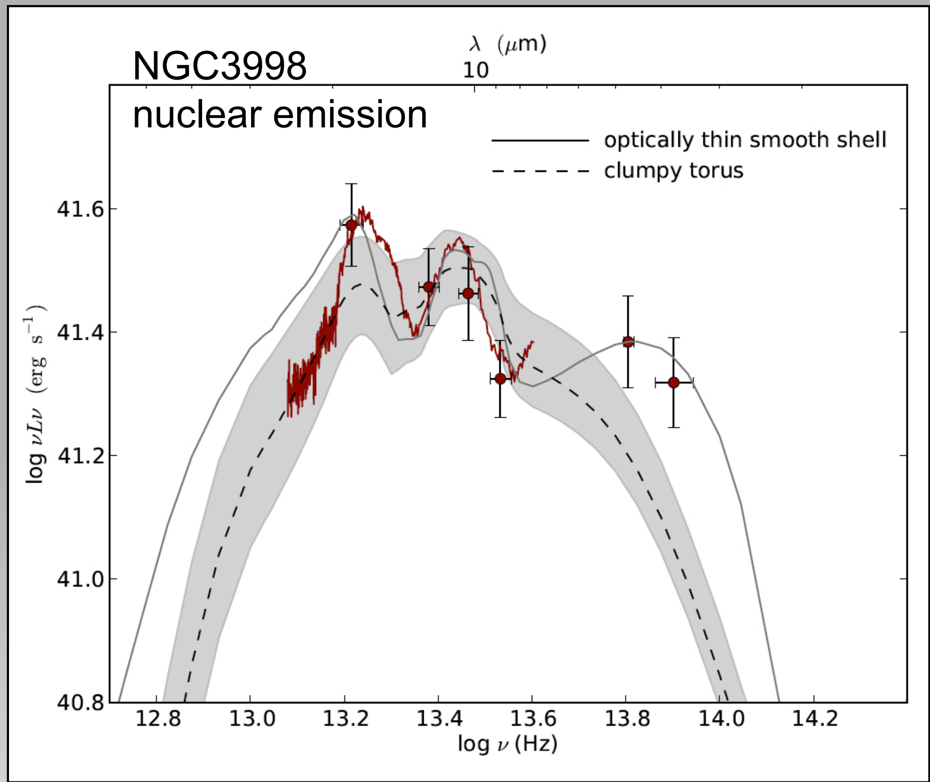
Numerical simulations: Hopkins & Quataert 2010

Empirical relation: Esquej et al. 2014

Is there a torus in low luminosity AGN?

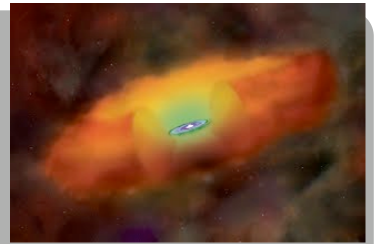


Theoretical models predict L_{bol}<10 ^{42}erg/s, low accretion cannot sustain the outflows required for large column densities



Mason et al. 2012, 2013

Conclusions



- Host galaxy obscuration even on <100pc scales is important when modeling torus properties
- Clumpy torus models reproduce nuclear IR emission of Seyfert galaxies but contamination by extended dust emission can be a problem
- Not a single torus? Sy1/high L tori are narrower and contain fewer clouds than those of Sy2/low L
- Torus extent: are ALMA observations our best hope?
- Role of nuclear star formation and destruction/survival PAHs especially at <10pc

High angular res mid-IR data + new VLTI data for large samples of AGN will help understand the torus

Los Piratas Team

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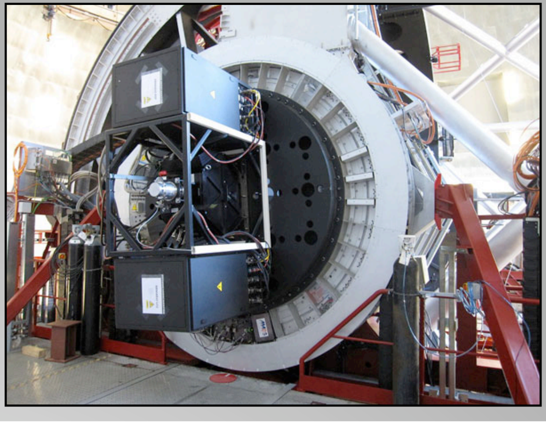
+ Carlos Alvarez, GTC, Spain
+ Charlie Telesco (PI of CanariCam Guaranteed Time)
+ Sebastian Hönig, Copenhagen, Denmark
+ Robert Nikutta, Chile

10.4m GTC

CanariCam



See https://sites.google.com/site/piratasrelatedpublications