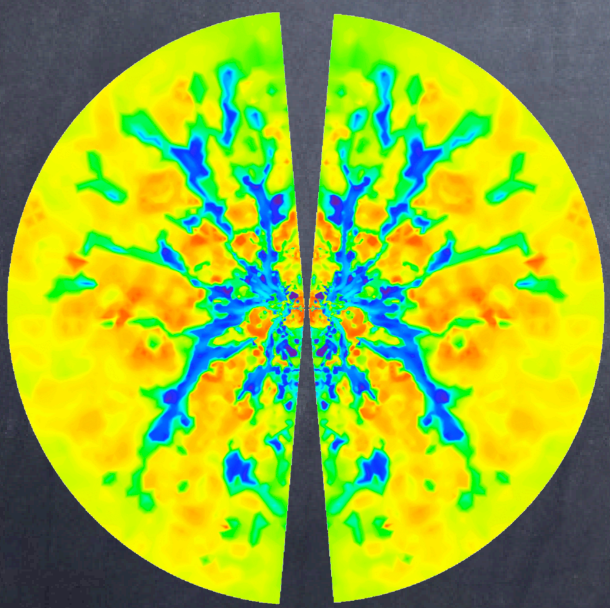
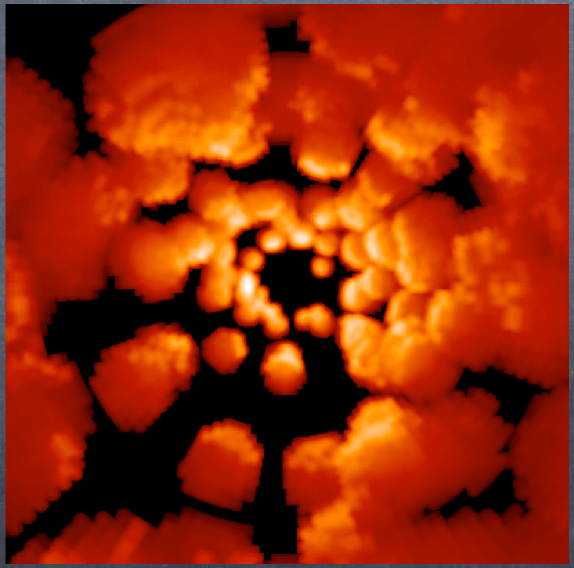
Marc Schartmann

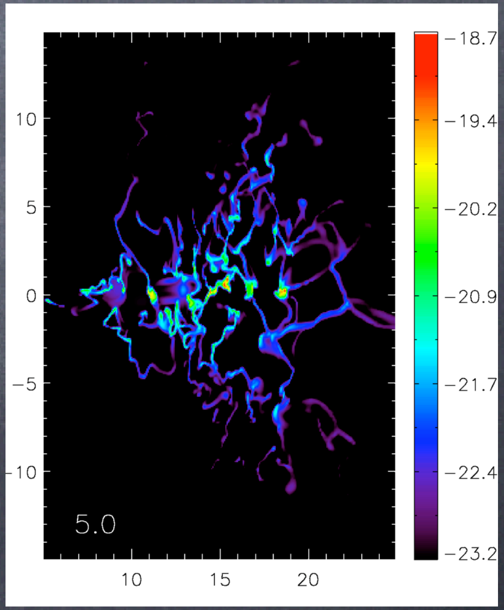
Turbulent AGN tori

MPIA/LSW:
Klaus Meisenheimer, Max Camenzind, Hubert Klahr, Sebastian Wolf, Thomas Henning, Konrad Tristram

MPE/USM:
Andreas Burkert, Martin Krause, Michaela Hirschmann, Christian Alig & CAST group



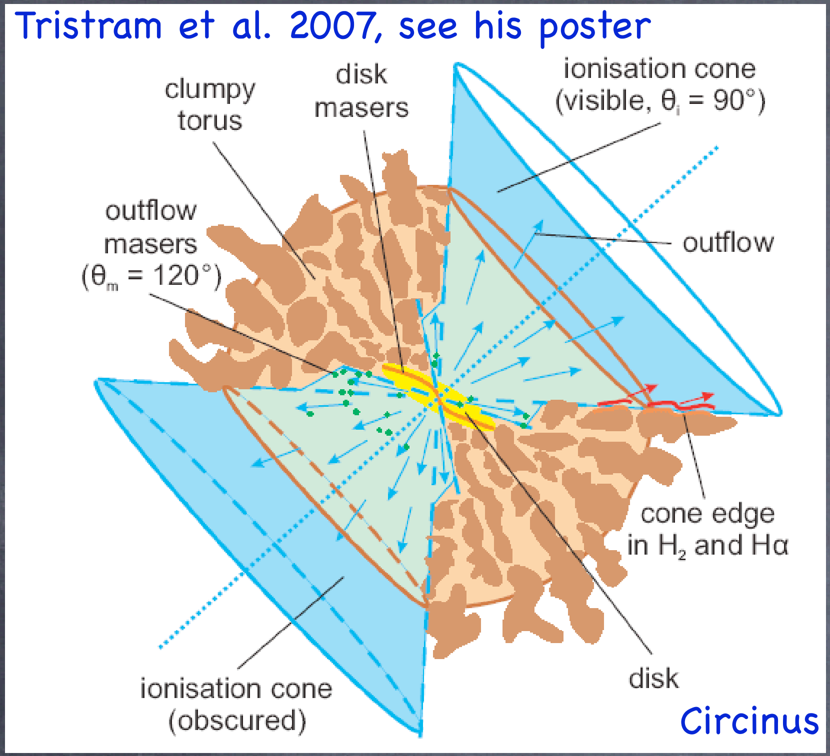




The central kpc:
AGN and their hosts

June, 5th 2008,
Ierapetra, Crete

Motivation: MIDI observations & toy models



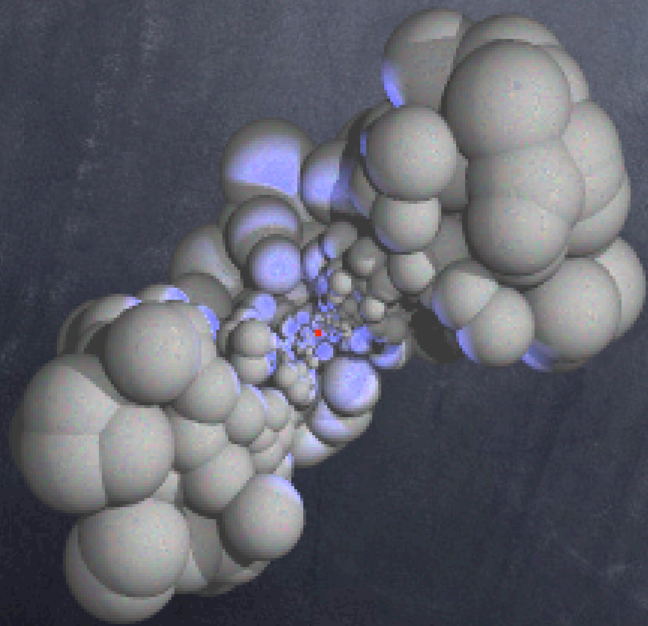
NGC 1068 & Circinus:

- ⋆ filamentary geometrically thick torus (brown)
- ⋆ thin disk (yellow)

MIDI = two-beam-combiner

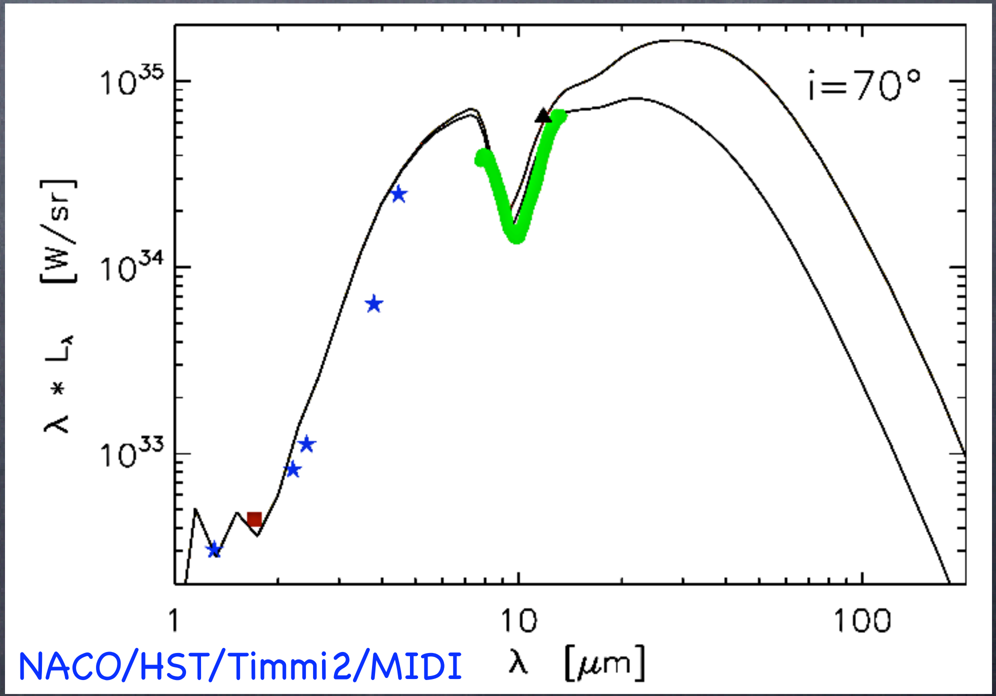
- ⋆ no direct imaging
- ⋆ models needed

Schartmann et al. 2008a



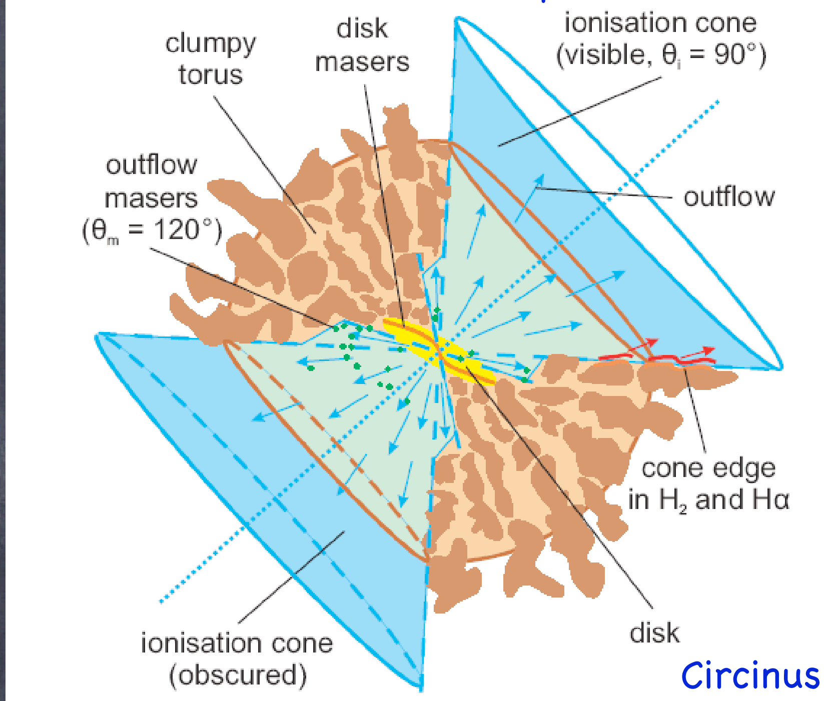
3D Clumpy torus models (MC3D)

data courtesy: Prieto et al., 2004



Motivation: MIDI observations & toy models

Tristram et al. 2007, see his poster



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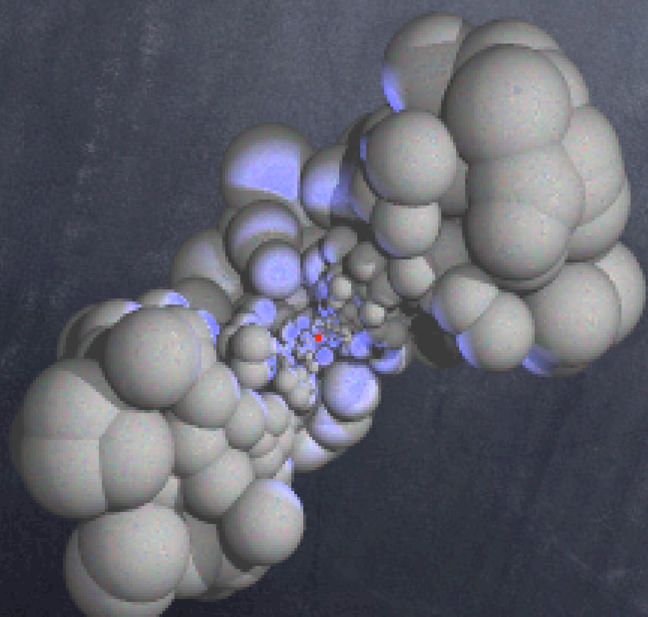

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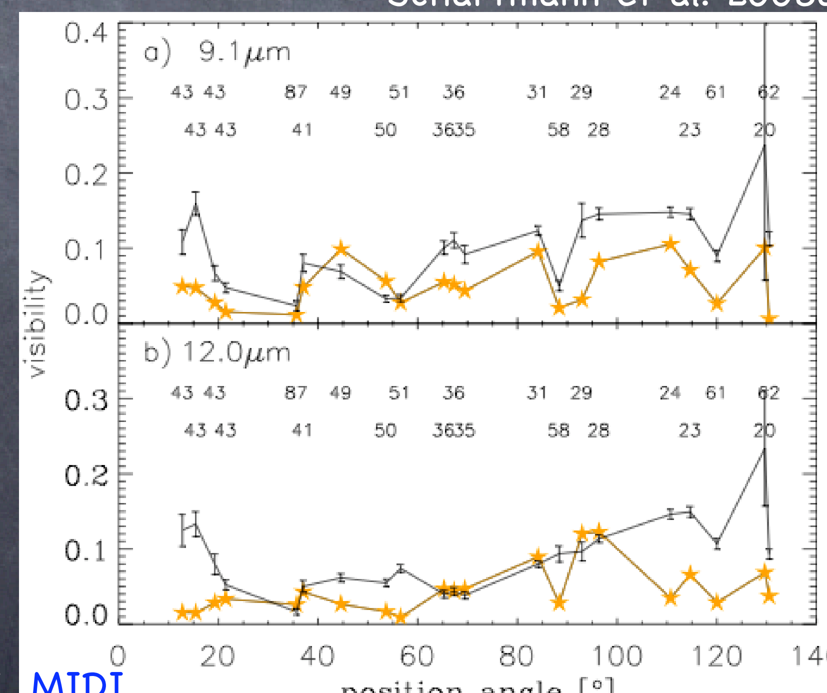
Schartmann et al. 2008a



data courtesy: Tristram et al., 2007

Hydro Models of Tori - setup

main aims:

- step from RT toy models (e.g. Schartmann 05, 08a) to a physical scenario
- investigate effect of stellar evolution of a nuclear star cluster (6.7e8 M_{sun}) on the torus evolution (Camenzind, 1995)
- separation into different evolutionary phases

Main ingredients:

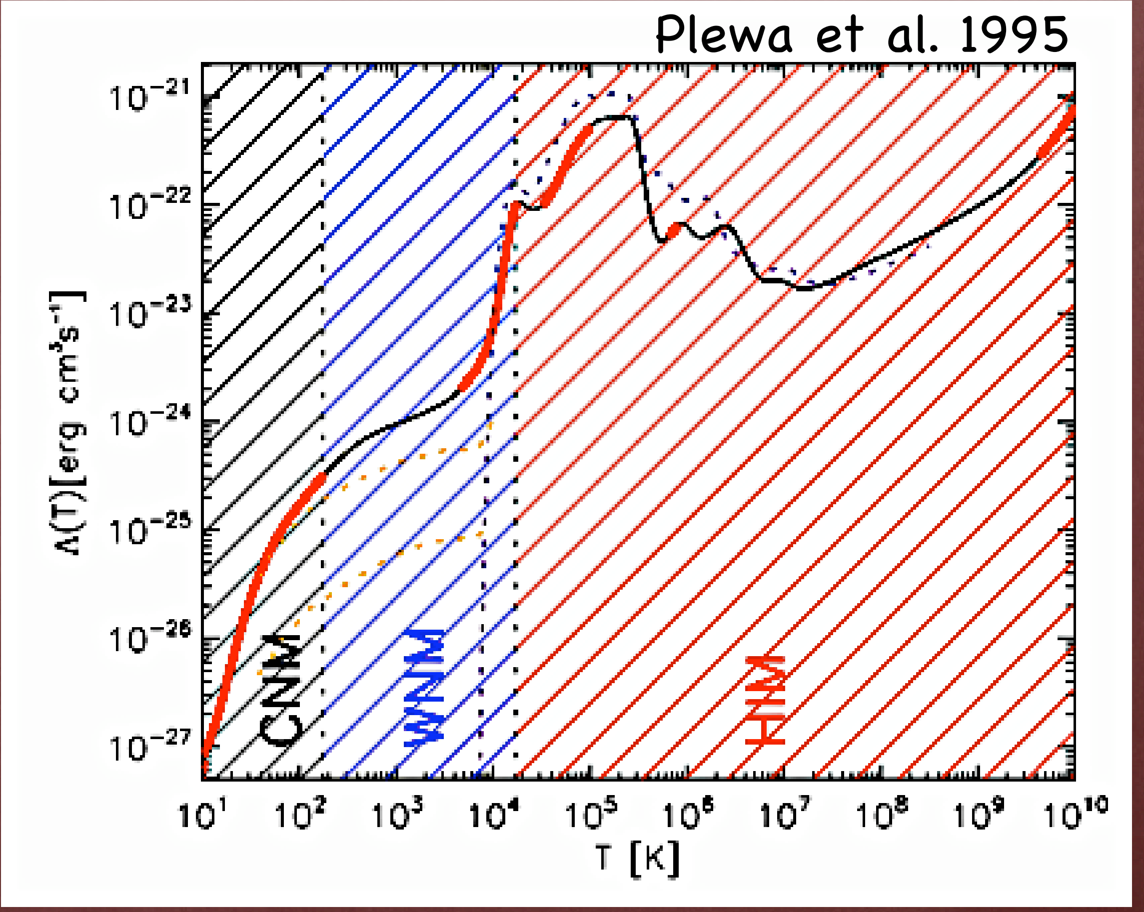
1.

- ⋆ after ≃50 Myr: planetary nebulae major contributors to mass input (M_{ini} < 8 M_{sun}) ⟹ model discrete mass input
- ⋆ average planetary nebulae mass distributed over 3^3 cells, velocity: $v_{turb} + v_{rot}$
- ⋆ mass loss rate = $6 \cdot 10^{-9}\, M_{sun}\, yr^{-1}\, M_{sun}^{-1}$ (Jungwiert et al., 2001)

Hydro Models of Tori - setup

2.
- discrete energy input due to SN Ia explosions
- SN-rate from observations & parameter study: 10^{-10} yr^{-1} M_{sun}^{-1}

3.
- optically thin gas cooling (Cloudy-code)
- solve hydrodynamic equations with TRAMP / PLUTO code



effective cooling curve

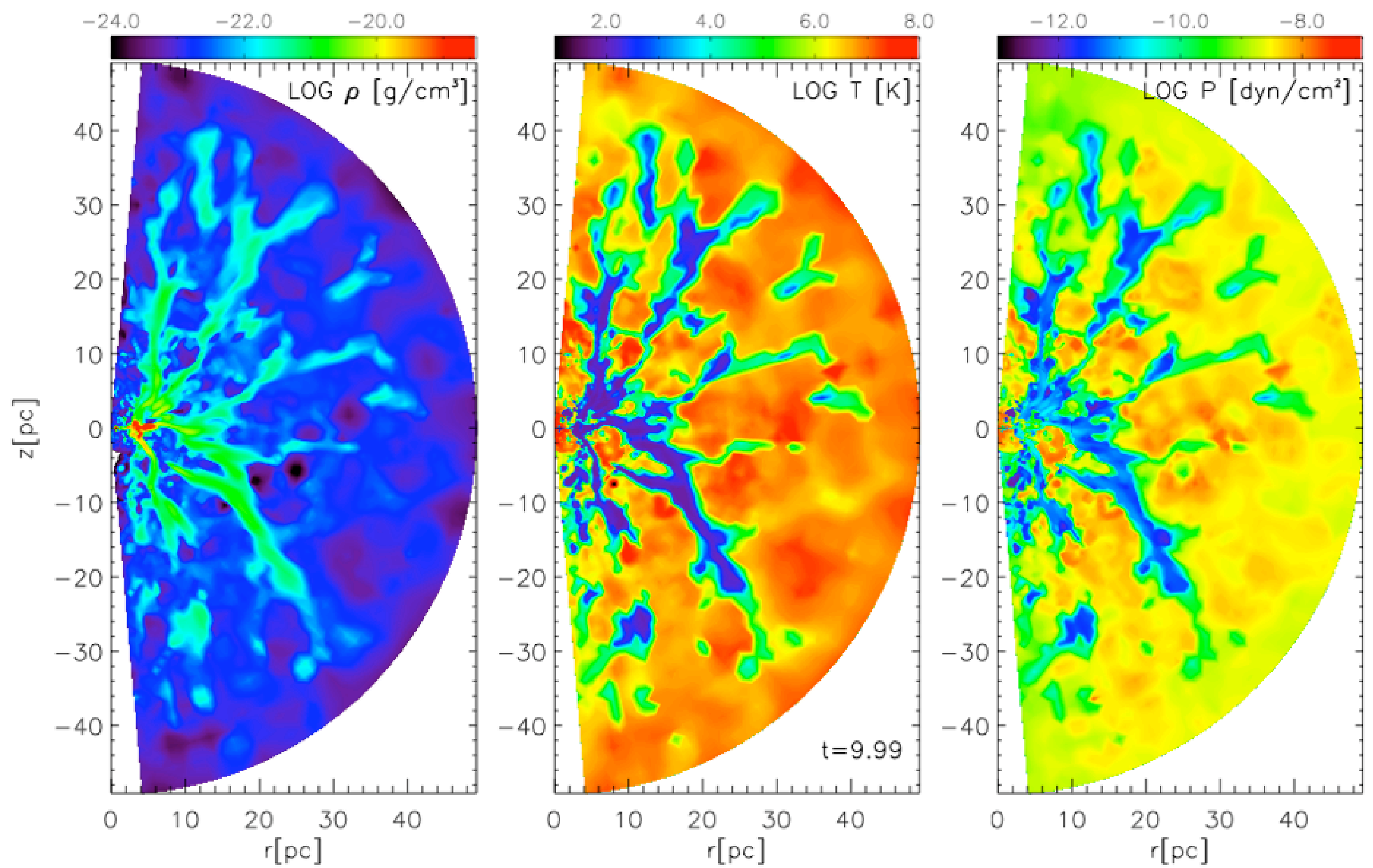
Schartmann et al. 2008b

T and ρ complement.

no pressure equilibrium

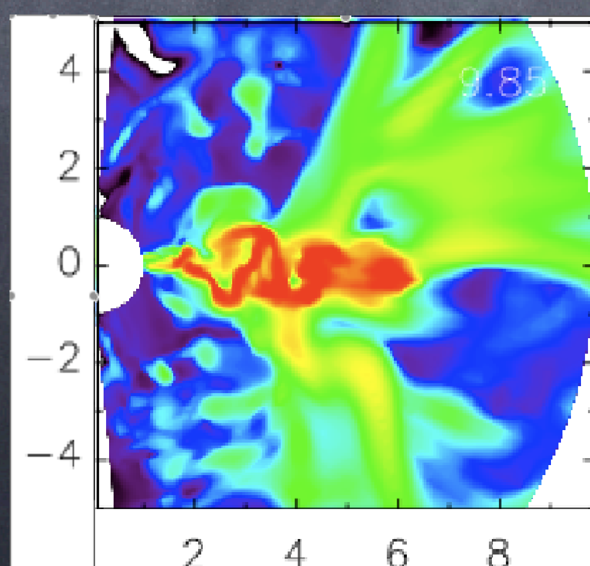
2 component model:

1. filamentary torus
2. dense, turbulent disk

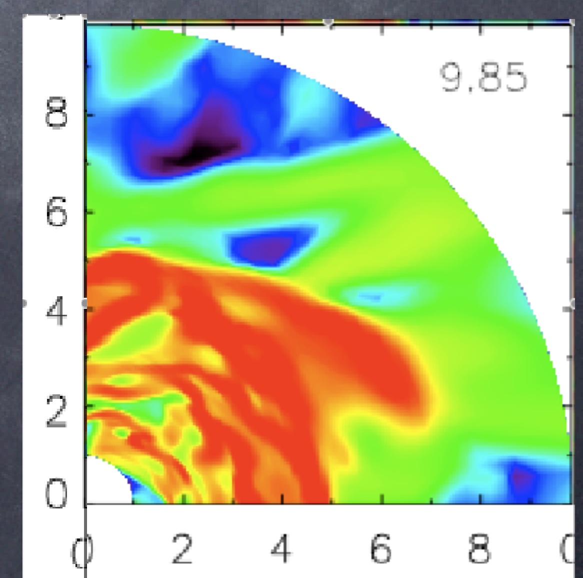


density temperature pressure

zoom: meridional

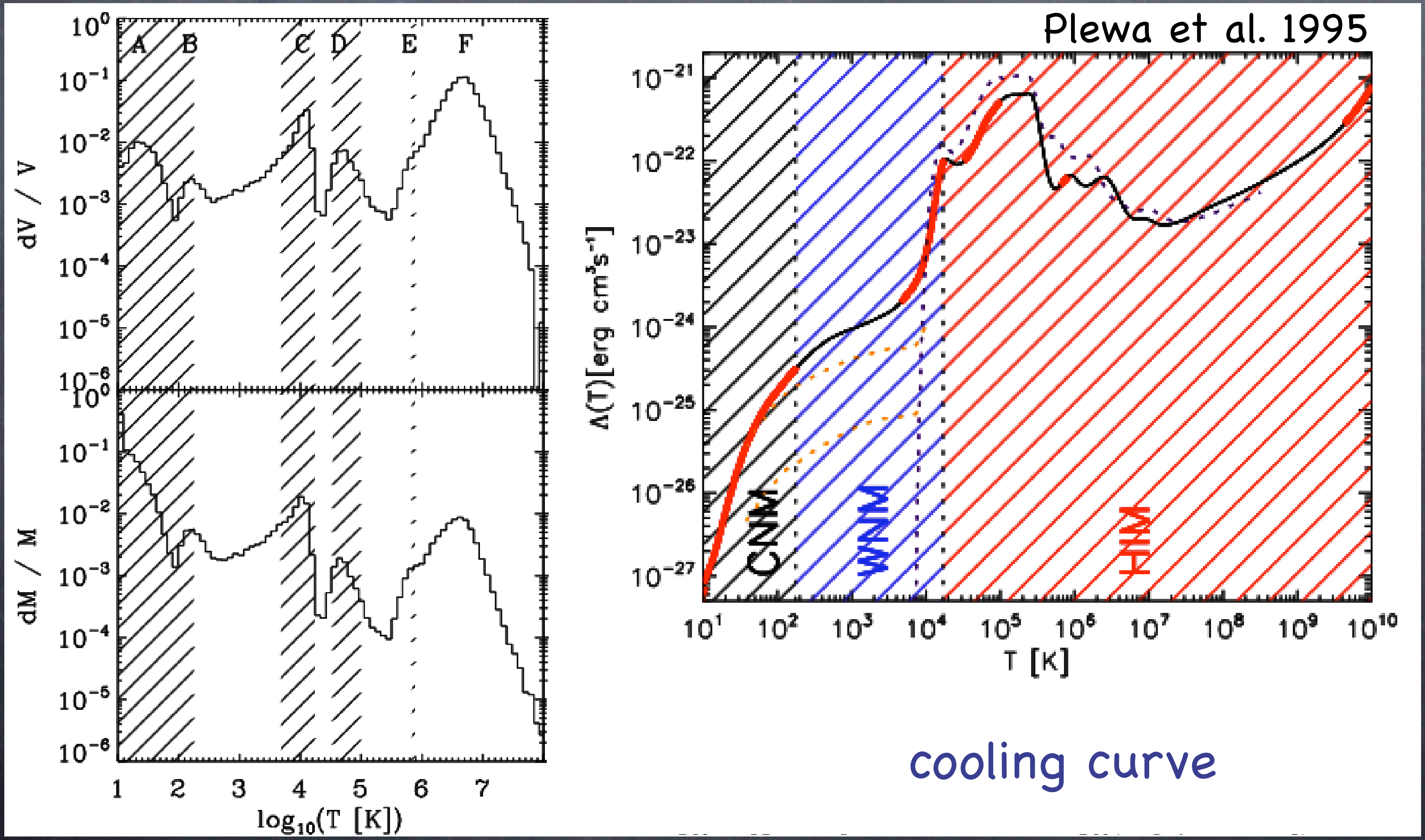


zoom: equatorial



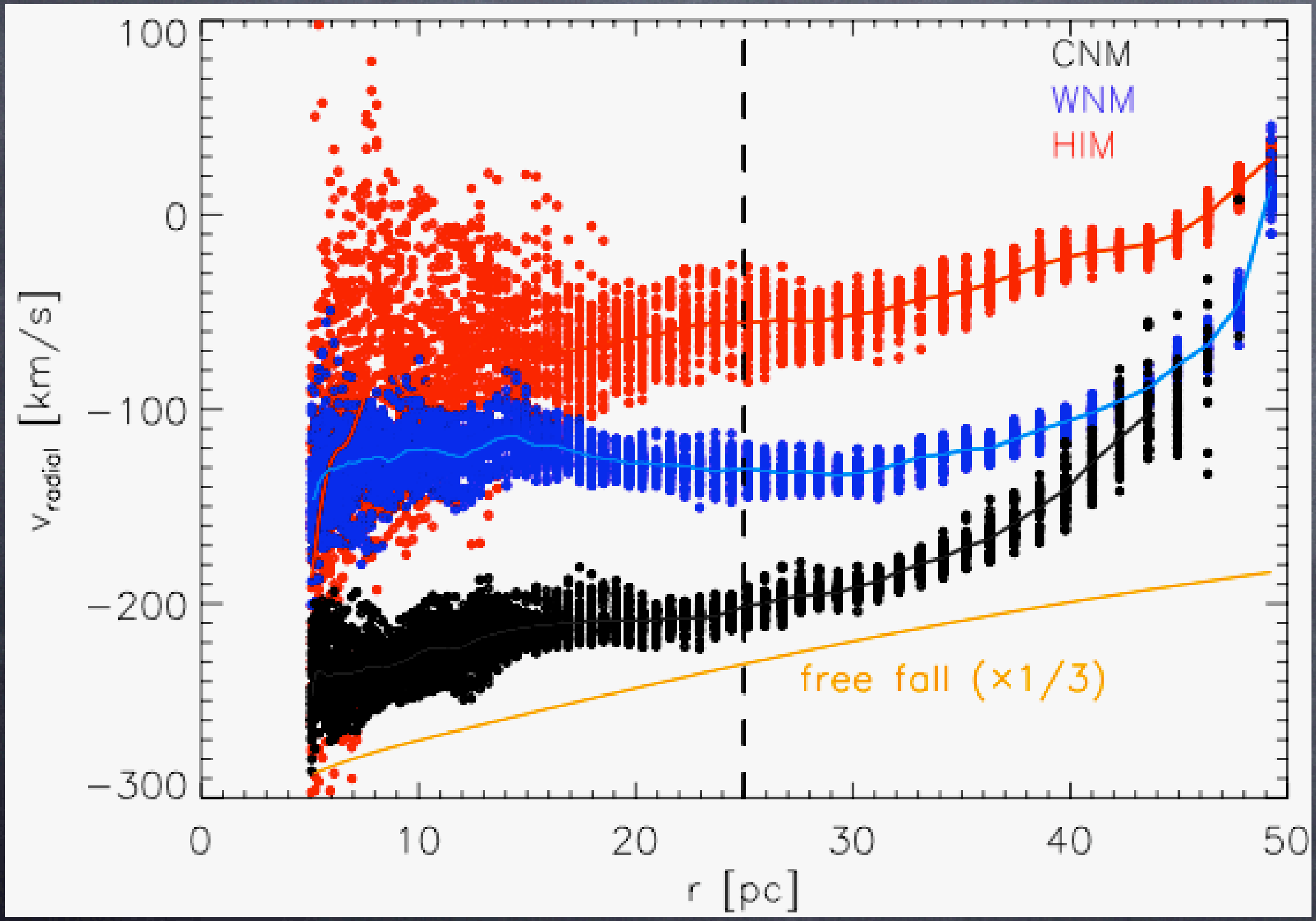
Multiphase medium evolves

temperature PDF shaped by: cooling curve: A, B, C, D, E
energy input: F



Radial velocities in outer torus region

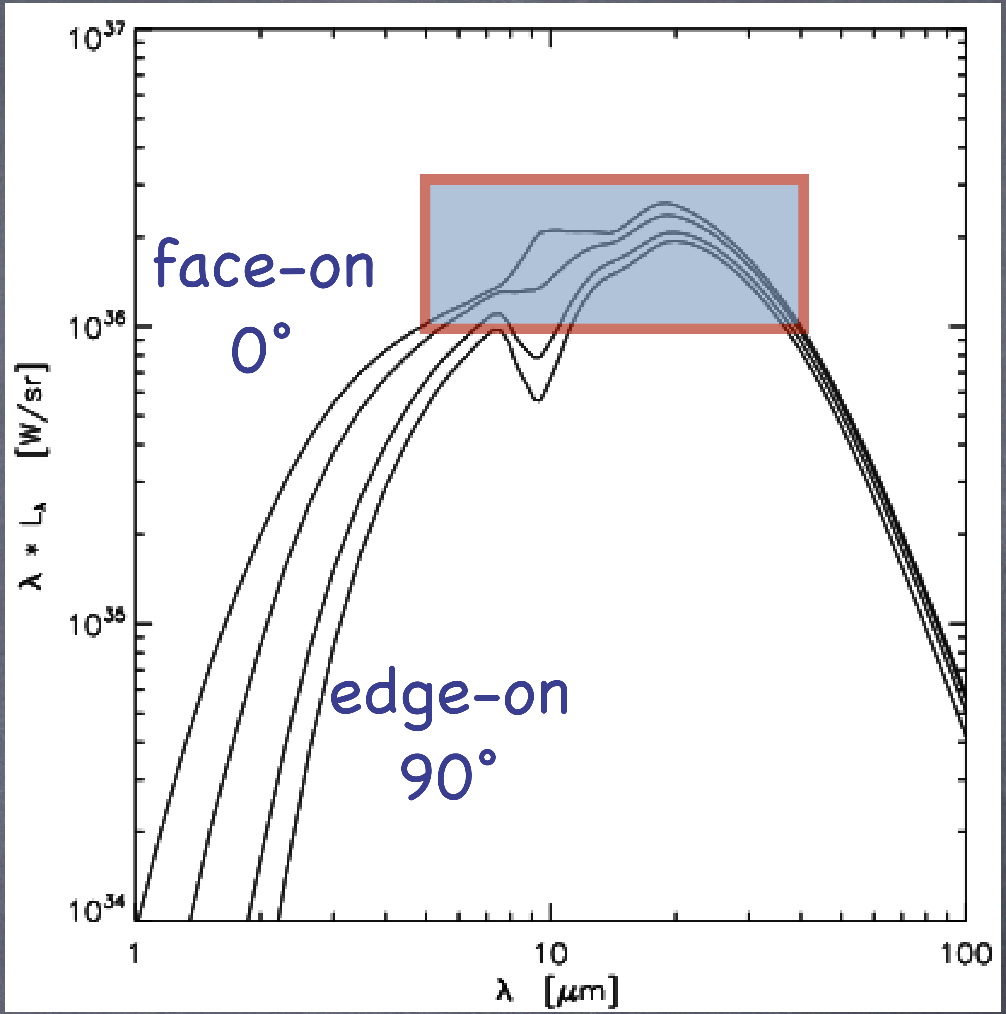
lines: averaged over orbits 8 to 10
dots: single data values in between

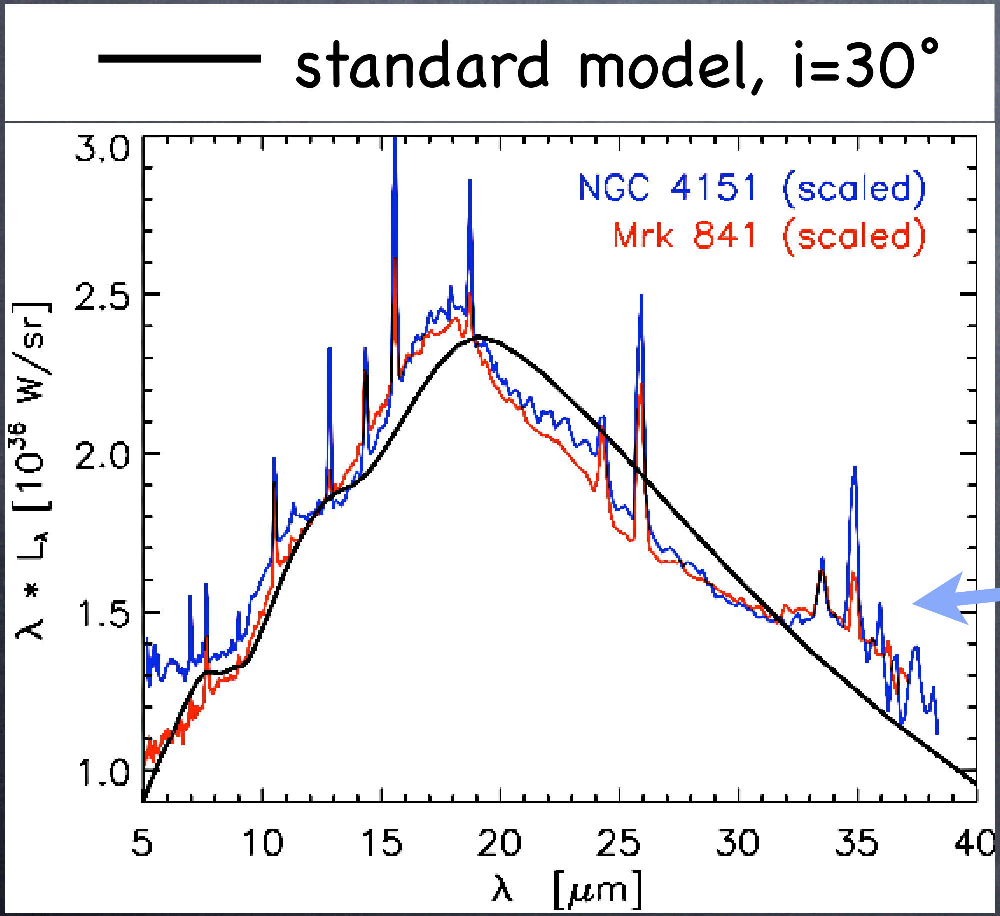


- separation of radial velocities in different temperature regimes
- fast infalling cold gas, hot gas with moderate velocity

Observables & data comparison

- assume gas-to-dust ratio, radiative transfer calculations (MC3D) yield dust reemission SEDs and images

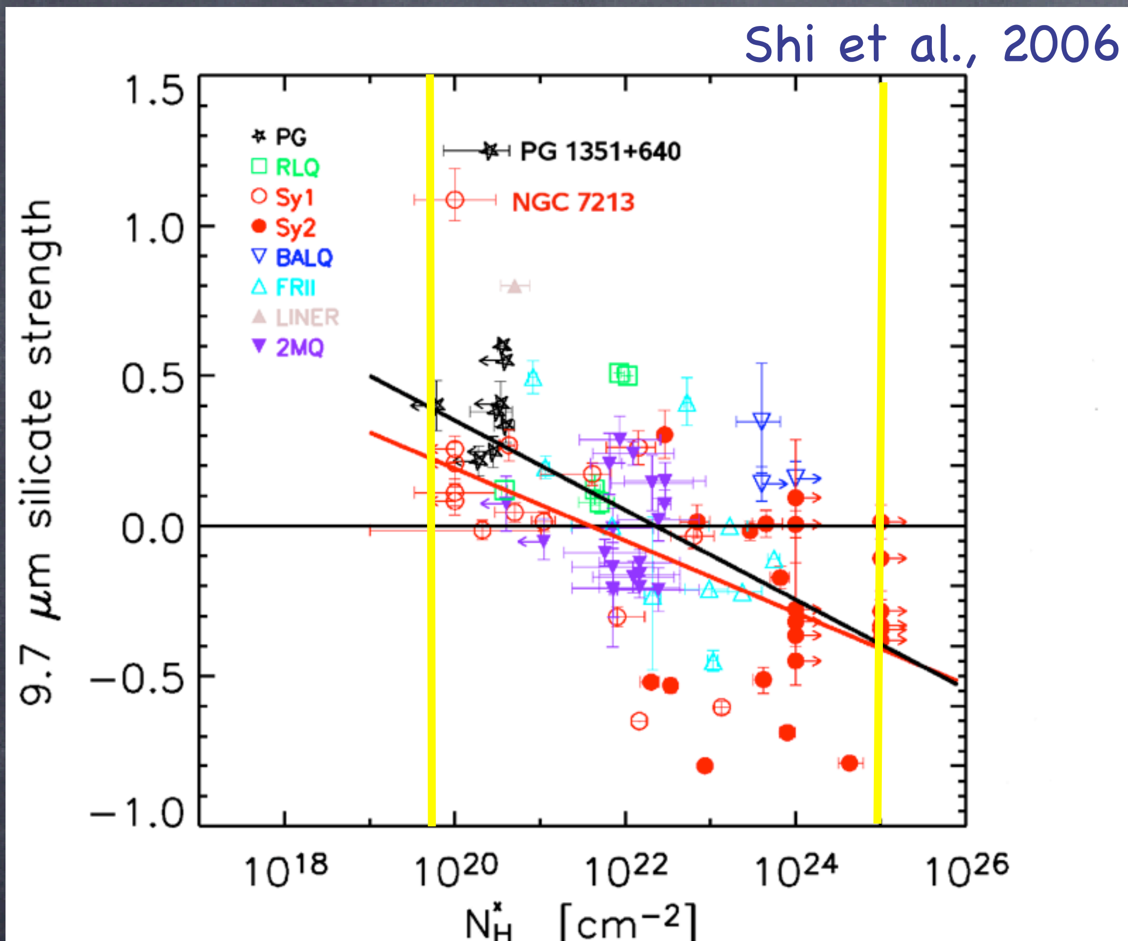


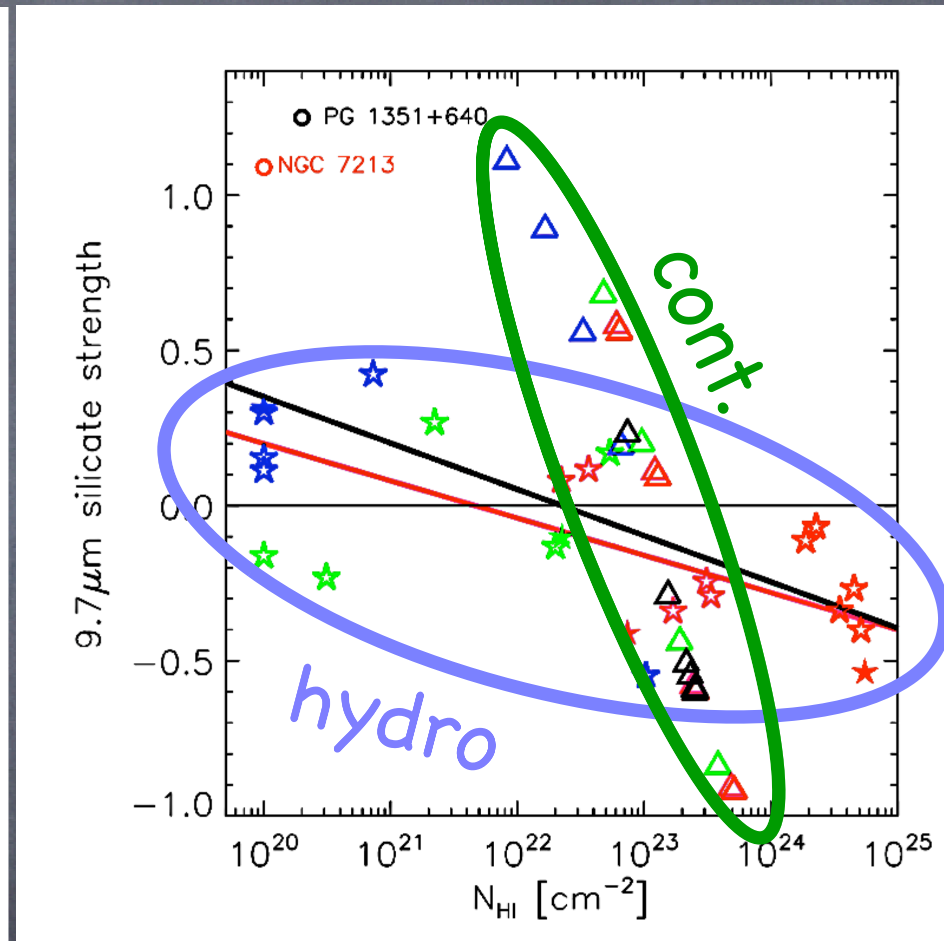


crystalline forsterite

data courtesy of Weedmann et al. (2005) & Spoon (2006)

Silicate feature strength – hydrogen column density relation





- linear relation
- large scatter interpreted as sign of clumpiness of the torus/disk

- filamentary tori in concordance with data, our cont. models not!

sample of 9 Seyferts:

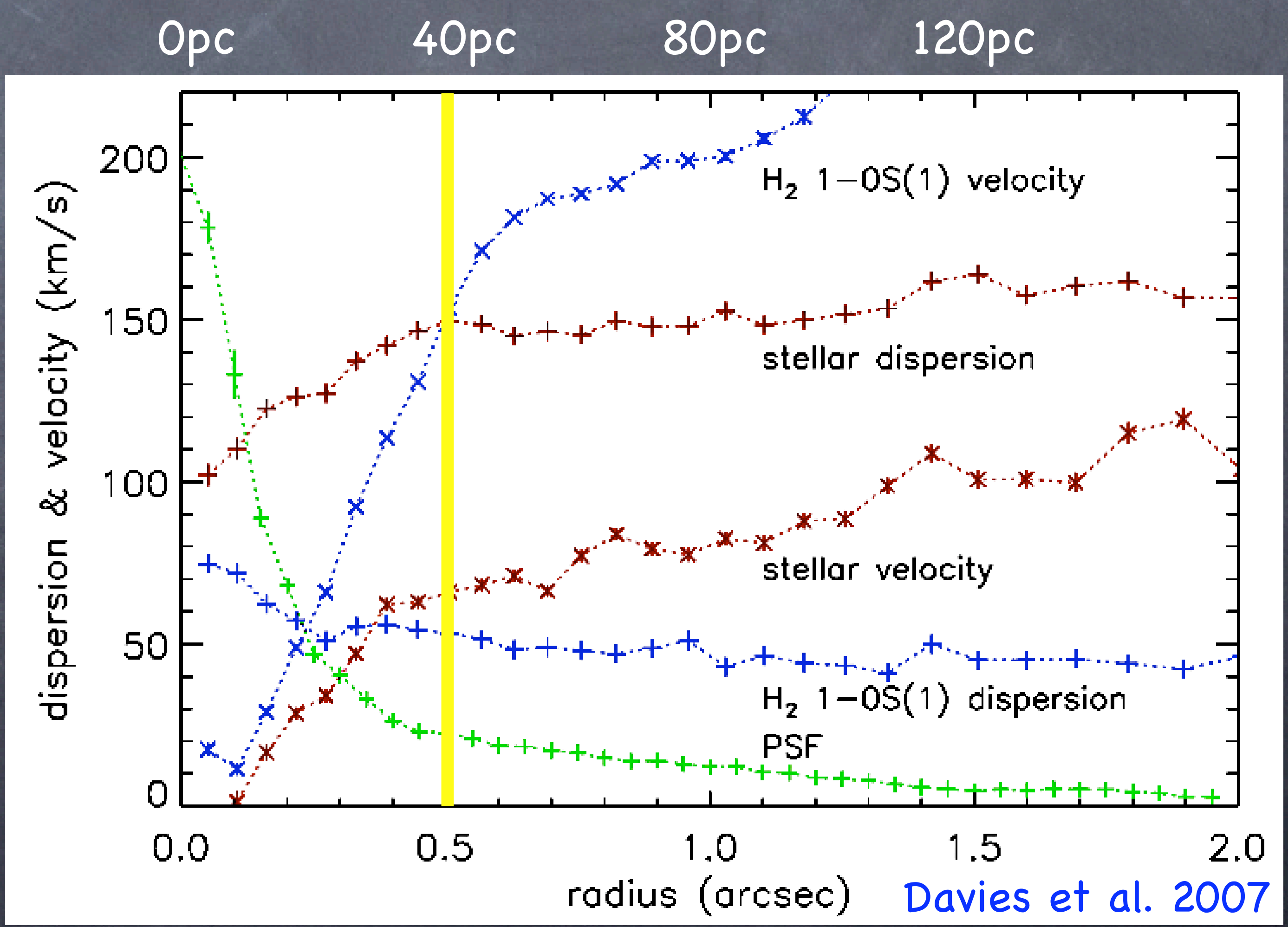
- nuclear star formation regions with half widths smaller than 50pc
- recent star formation (50-100 Myr)
- starburst no longer active, short-lived

SINFONI observations (Davies et al. 2007)

example of NGC 1097:

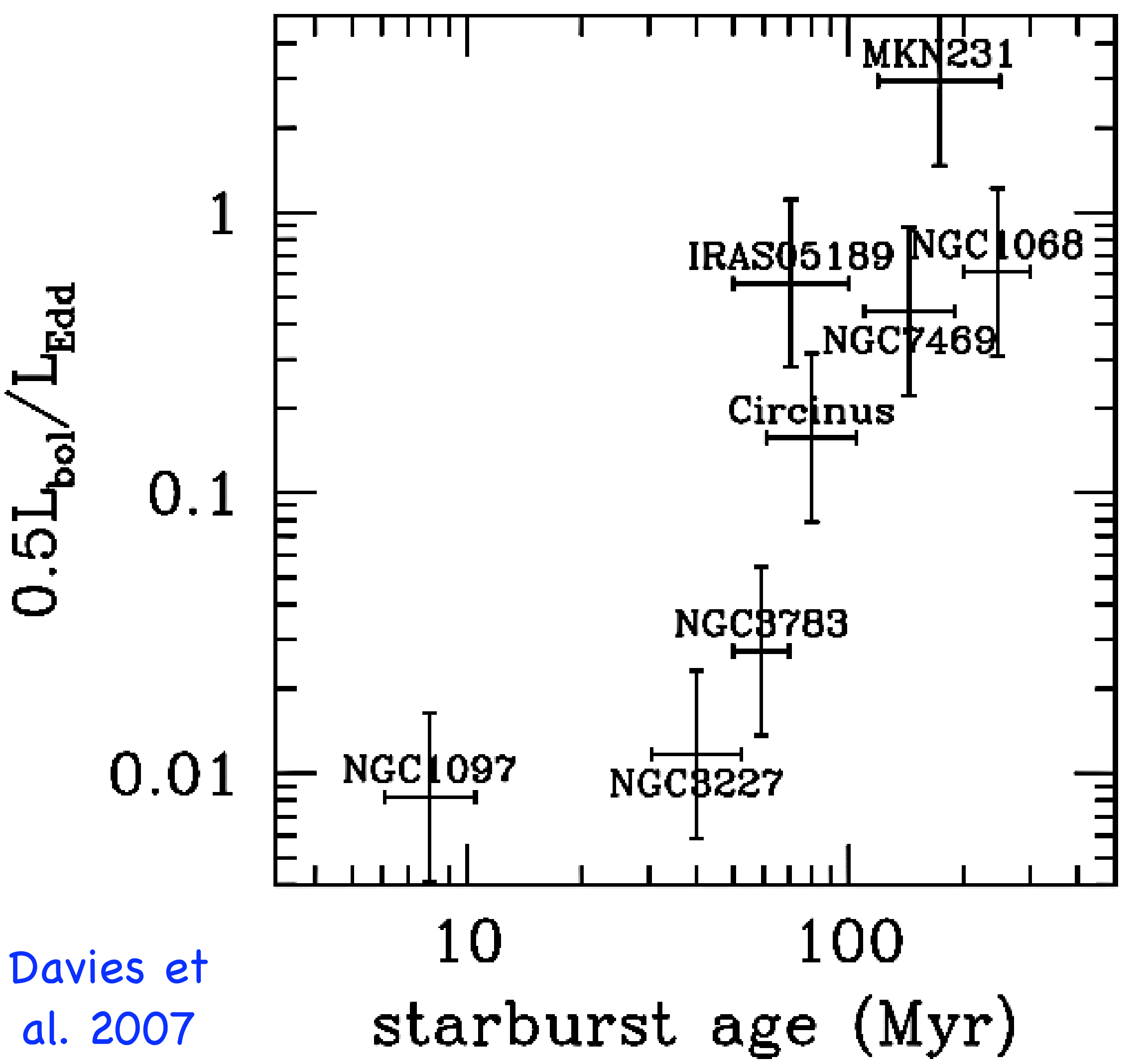
- velocity curves of gas & stars different for r > 0.5" (stars - spheroid, gas - thin disk)
- r < 0.5": kinematics of gas and stars similar

→ gas & stars mixed



Davies et al. 2007

starburst AGN connection



Davies et al. 2007

- AGN switched on 50-100 Myr after the starburst
- SN & OB stars with high velocity ejecta
  ⇒ outflow
- AGN star winds & planetary nebulae
  ⇒ accretion

Conclusions

- trace evolution of nuclear stellar cluster: supplies gas and energy for obscuration and feeding of BH
- two components: disk + filamentary torus, with very different characteristics, e.g. N_H column density
- clumps or filaments in central part enable various silicate feature strengths (inclination dependent) over a broad range of gas column densities ⇒ good comparison with Shi et al. 2006
- perpetual mass input circumvents scale height problem

Outlook

- long term evolution, various phases of stellar evolution, adapt the parameters of well studied Seyfert galaxies like NGC 1068
- detailed study of turbulent tori, stirring mechanisms: radiation, stellar winds, disc wind, ...