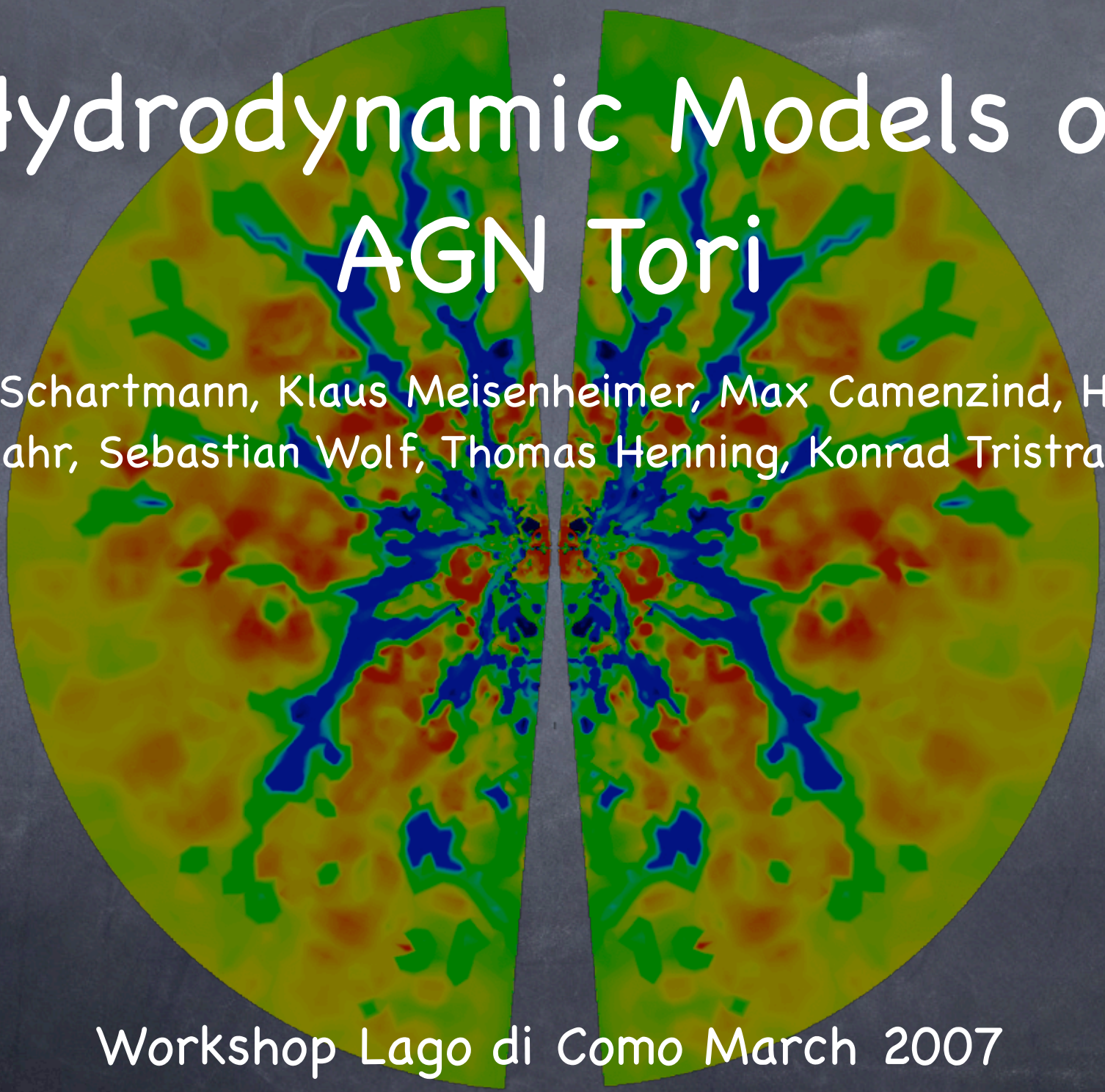
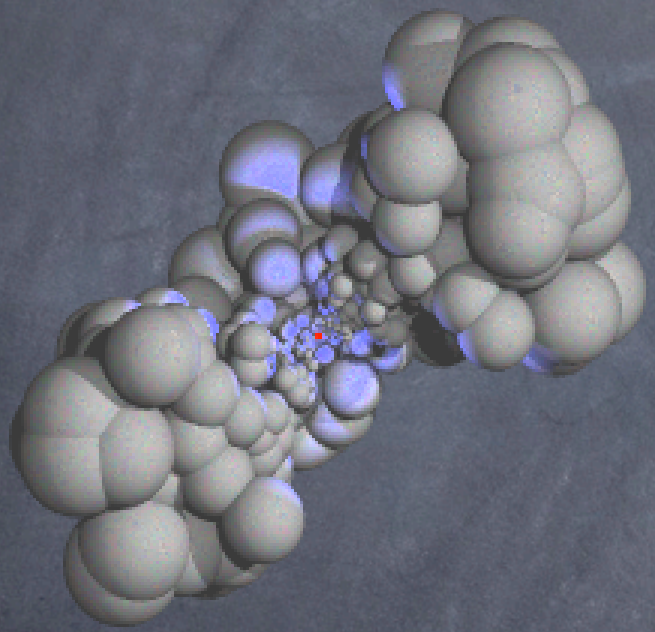
Hydrodynamic Models of AGN Tori

Marc Schartmann, Klaus Meisenheimer, Max Camenzind, Hubert Klahr, Sebastian Wolf, Thomas Henning, Konrad Tristram



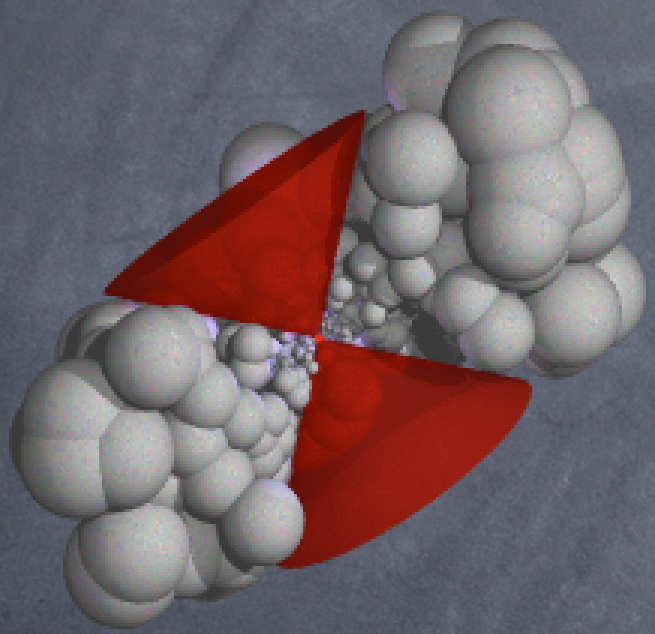
Workshop Lago di Como March 2007

AGN - Unified Scheme



- central black hole (10^6–10^{10} $M_\odot$)
- accretion disk
- Obscuring torus
- Narrow line region
- (hidden) broad line region

AGN - Unified Scheme



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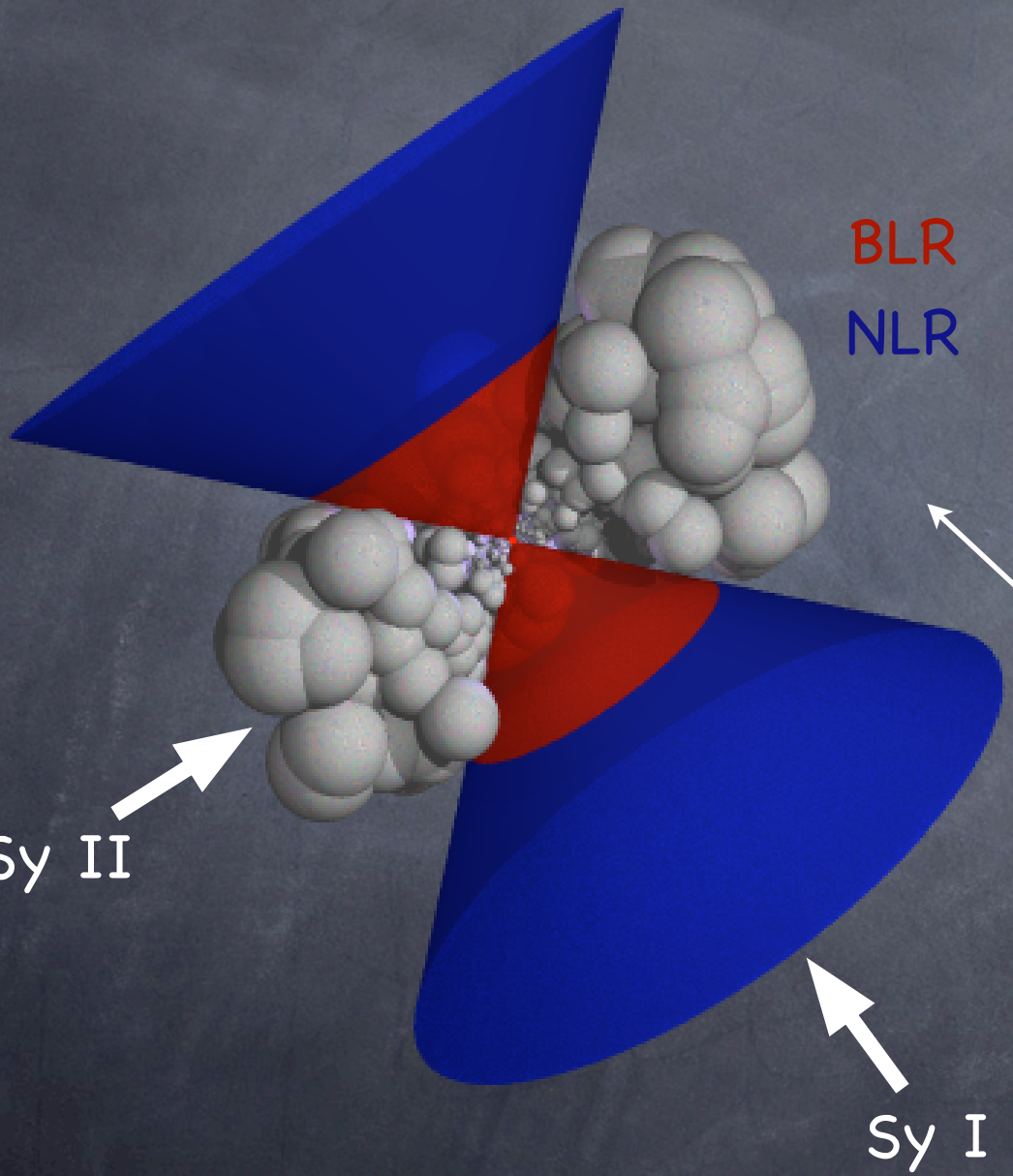

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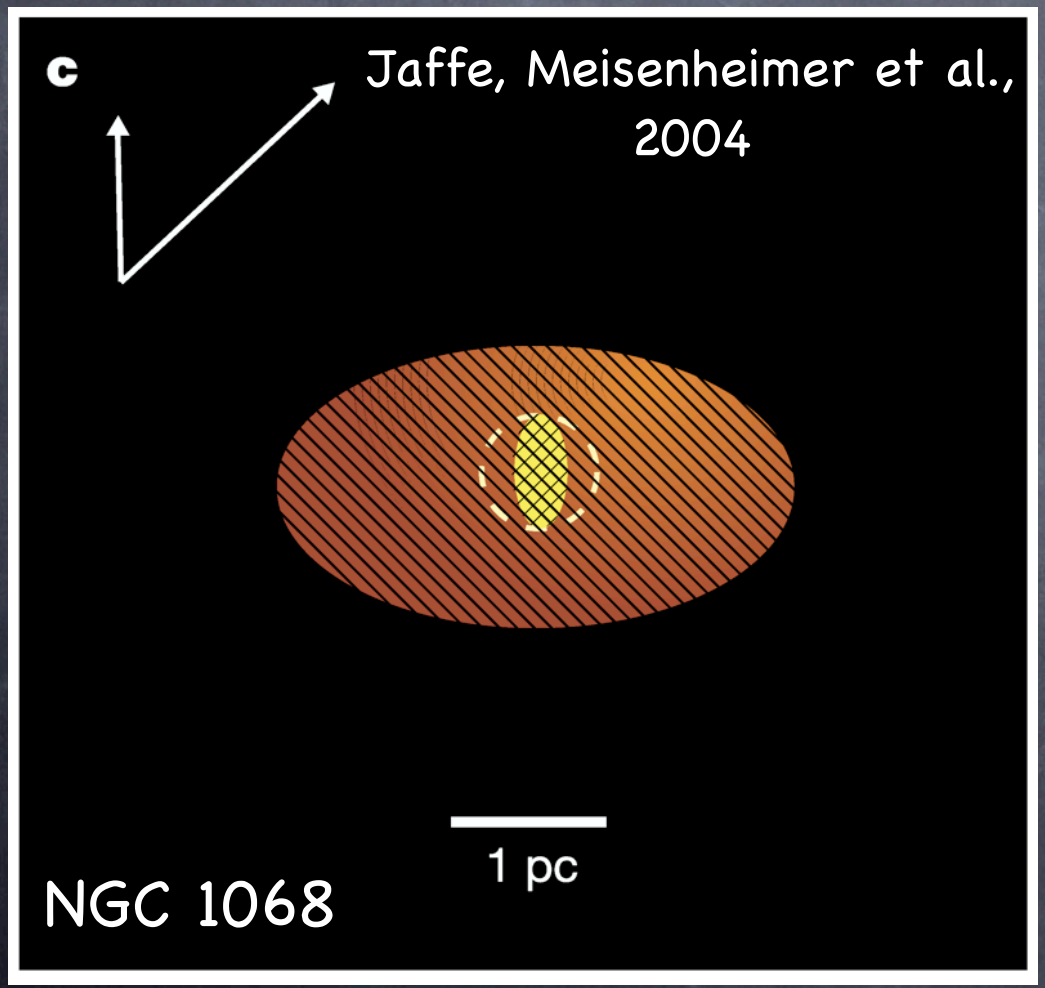
First direct observations of dust tori

two components found: hot dust: T>800K, d<1pc

warm dust: T≈320K, 3.4x2.1pc



but MIDI = two-beam-combiner

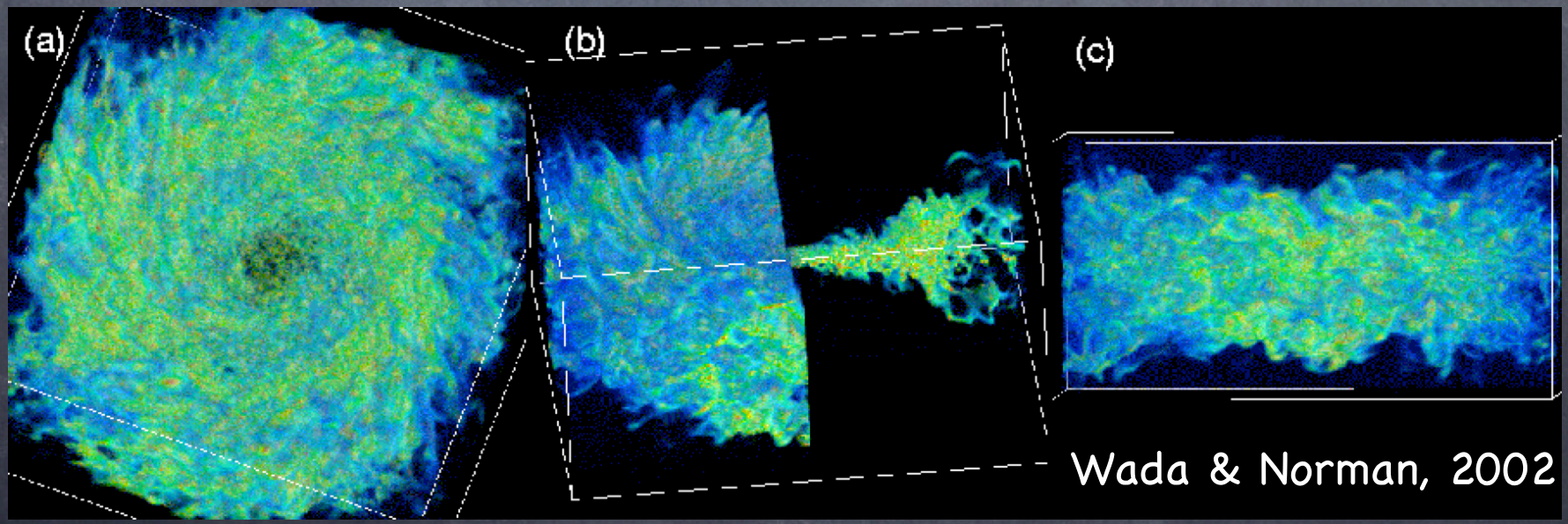
→ no direct imaging

→ models necessary for comparison

see more details in Hauskolloquium next week

Hydrodynamic models

- from modelling: found dust structure in agreement with observations
- now: find physical realisation of similar dust structures
- main problem: hydrodynamic simulations including gas cooling collapse to a thin disk



- first attempt: thin disk ⟹ disk height can be sustained under starburst conditions

Hydrodynamic models of tori

- IC: hydrostatic analytical model
- central stellar distribution yields mass and energy input

- ⋆ short-duration starburst
- ⋆ very violent phase, SN II in first 40 Myr
- ⋆ after 40 Myr: planetary nebulae major contributor to mass input ($M_{ini} < 8\ M_{sun}$) ⟹ model discrete mass input

- ⋆ mass loss rate = $$\dot{M}(t) = \int_{m_{min}}^{m_{max}} \dot{m}(t, m_i)\, \psi(m_i)\, dm_i$$

$$\dot{M}(t)_{\mathrm{n}} = \frac{5.55 \cdot 10^{-2}}{t + 5.04 \cdot 10^{6}\ \mathrm{yr}}$$

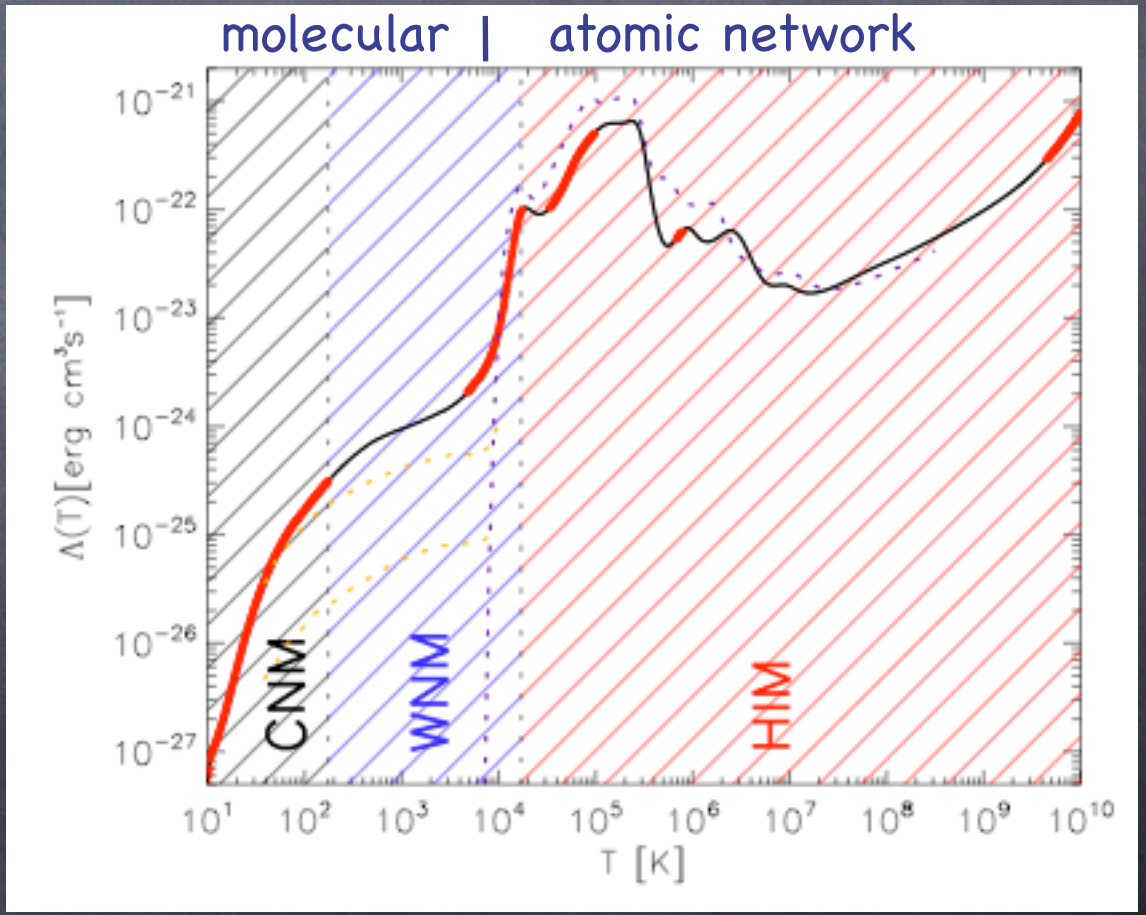
(Jungwiert et al., 2001)

- ⋆ SN Ia dominate energy input to ISM

Step 3: Hydrodynamic models of tori

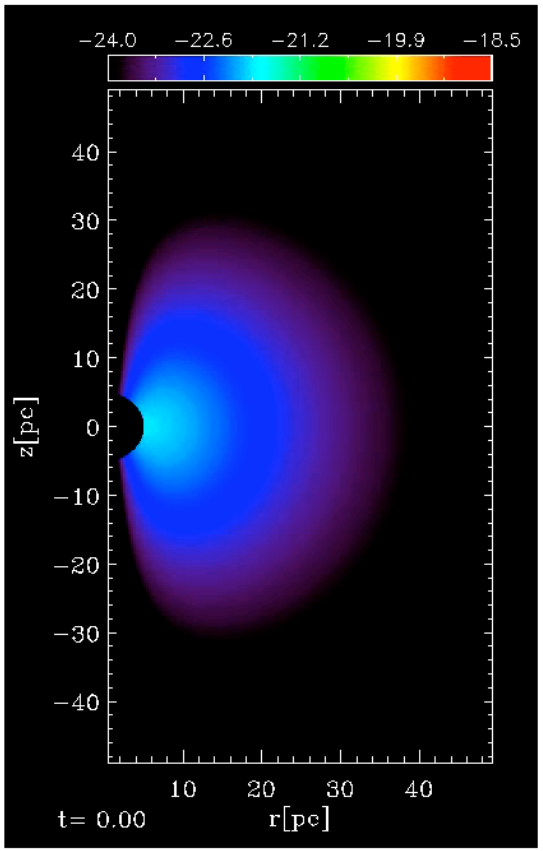
- IC: hydrostatic analytical model
- central stellar distribution yields mass and energy input

- optically thin gas cooling (Cloudy-code)
- solve hydrodynamic equations with TRAMP (Klahr et al., 1999)
- domain decomposition
- boundary conditions



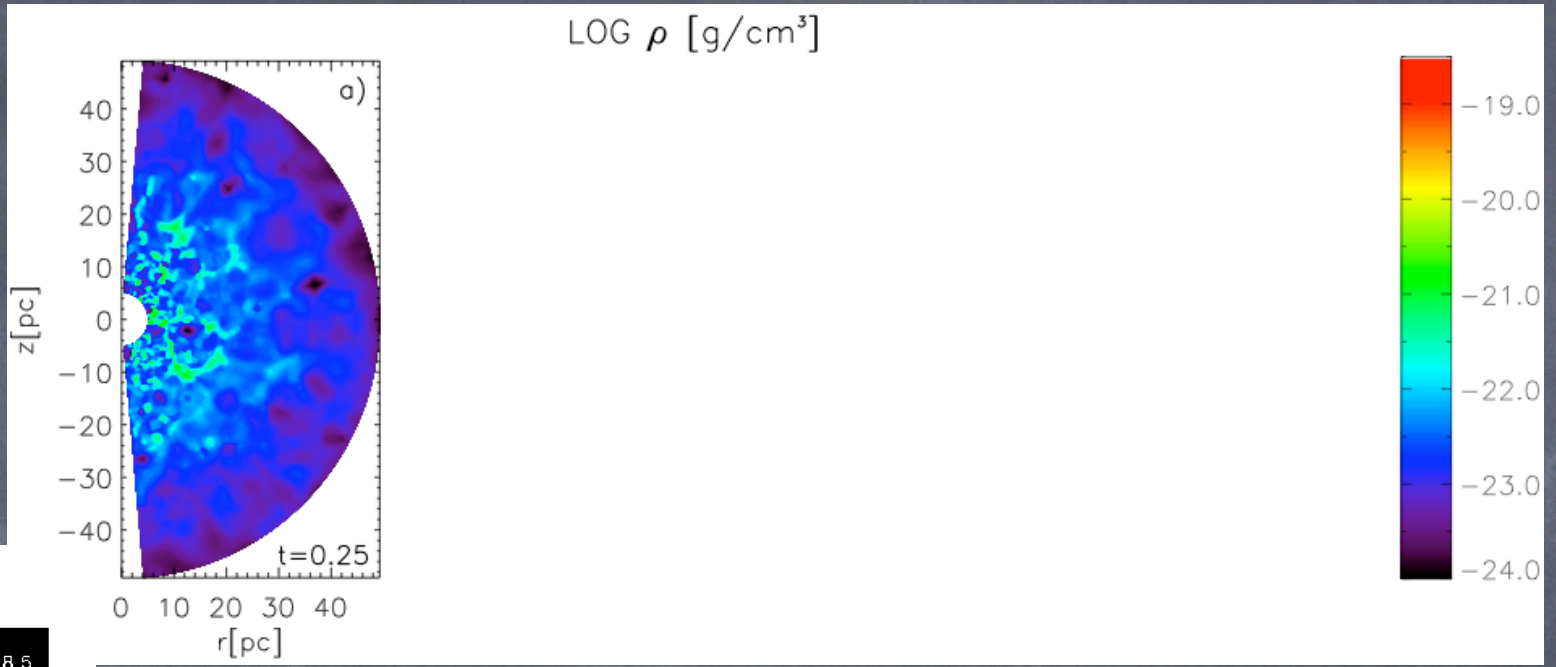
effective cooling curve

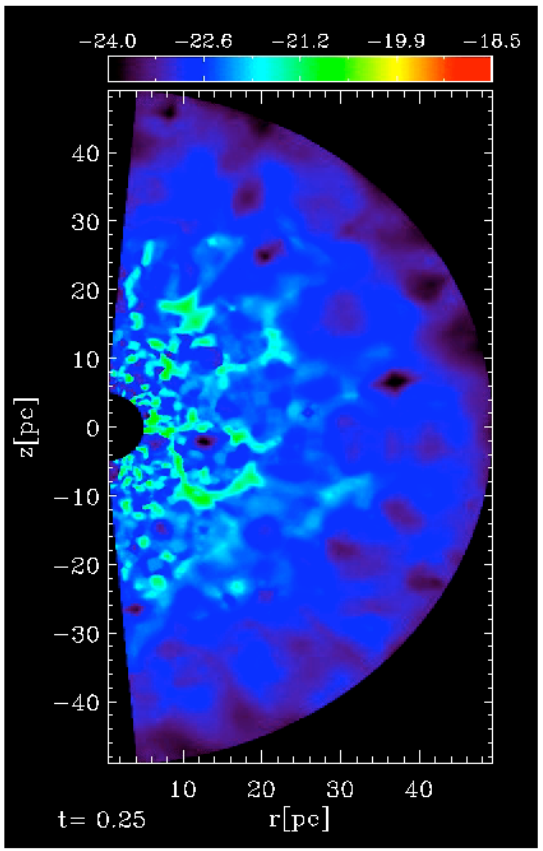
temporal evolution of the logarithmic gas density



- initial condition
- formation of small clumps
- merging to larger clumps
- filamentary flow towards centre
- formation of turbulent disc

temporal evolution of the logarithmic gas density





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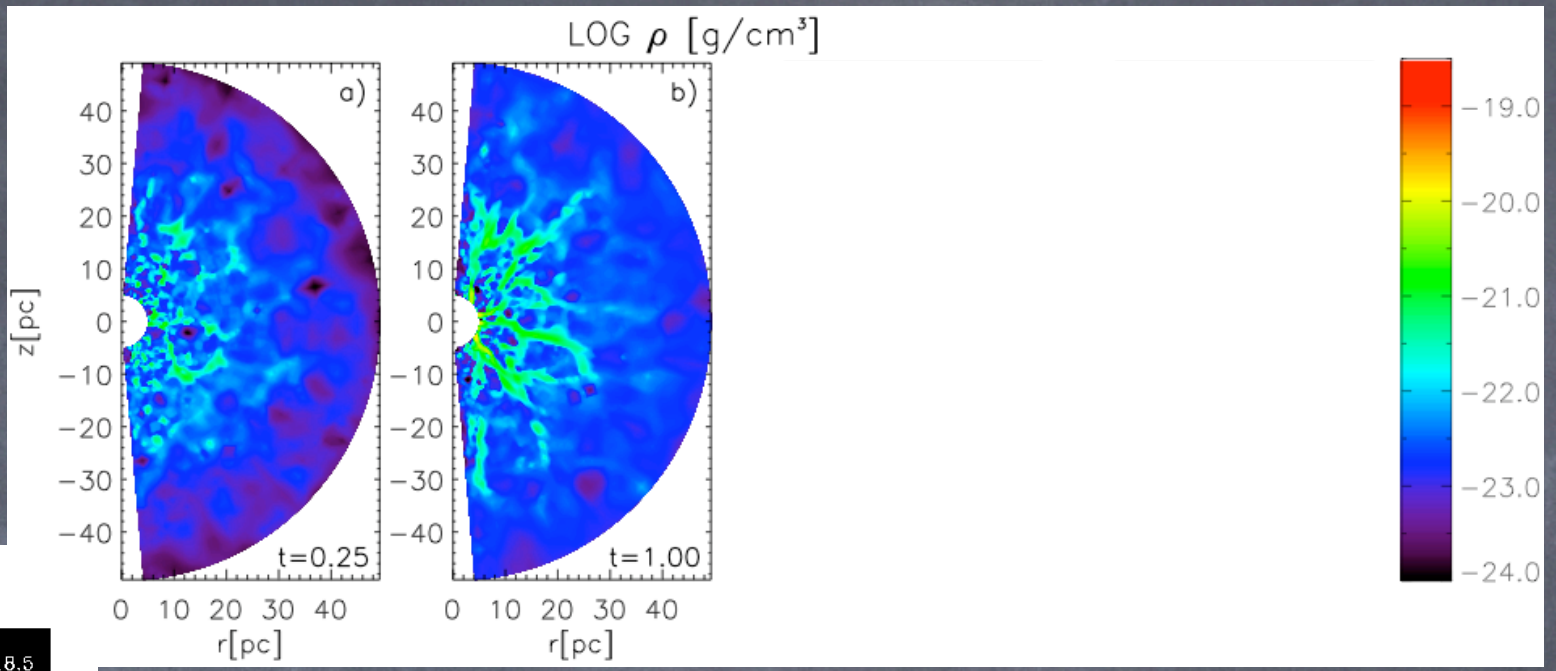

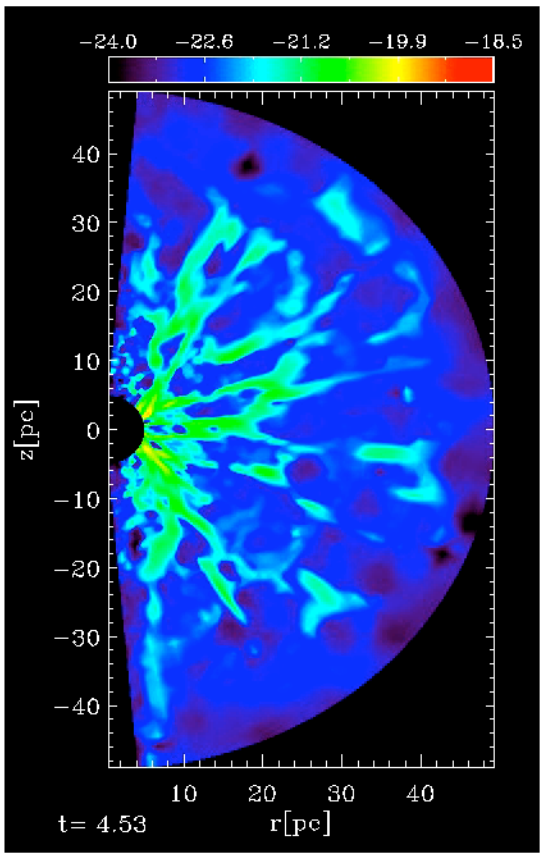

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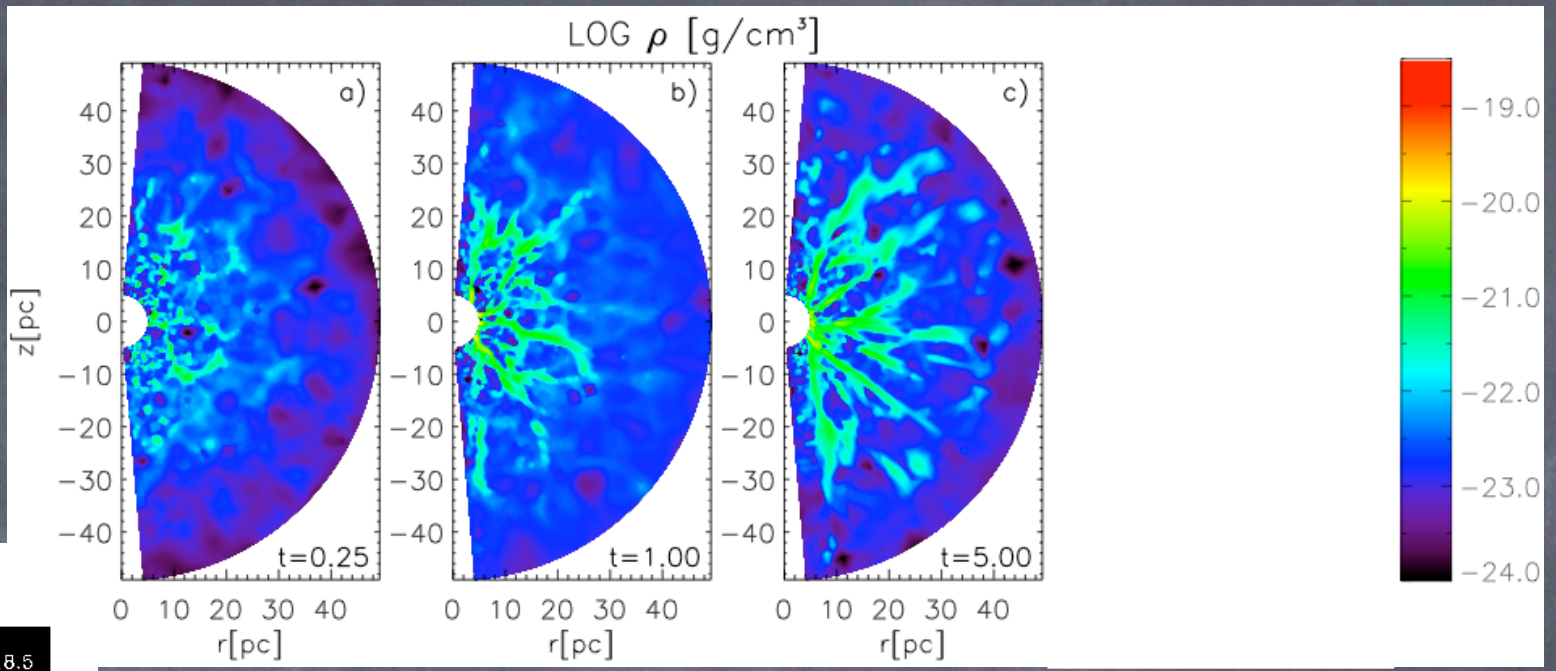

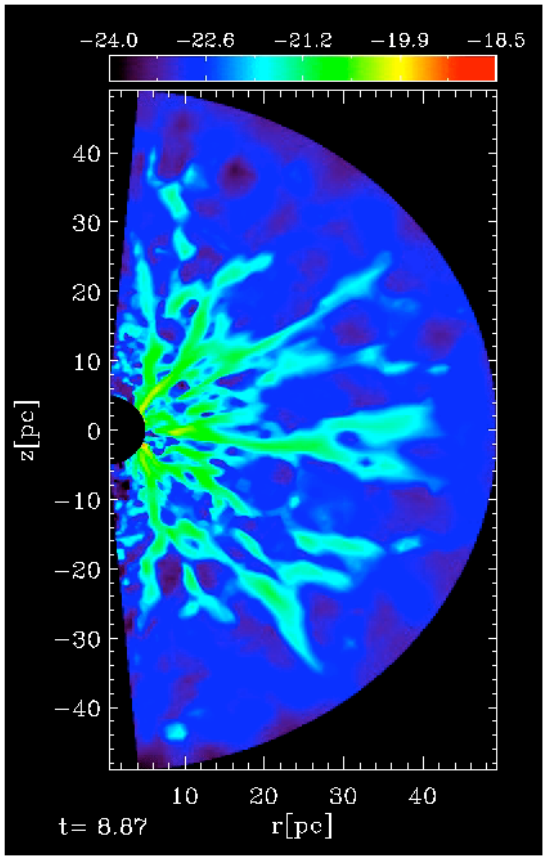

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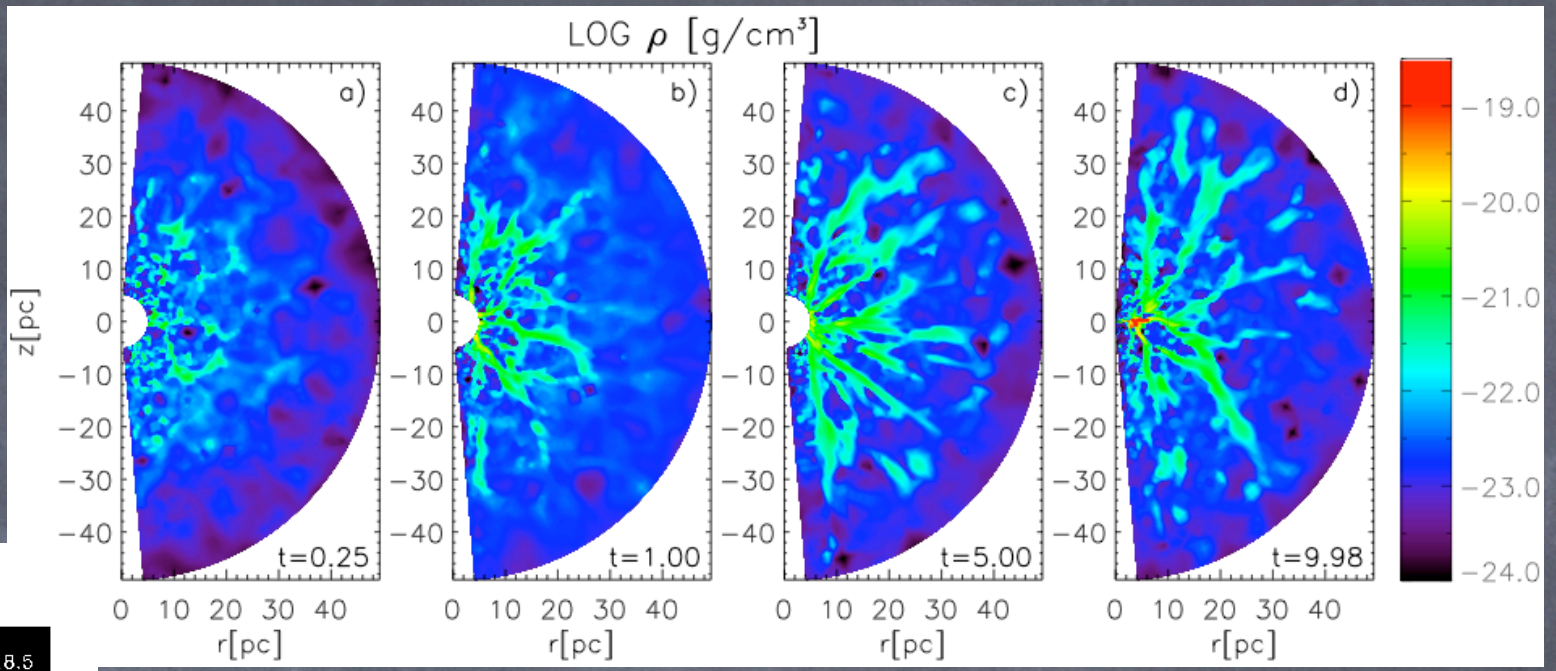

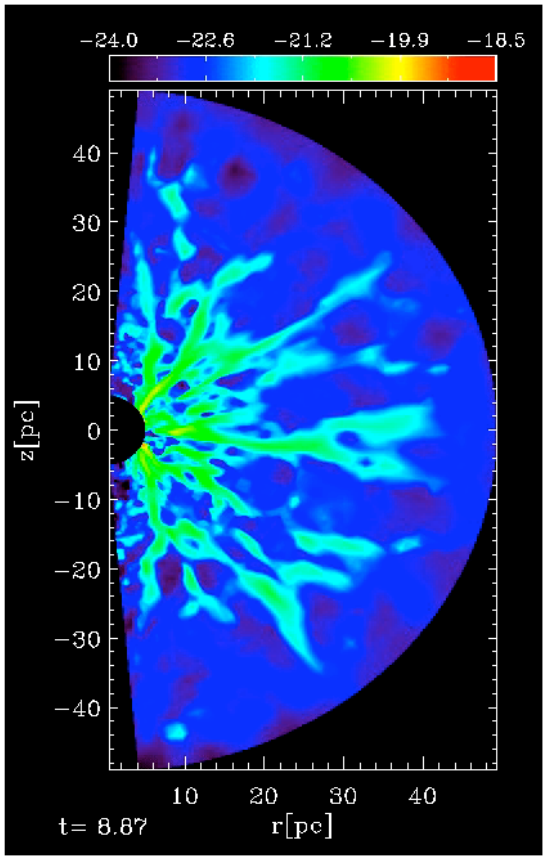

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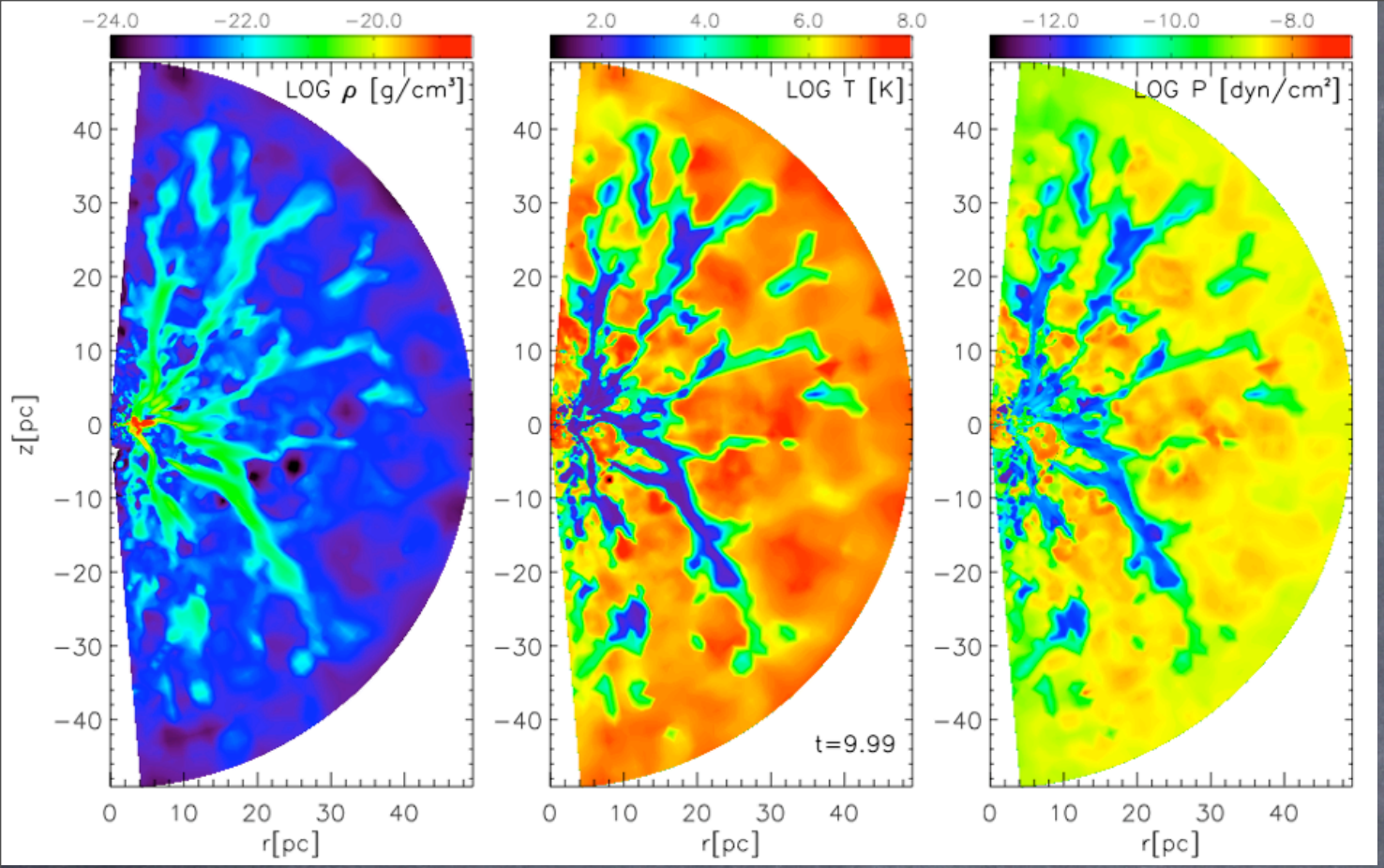


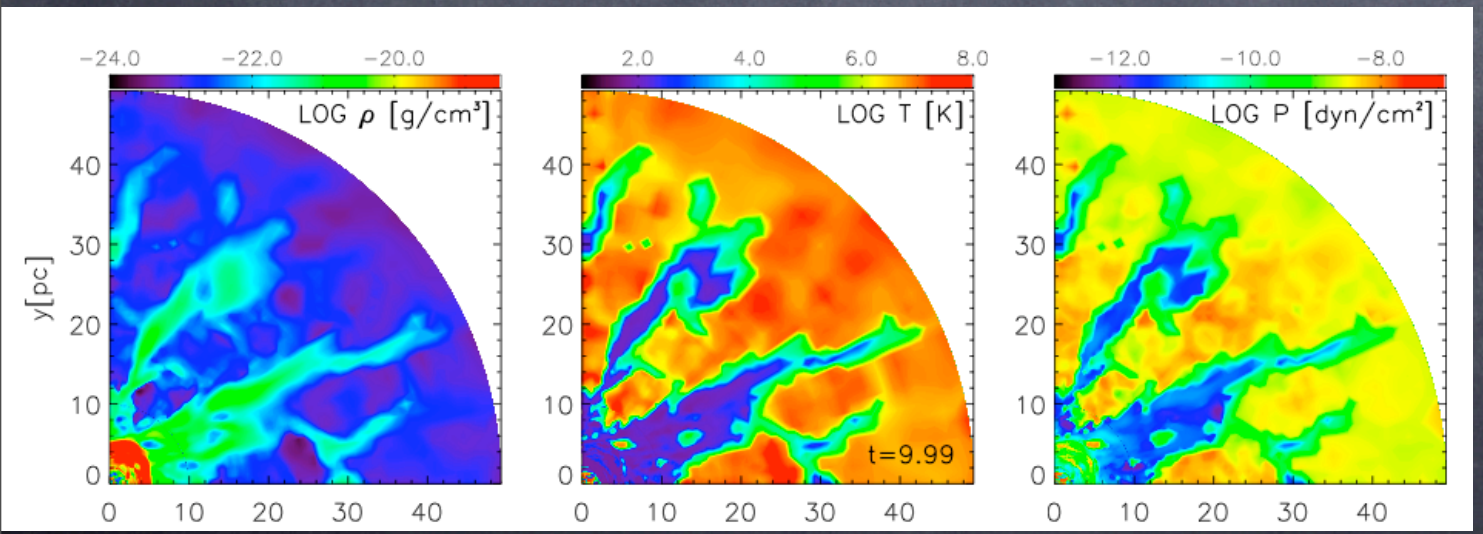
T and ρ complement.

no pressure equilibrium

2 component model:

1. dense disk
2. filamentary torus

density temperature pressure



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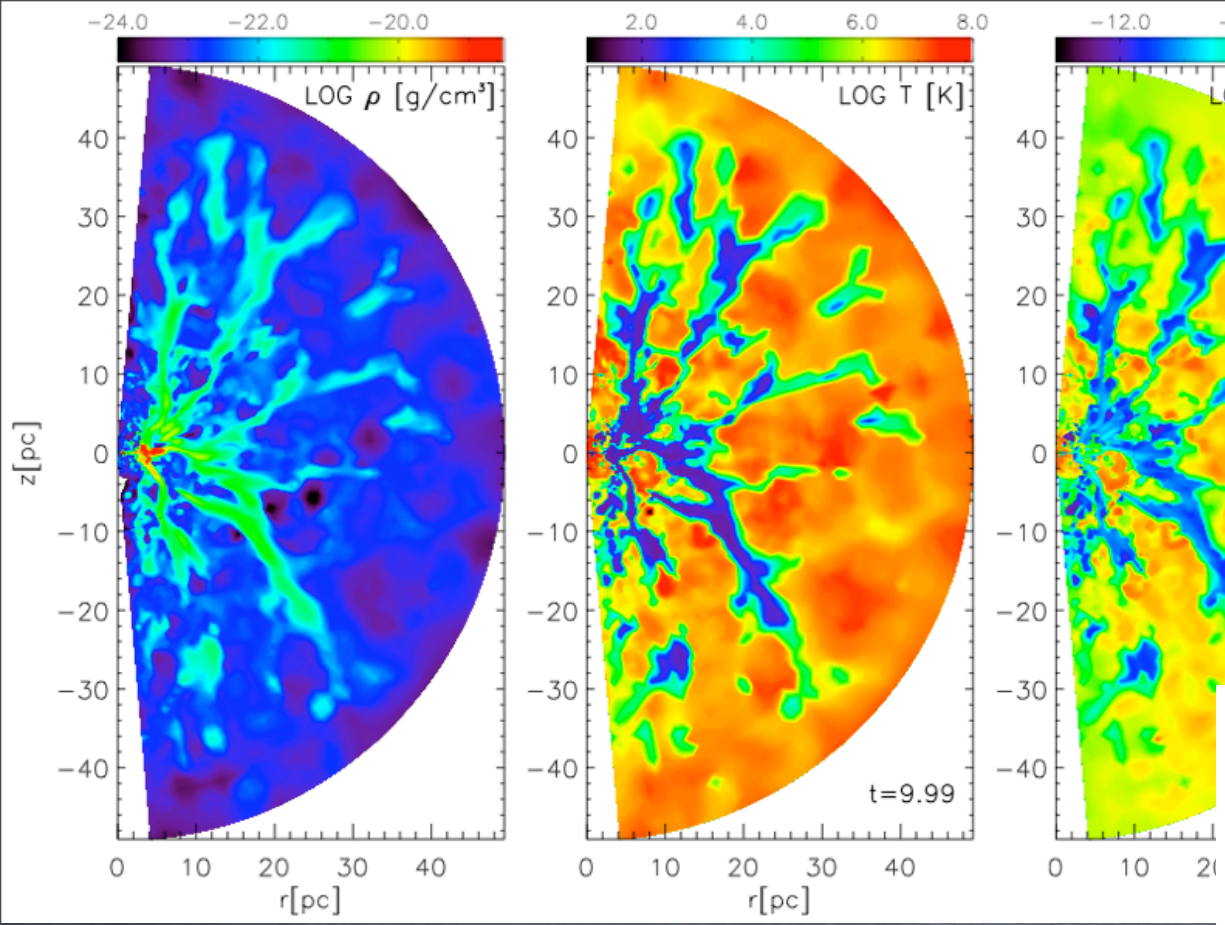

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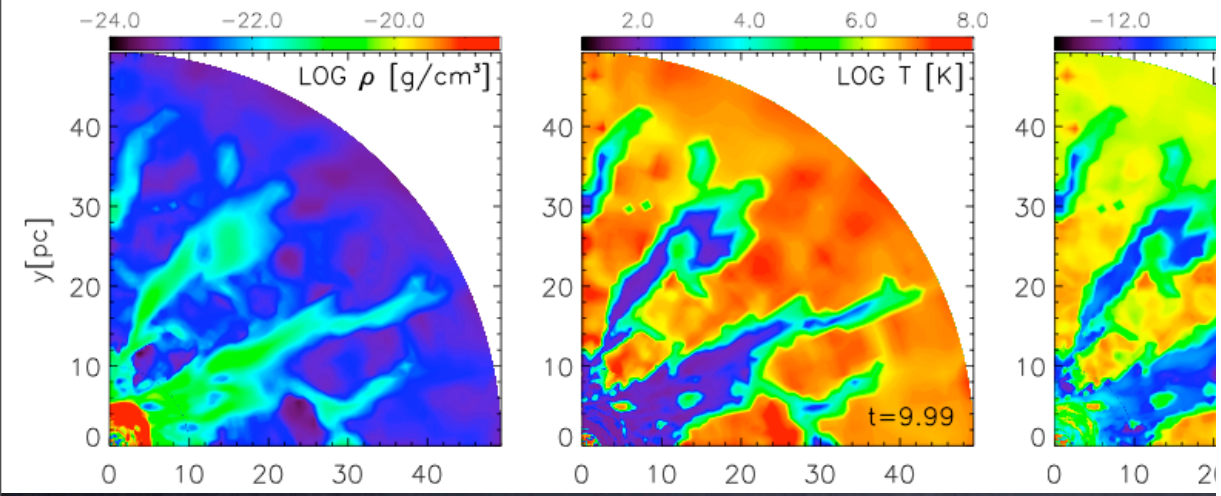
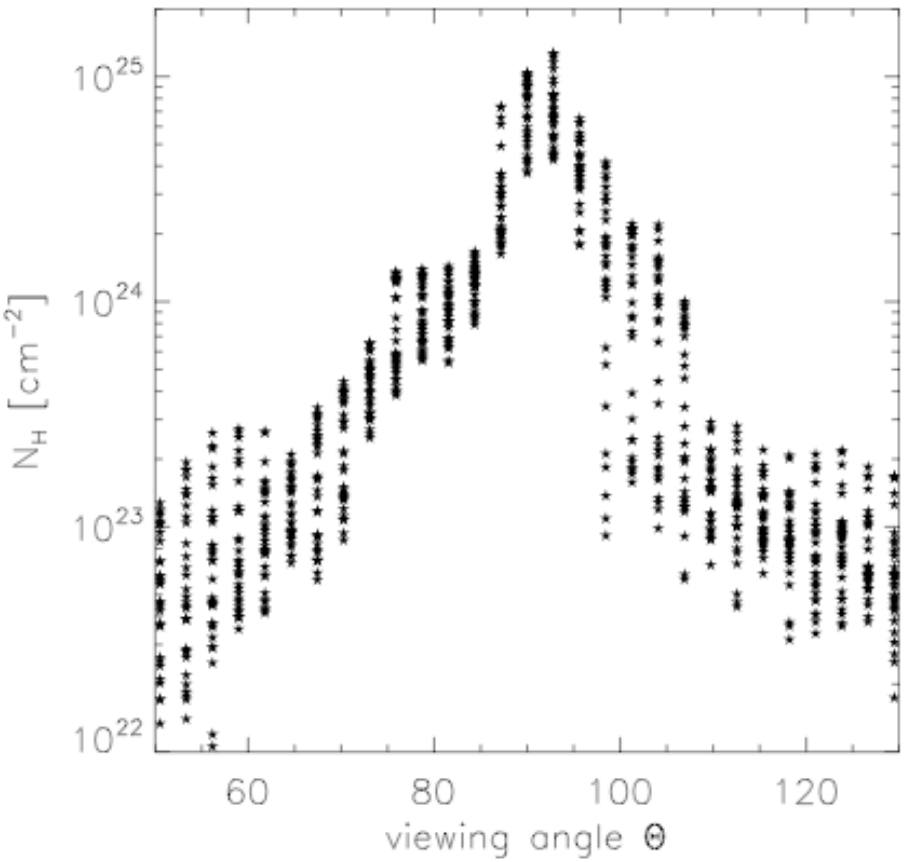
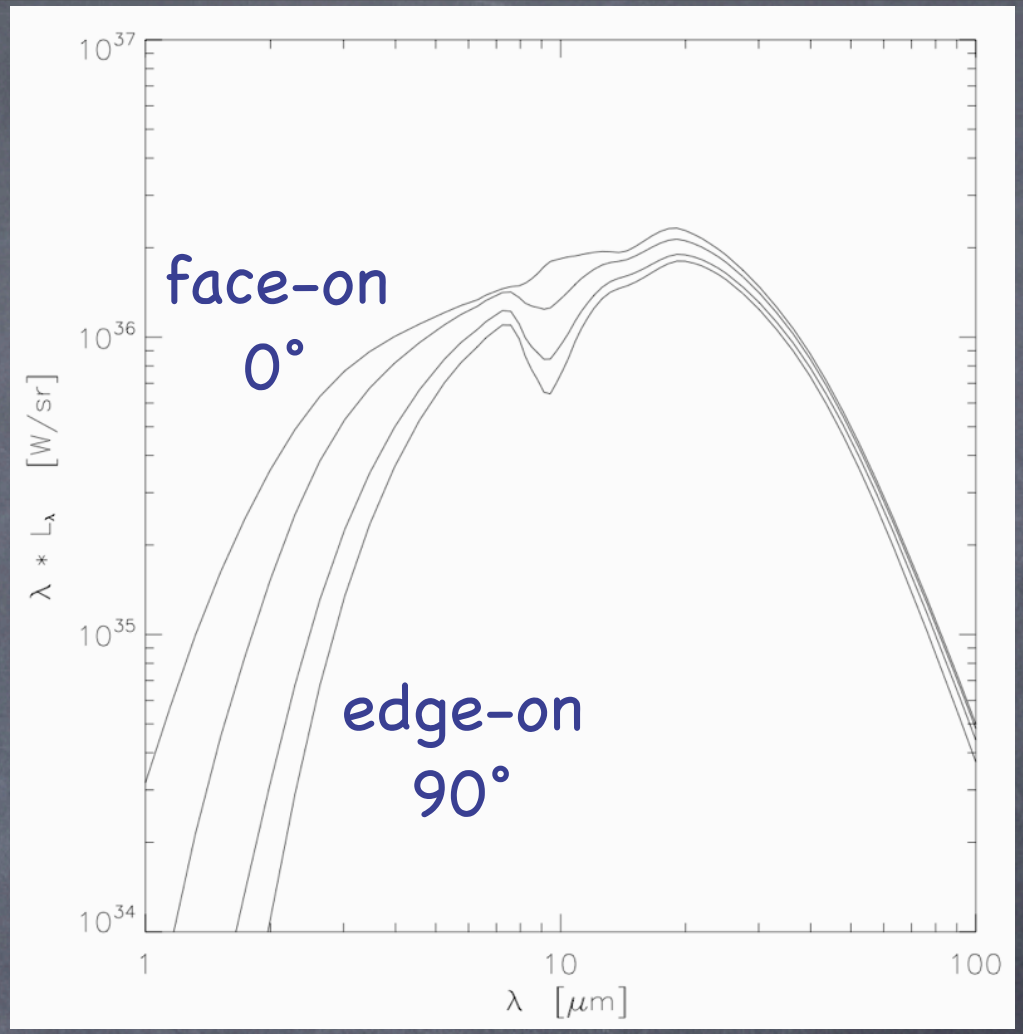
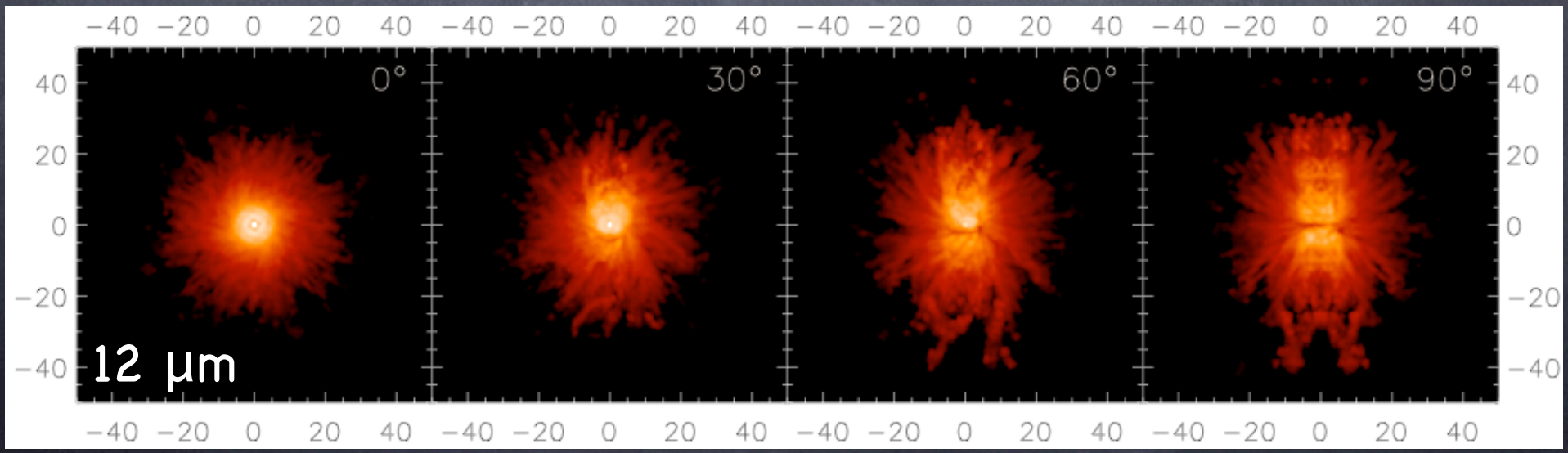




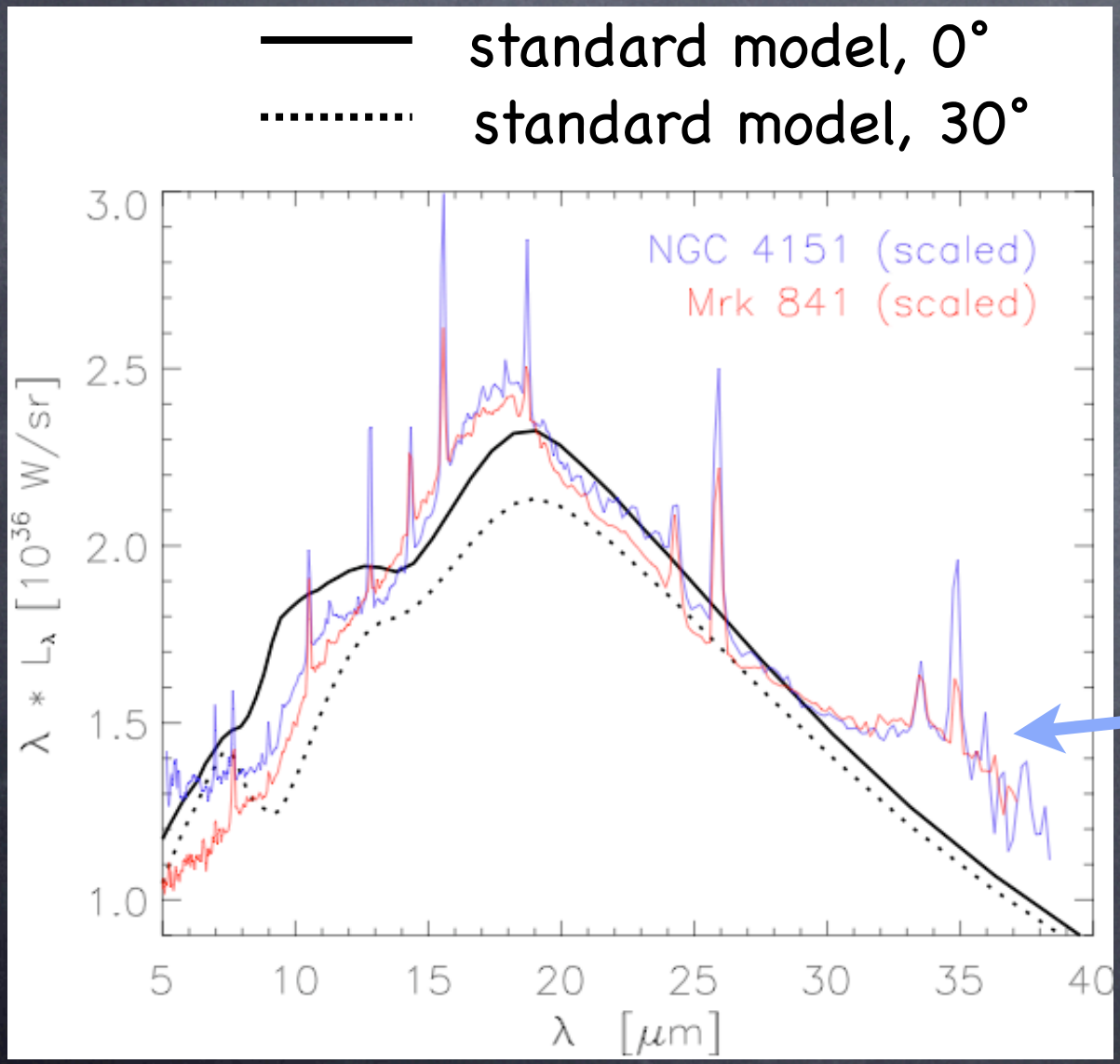
Derivation of observable quantities

- transform gas to dust distribution
- radiative transfer calculations yield dust reemission SEDs and images
- results of our mean Seyfert galaxy model





Comparison to Spitzer spectra of 2 Seyfert galaxies

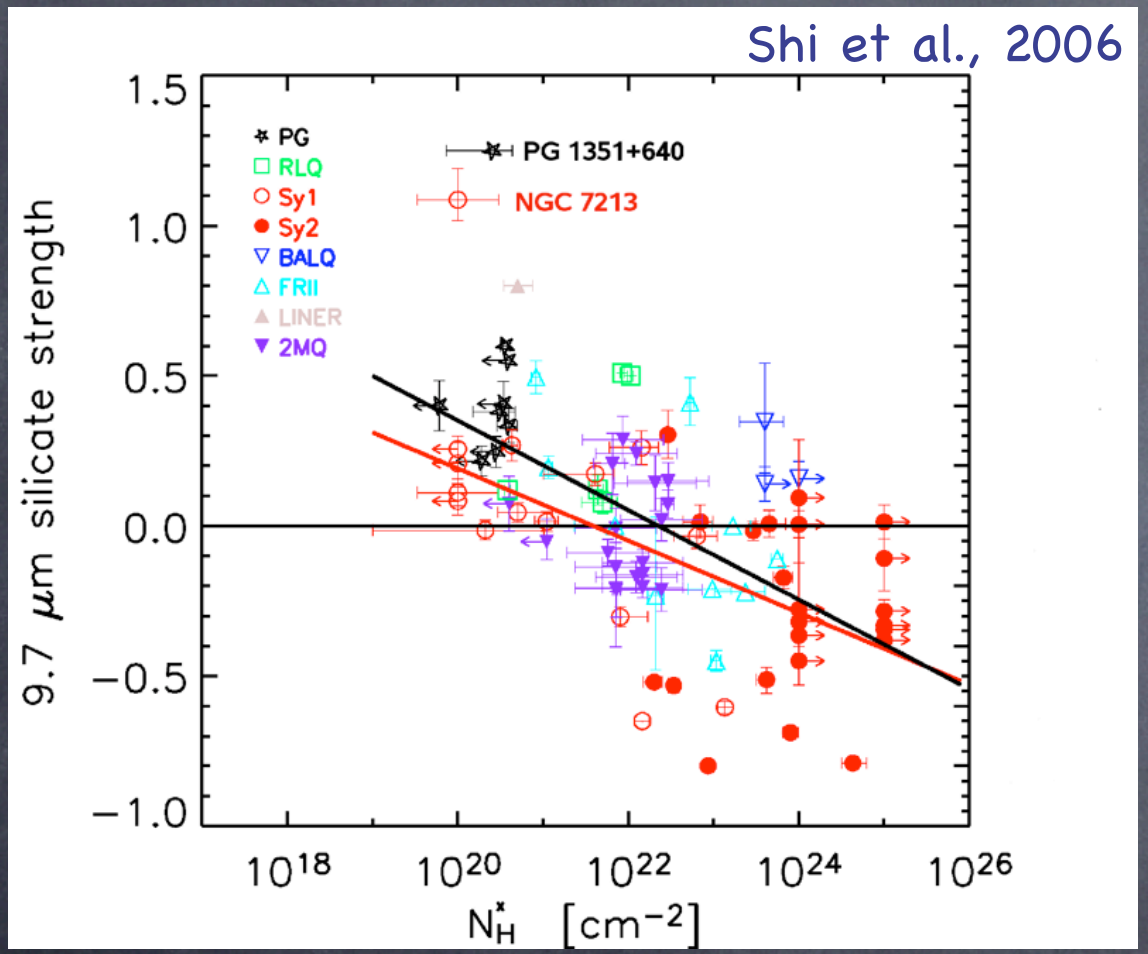


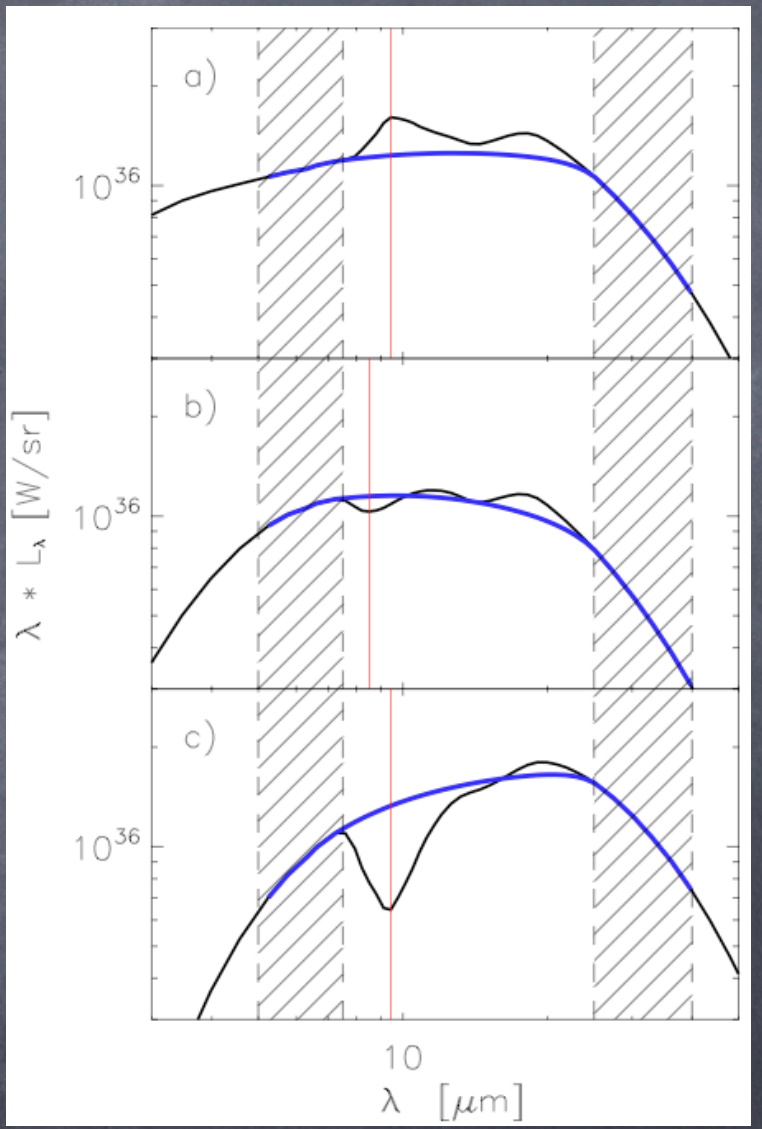
- no fit !!!
- shapes in reasonable agreement

crystalline forsterite

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

Silicate feature strength - hydrogen column density relation



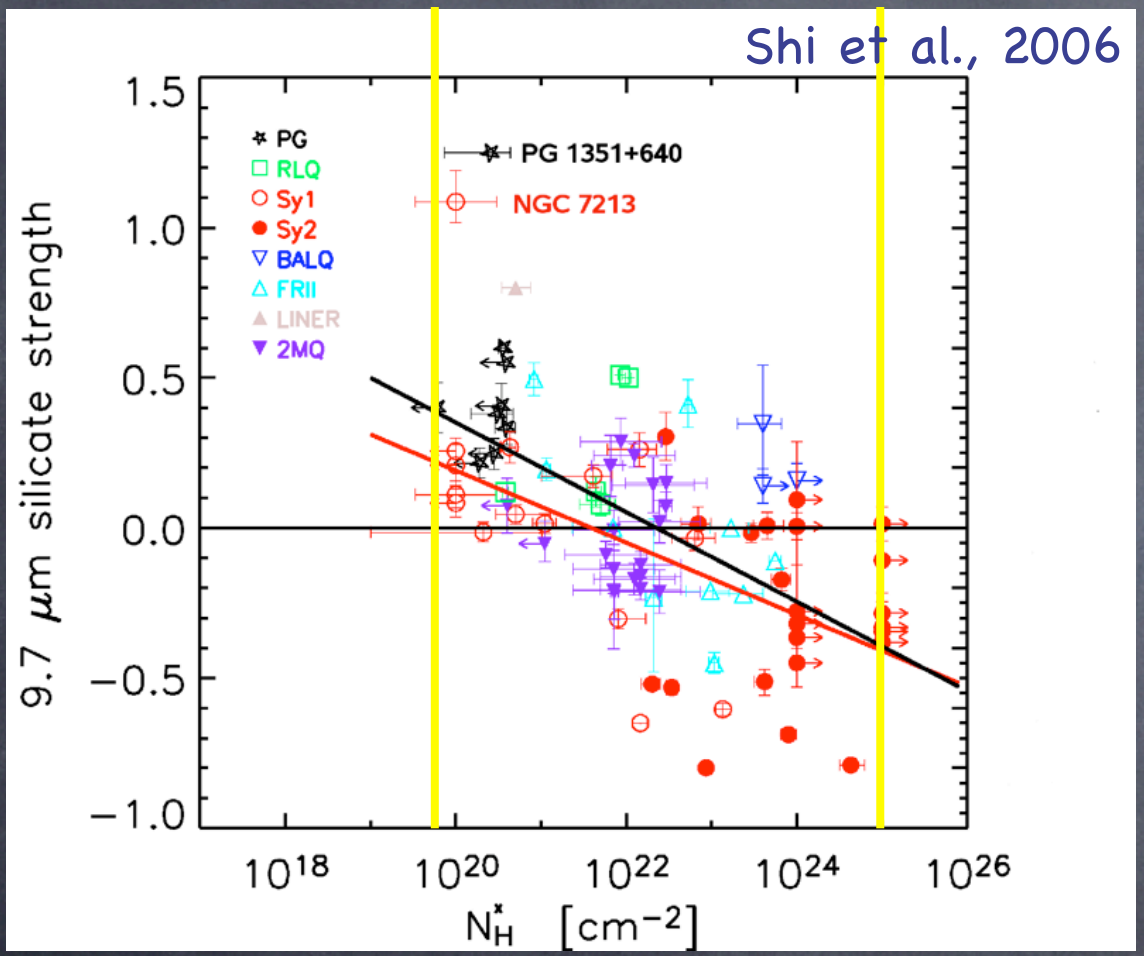


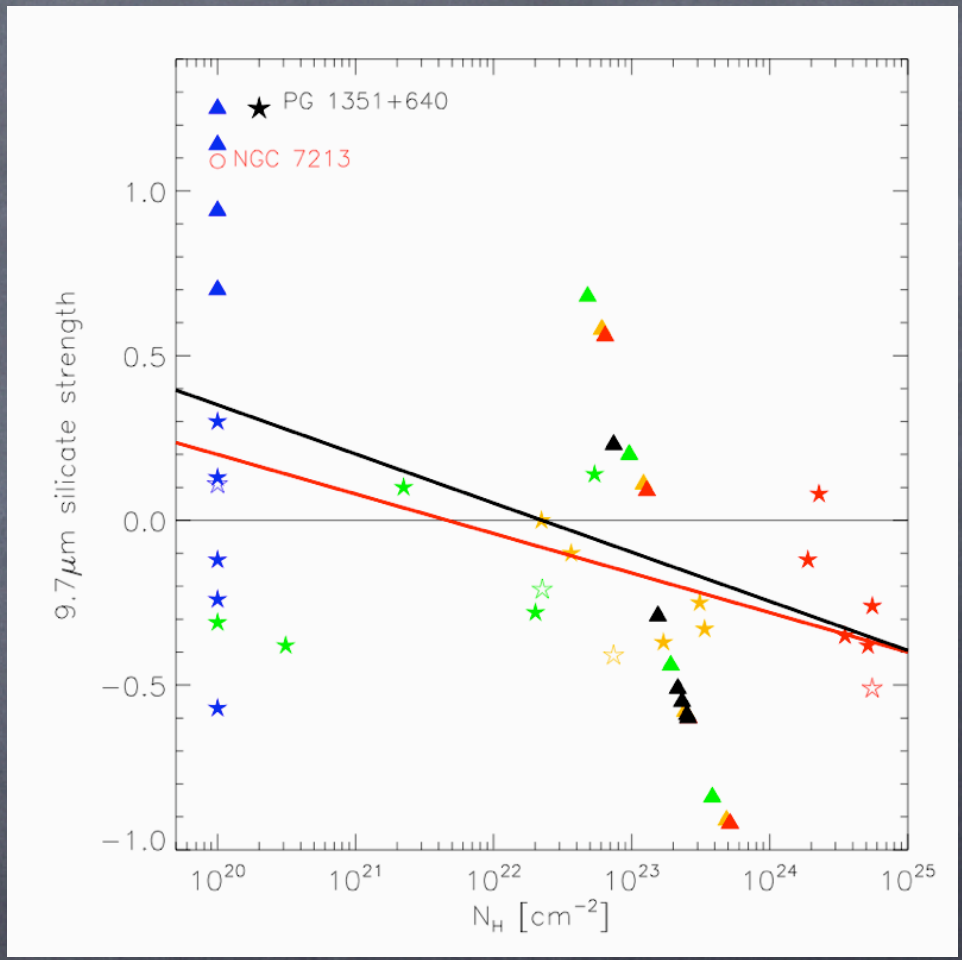
- linear relation
- large scatter interpreted as sign of clumpiness of the torus/disk

- column densities: direct integration
- feature fitting procedure

Silicate feature strength – hydrogen column density relation

different scales!





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

Silicate feature strength – hydrogen column density relation

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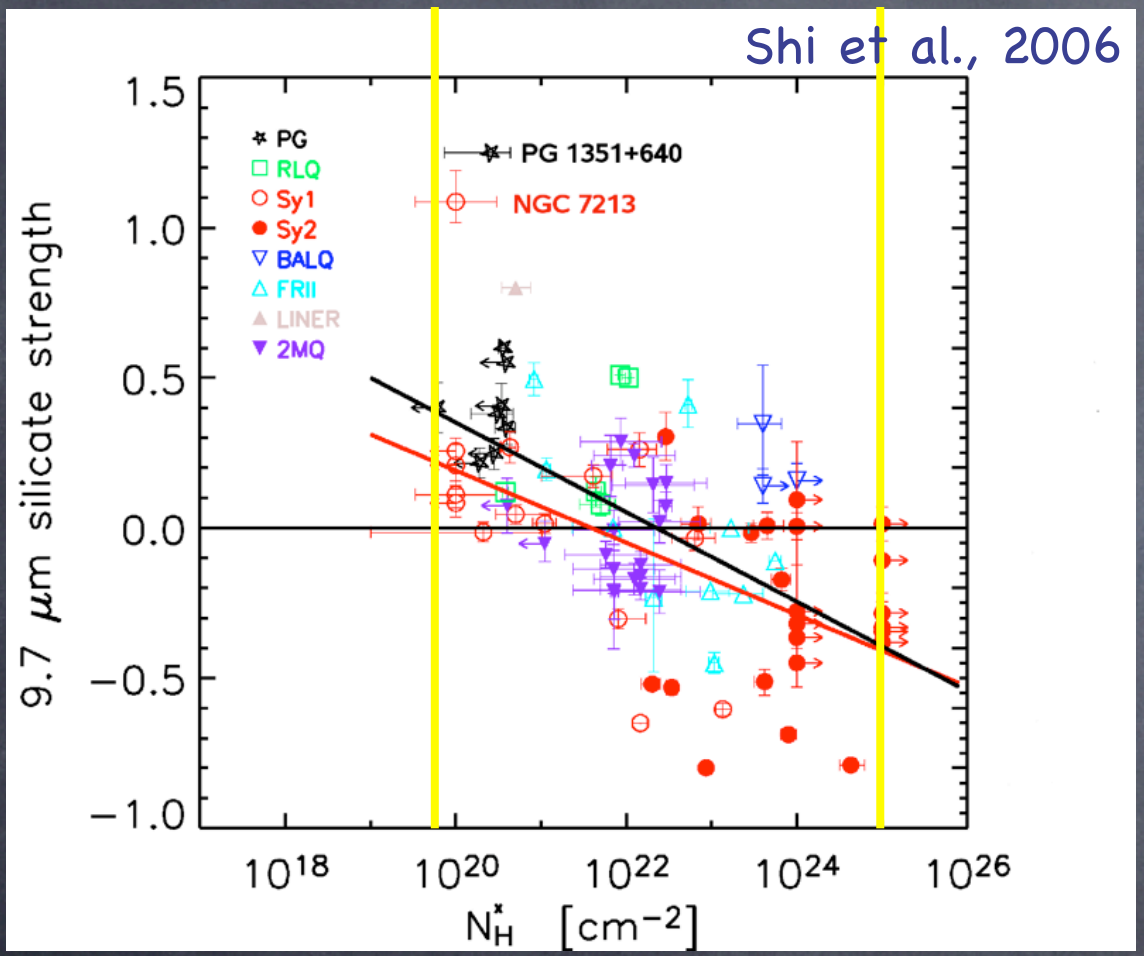

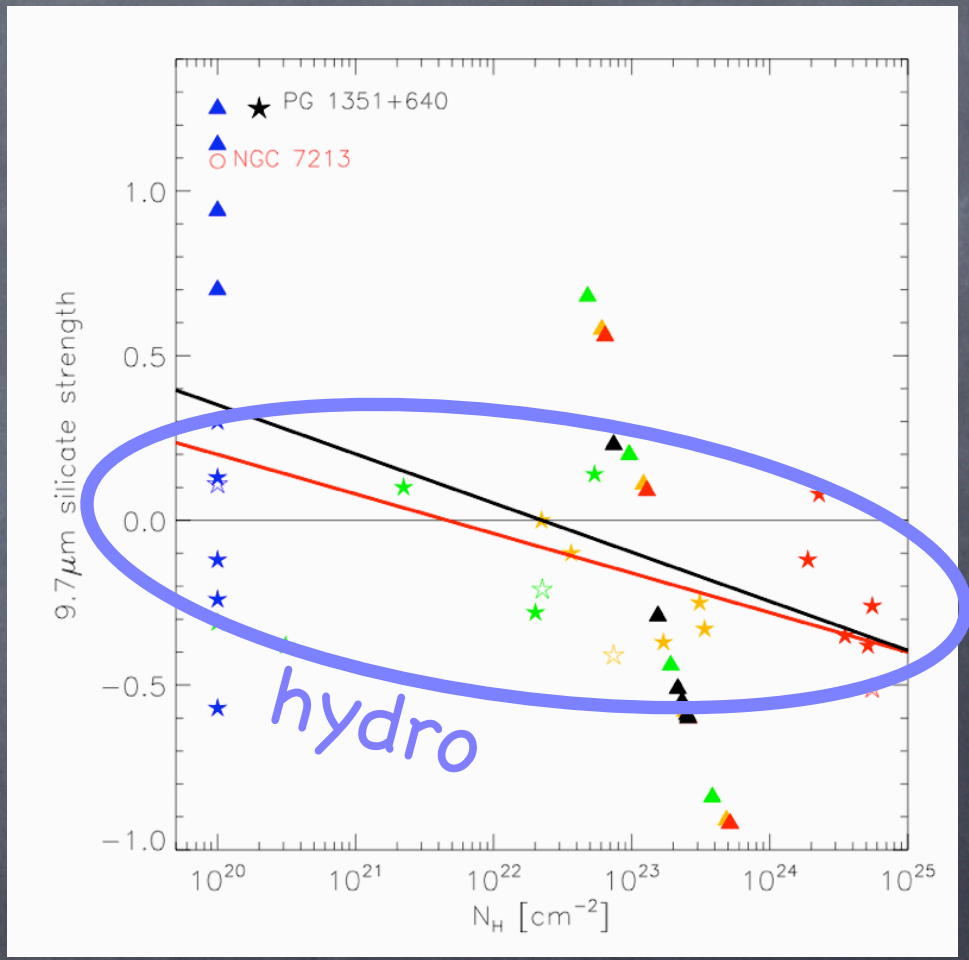

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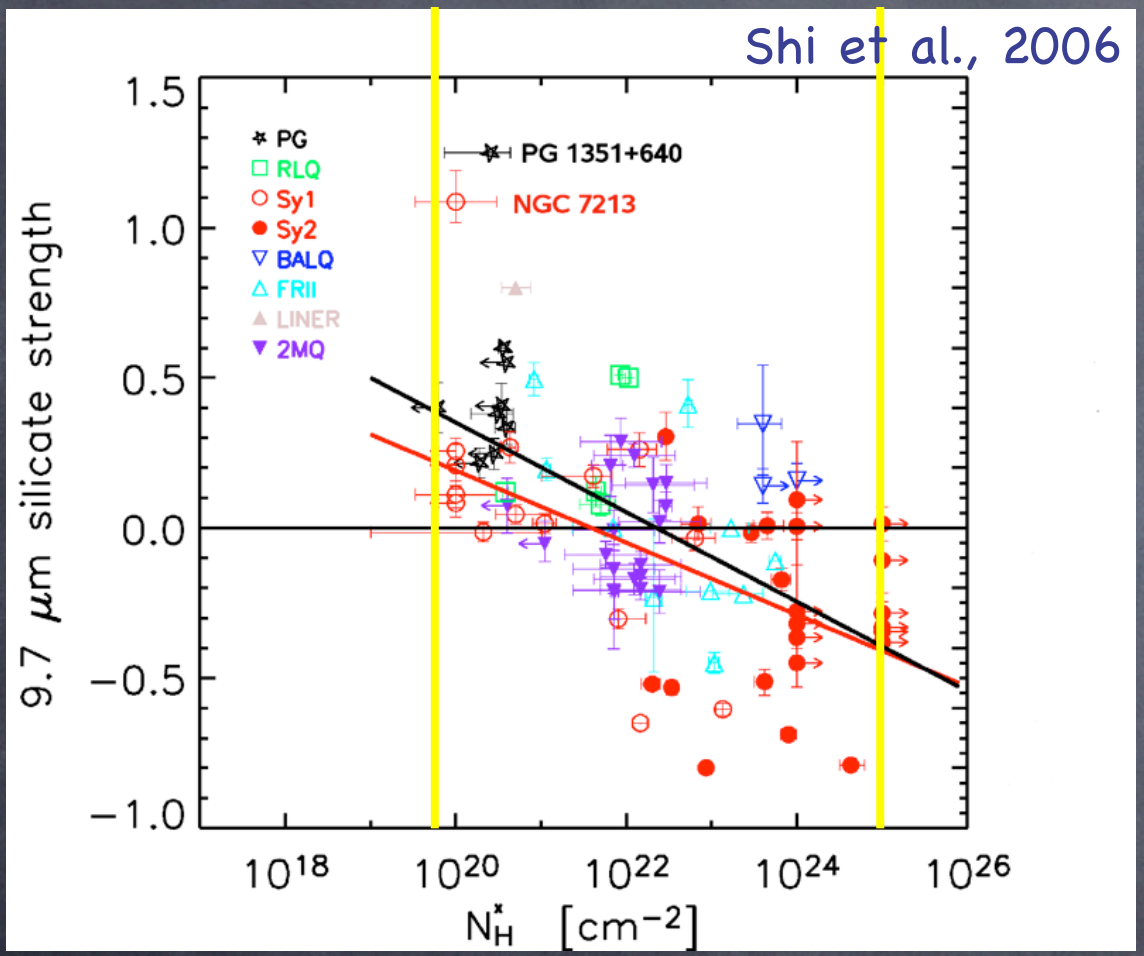

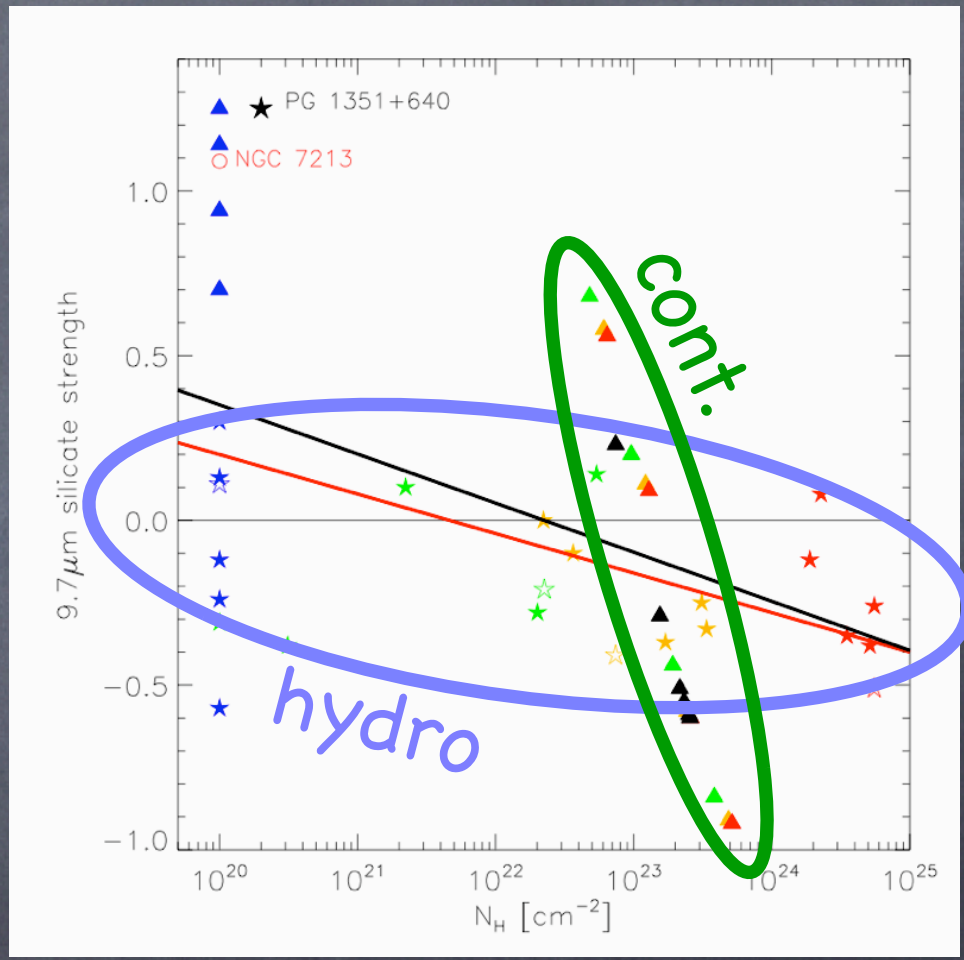

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Conclusions

- gas and dust distributions resulting from hydrodynamic models in concordance with some observations (Spitzer, feat.-N_H-relation)
- N_H depends highly on line of sight
- found possibility to sustain torus height
- two components: disk + filamentary torus, with very different characteristics, e.g. N_H column density