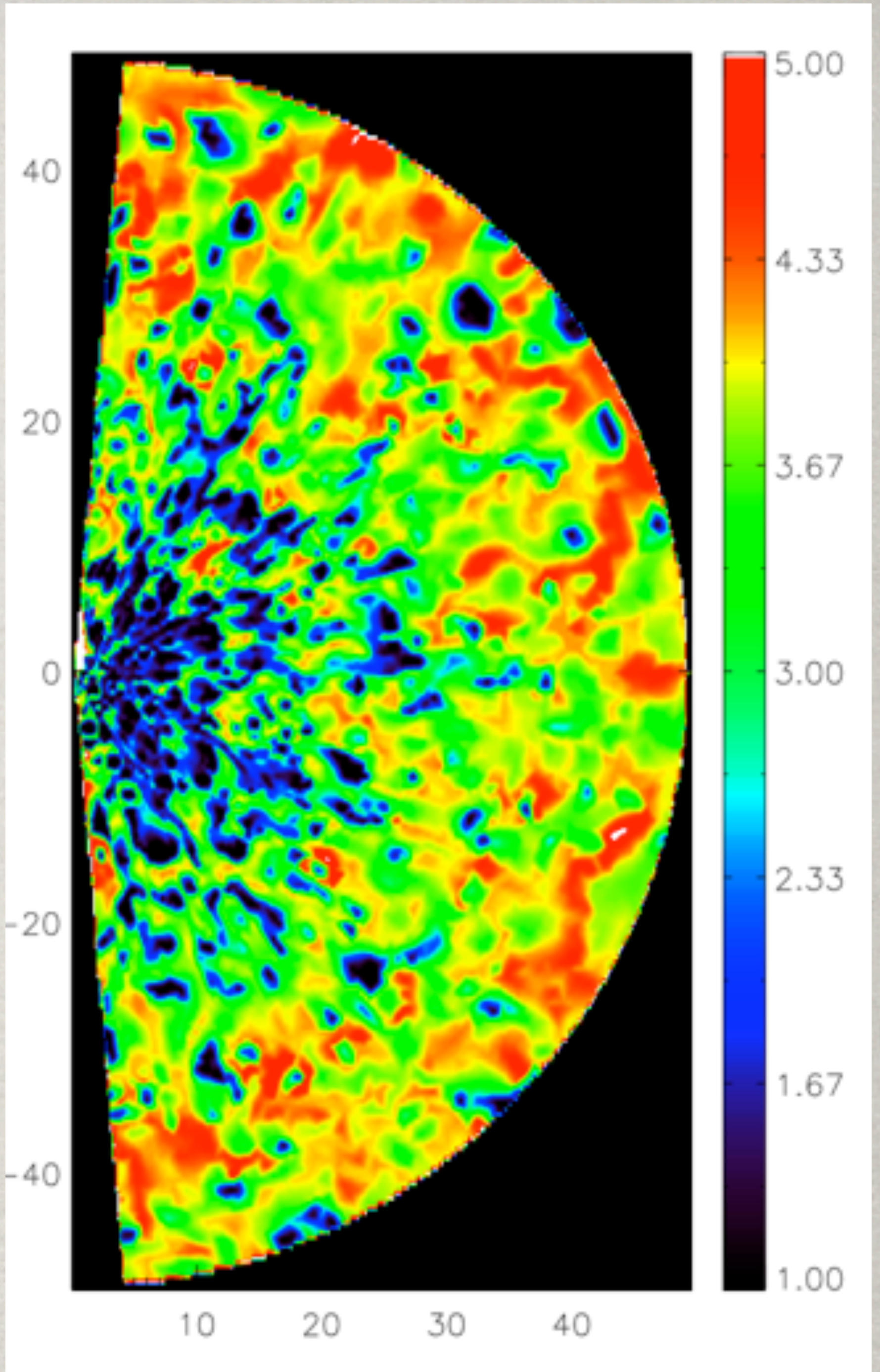
Evolution from nuclear starbursts to discs and tori in Active Galactic Nuclei

Marc Schartmann, Andreas Burkert, Martin Krause, Richard Davies, Klaus Meisenheimer, Max Camenzind, Konrad Tristram



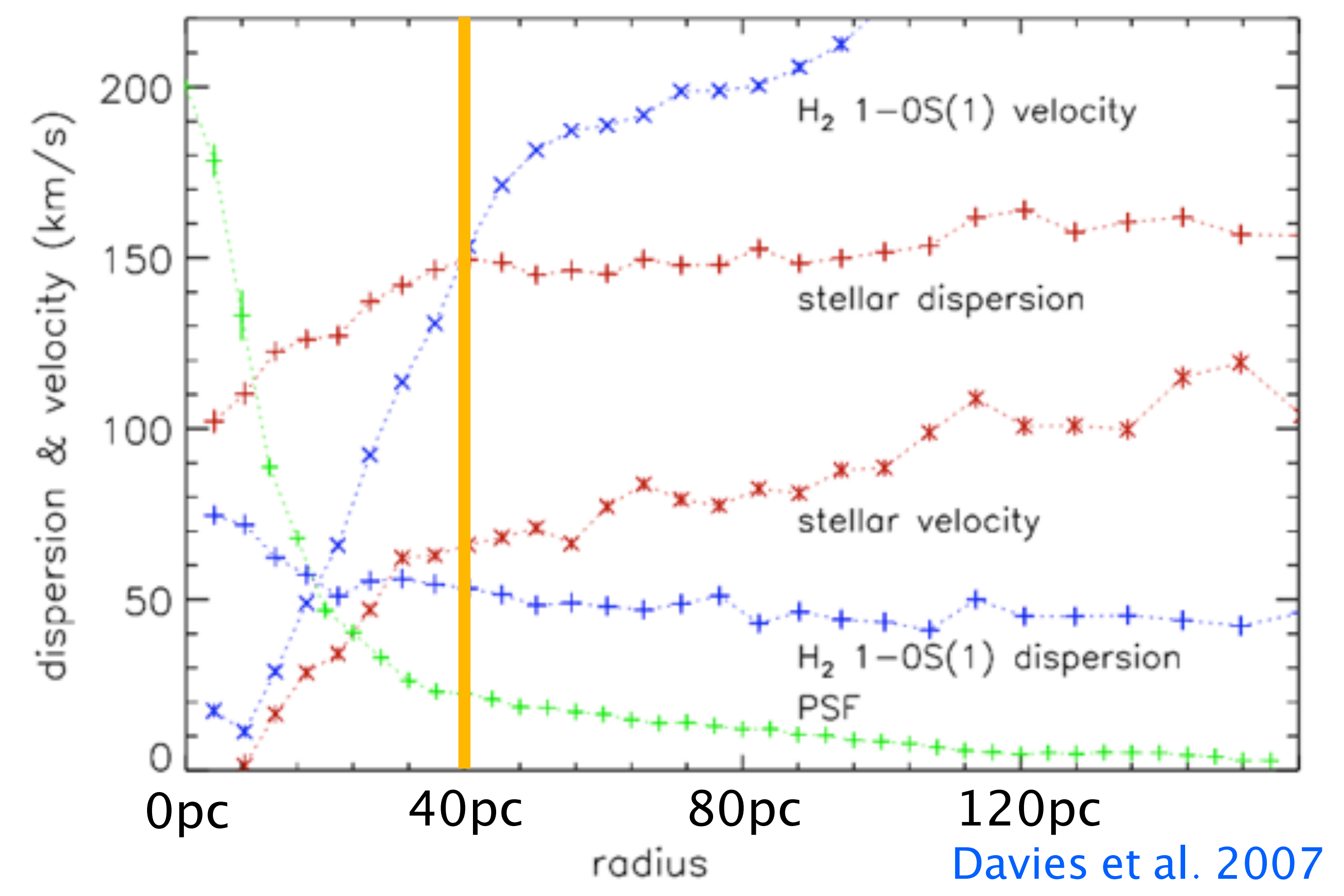
Munich University Observatory
CAST
Computational Astrophysics Group

“Central Massive Objects” Conference

ESO Garching, June 24th, 2010

1. SINFONI Observations of Nuclear Star Clusters in nearby Seyfert Galaxies

(reminder of R.Davies talk)

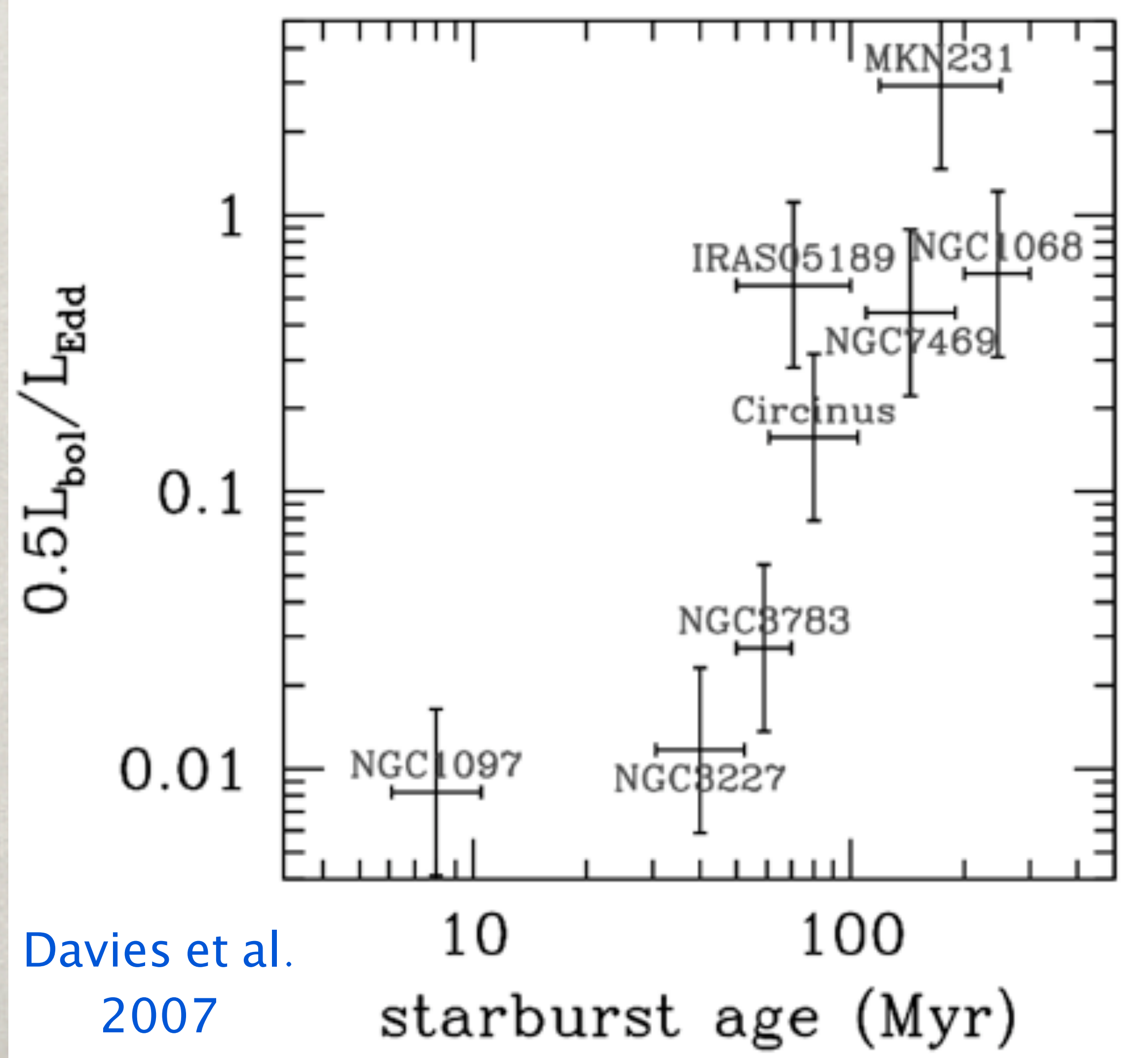


Davies et al. 2007

example of NGC 1097:

- r > 0.5" stars - spheroid, gas - thin disk
- r < 0.5": kinematics of gas and stars similar, dispersion dominated

→ gas and stars intermixed, common origin?



Davies et al. 2007

- recent SF (< few 100 Myr), short-lived
- AGN switched on 50-100 Myr after starburst
- explainable with onset of AGB phase

How does this mass loss relate to the torus build up and evolution?

2. Molecular Tori in Active Galactic Nuclei

Unified Scheme of Active Galactic Nuclei

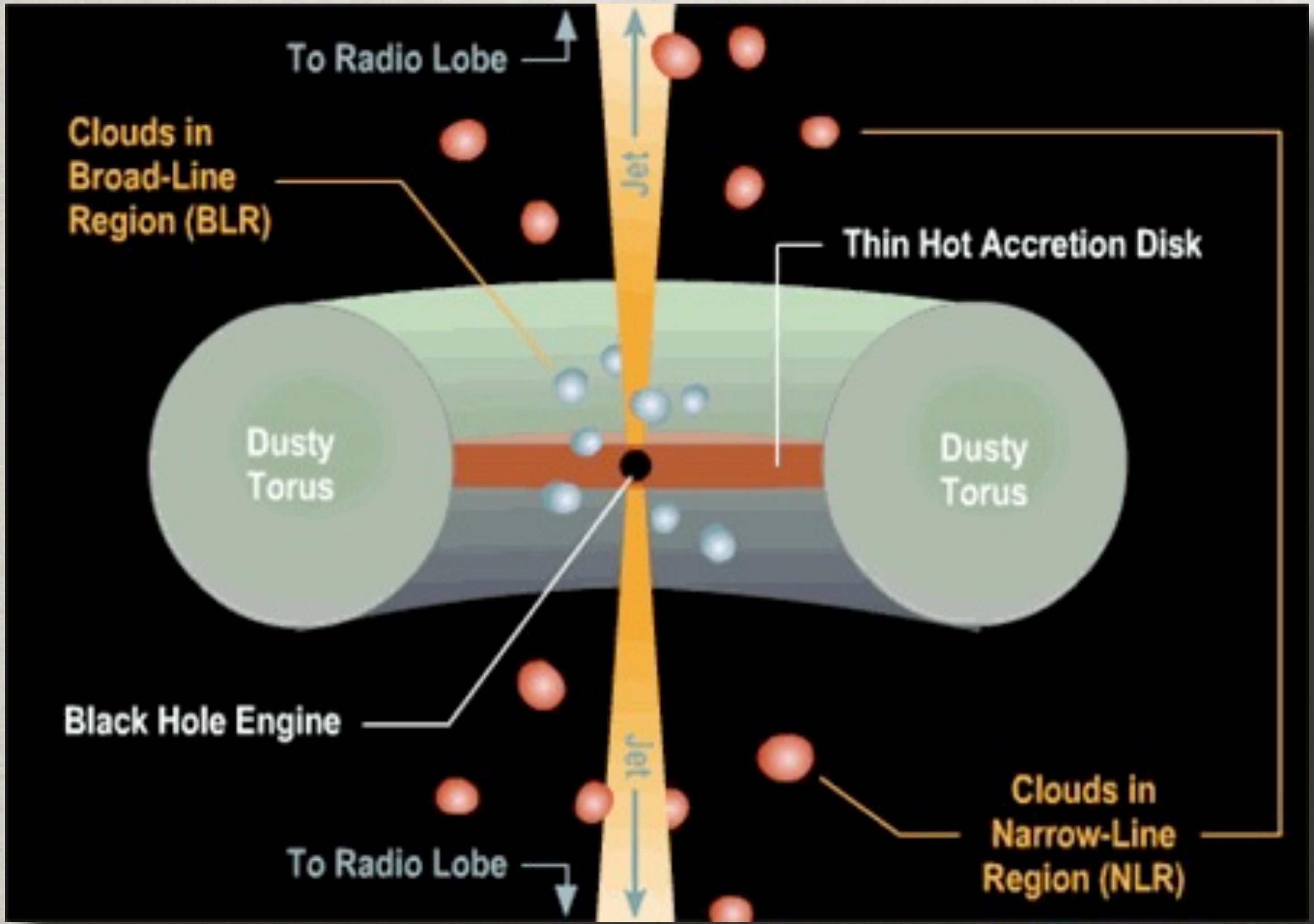


Image credit: Brooks/Cole Thomson Learning)

- central black hole (10^6 to 10^{10} $M_\odot$)
- accretion disc
- obscuring torus
- (hidden) broad line region
- narrow line region

- dusty torus needed to unify 2 types of objects
- geometrical unification
- indirectly inferred from polarimetric observations

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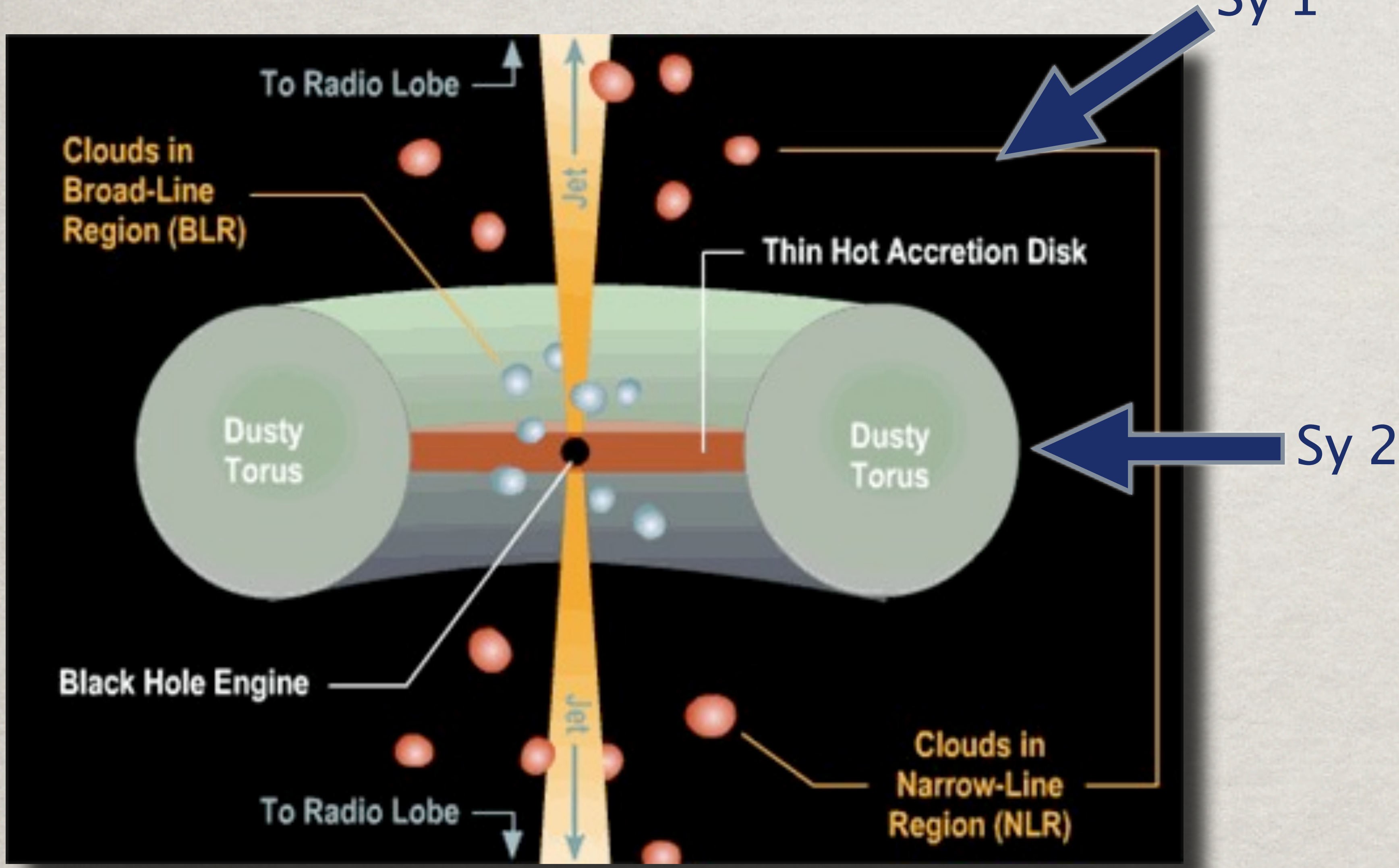

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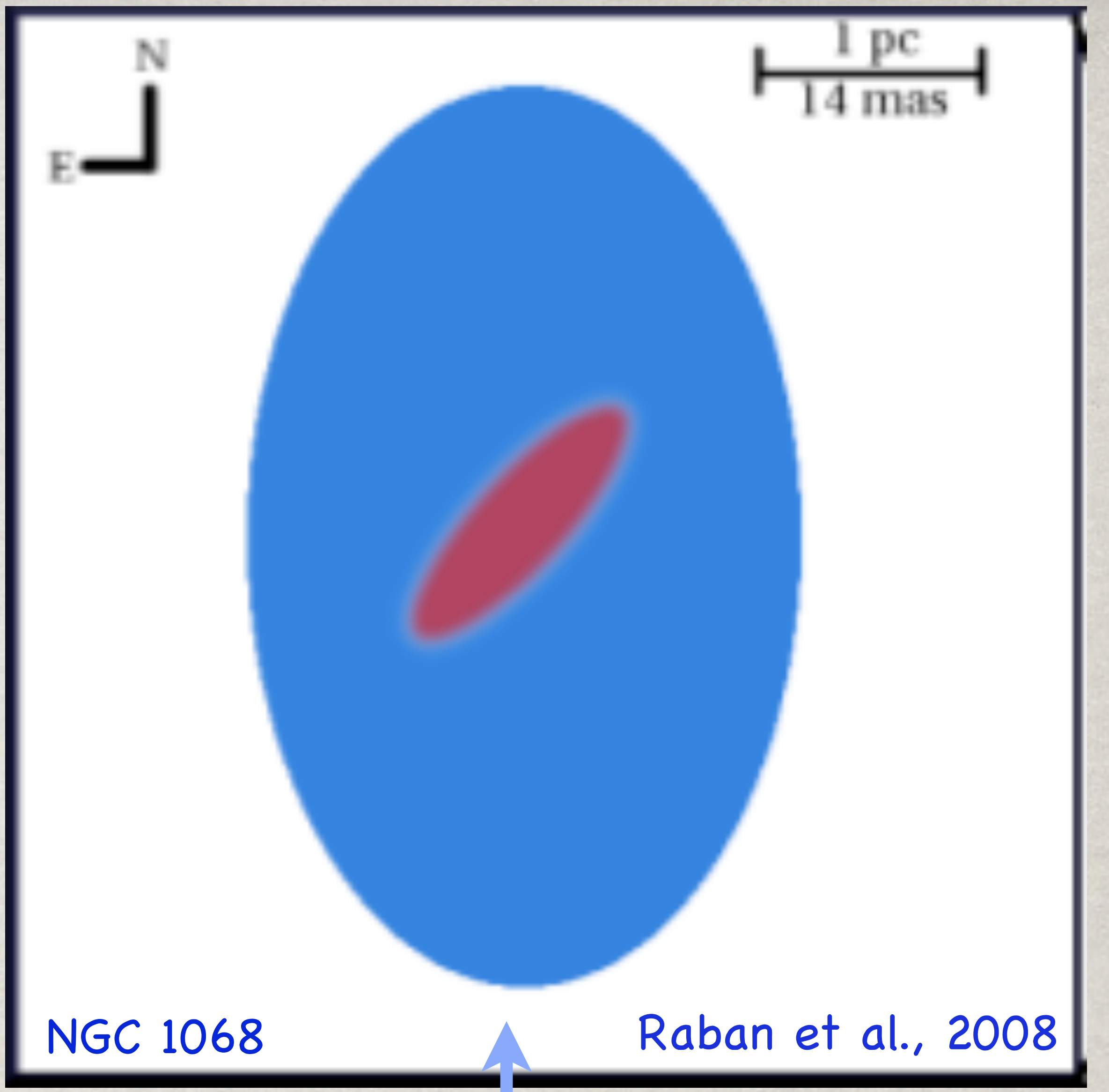
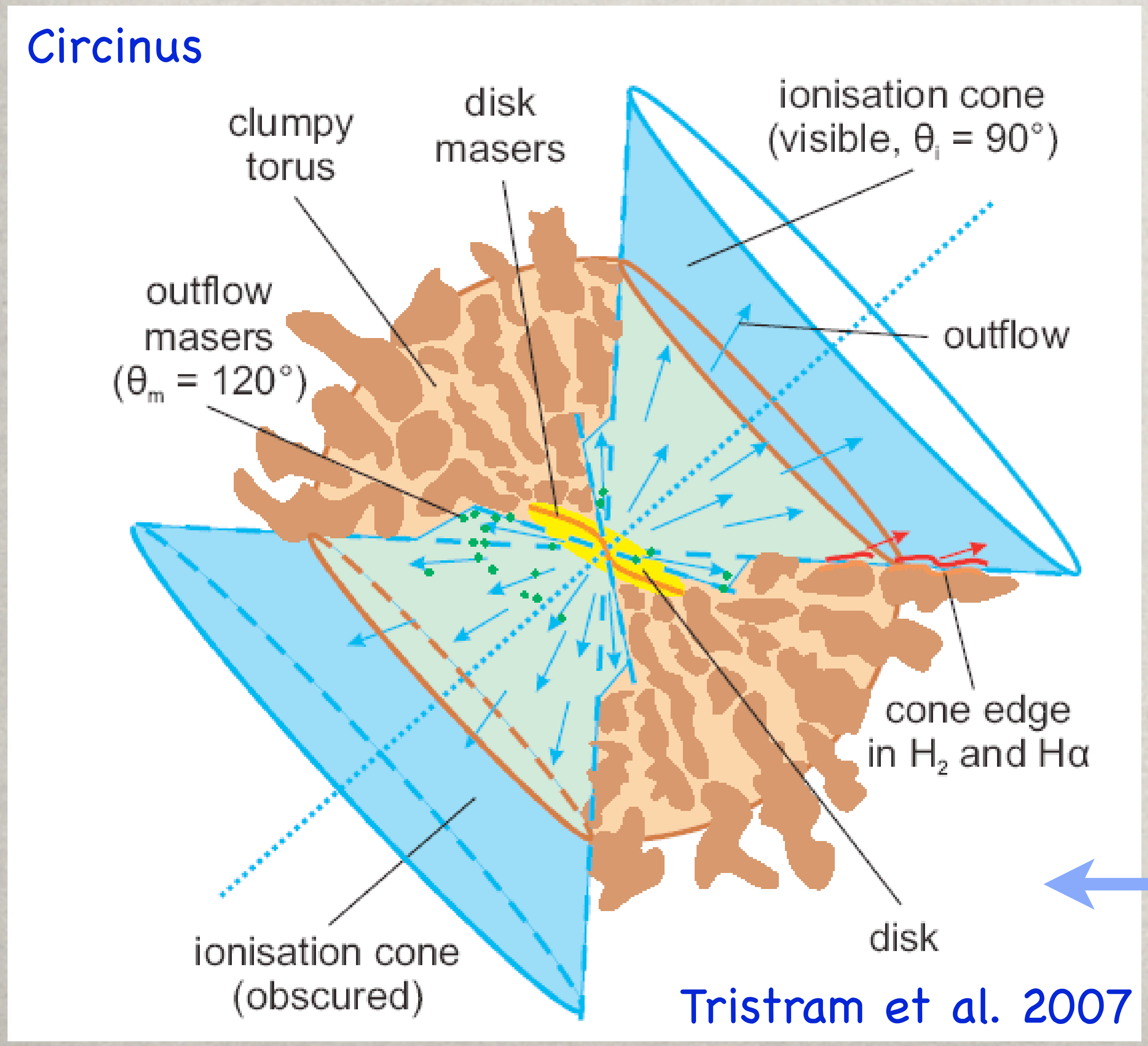
2. Molecular Tori in Active Galactic Nuclei

- torus morphology revealed by MIDI
- find two-component structure



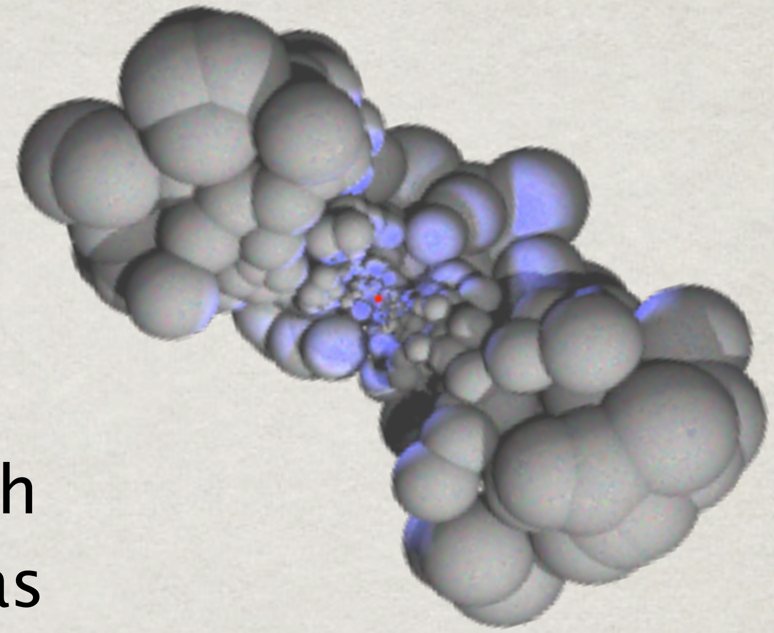
NGC 1068
- hot (800K) thin disk (1.35 x 0.45 pc)
- cold (300K) larger torus (3.0 x 4.0 pc)

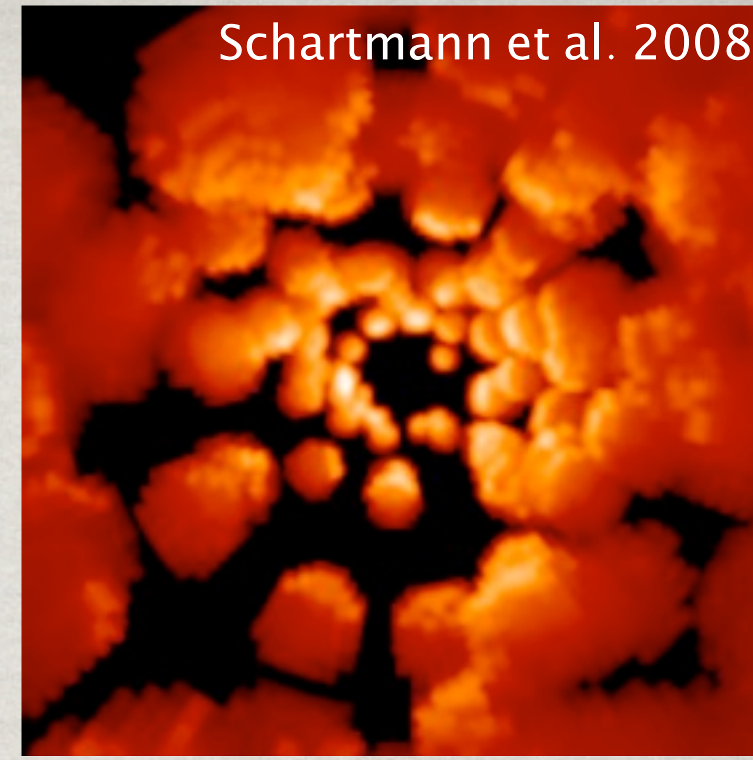


Circinus
- warm (330K) thin disk (0.4 pc)
- slightly colder (300K) clumpy torus (2 pc)

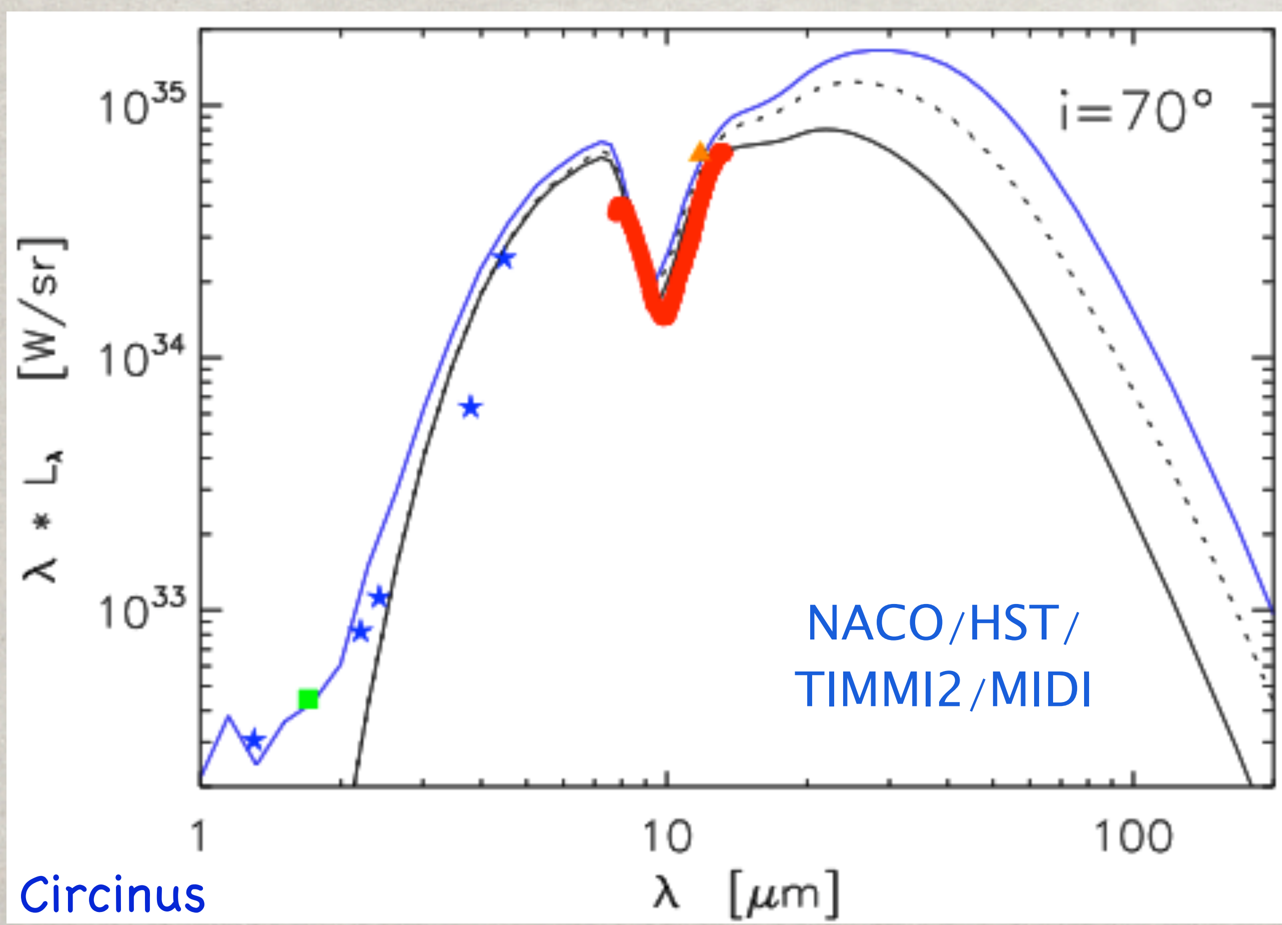
3. Radiative Transfer Modelling

- infer dust morphology
- parameter study for various clumping parameters in a toy model
- simultaneously account for high spatial resolution data as well as visibility information

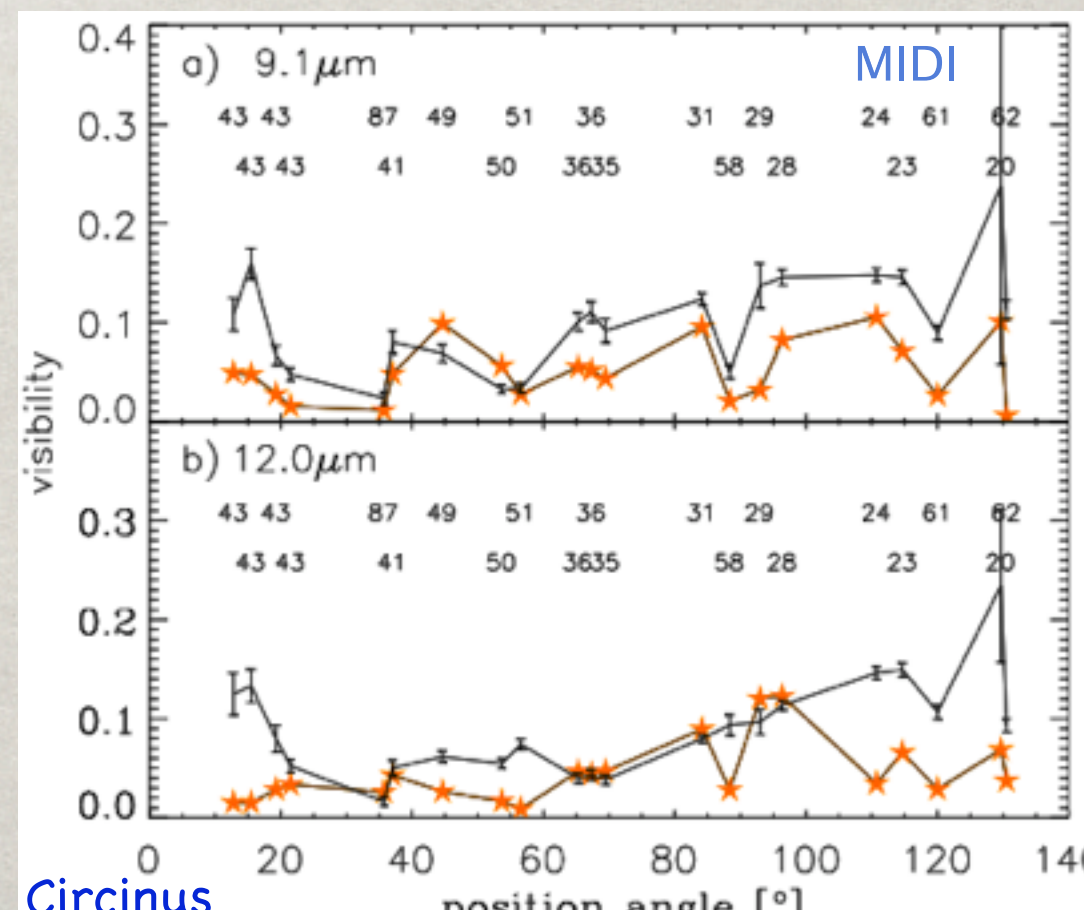




→ good idea of structural properties of tori

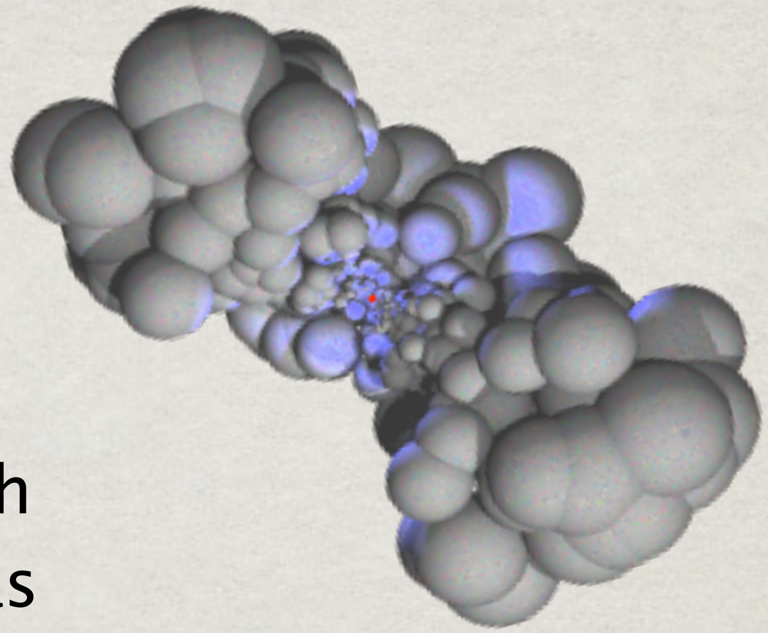


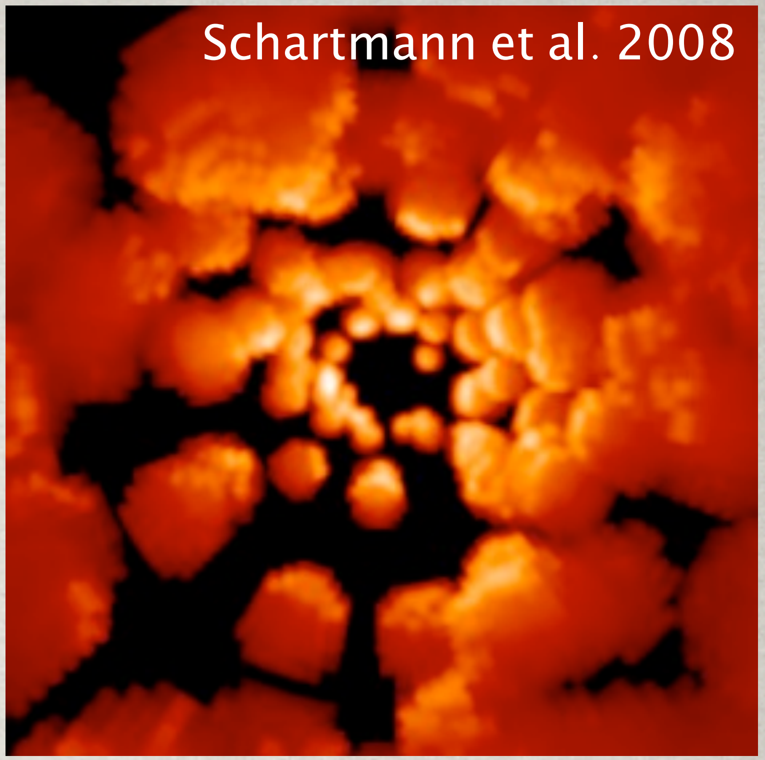
data courtesy: Prieto et al., 2004



data courtesy: Tristram et al., 2007

3. Radiative Transfer Modelling





- infer dust morphology
- parameter study for various clumping parameters in a toy model
- simultaneously account for high spatial resolution data as well as visibility information

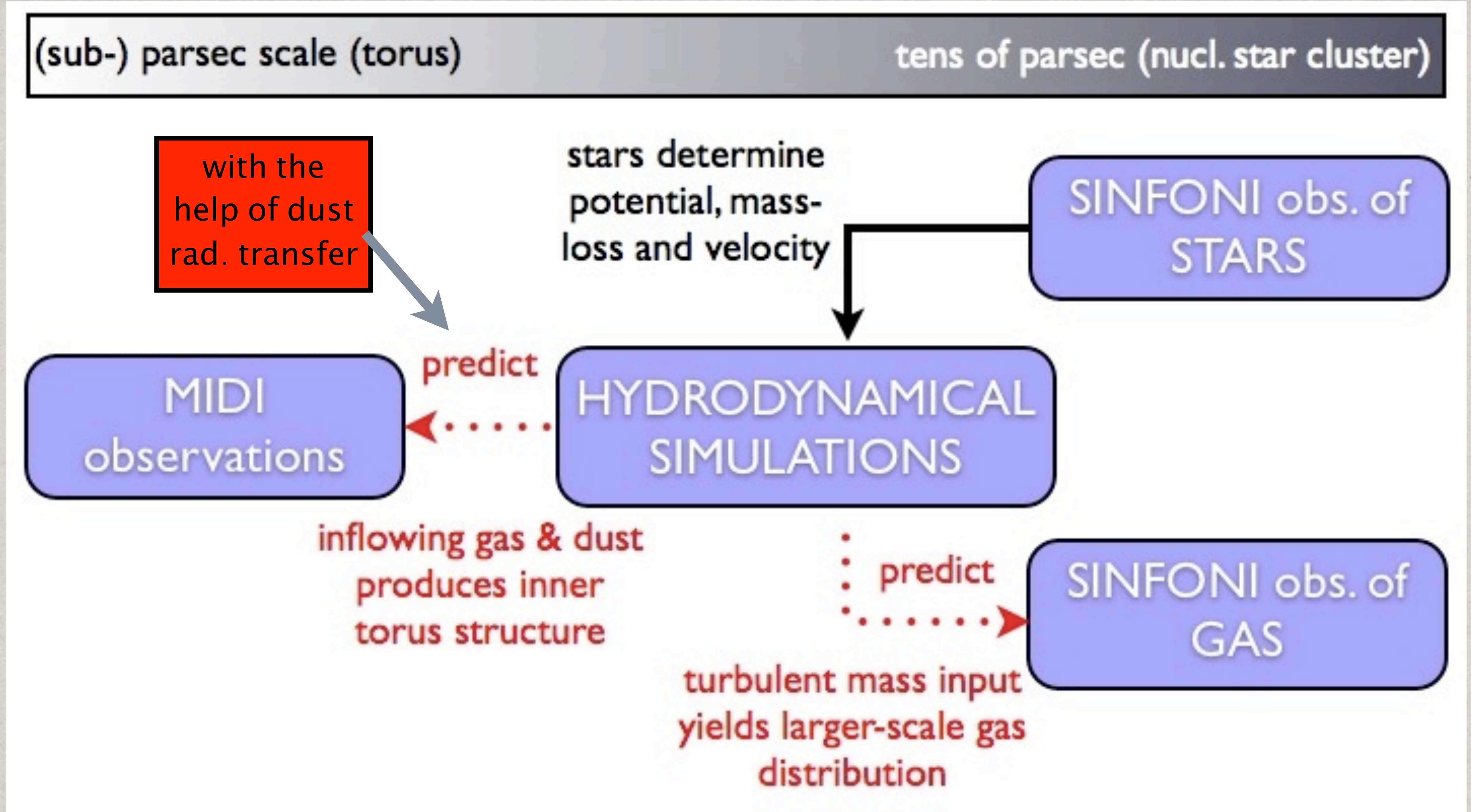
→ good idea of structural properties of tori

However:

- Where does the gas come from?
- How are tori stabilised against gravity?
- What governs the dynamics of tori?

→ Hydrodynamical torus models needed, which produce similar gas morphologies

4. Connecting 3D Simulations with Observations



- Sample of nearby Seyfert galaxies, for which SINFONI & MIDI observations are available
- hydrodynamical simulations combine large and small scale observations
- MIDI Large Program 184.B-0832 and SINFONI proposal for P86

→ first results on NGC 1068 presented here

5. 3D Hydrodynamical Simulations with PLUTO

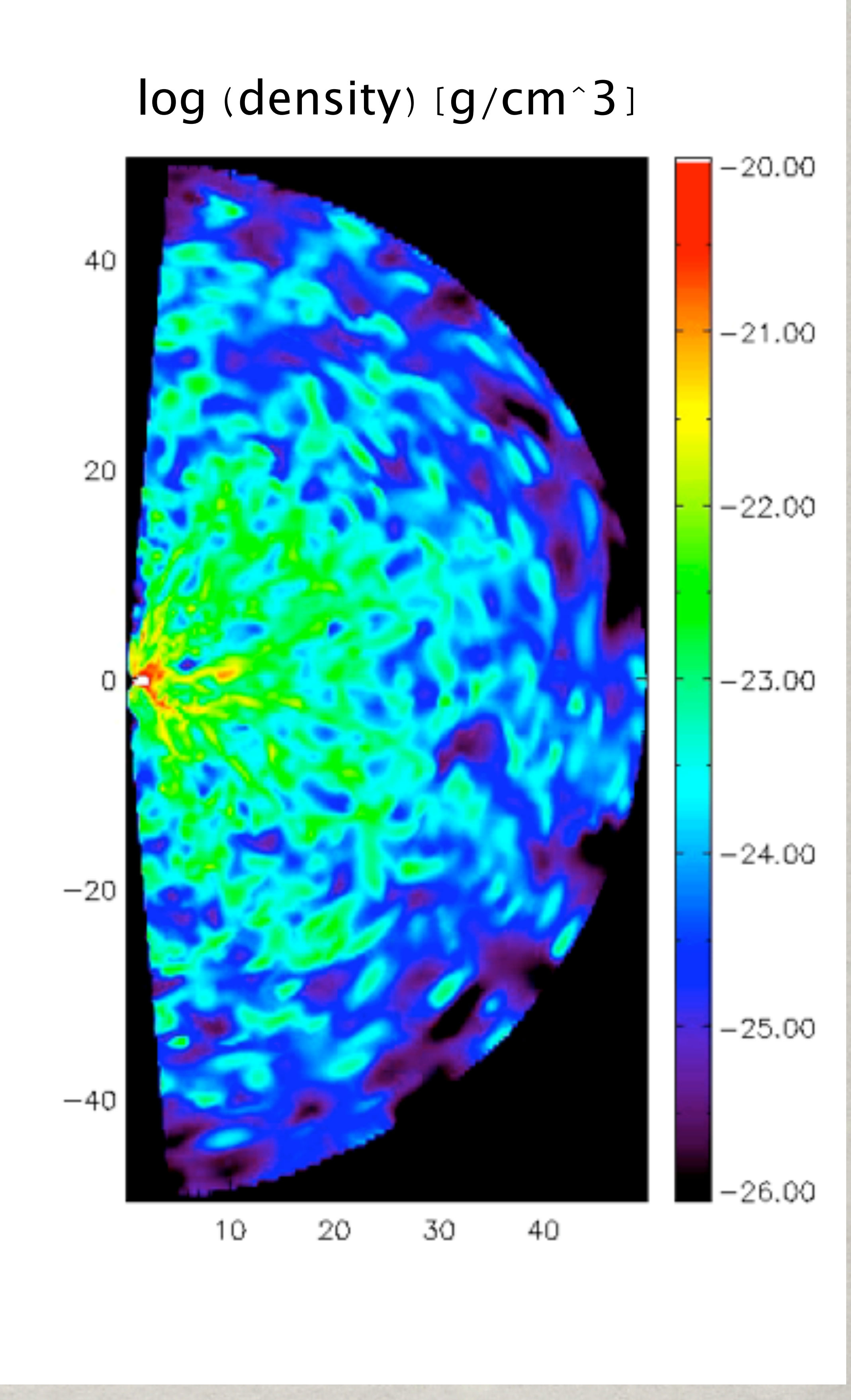
Torus build-up and BH feeding in NGC 1068

- start after violent SN II phase, following short-duration star-burst, which built up central star cluster
- then AGB stars with slow winds main mass contributors:
    - discrete mass input
    - velocity (rotation plus random) from emitting star
    - mass loss rate (Jungwiert et al. 2001):

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

$$= 9 \cdot 10^{-10} \, M_{sun} \, yr^{-1} \, M_{sun}^{-1}$$

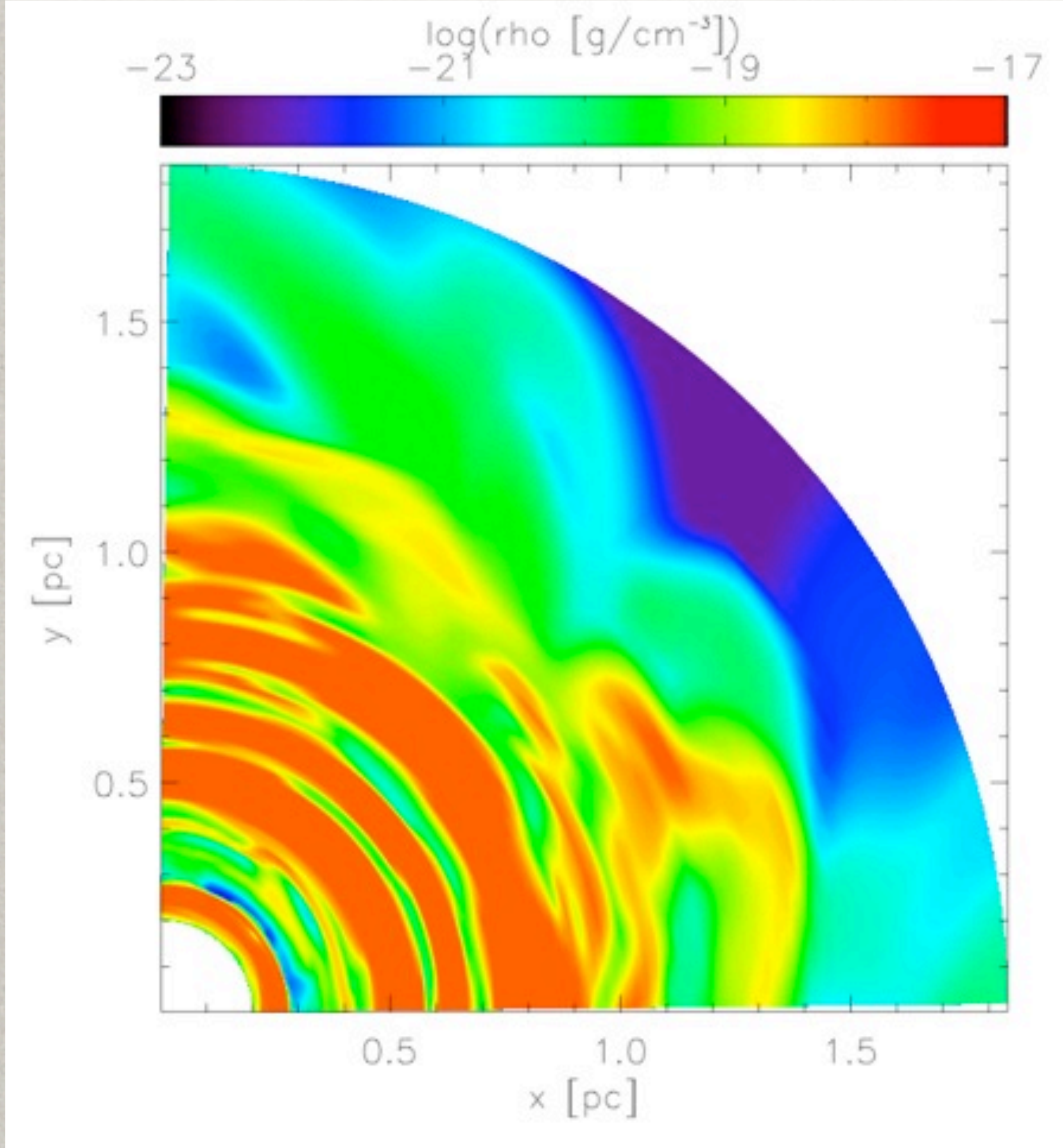
- effective cooling curve
- solved with PLUTO -code (Mignone et al. 2007)



Schartmann et al. 2009 & 2010

5. 3D Hydrodynamical Simulations with PLUTO

nuclear disk



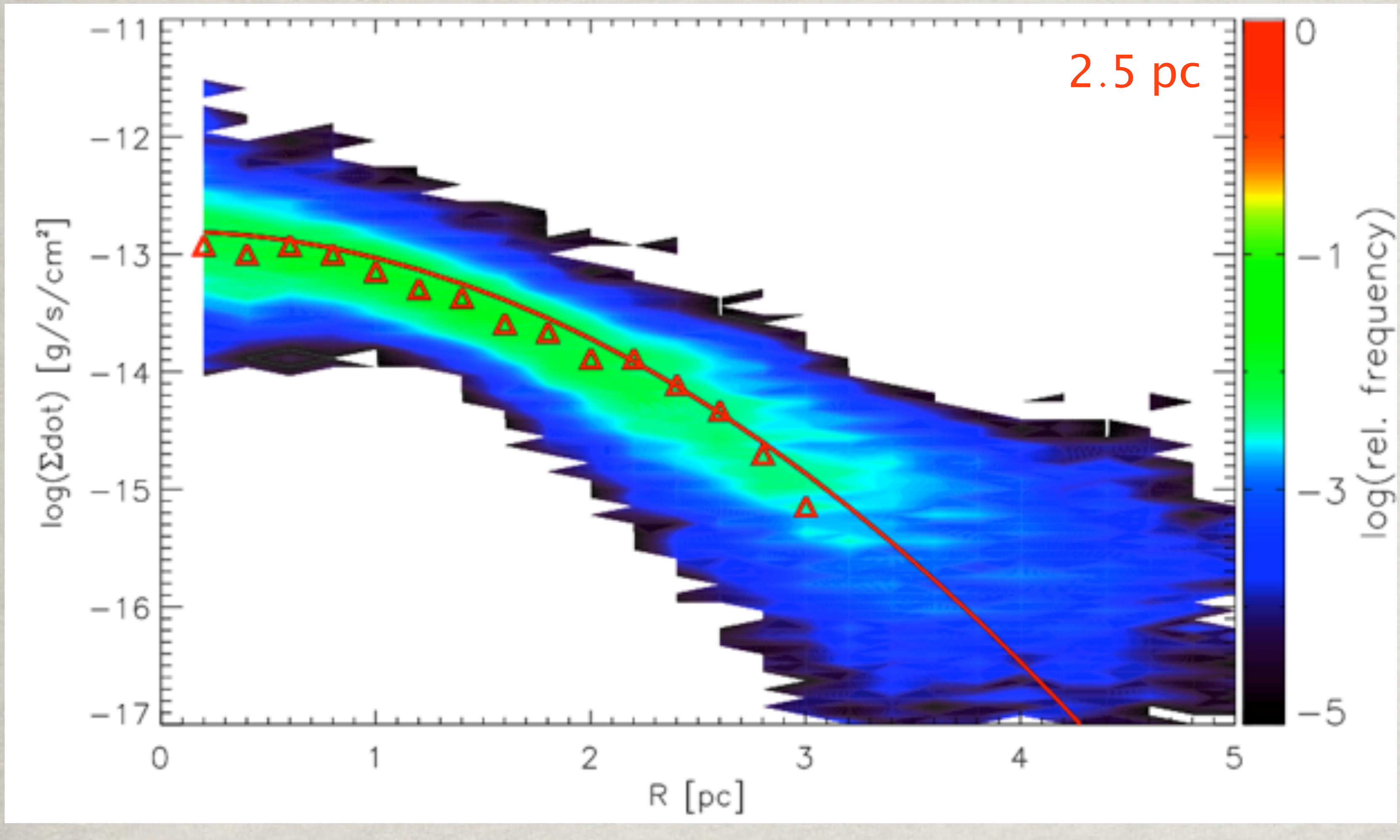
- disk extent: 0.5 to 1pc
- maser disk in NGC 1068: 0.65 to 1.1pc (Greenhill & Gwinn 1997)

→ angular momentum distribution of gas coming into centre seems to be reasonable

However:
- outer torus component in equilibrium (>2.5pc), but mass pile up in nuclear disk
- accretion & star formation physics not included
- very computationally extensive, only short time evolution possible

→ idea: 1D effective disk model for nuclear disk

6. 1D Effective Disc Simulations



- mass infall onto the disk from 3D hydro models
- time dependence from Jungwiert et al. 2001
- use angular momentum of mass inflow to derive radial position in a Keplerian disk

calculate viscous evolution with mass input source term and SF sink term:

$$\frac{\partial}{\partial t}\Sigma(t,R)+\frac{1}{R}\frac{\partial}{\partial R}\left[\frac{\frac{\partial}{\partial R}\left(\nu\Sigma(t,R)R^{3}\Omega'(R)\right)}{\frac{d}{dR}\left(R^{2}\Omega\right)}\right]=\dot{\Sigma}_{input}(t,R)-\dot{\Sigma}_{SF}(t,R)$$

Lin & Pringle, 1987

→ compare resulting disk properties (mass, size, ...) to observations

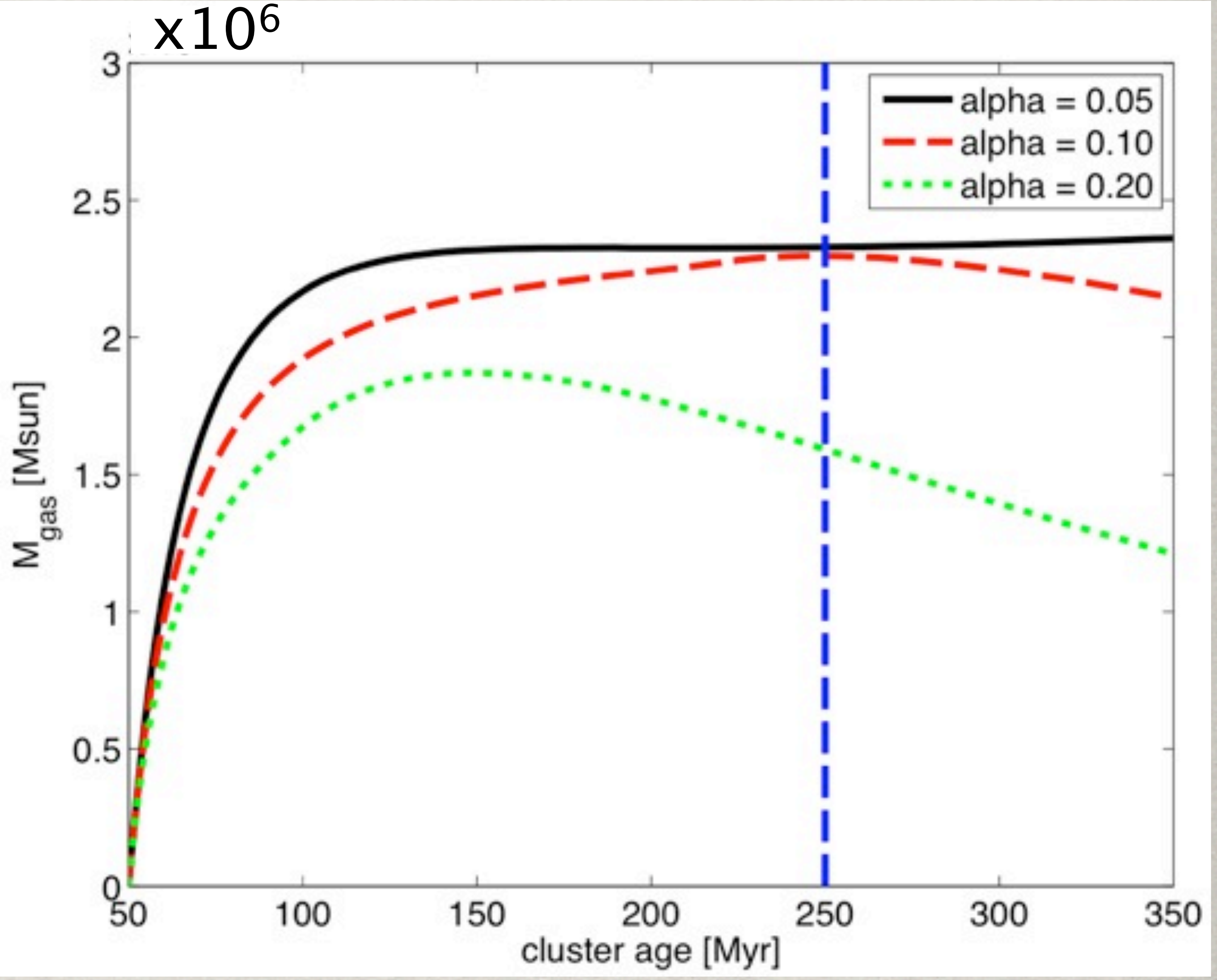
6. 1D Effective Disc Simulations: Disk Mass

alpha viscosity value unclear:

observations of fully ionised disks: 0.1 to 0.4 (King 2007)

→ alpha parameter study

nuclear disk mass in alpha parameter study

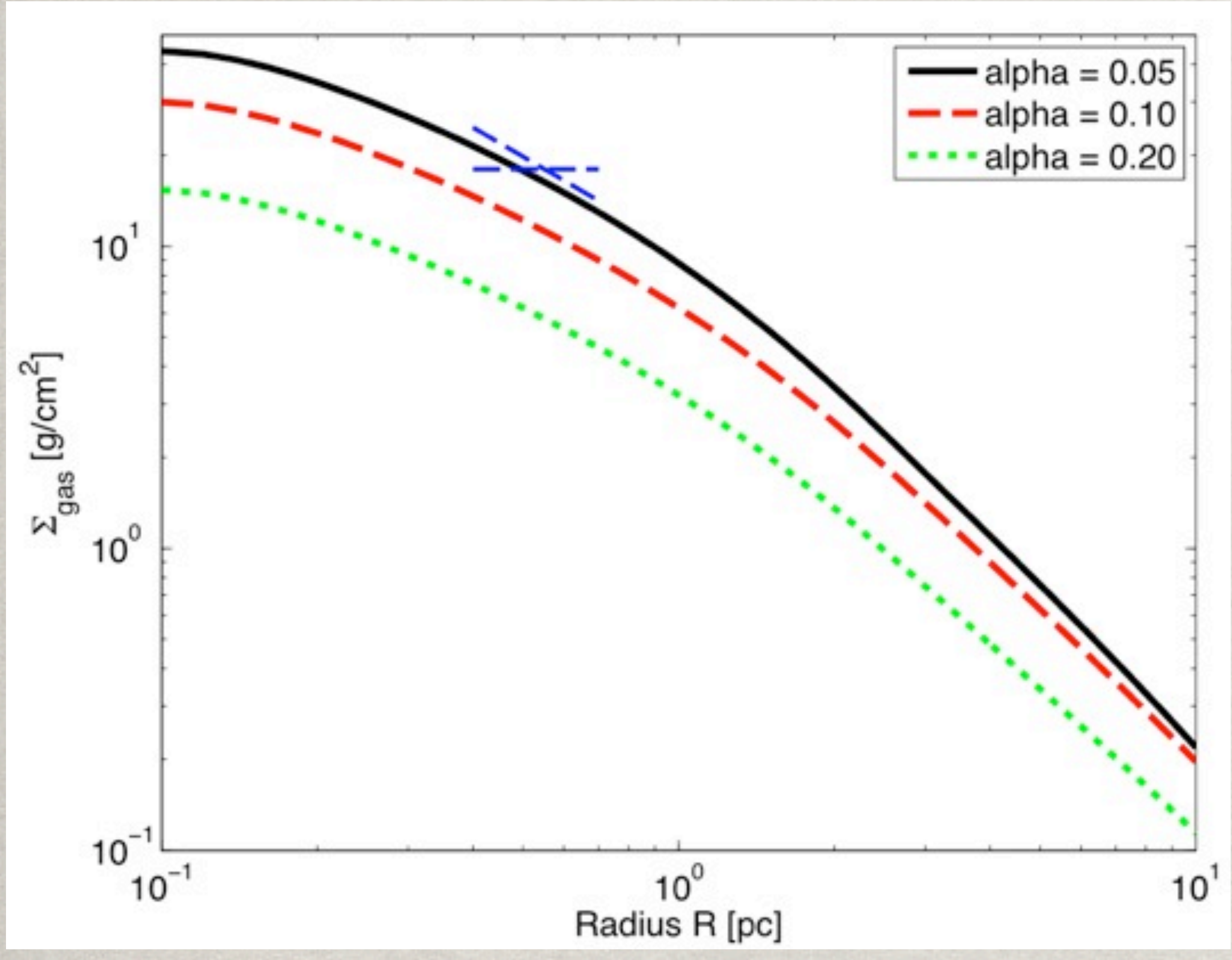


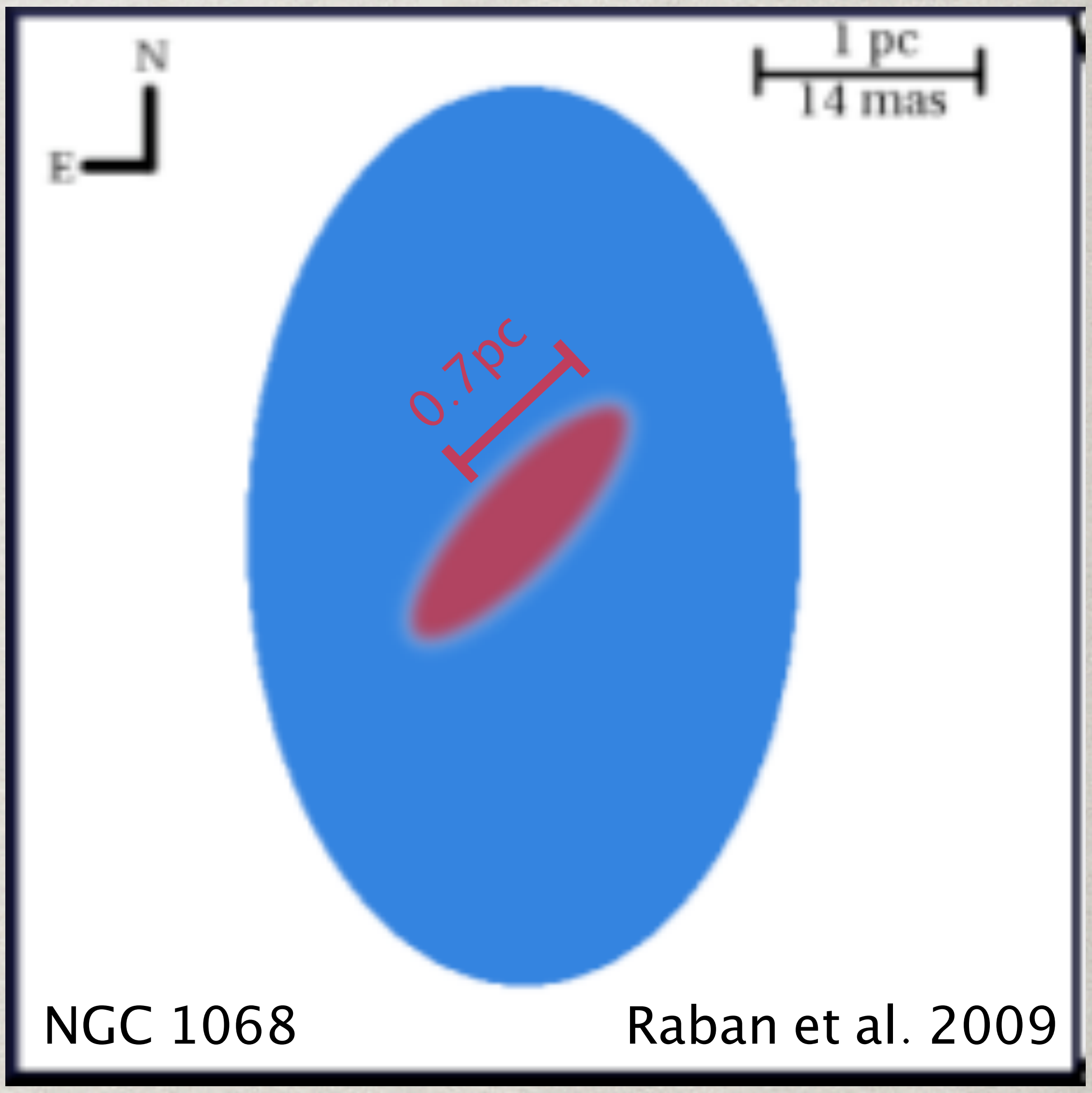
- Models reproducing maser observations: $\sim 10^6\ M_{sun}$ in clumpy disk model (Kumar 1999)

- observations of the CND in the Galactic centre: $1.3 \cdot 10^6\ M_{sun}$ in molecular mass (Montero-Castano et al. 2009)

6. 1D Effective Disc Simulations: Disk Structure

surface density of the disk



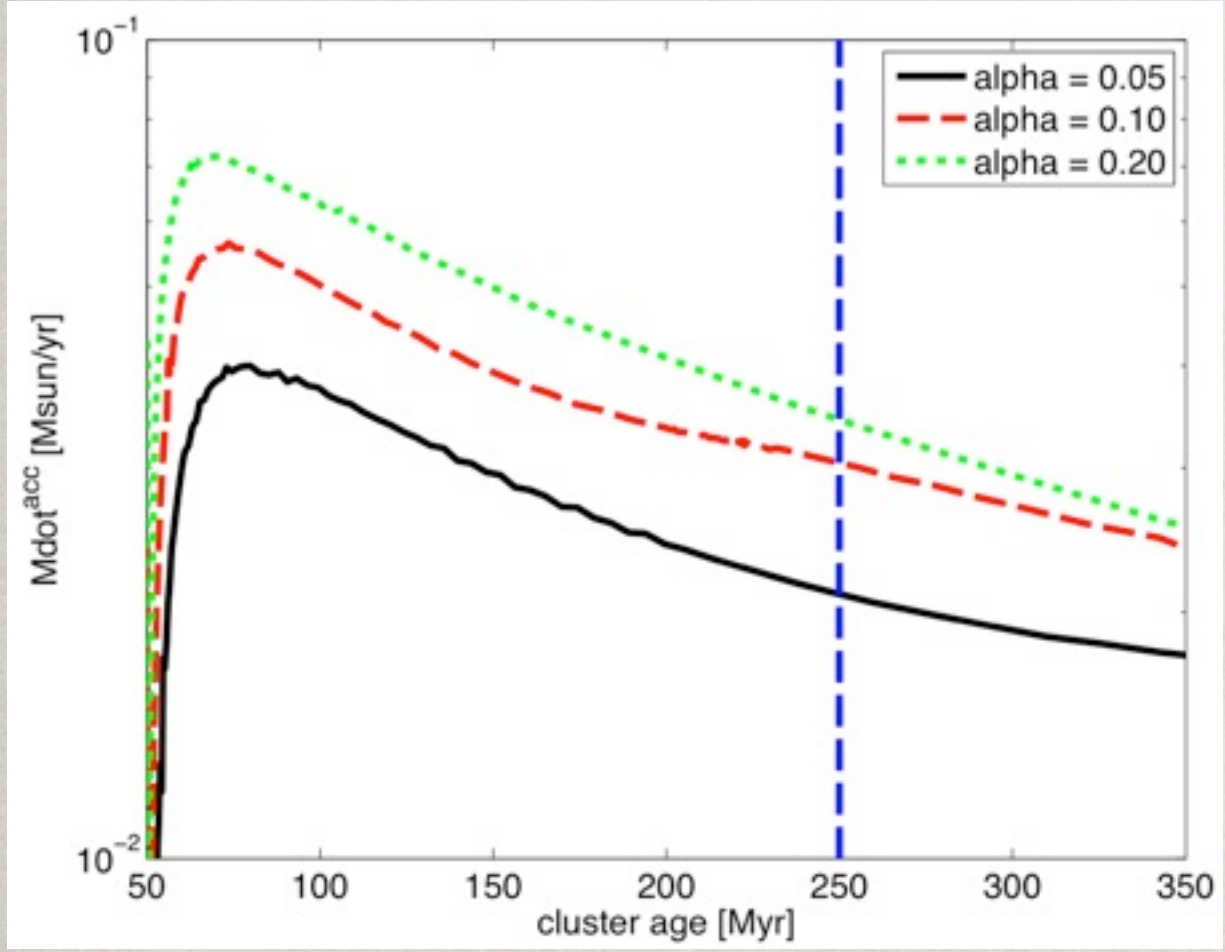


HWHM=0.85 pc dust disk

0.7 pc HWHM of hot component

common radial structure from MIDI observations (blue dashed lines, Kishimoto et al. 2009)

6. 1D Effective Disc Simulations: Current Mass Accretion Rate



acc.rate @2.5pc (250Myr): 0.03 M_{sun}/yr

→ $3\cdot10^{-3}$ to $3\cdot10^{-2}$ M_{sun}/yr onto centre (?)

observations of Seyfert galaxies: 10^{-3} to 10^{-2} M_{sun}/yr (Jogee, 2006)

bolometric luminosity: $$L_{bol} \approx 9.4 \cdot 10^{10} \left(\frac{f_{refl}}{0.01}\right)^{-1} \left(\frac{D}{14.4\,Mpc}\right)^{2} L_{\odot} \approx 3.6 \cdot 10^{44} \frac{erg}{s}$$

Pier et al. 1994

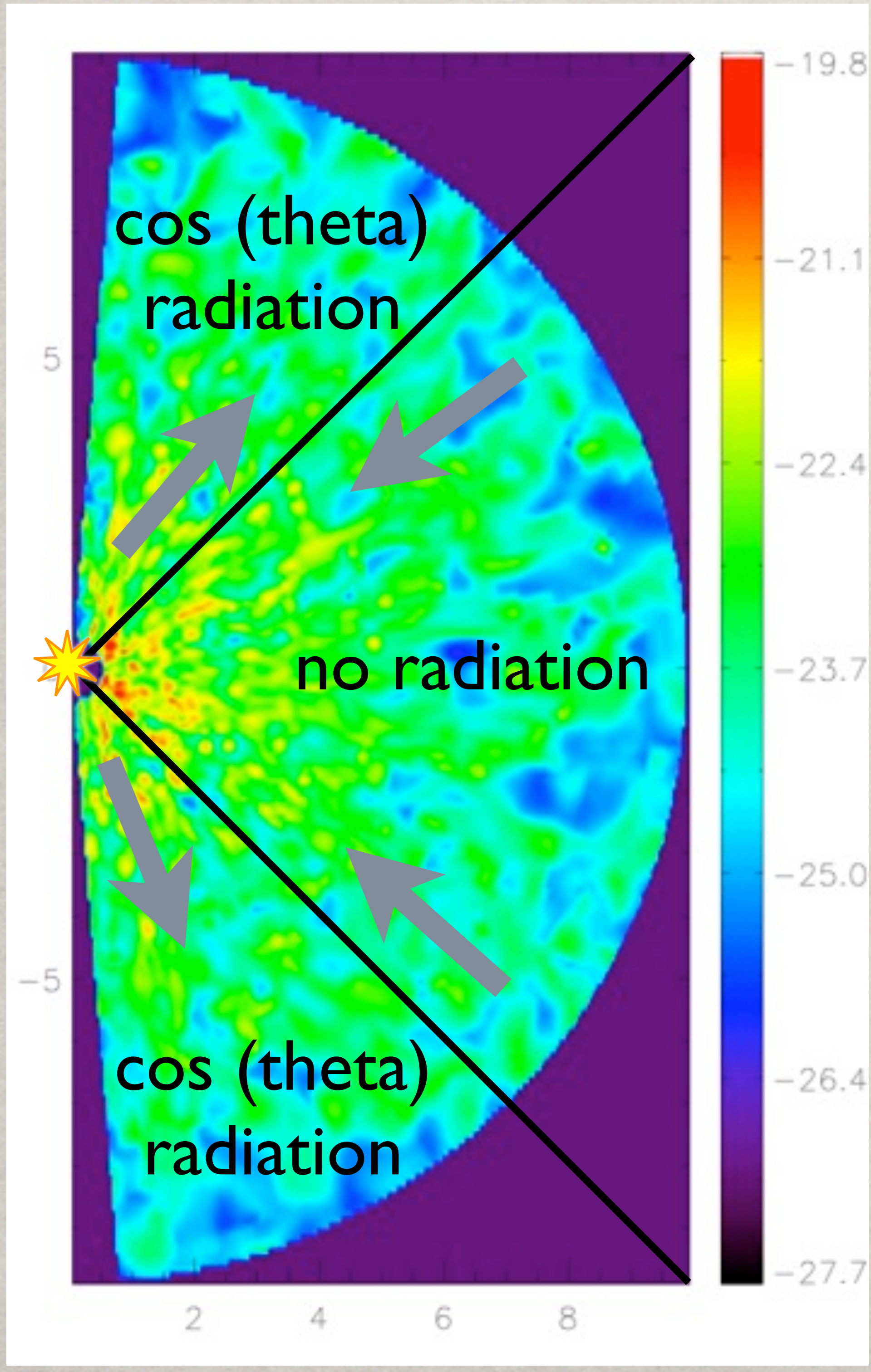
assuming 100% reaches the BH:
L_{bol} = $1.8\cdot10^{44}$ erg/s
(in Schartmann et al. 2005,
L_{bol} = $2.1\cdot10^{44}$ erg/s gives a good adaptation to highres. data)

→

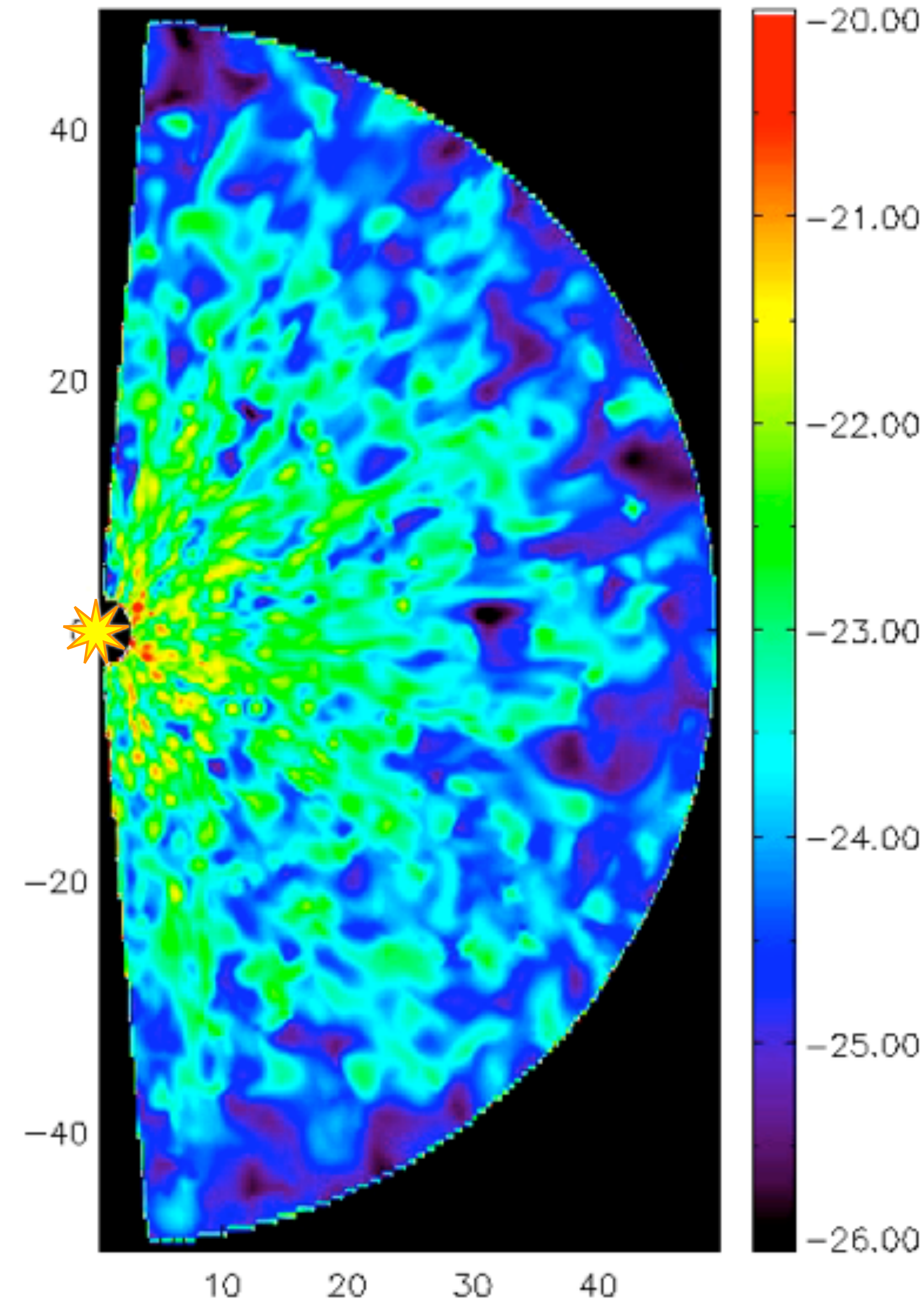
- accretion from nuclear disk might be clumpy as e.g. observed in Galactic Centre (Montero-Castano et al. 2009)
- additional inflow?/outflow (scales)?

7. Outlook: Effects of Continuum Radiation Pressure

- accretion flow triggers central activity
- investigate radiation feedback on the gas inflow
- inner torus not modelled → assume obscuration profile



switch on radiation



8. Conclusions

- ⋆ observations (e.g. MIDI, SINFONI) directly show geometrically thick gas and dust structures in Seyfert cores
- ⋆ dust radiative transfer models give us good idea of parameter dependencies, effect of clumpiness, shape of dust distribution, simultaneous agreement with highres SEDs & MIDI
- ⋆ investigations of effects of evolving nuclear star cluster with hydrodynamical models yield two-component structure
- ⋆ feed mass inflow into 1D disk simulations, in order to check obscuration and feeding properties on small scale as well as dynamics
- ⋆ good agreement with observation
- ⋆ evolving nuclear star cluster important mechanism for feeding nuclear disks and nuclear activity
- ⋆ investigate addiational physics: radiation pressure effects on dust torus
- ⋆ finally (not so near future): put all we learned together in one large simulation