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

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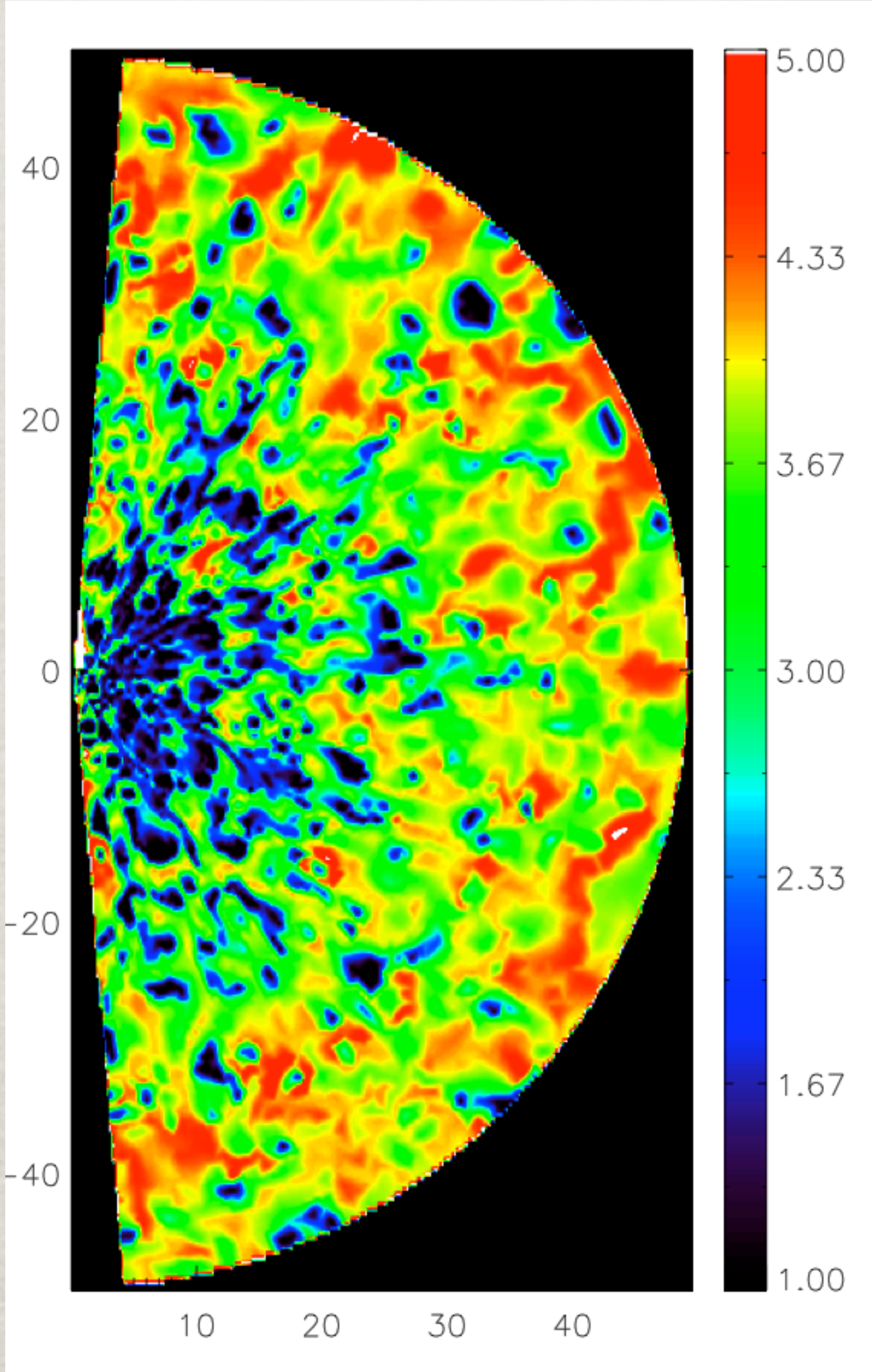

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CAST
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What drives the growth of black holes?

July 26, 2010, Durham

1. Introduction

Seyfert activity

- otherwise normal spiral galaxies light up, when enough gas is accreted onto the centre
- core luminosity comparable to stars of whole galaxy

Unified Scheme of Active Galactic Nuclei

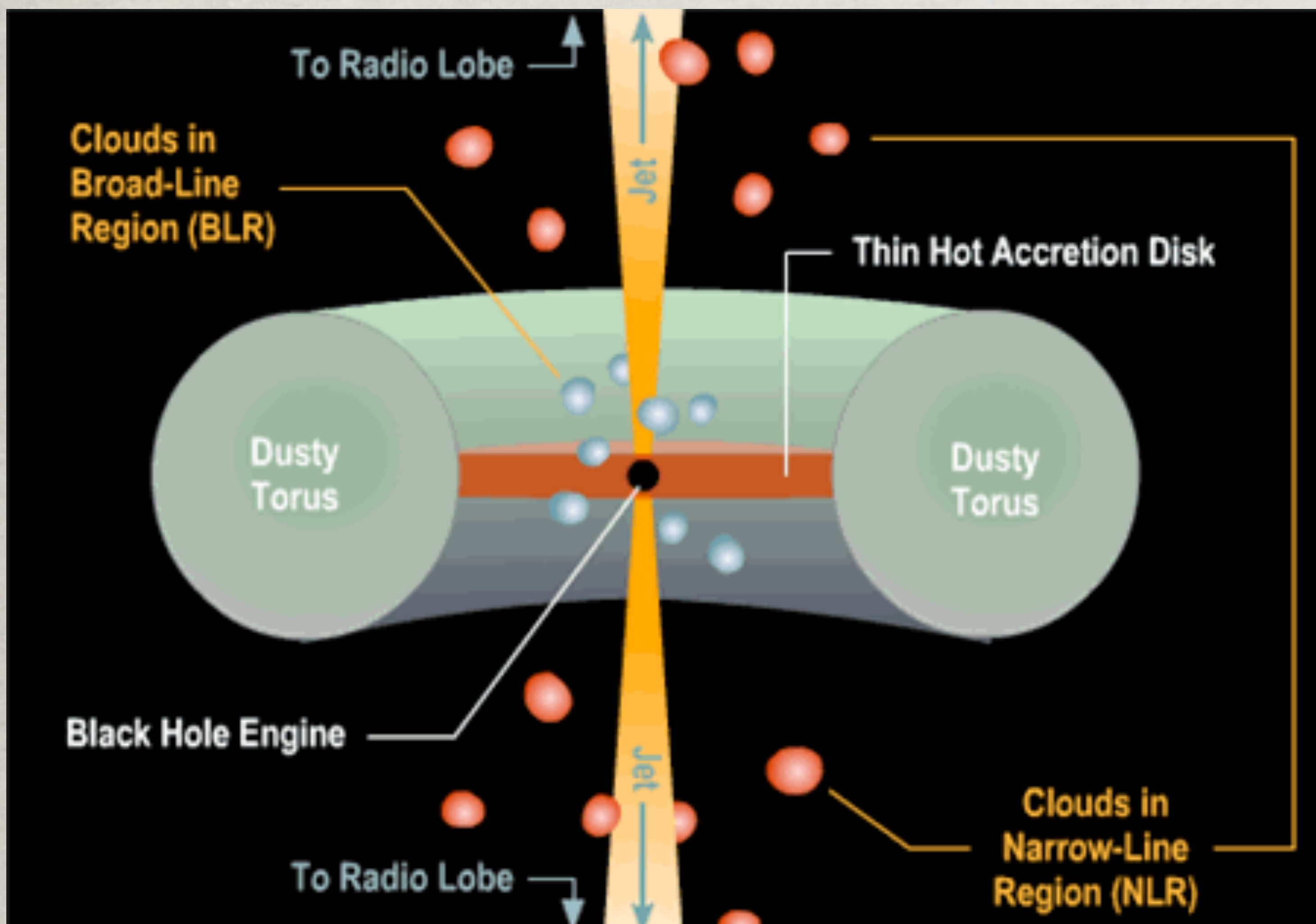

Image credit: Brooks/Cole Thomson Learning)

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

Idea: better understand the distribution of gas and dust near galactic nuclei

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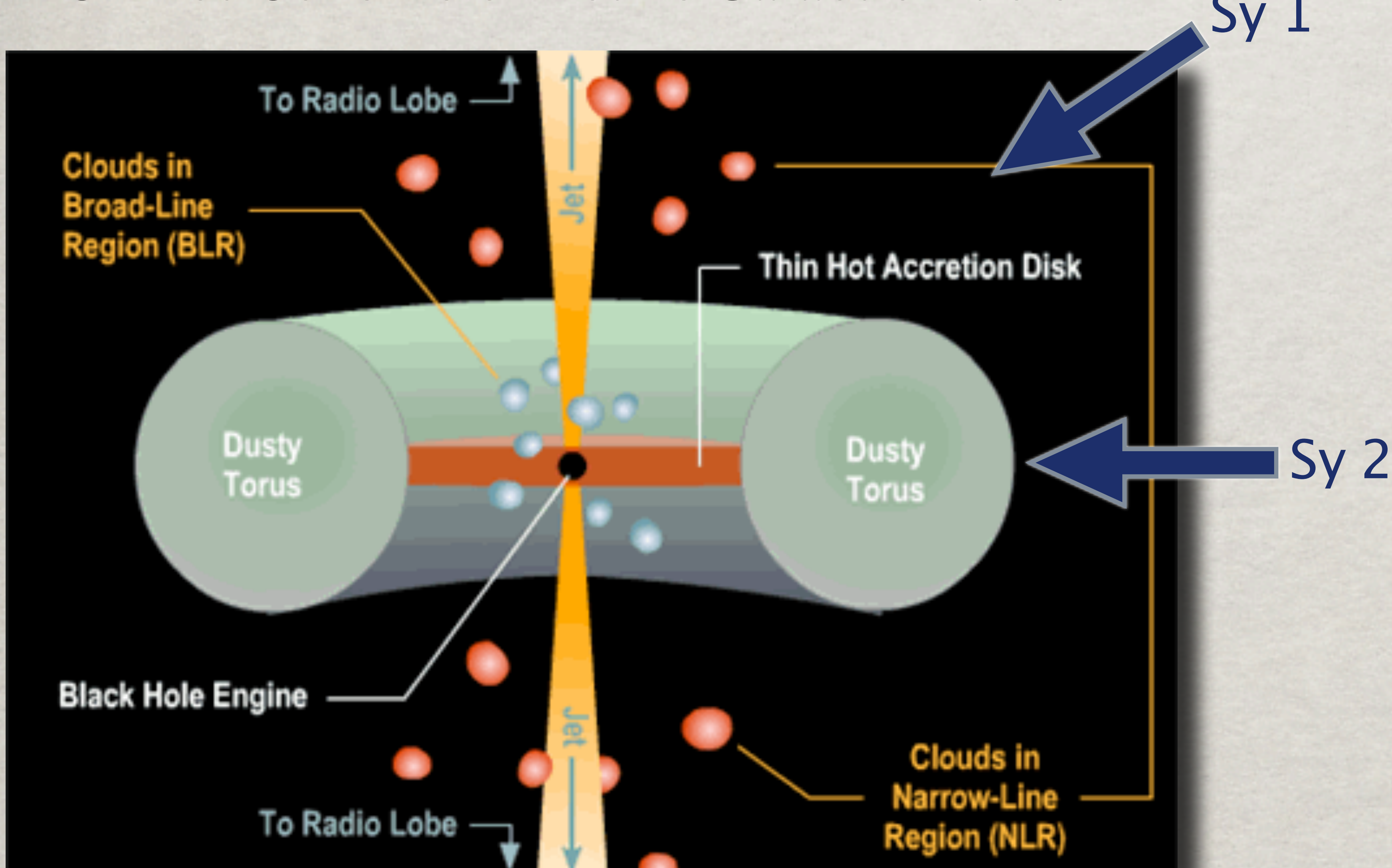

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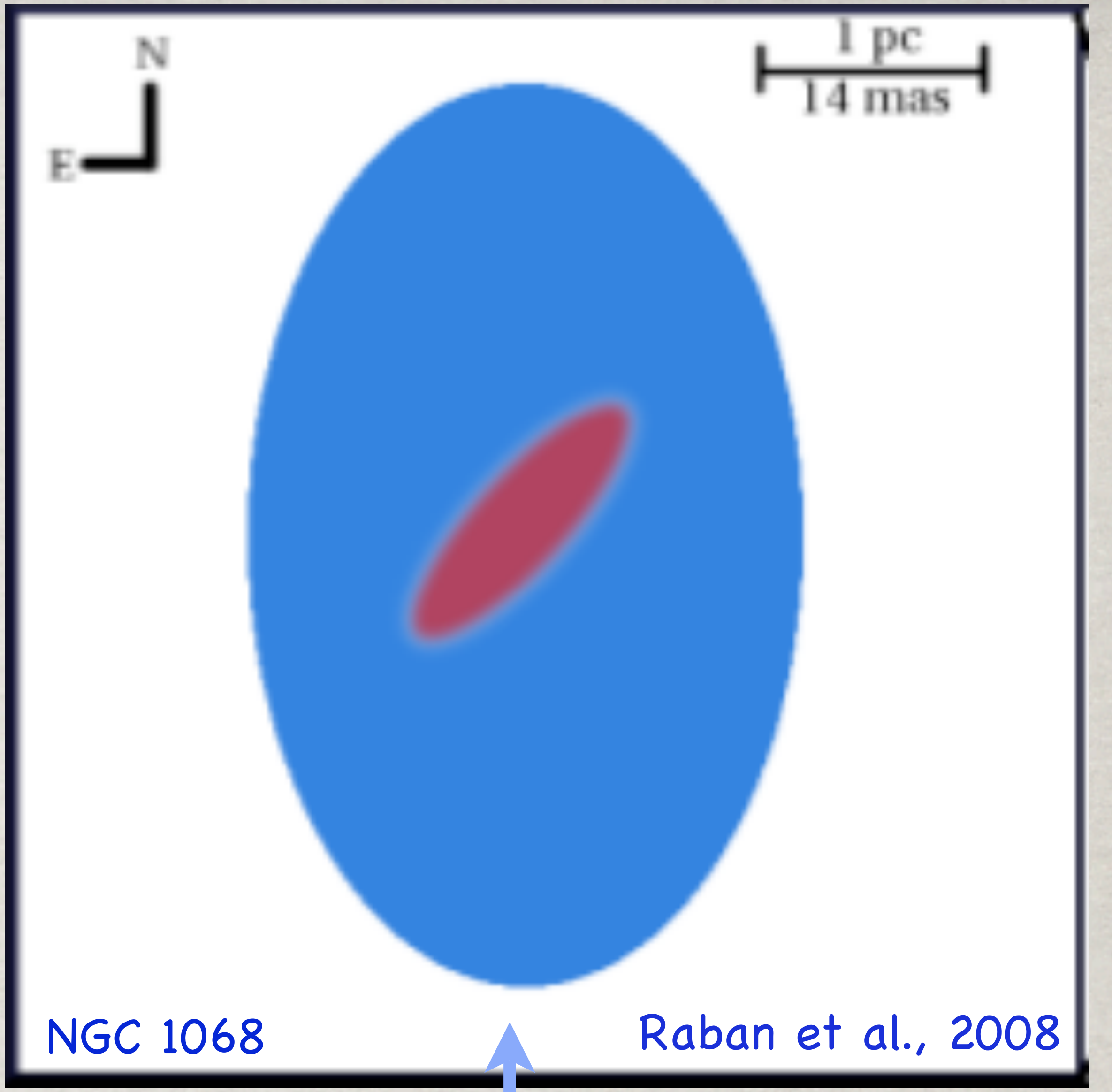
Idea: better understand the distribution of gas and dust near galactic nuclei

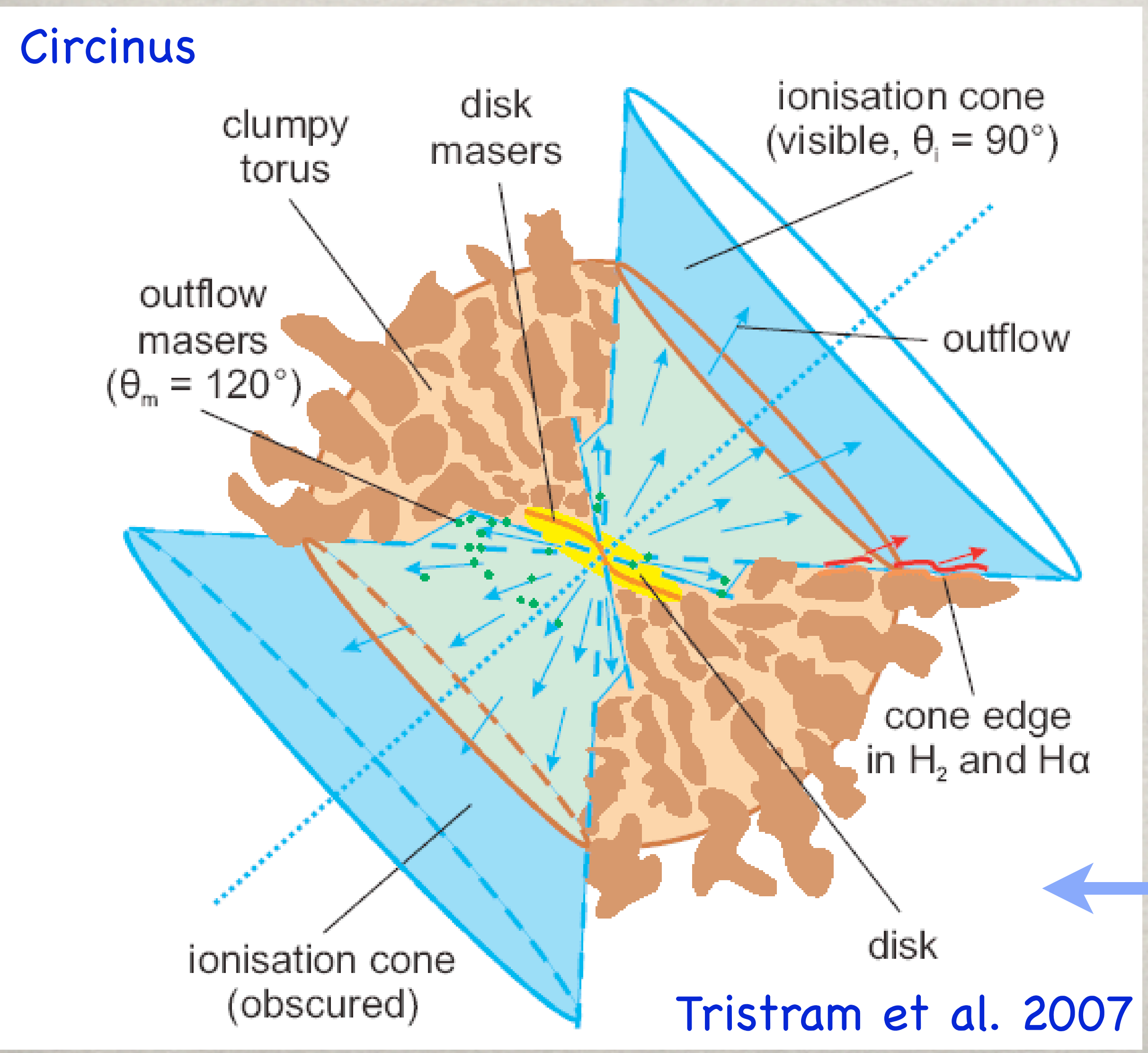
2. Motivation

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



NGC 1068

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



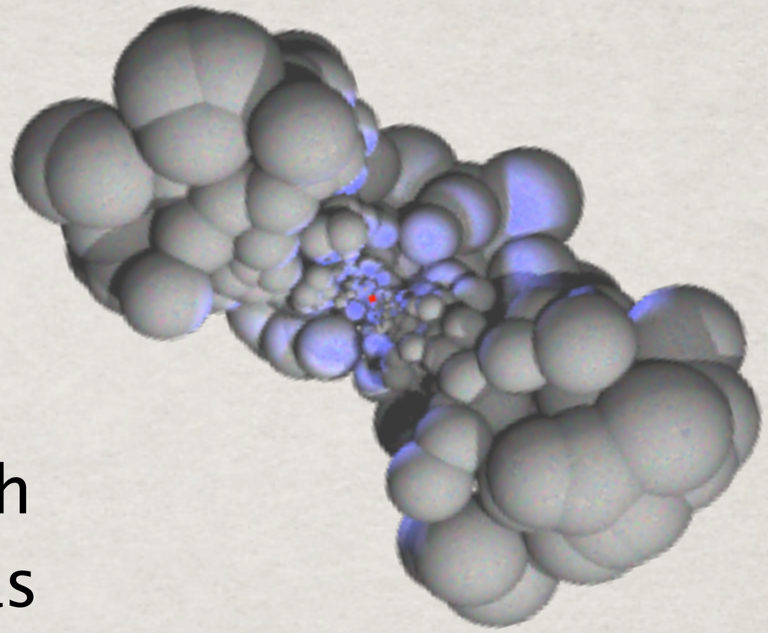
Circinus

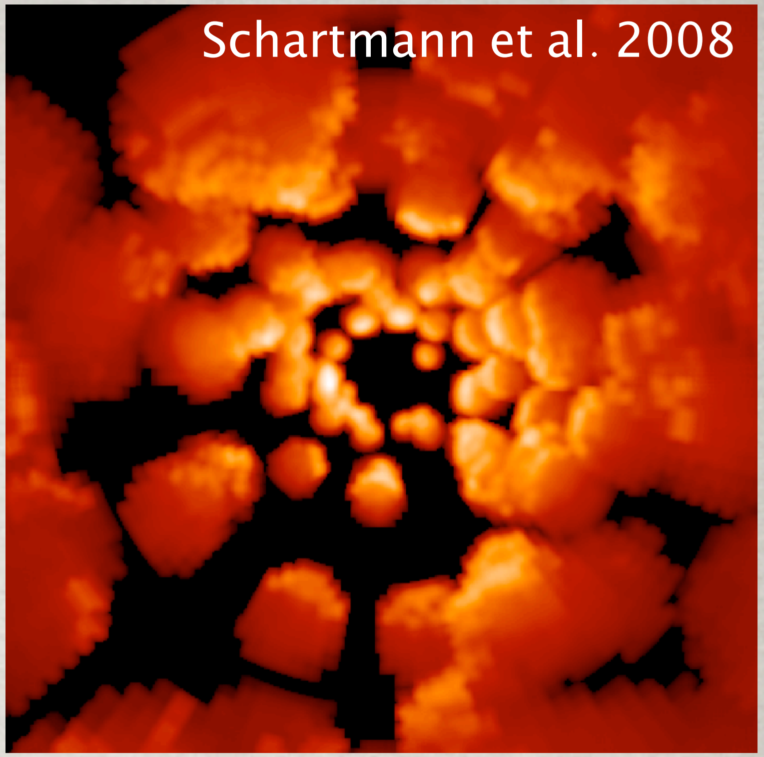
- warm (330K) thin disc (0.4 pc)
- slightly colder (300K) clumpy torus (2 pc)

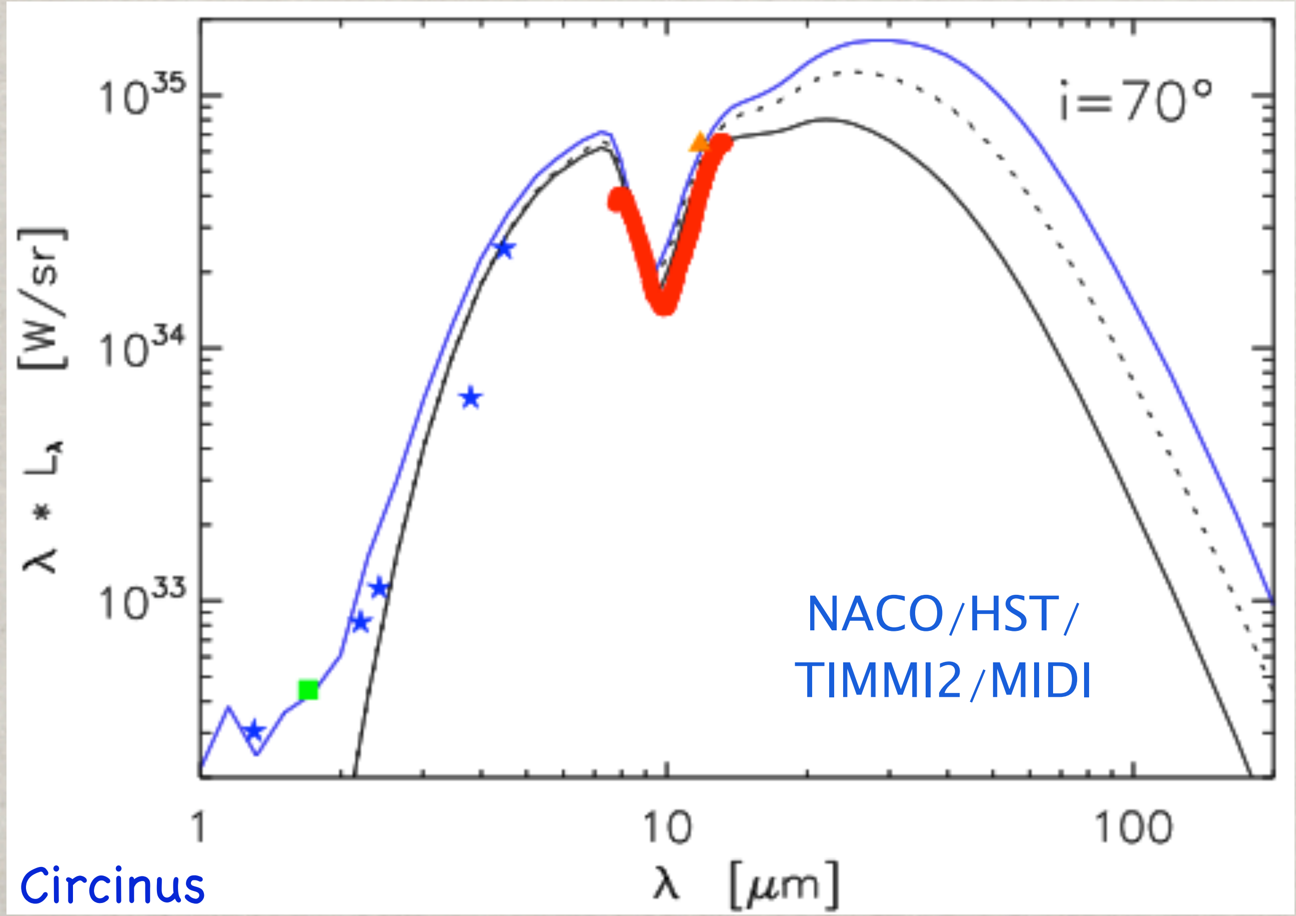
3. Radiative transfer modelling

- 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

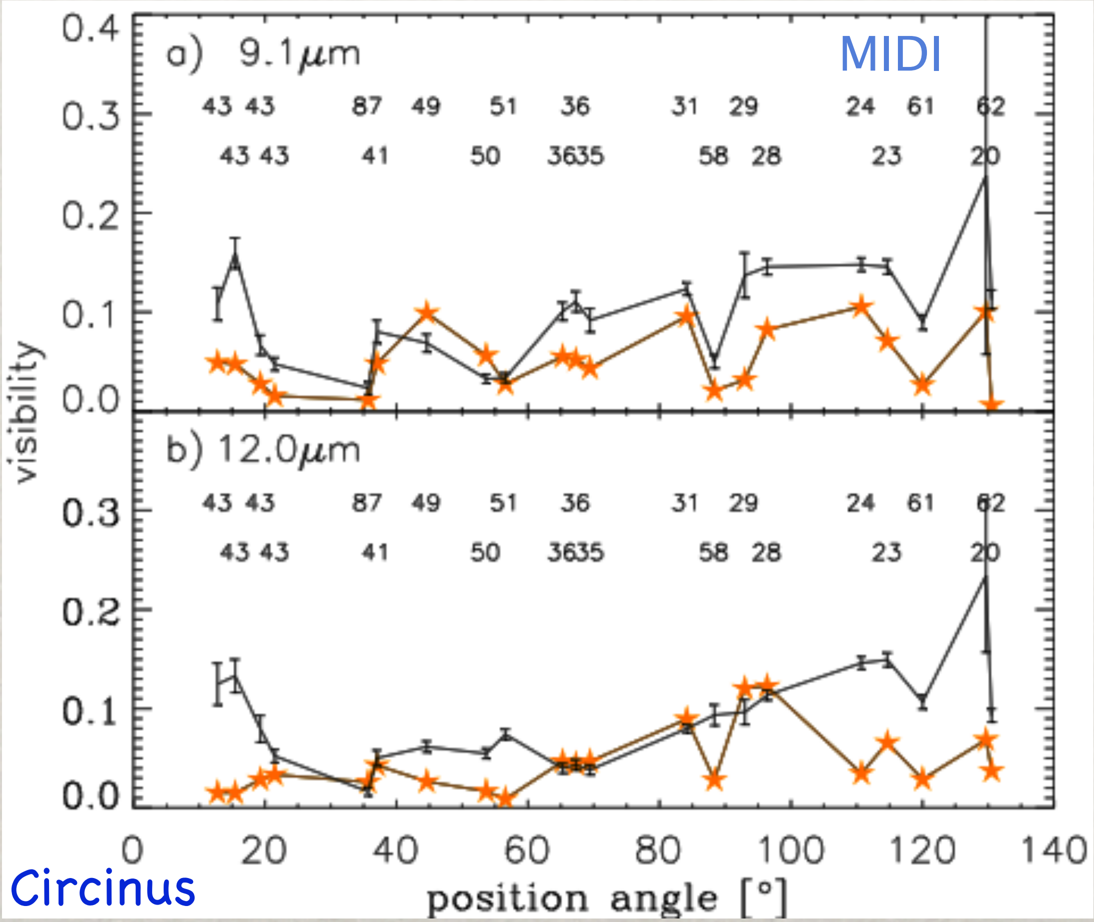
→ good idea of structural properties of tori







data courtesy: Prieto et al., 2004



data courtesy: Tristram et al., 2007

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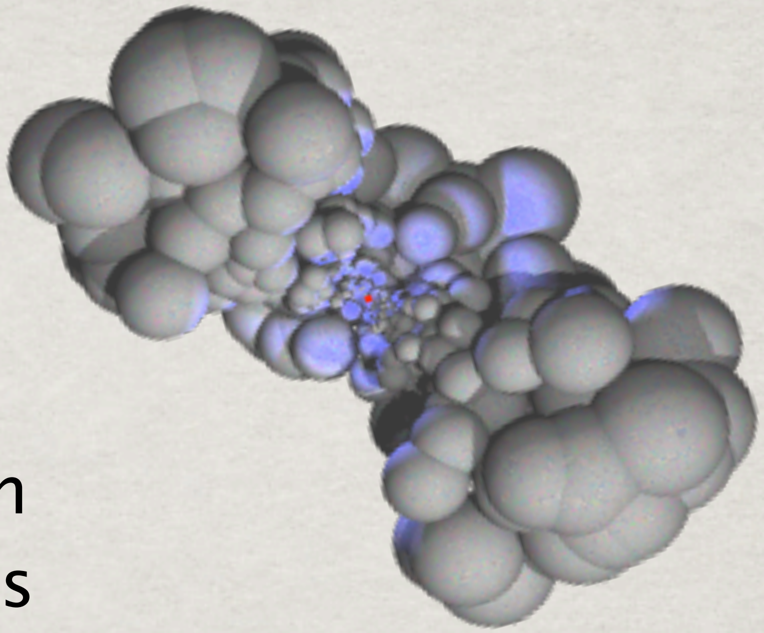

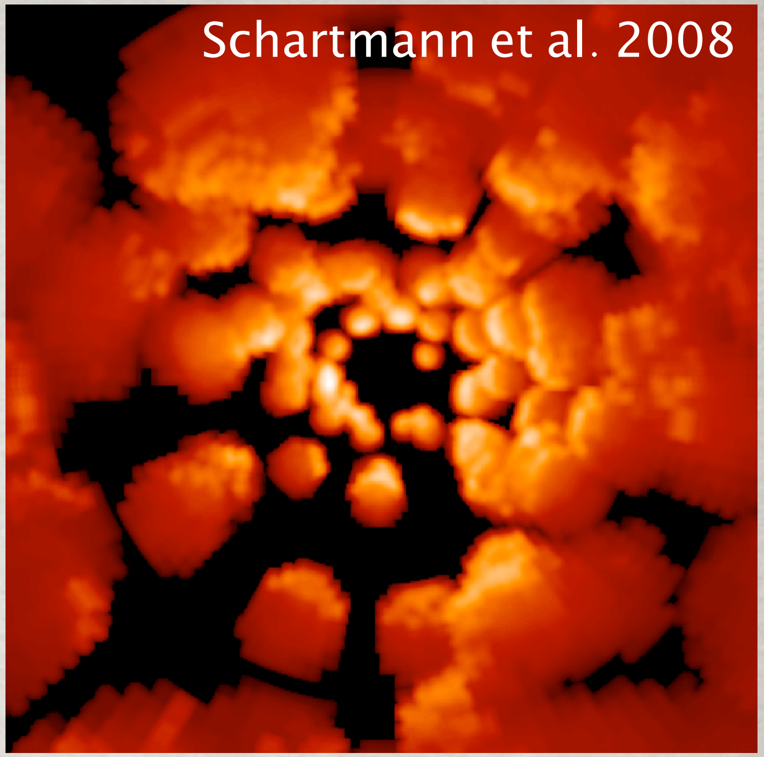

- infer dust morphology
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- simultaneously account for high spatial resolution data as well as visibility information

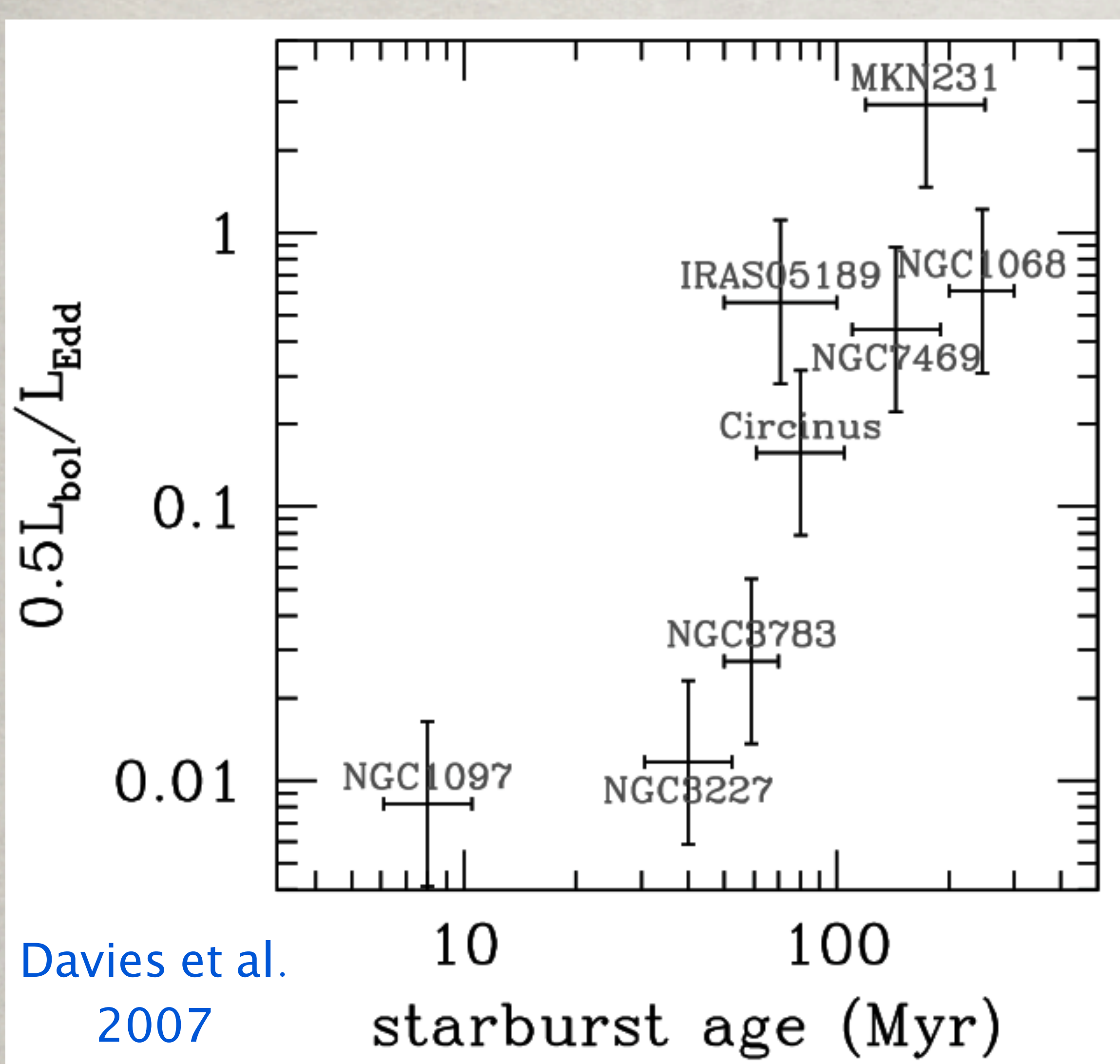
→ good idea of structural properties of tori

However:

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

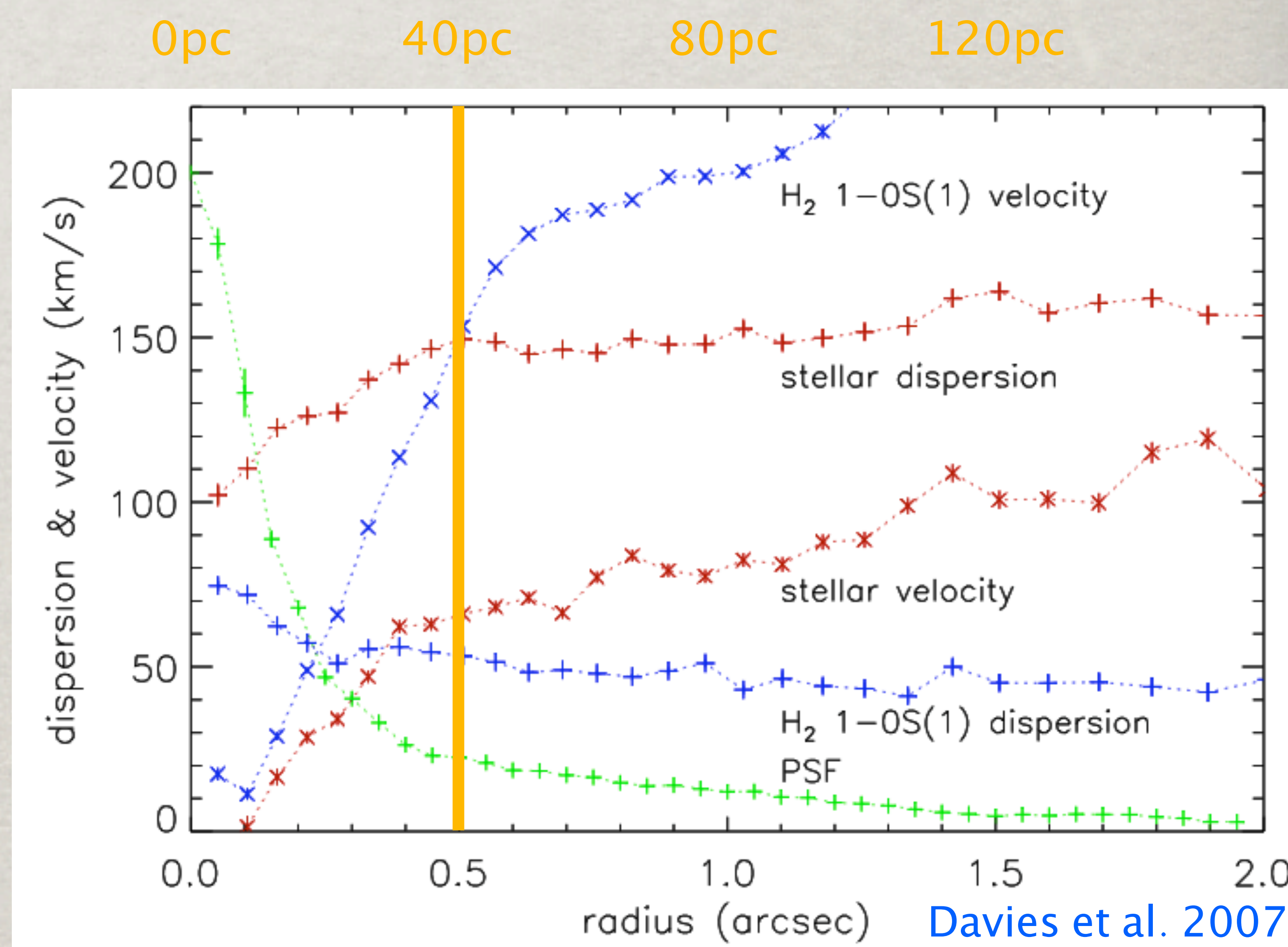
→ Hydrodynamical torus models needed, which produce similar gas morphologies

4. Effects of an evolving nuclear star cluster: Observations



Davies et al. 2007

- recent SF (> few 100 Myr), short-lived
- AGN switched on 50-100 Myr after starburst



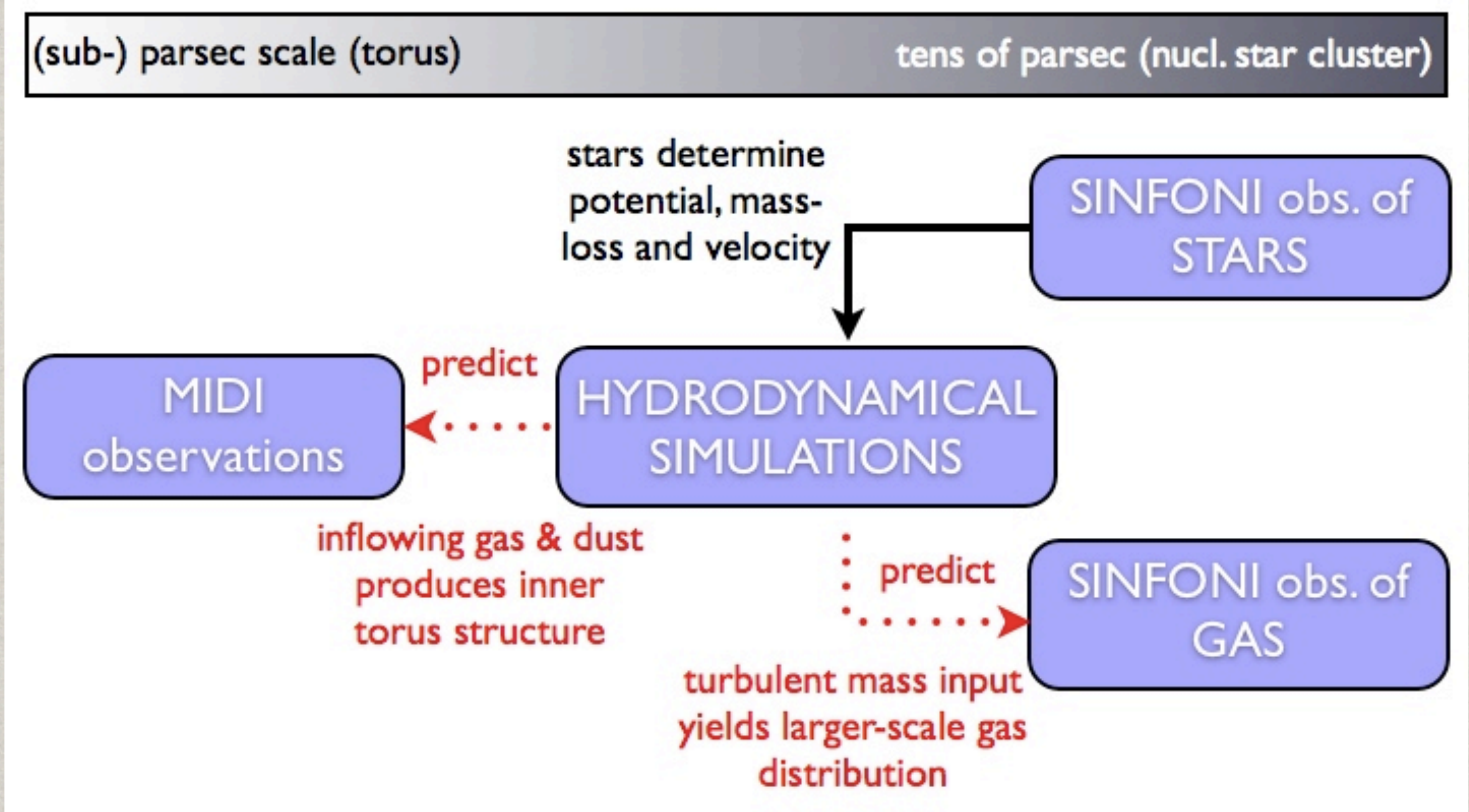
Davies et al. 2007

example of NGC 1097:

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

→ realise with hydrodynamical simulations

5. Global strategy



- 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

6. 3D Hydrodynamical simulations with PLUTO

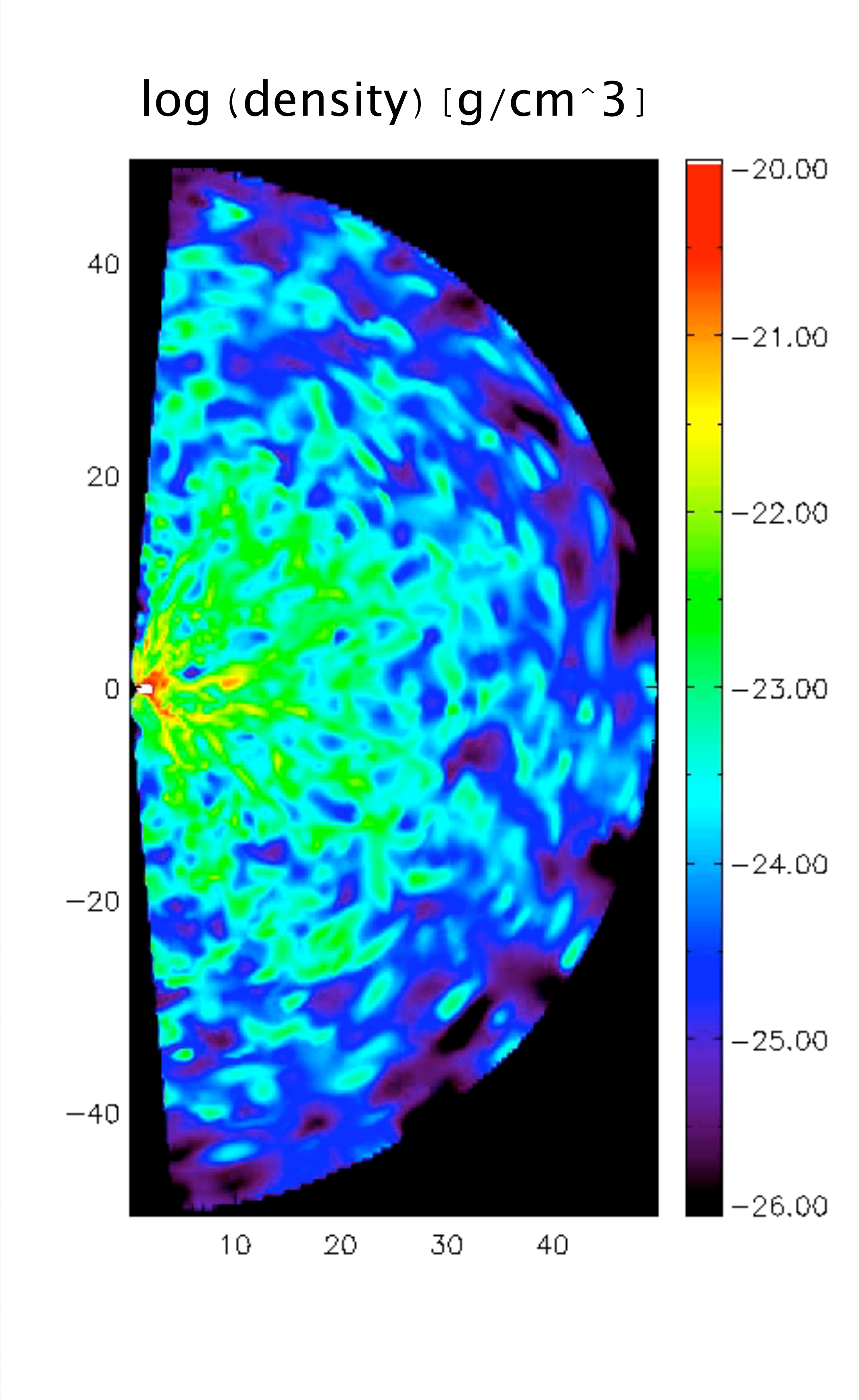
Torus build-up and BH feeding in NGC 1068

- 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):

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

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

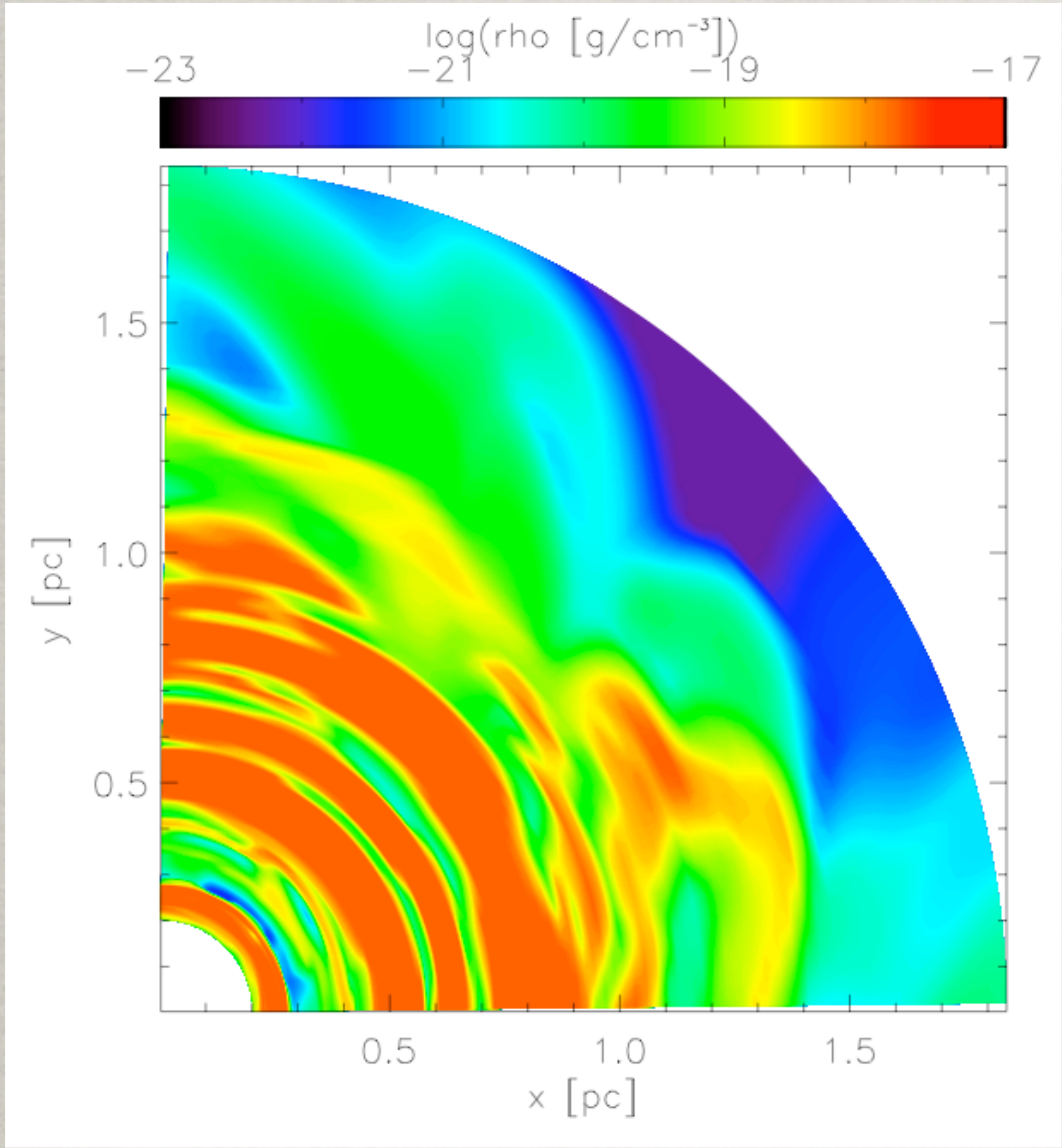
- effective cooling curve
- solved with PLUTO -code (Mignone et al. 2007)



Schartmann et al. 2009 & 2010

6. 3D Hydrodynamical simulations with PLUTO

nuclear disc



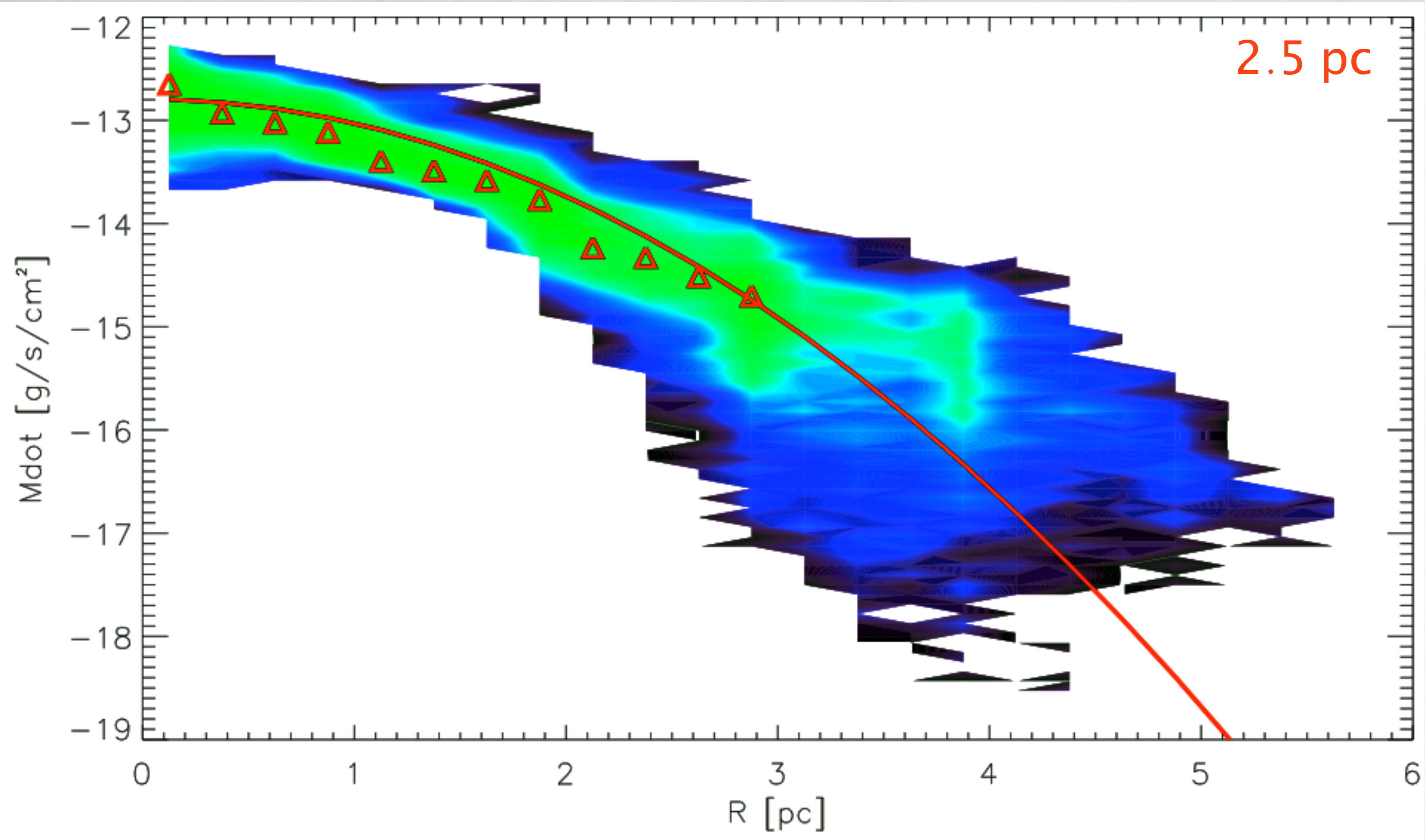
- disc extent: 0.5 to 1pc
- maser disc in NGC 1068: 0.65 to 1.1pc (Greenhill & Gwinn 1997)

→ 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 disc
- accretion & star formation physics not included
- very computationally extensive, only short time evolution possible

→ idea: 1D effective disc model for nuclear disc

7. 1D effective disc simulations: the model



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

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 disc properties (mass, size, ...) to observations

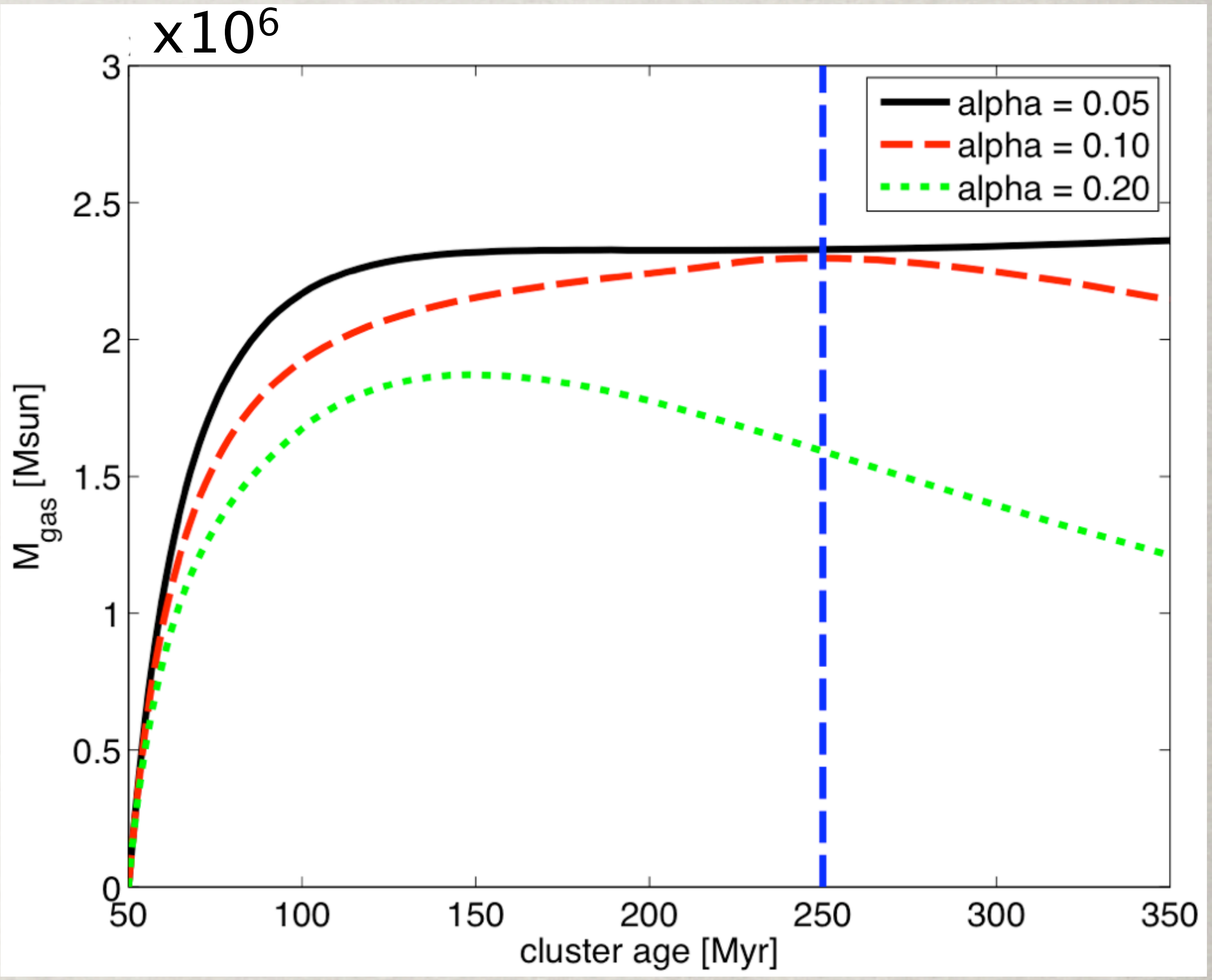
7. 1D effective disc simulations: disc mass

alpha viscosity value unclear:

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

→ alpha parameter study

nuclear disc mass in alpha parameter study

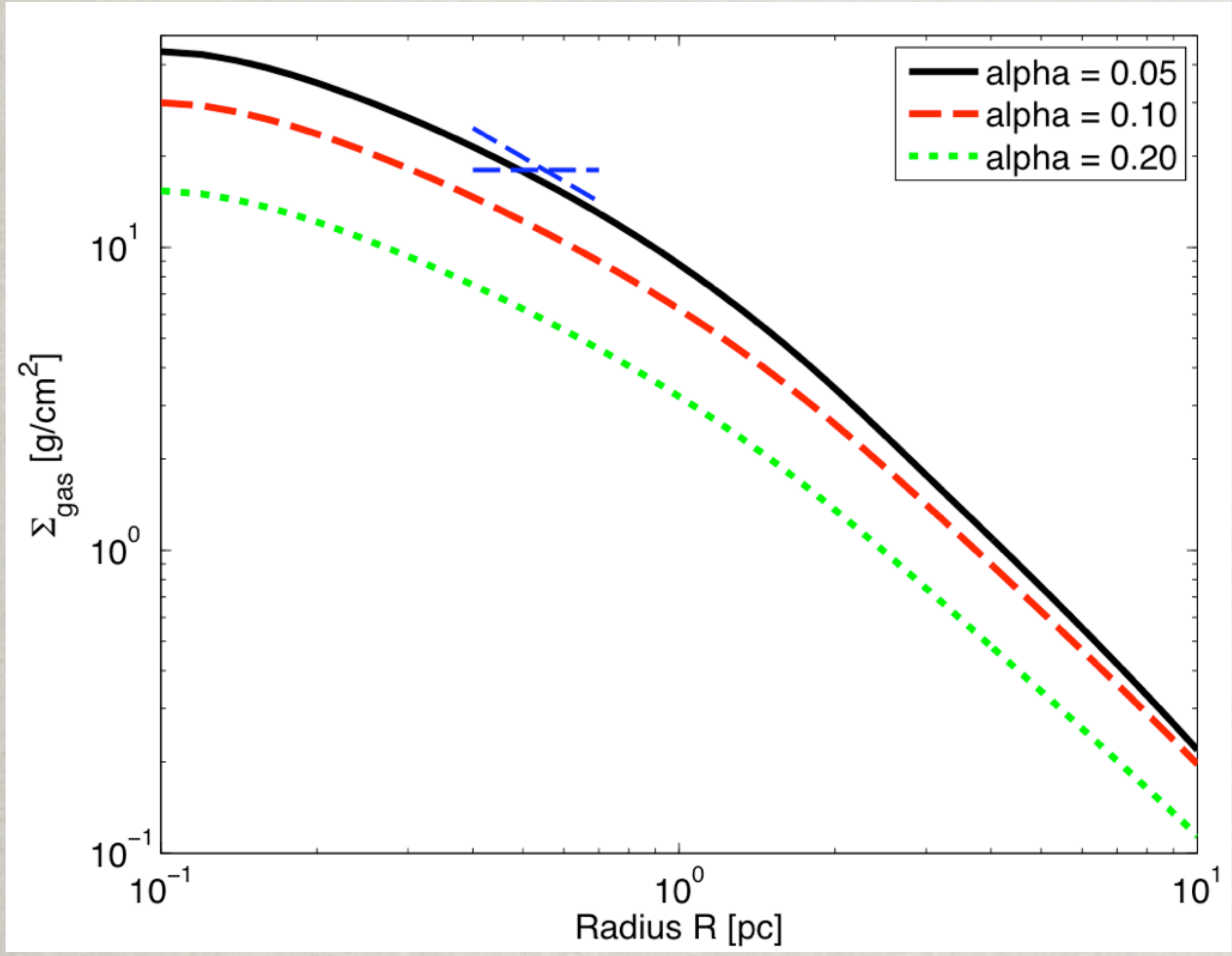


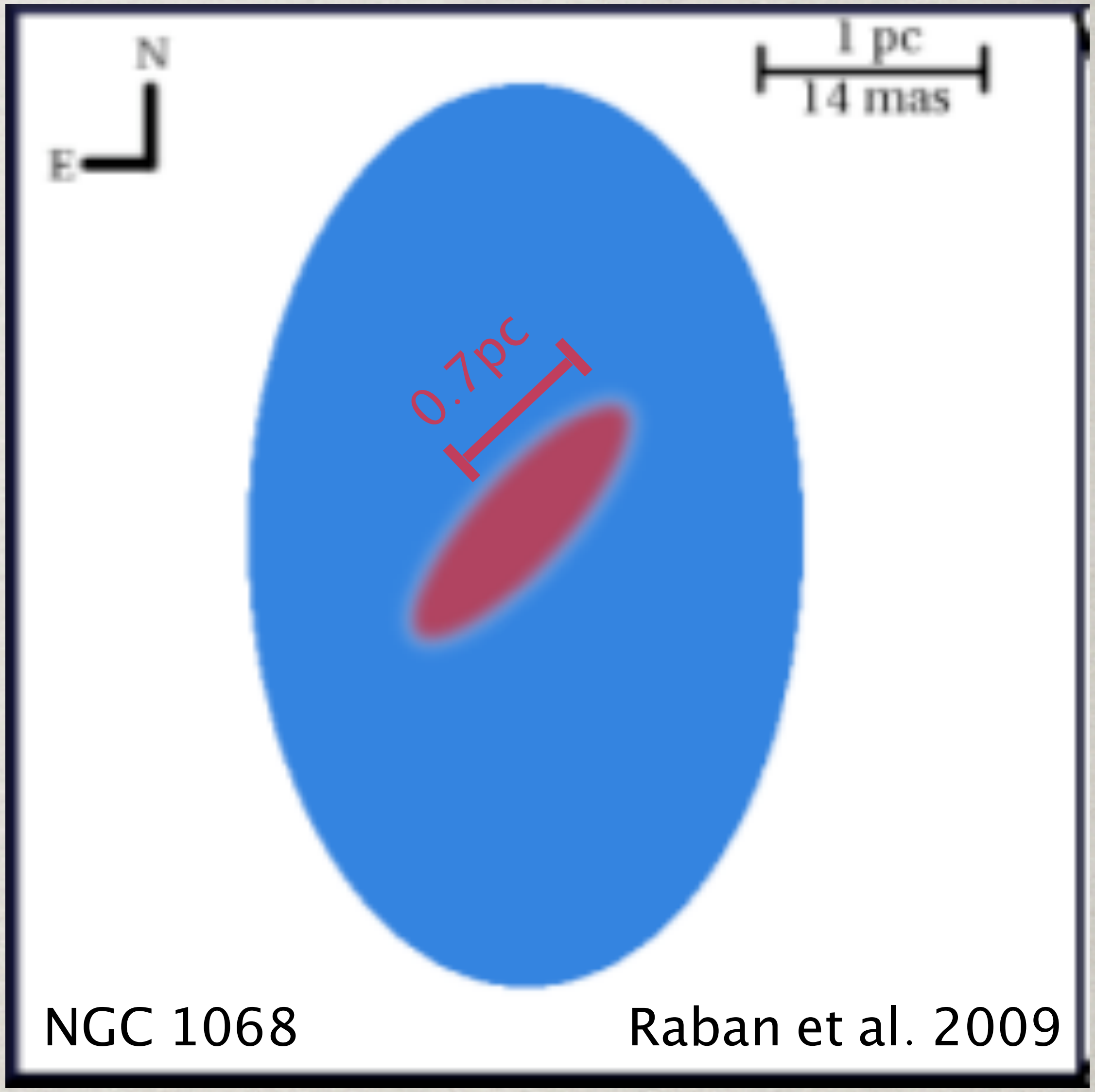
- Models reproducing maser observations: ~10^6 M_{sun} in clumpy disc model (Kumar 1999)

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

7. 1D effective disc simulations: disc structure

surface density of the disc



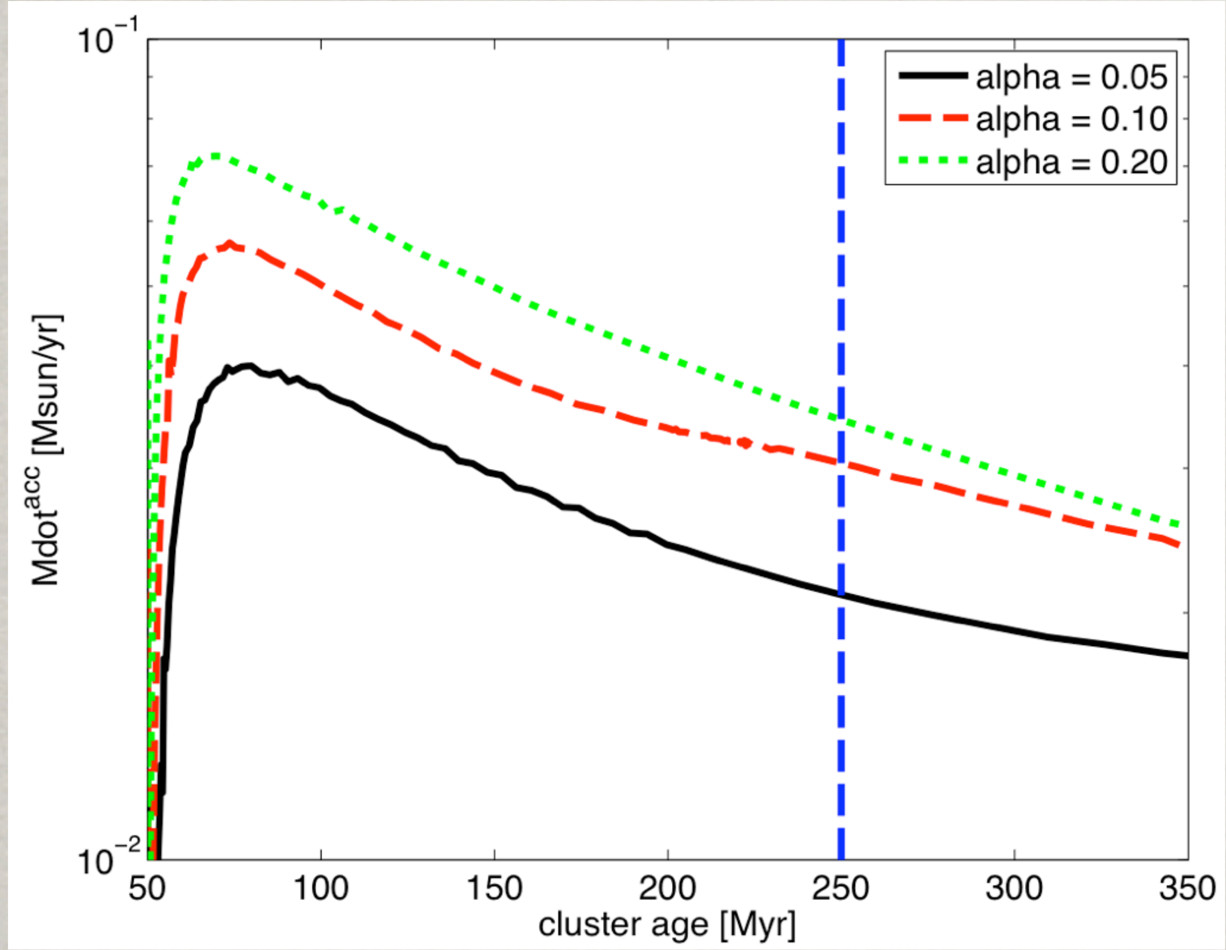


HWHM=0.85 pc dust disc

0.7 pc HWHM of hot component

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

7. 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: $$L_{bol} \approx 9.4\cdot10^{10}\left(\frac{f_{refl}}{0.01}\right)^{-1}\left(\frac{D}{14.4\,Mpc}\right)^{2} L_{\odot} \approx 3.6\cdot10^{44}\,\frac{erg}{s}$$

Pier et al. 1994

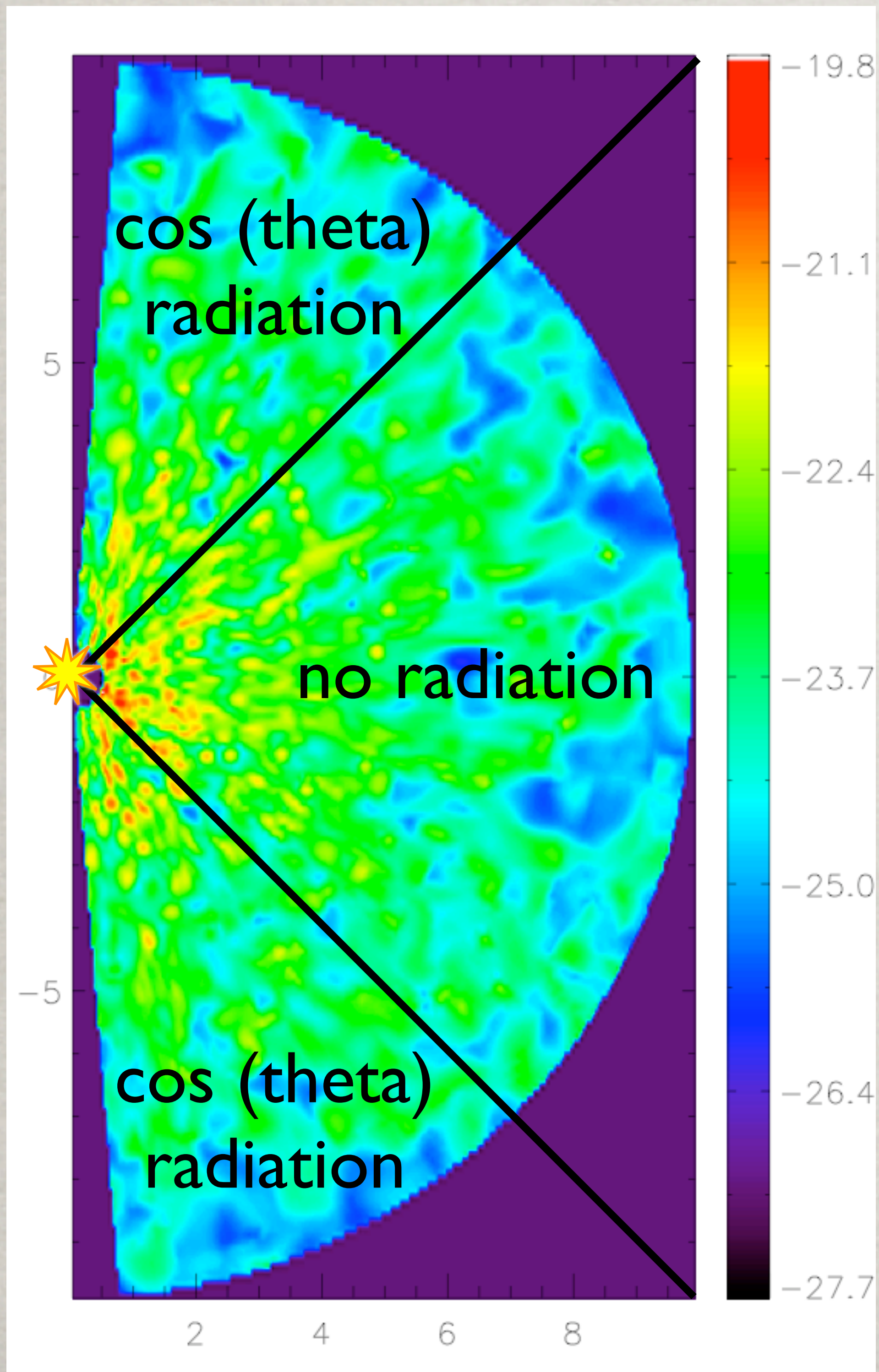
assuming 100% reaches the BH:
L_{bol} = $1.8\cdot10^{44}$ erg/s
(in Schartmann et al. 2005,
L_{bol} = $2.1\cdot10^{44}$ erg/s gives a good adaptation to highres. data)

→

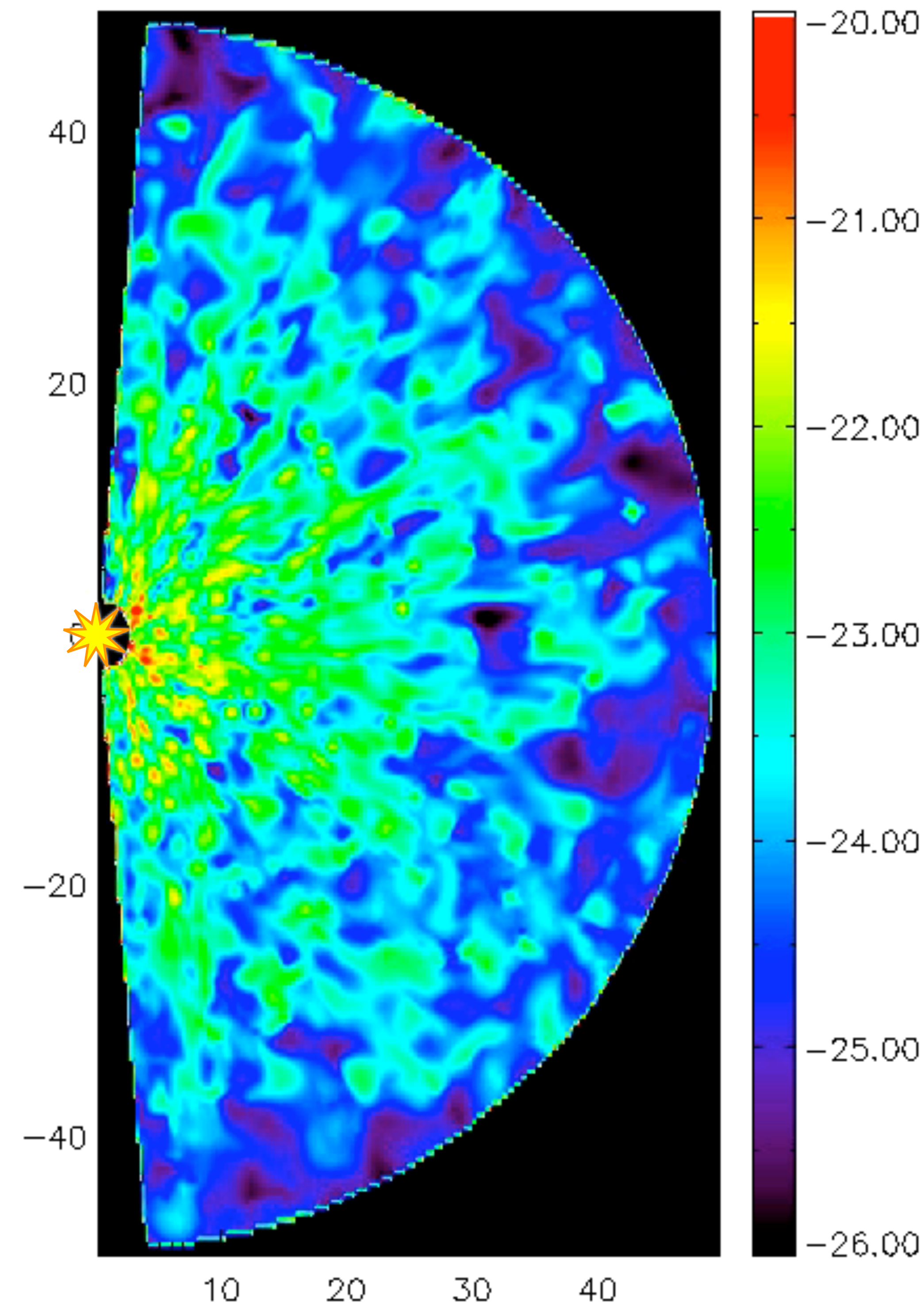
- accretion from nuclear disc might be clumpy as e.g. observed in Galactic Centre (Montero-Castano et al. 2009)
- additional inflow?/outflow (scales)?

8. 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



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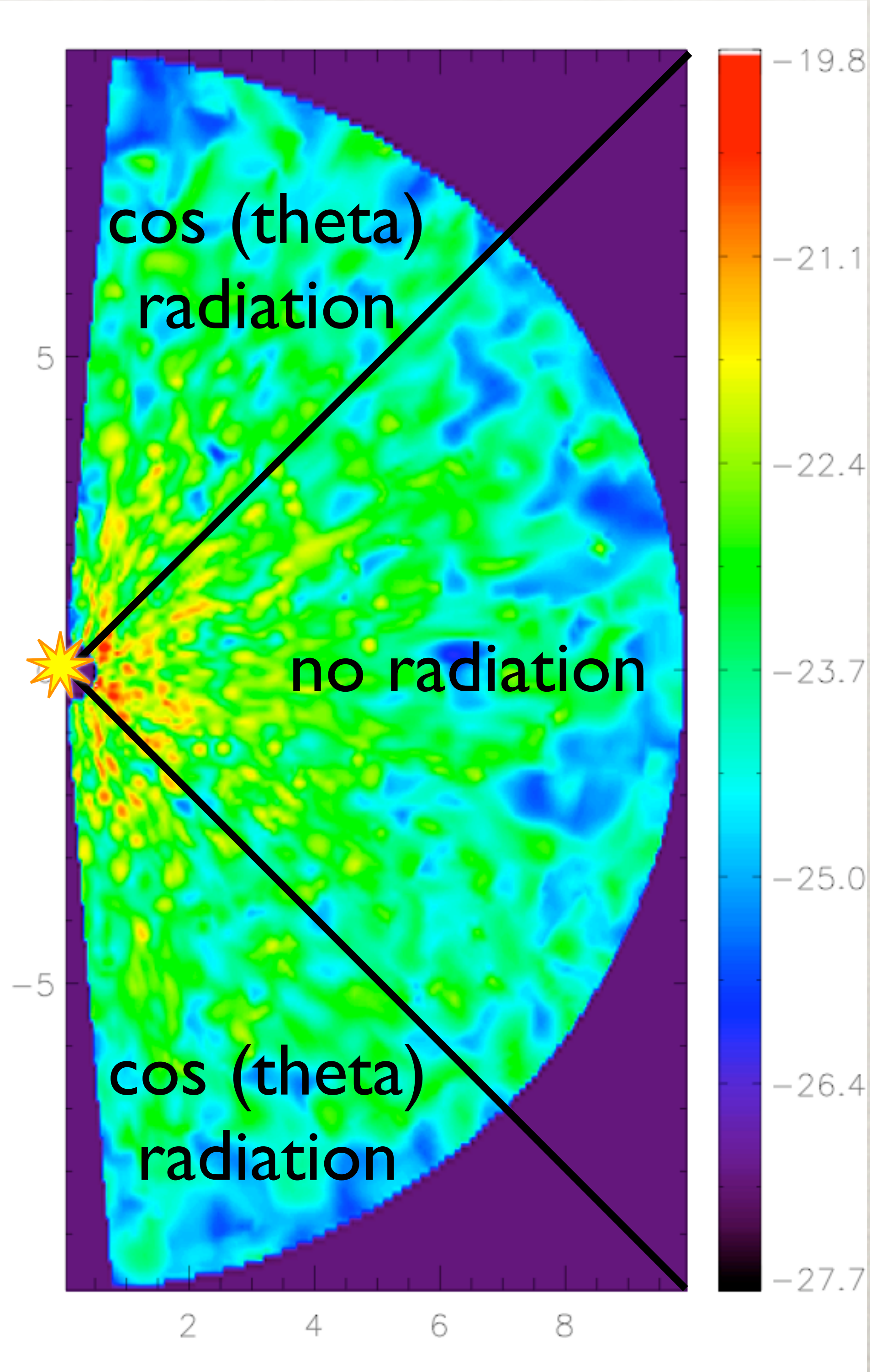

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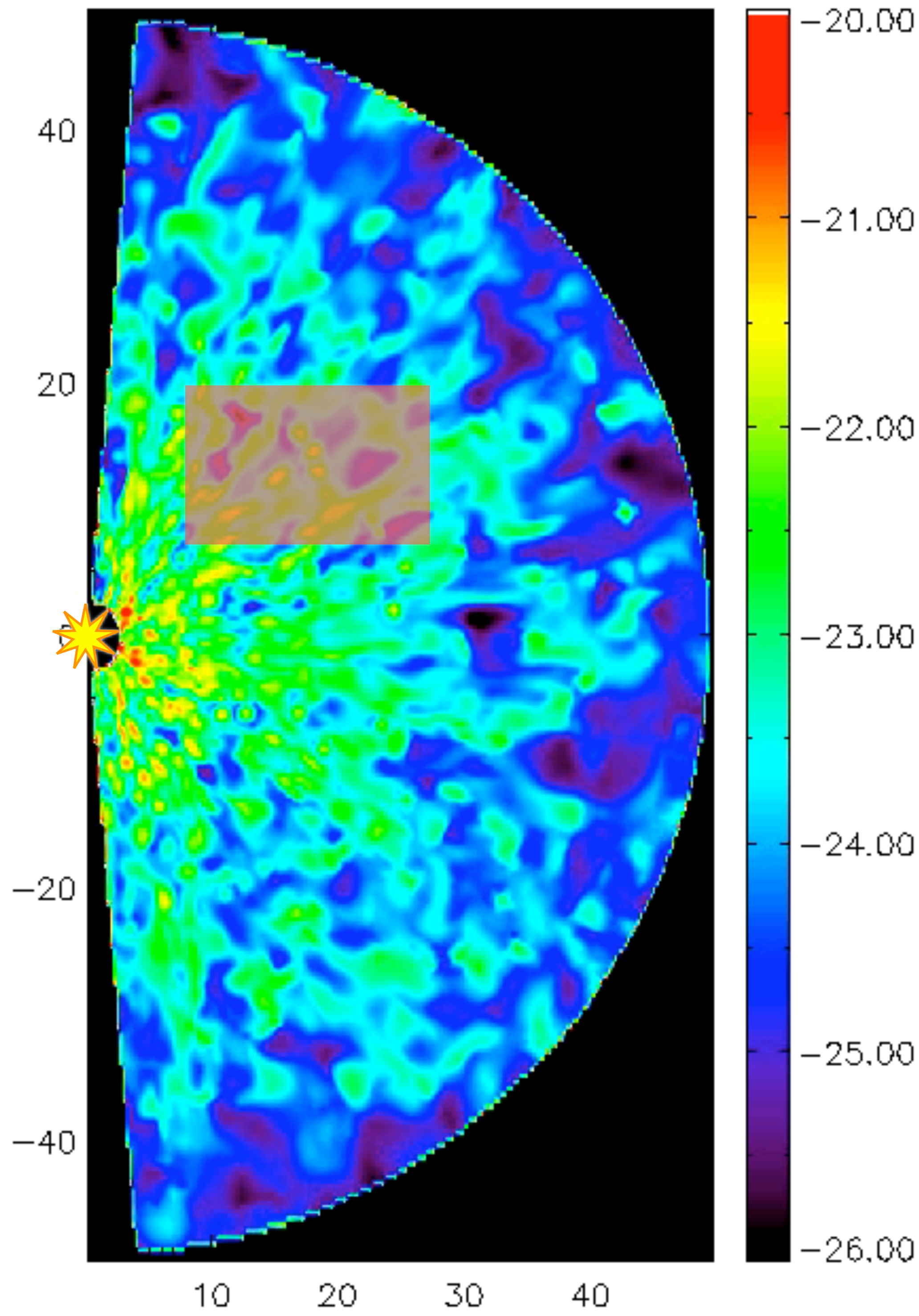
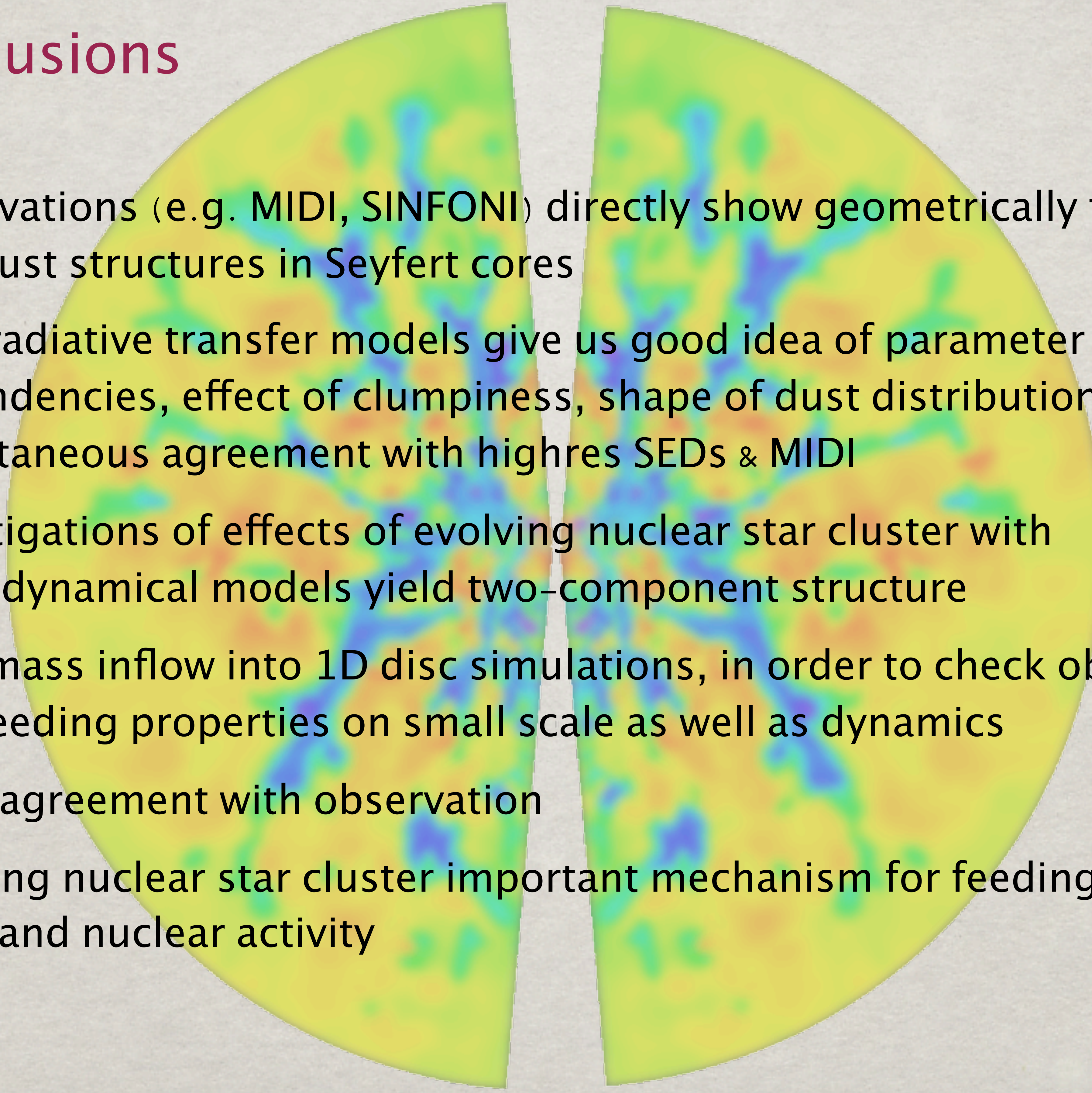


9. Conclusions



- 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 disc 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 discs and nuclear activity