Dynamical Structure of a Clumpy and Dusty Torus

"The Dusty Vail around AGN"

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MPIfR

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In collaboration with

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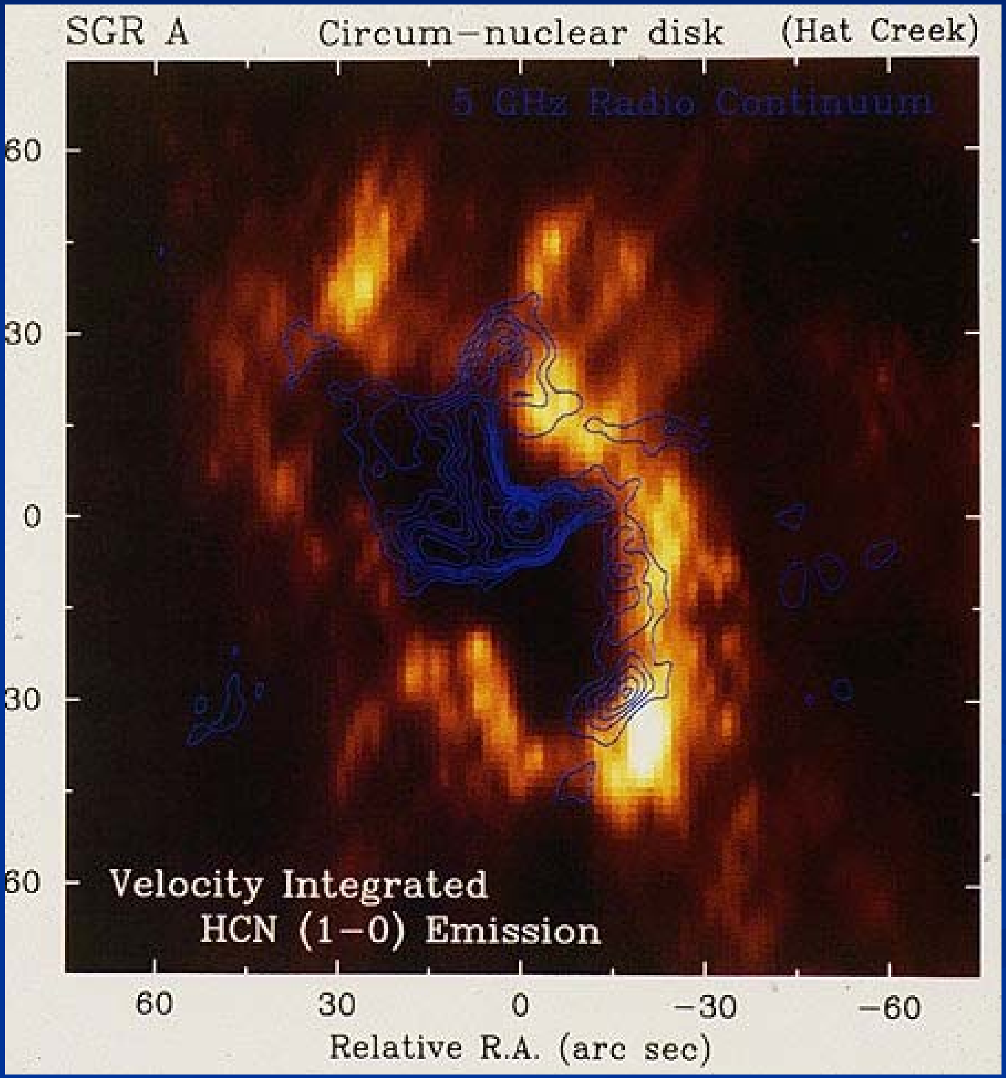
„From the circumnuclear disk in the Galactic Center to thick, obscuring tori of AGNs“
B. Vollmer, T. Beckert, W. J. Duschl 2004, A&A 413, 949

„The dynamical structure of a thick cloudy torus“
T. Beckert, W. J. Duschl (in preparation)

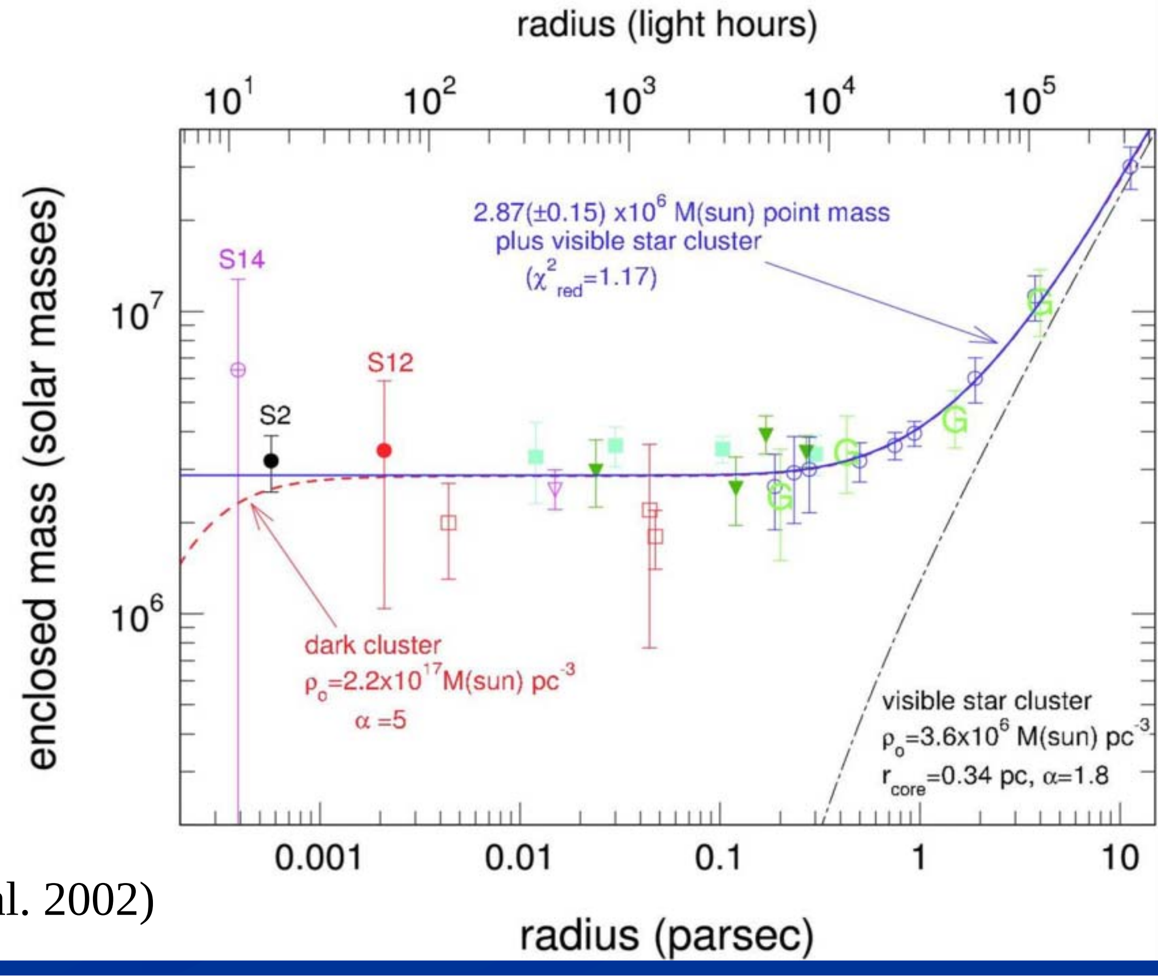
Overview

- Quick look at our Galactic Centre
- Concept and Assumption
  of the accretion scenario
- Vertical and radial cloud distribution
- The physics of clouds in a torus
- Consequences for NIR imaging and Unified Schemes
- Summary

In our Galactic Centre



The Mass Distribution (GC)



(Schödel et al. 2002)

No Go Concepts

- No multi-phase medium (where clouds form and vanish from other phase) like the ISM in the galaxy *(Vollmer, Beckert, Duschl 2004)*
- Supernova stirring cannot provide the energy to maintain a large velocity dispersion (thickness)

Assumptions

- Dust can only survive in cold clouds
- Hydrostatic equilibrium vertically in the Combined Potential
  (Black Hole & Quasi-isothermal star cluster)
  [core-radius, core-density, power-law index α]
- Radial accretion flow due to cloud-cloud collisions
- Stationary solution $\dot{M} = const.$

The Accretion Scenario

- Cloud-Cloud Interactions:

  effective viscosity $\nu_{eff} = \frac{\tau}{1+\tau^2}\frac{\sigma^2}{\Omega}$

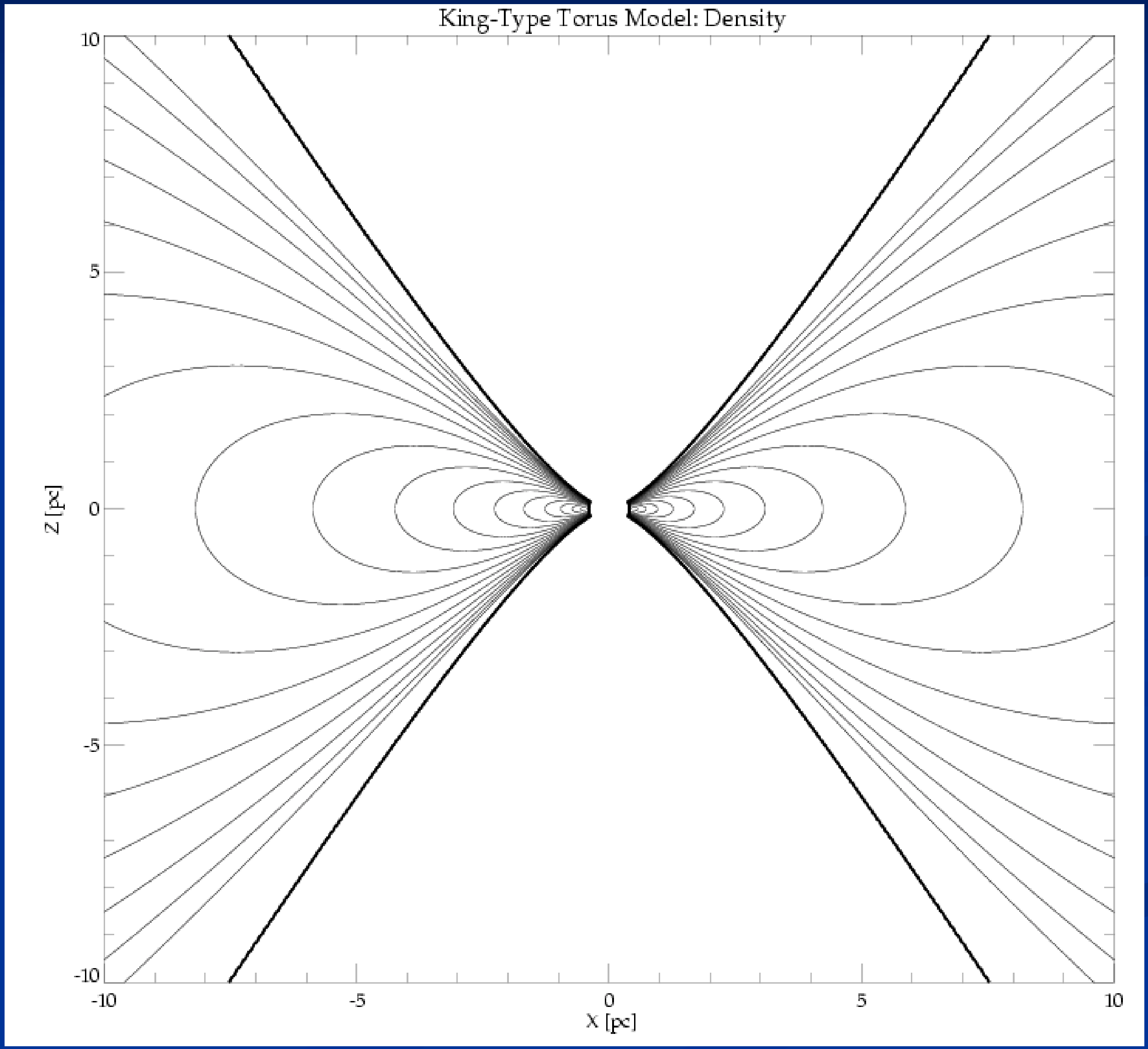
  dimensionless collision frequency $\tau = \omega_{coll}/\Omega$

- Mass accretion from differential rotation & angular momentum redistribution determines

  $\sigma(\dot{M},\tau,\Omega)$

- Vertical scale height $H = \sigma/\Omega = l_{coll}\tau$

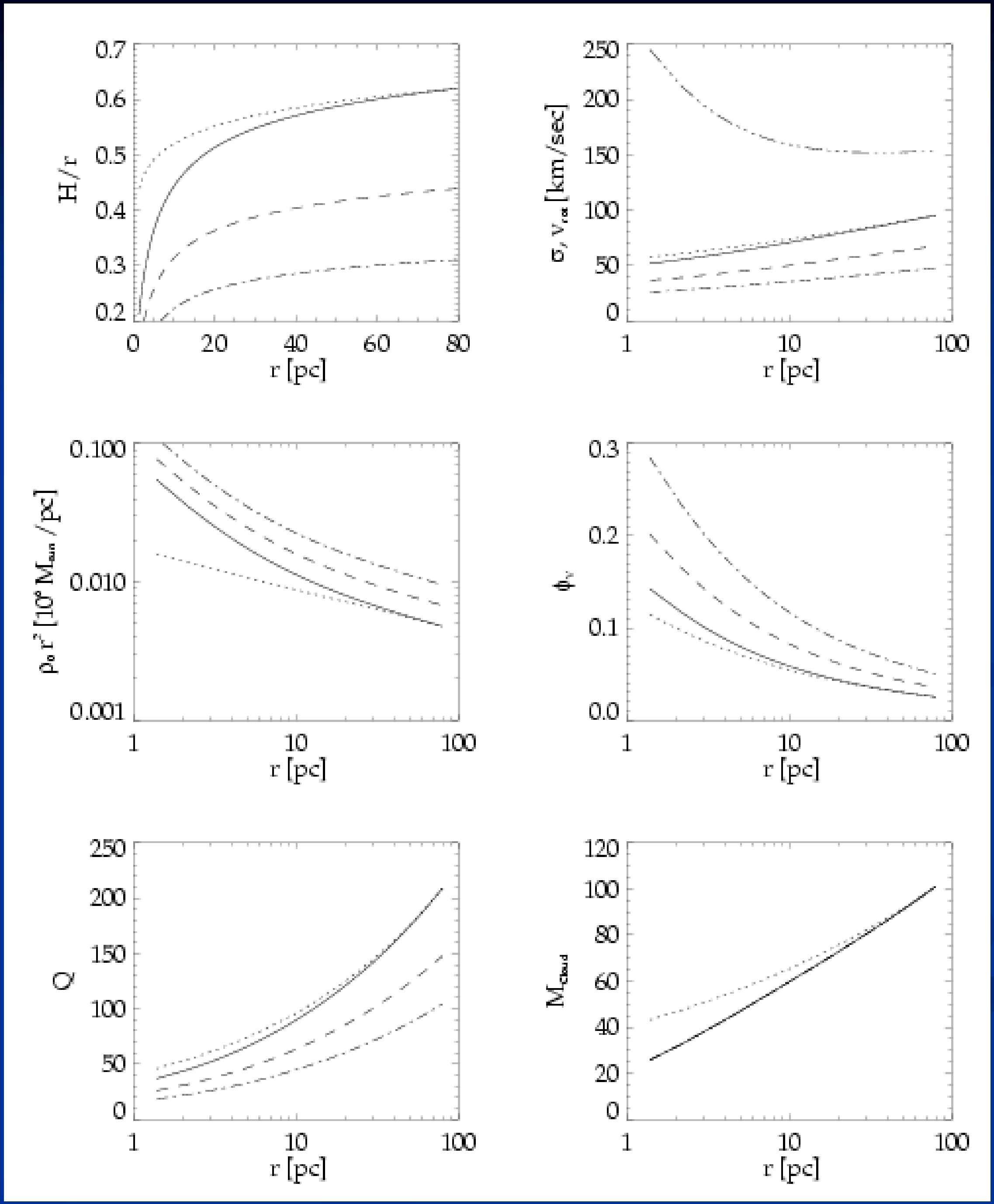
The vertical structure



Cloud Properties

- Distribution is dominated by larges clouds
  living at the shear-limit
  (larger clouds are torn apart by tidal forces)
- Quasi-stable clouds
  hold together by self-gravity
- Typical cloud mass $M \approx 50 M_{solar}$
- Obscuration implies $\tau \approx 1$

Radial Structure



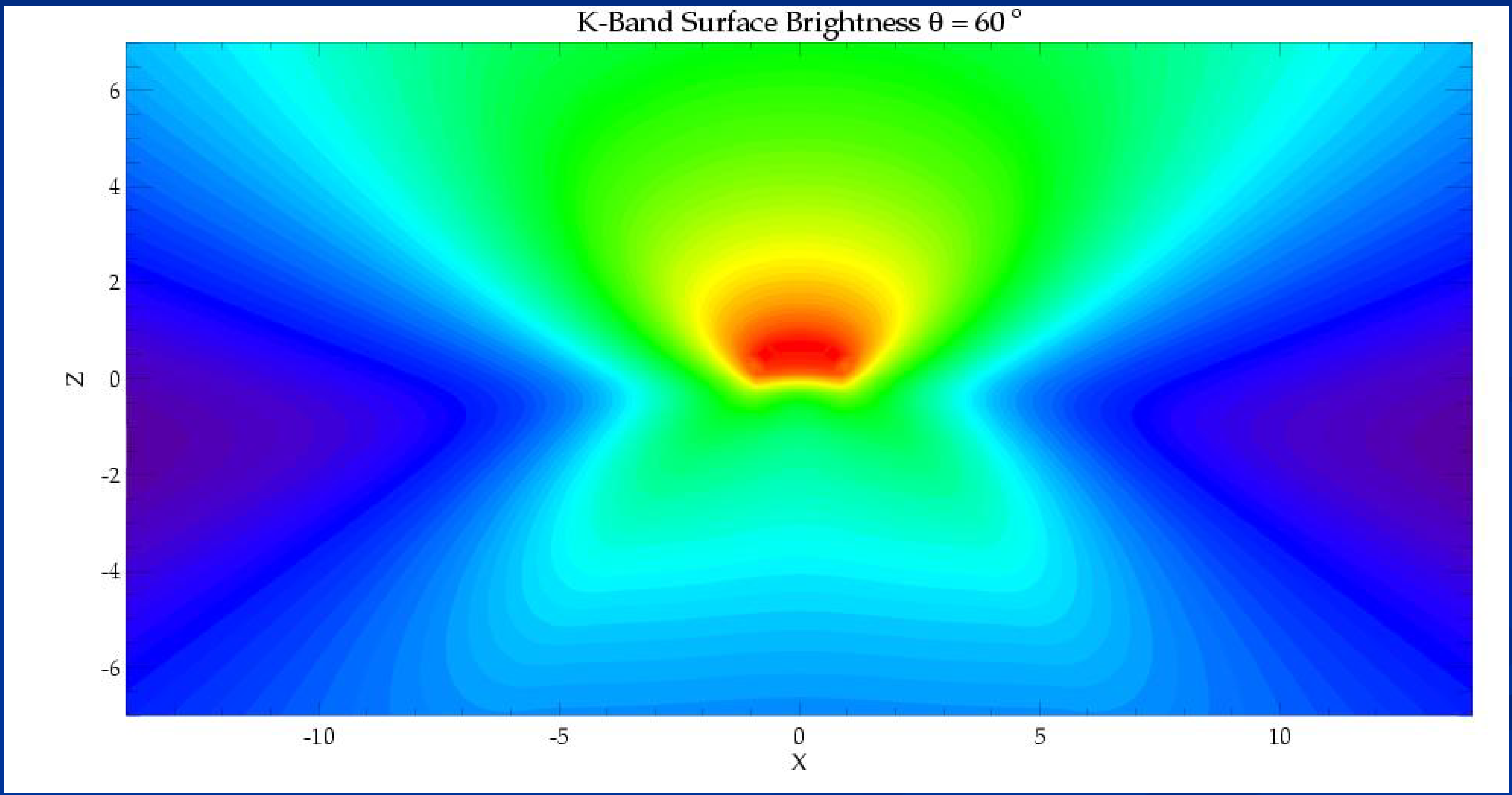
Results

- Required accretion rate: ~ 1 M_{solar}/yr
- Gas Mass 4 Mio. M_{solar} (within 80 pc)
- Surface density is independent of accretion rate

$$\Sigma \propto R^{-\alpha/2 - 1/4}$$

- Scale height: *H ~ 0.2 – 0.7 R*
- Velocity dispersion ~ 60 – 100 km/s
- Cloud Masses: 25 – 100 M_{solar} (also independent of accretion rate)
- Accretion lifetime ~ 1 Mio. years (50 pc)

Appearance in NIR



Based on the formalism of Nenkova, Ivezić & Elitzur (2002)

Summary

- Dusty tori can be modelled as thick, clumpy accretion flows
- Geometrically thick tori need huge mass accretion rates

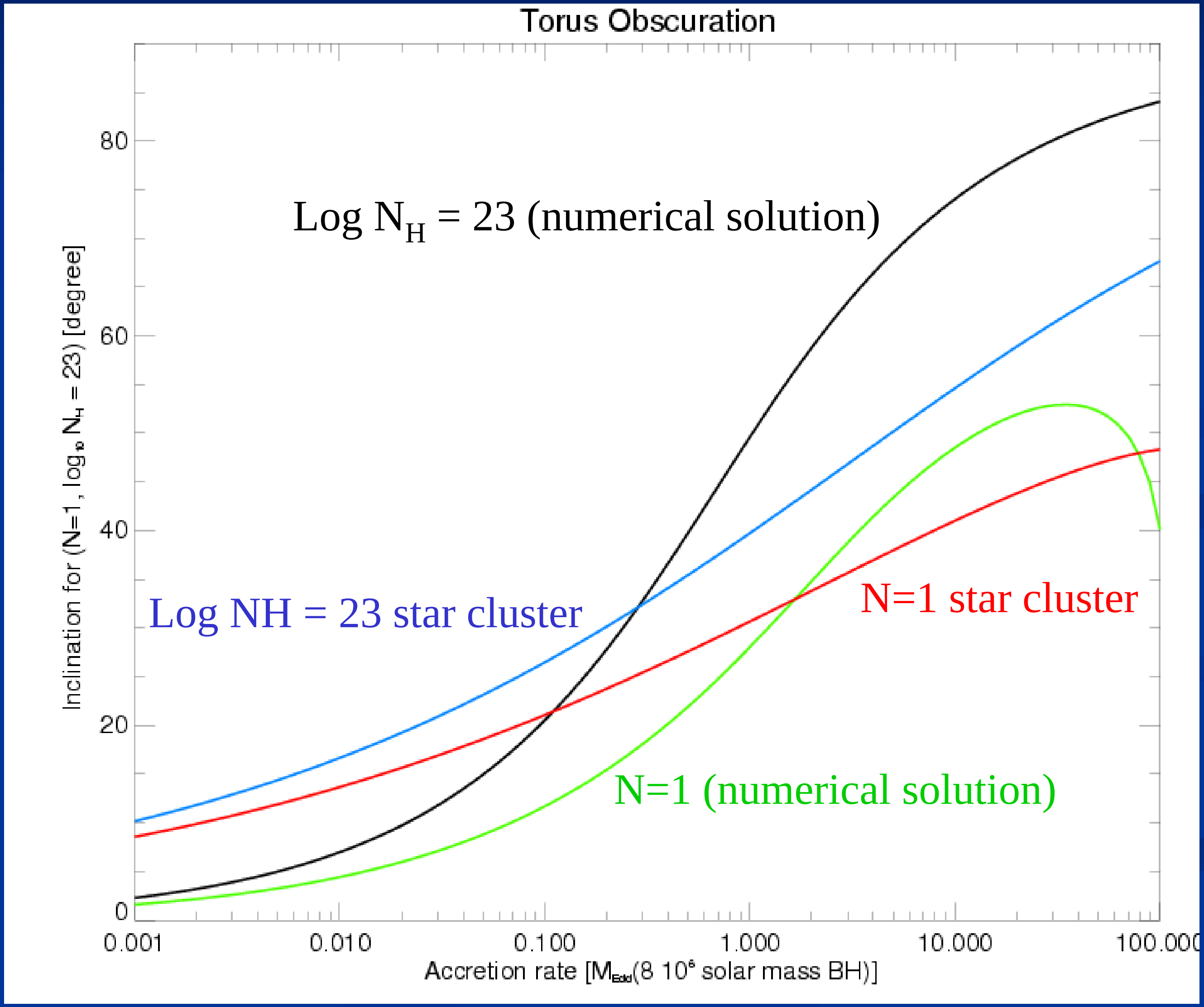
$$\dot{M}_{\mathrm{Torus}} > \dot{M}_{\mathrm{Edd,BH}}$$

- Obscuration ($N > 1$) only for $\theta < 45^{\circ}$
- Provides a basis for radiative transfer models

The Inner Boundary

- Clouds must be compact to prevent tidal disruption
- Clouds more massive than the Jeans-limit collapse → Central Cavity in GC
- Dust shields cool clouds against UV radiation
  Dust evaporation/sublimation sets inner radius for clouds
- Unshielded clouds loose mass in an evaporation flow (→ hot outflow from the AGN)

Torus & Unified Scheme



Appearance at higher Inclination