An axisymmetric, hydrodynamical model for the torus wind in AGN.

Dorodnitsyn A.

GSFC NASA
Space Research Institute (IKI)

T. Kallman
GSFC NASA

D. Proga
UNLV

Origin of “warm absorbers”

- We report on time-dependent axisymmetric simulations of an X-ray excited flow from a parsec-scale, rotating, cold torus around an active galactic nucleus. Our simulations account for radiative heating and cooling and radiation pressure force. The simulations follow the development of a broad bi-conical outflow induced mainly by X-ray heating.

- We compute synthetic spectra predicted by our simulations. The wind characteristics and the spectra support the hypothesis that a rotationally supported torus can serve as the source of a wind which is responsible for the warm absorber gas observed in the X-ray spectra of many Seyfert galaxies.

Figure 1 shows the flow streamlines and density contours at three orbital periods. At this time the high pressure region expands vertically, to $z \simeq 10$pc from the inner torus. The torus inner edge can be inferred from the temperature and density maps: $\varpi^- \simeq 1.3\,\mathrm{pc}$. Inside a throat of this torus, $T \simeq 10\,T_{\rm vir}$

The contours of T become more flattened:. $z_{\rm max} \simeq 4\,\mathrm{pc}$ The conservation of angular momentum helps to keep the outer edge of the torus at ~ 5 pc. However, there is an envelope around this dense torus: $z_{\rm max} \simeq 4\,\mathrm{pc}$, $\varpi^+ \simeq 8.1\,\mathrm{pc}$.

The values of the minimum ionization parameter and the column density vary significantly with the inclination angle: $\xi_{\rm min}(\theta = 8^\circ) = 2000, N_{22} = 0.3$, at $\theta \simeq 25^\circ$, the ionization parameter decreases significantly: $\xi_{\rm min}(\theta = 26^\circ) = 63, N_{22} = 2.3$; and at higher inclination, the ionization parameter is quite low: $\xi_{\rm min}(\theta = 53^\circ) = 6.6$, and the obscuration is quite high: $N_{22} = 75$.

The mass loss rate changes slowly $d\dot{M}/dt((M_\odot\,{\rm yr}^{-1})/{\rm yr}) \simeq 1.53 \cdot 10^{-6}$, The mass-loss rate peaks at at $\dot{M}_\Omega^{\rm max} = 0.05$ at $\theta \simeq 20^\circ$, where $v_{\rm max}(\theta = 20^\circ) = 616\,\mathrm{km\,s^{-1}}$; The total mass-loss rate is $\dot{M}(M_\odot\,{\rm yr}^{-1}) \simeq 0.08$

It is this evolved model that gives mass-loss rate in accord with the estimates of Krolik & Begelman *1986*.

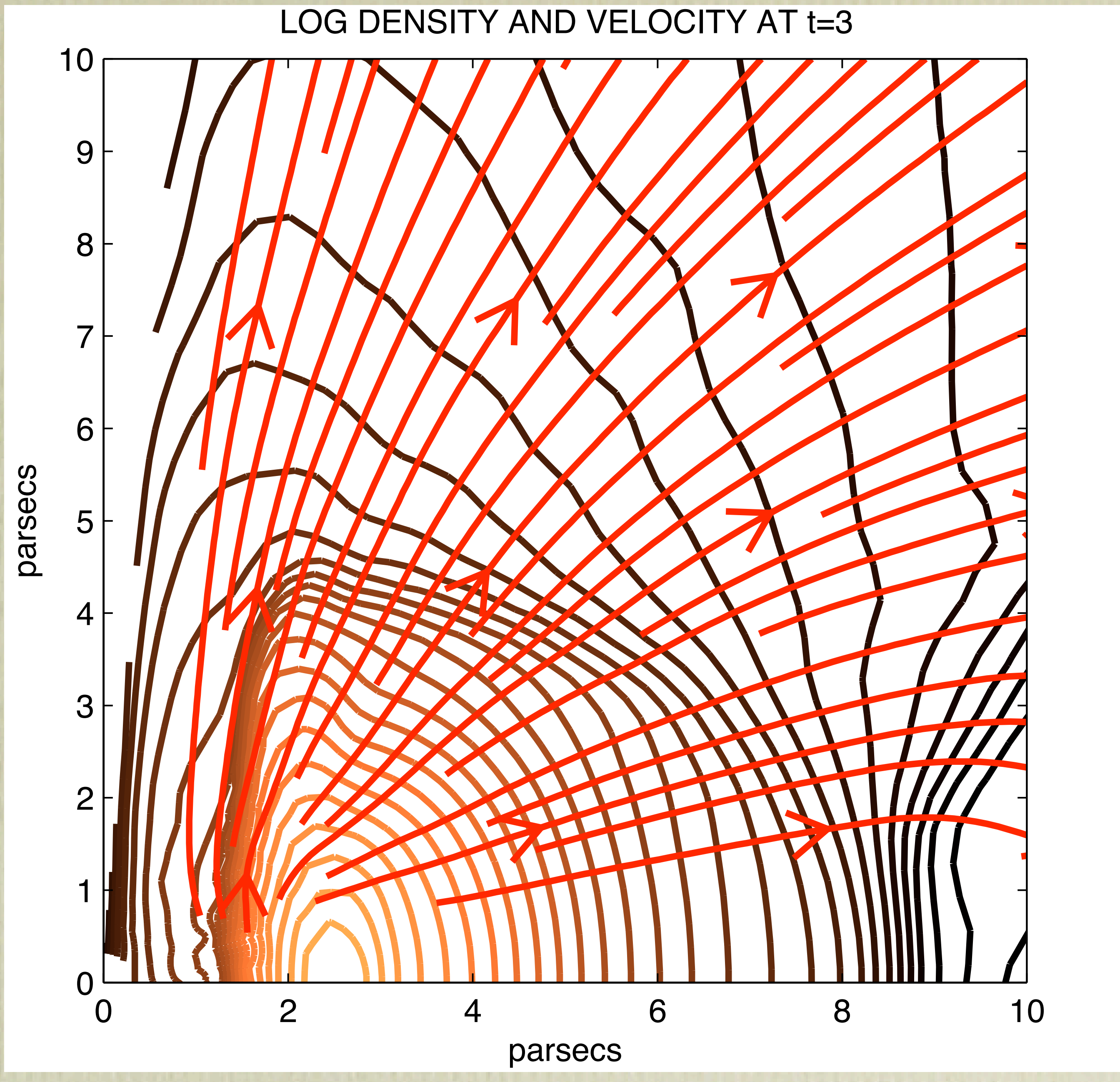

Figure 1.

- We have performed multidimensional simulations of a wind excited by X-ray heating of a rotationally supported torus. Our dynamical calculations predict the velocity field and the spatial distribution of opacity and emissivity of the gas in both continuum and lines as a function of position. (Synthesizing the spectrum provides a key test for our model).

- We have calculated synthetic spectra by integrating over the wind and using the formal solution of the transfer equation. This is done by passing the results of the hydrodynamical calculations into a code which calls the subroutines from the xstar code KallmanBautista 2001 to calculate the transmitted flux.

- Here we present absorption spectra. This approximately represents the case when warm absorber gas lies on the line of sight to the observer and we see only transmitted spectra. These are shown in Figure 3, (for various angles $\theta = 26°, 35°, 44°$ at three orbital periods). These show that our simulations provide gas with intermediate ionization and sufficient column to produce observable warm absorber features. This supports the idea that it is this wind that is responsible for the warm absorber gas observed in Seyfert galaxies.

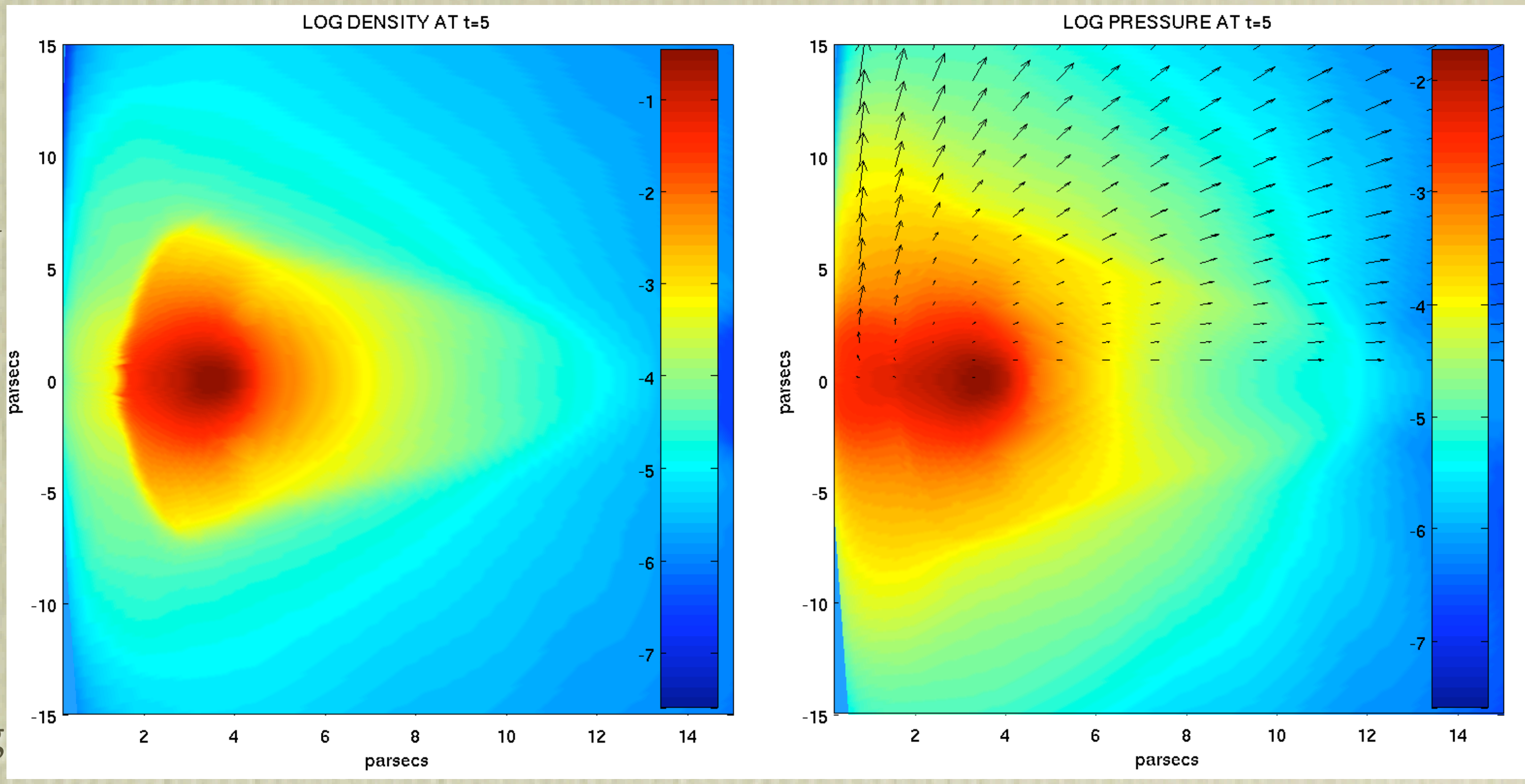

Figure 2. Density and pressure at five orbital periods

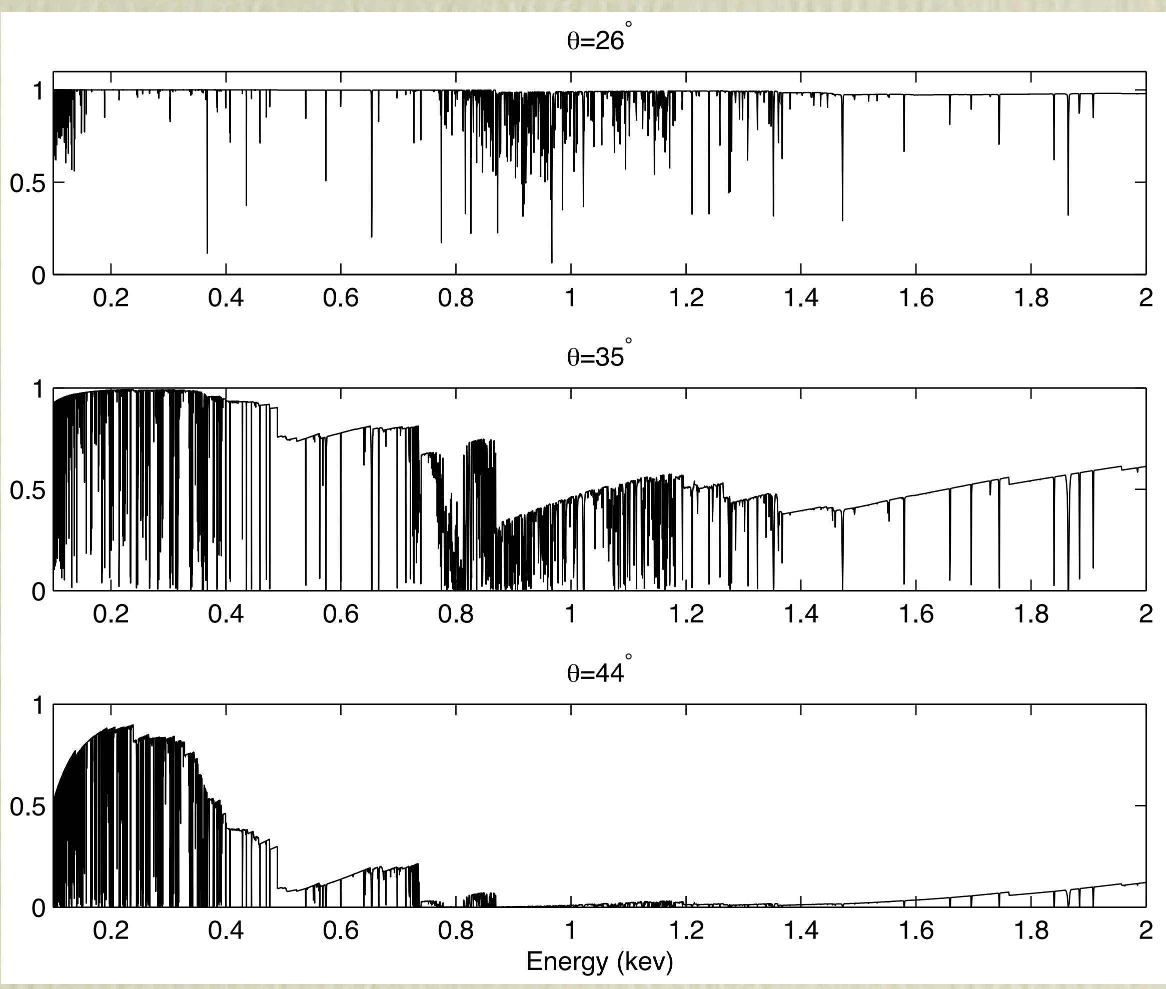

Figure 3. The transmitted spectra observed at three orbital periods from 2.5D model of the evaporative torus wind.

Dorodnitsyn et al. ApJ Lett. subm.