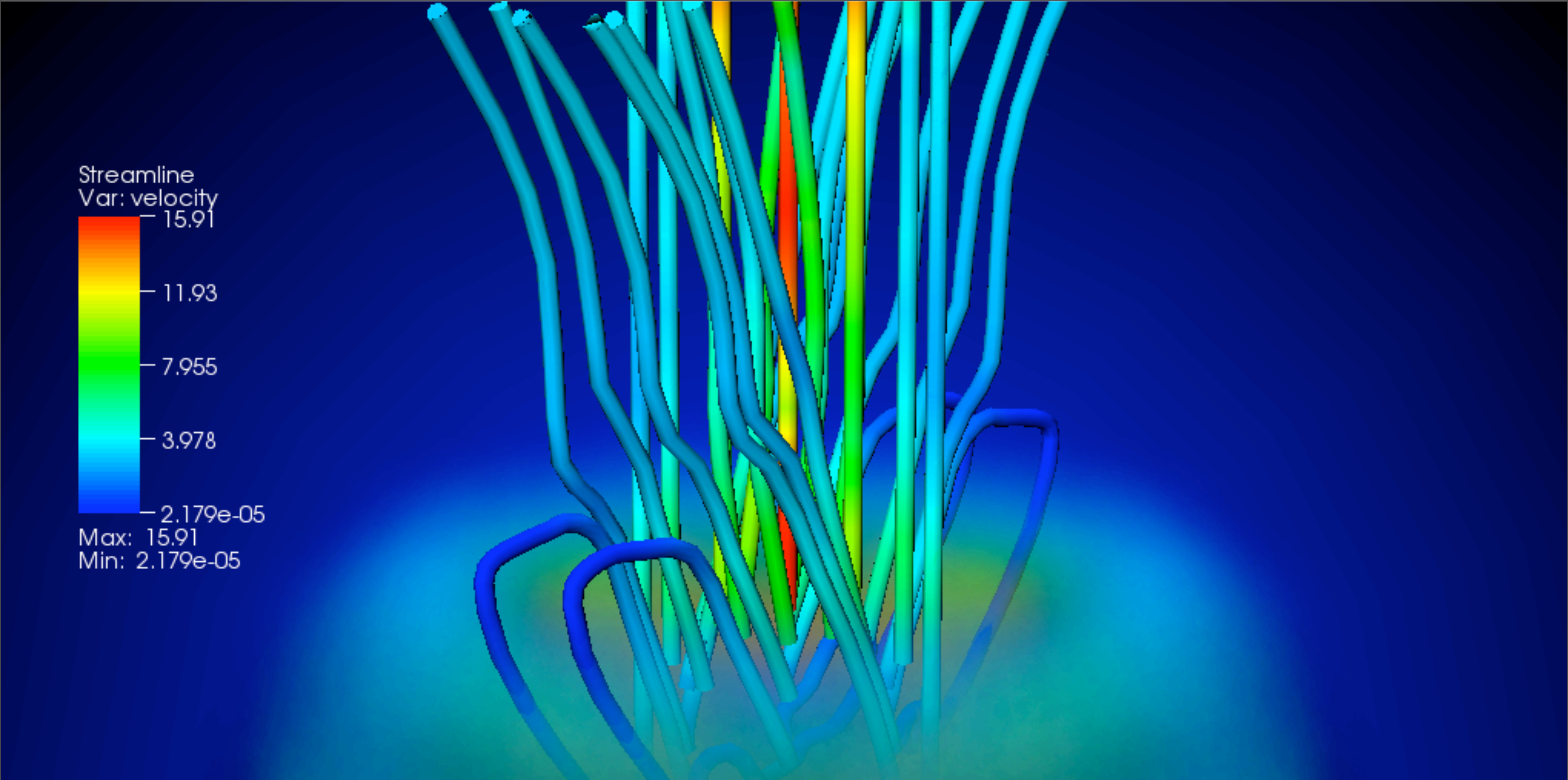

How to hide a supermassive Black Hole: AGN obscuration through dusty infrared dominated flows.

Anton Dorodnitsyn
NASA GSFC / UMD

Special Thanks

- Tim Kallman
- G.S. Bisnovatyi-Kogan

Dorodnitsyn, Kallman, Bisnovaty-Kogan, ApJ, 2012, 747, 8

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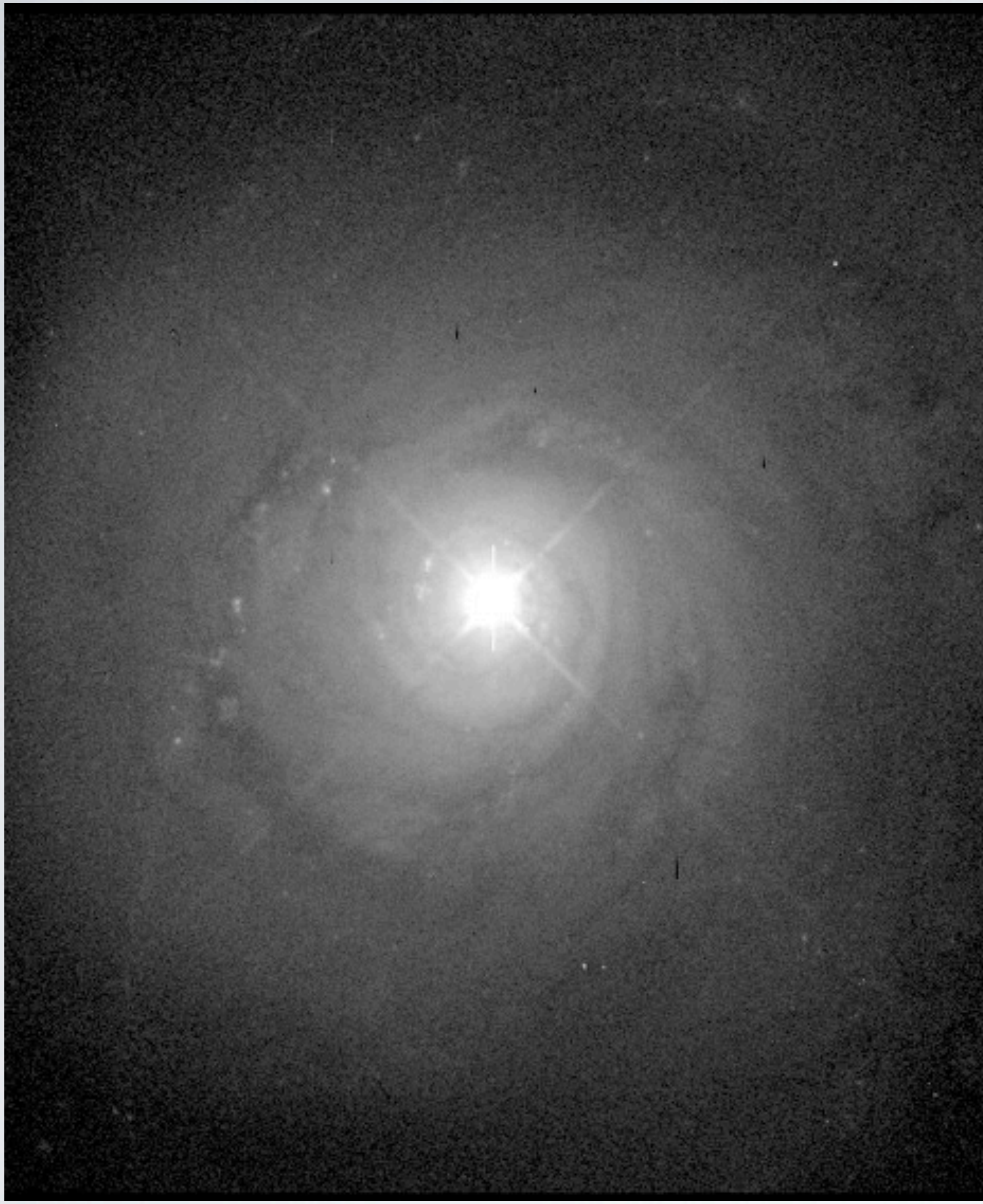
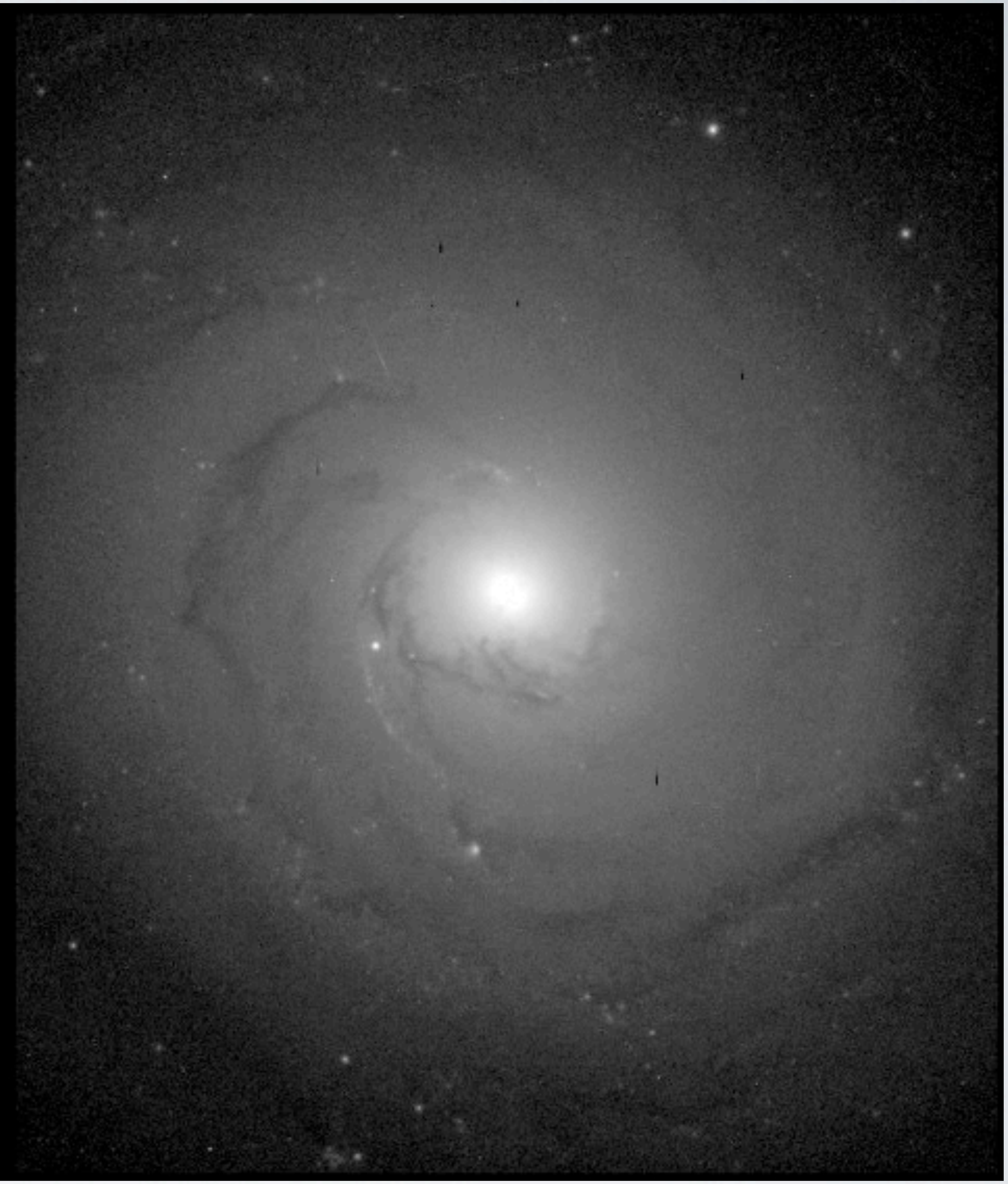
Dorodnitsyn, A., Kallman, T., Proga, D. 2008, ApJ, 687, 97

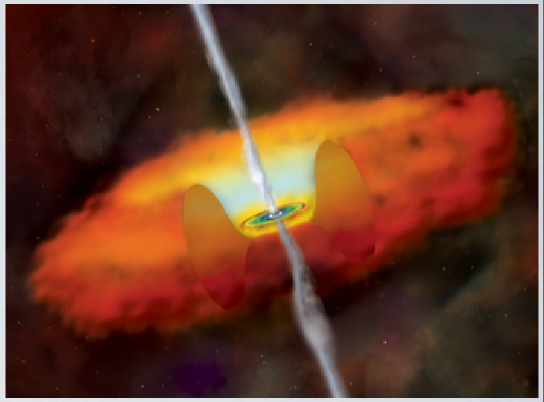


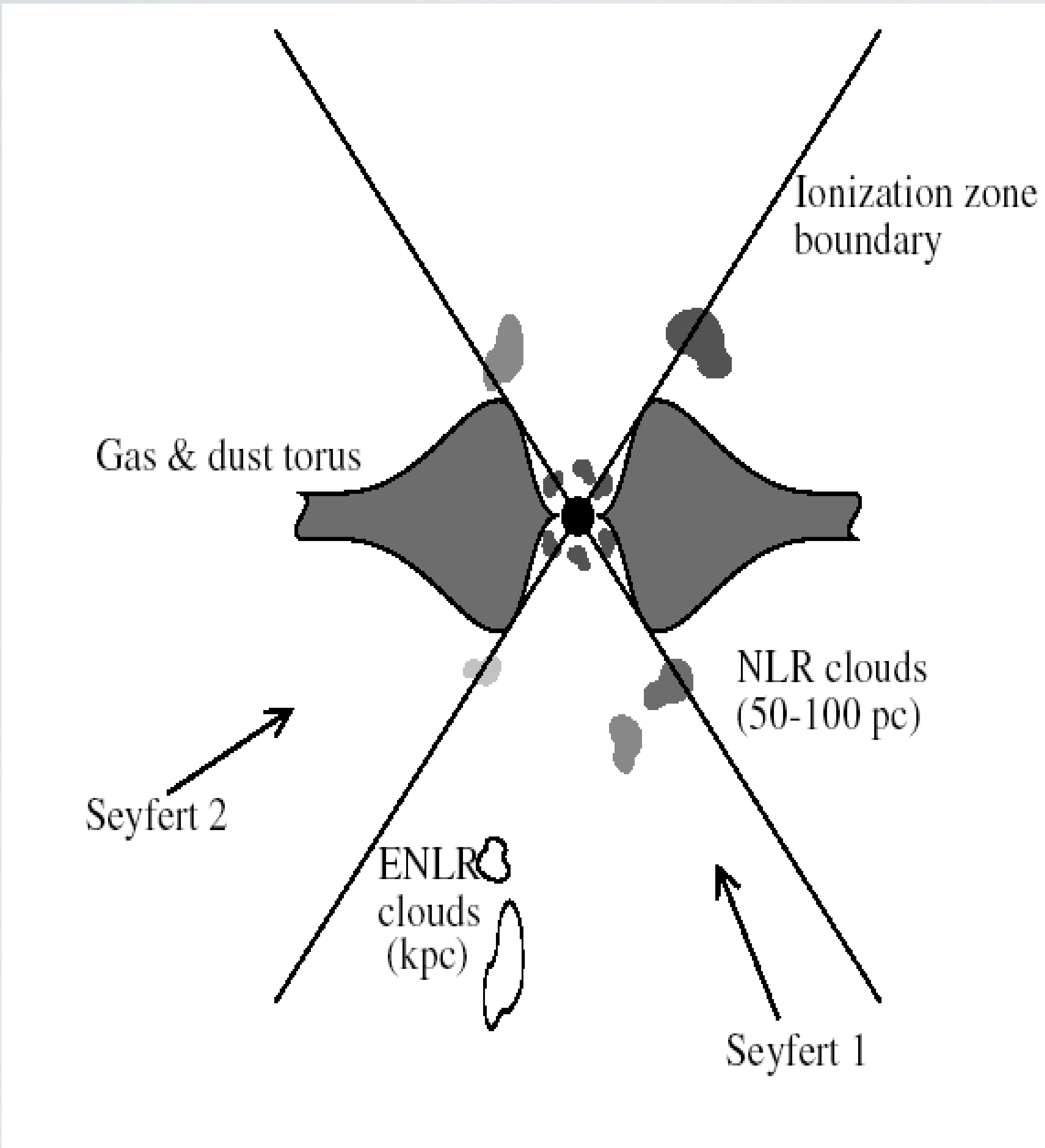


Seyfert 1, galaxy, NGC 5548

NGC 3277

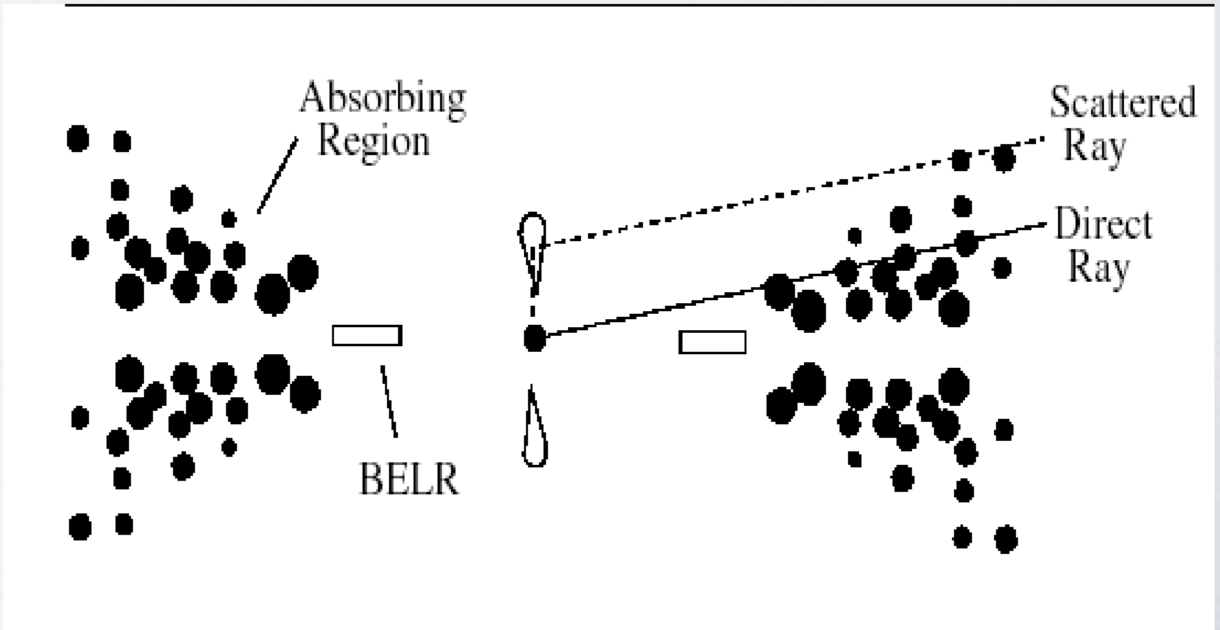
AGN UNIFICATION





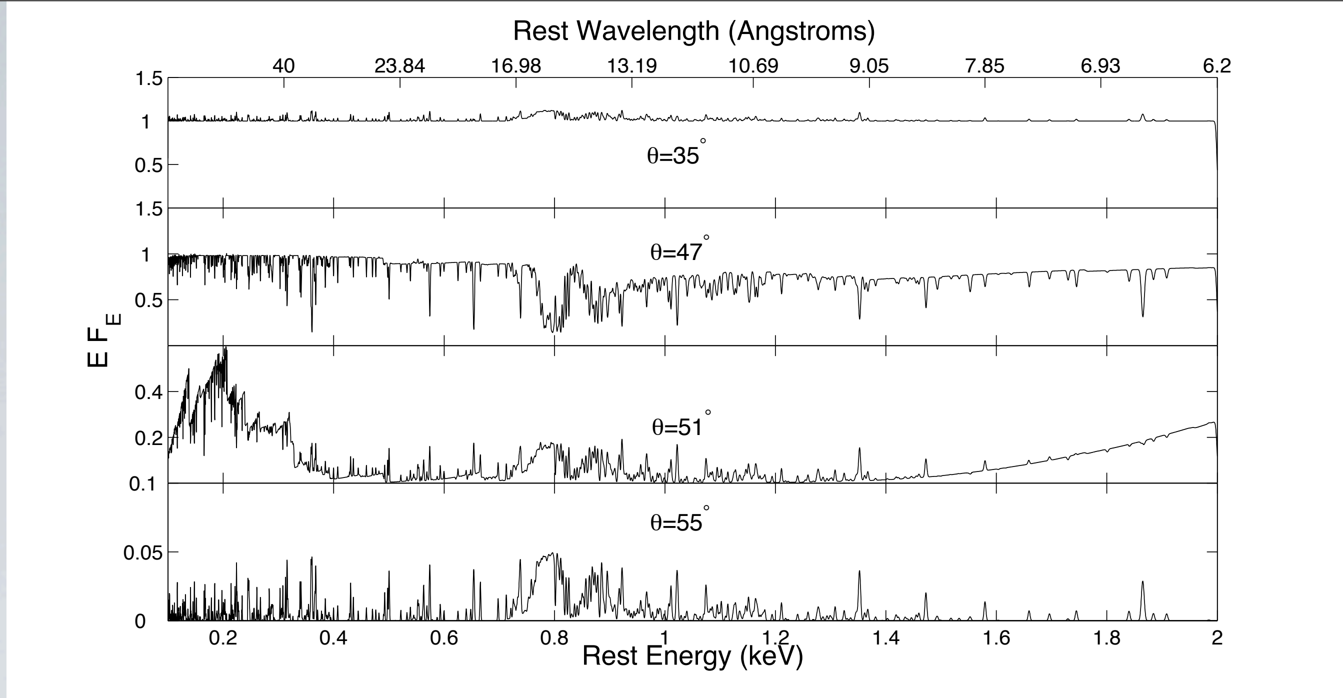
- Seyfert 1: broad emission lines
- Seyfert 2: narrow lines only

So, "type 2" AGN seem to be "type 1" but with no broad lines. Typically, Type 2 are less luminous in optics



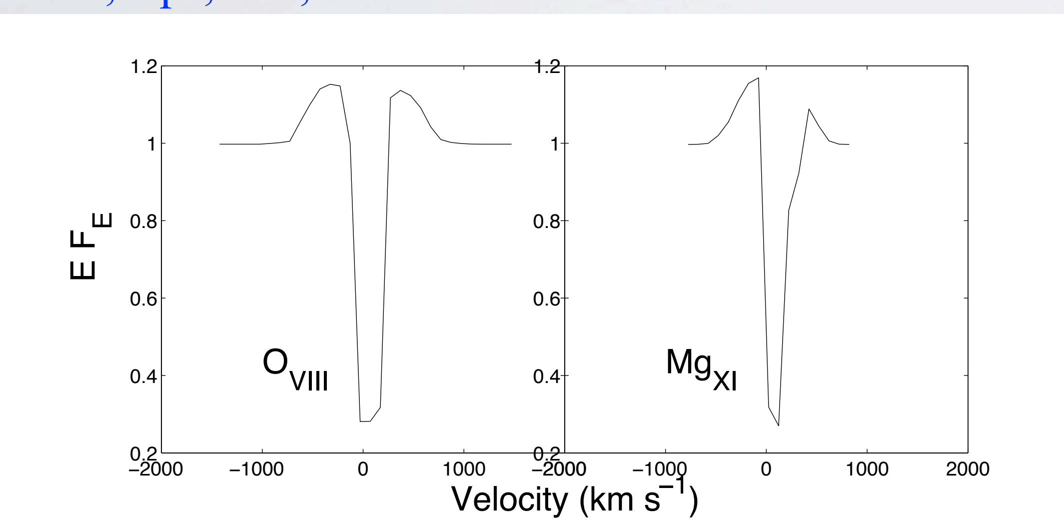
Warm absorbers

- The grating spectrographs on the X-ray telescopes *Chandra* and *XMM-Newton* provide unprecedented spectral resolution up to ~ 10 keV.
- These show that X-ray spectra obtained from ~ half of low-red-shift active galactic nuclei (AGN) contain many lines from ions of Fe, Si, S, O, Mg, and Ne, and that these are generally broadened and blueshifted by 100-500 km/s Kaspi, S., et al. 2002, ApJ, 574, 643; Steenbrugge, K.C. 2005, A&A, 432, 453
- The presence of X-ray absorbing gas has been confirmed in the majority of AGNs which are bright enough to allow detections.
- There is also a partial correspondence between UV and X-ray absorbers



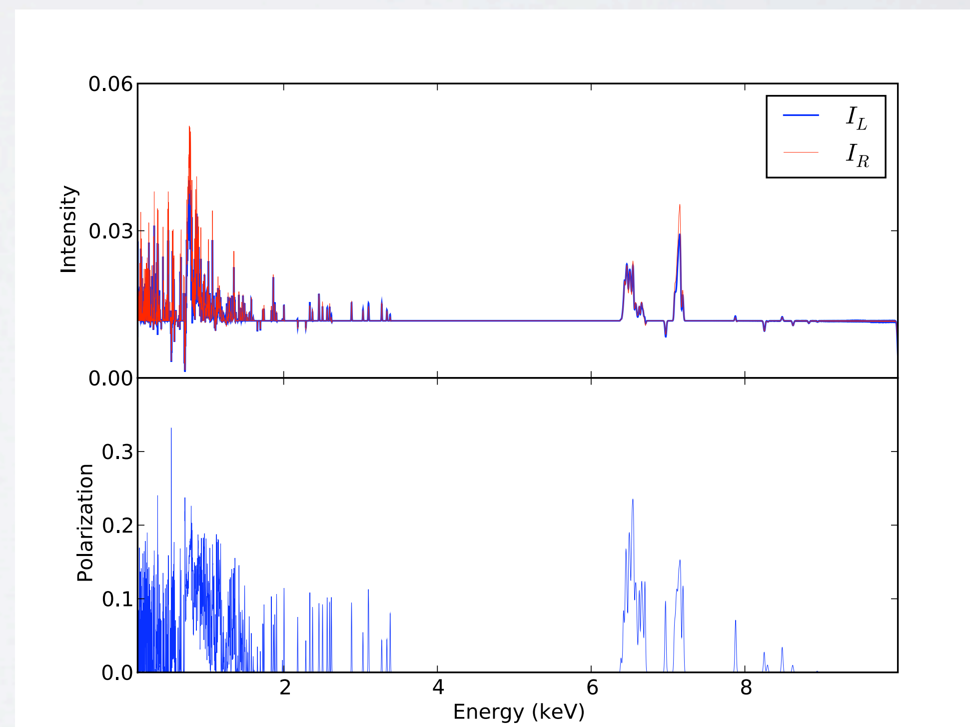
Model X-ray spectra,
observed as a function of angle.

Dorodnitsyn, A., Kallman, T. 2009, ApJ, 703, 1797



Profiles of individual lines of OVII(left) and MgXI (right).
Blueshifts correspond to positive velocities, redshifts to negative

X-ray polarimetry of warm absorbers



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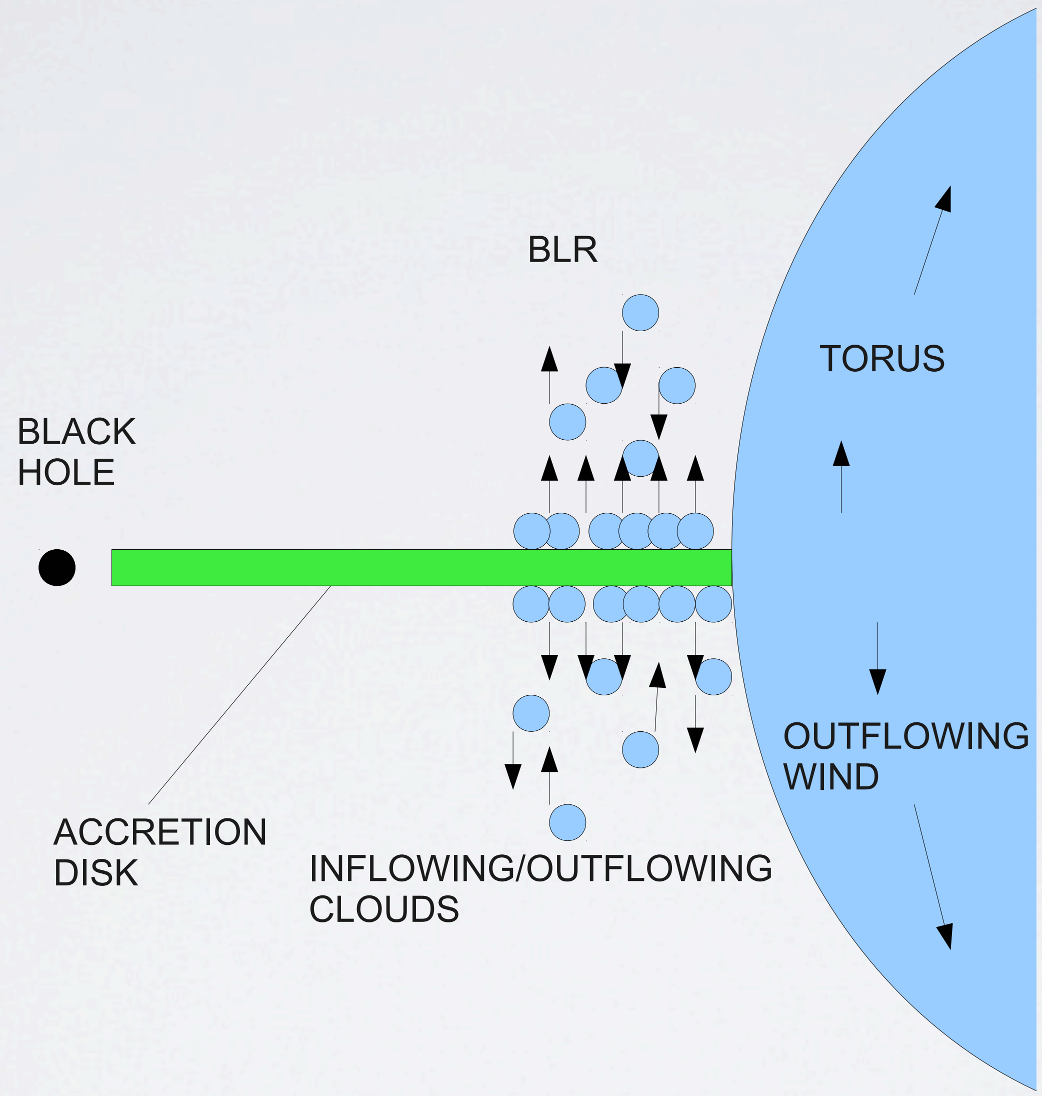
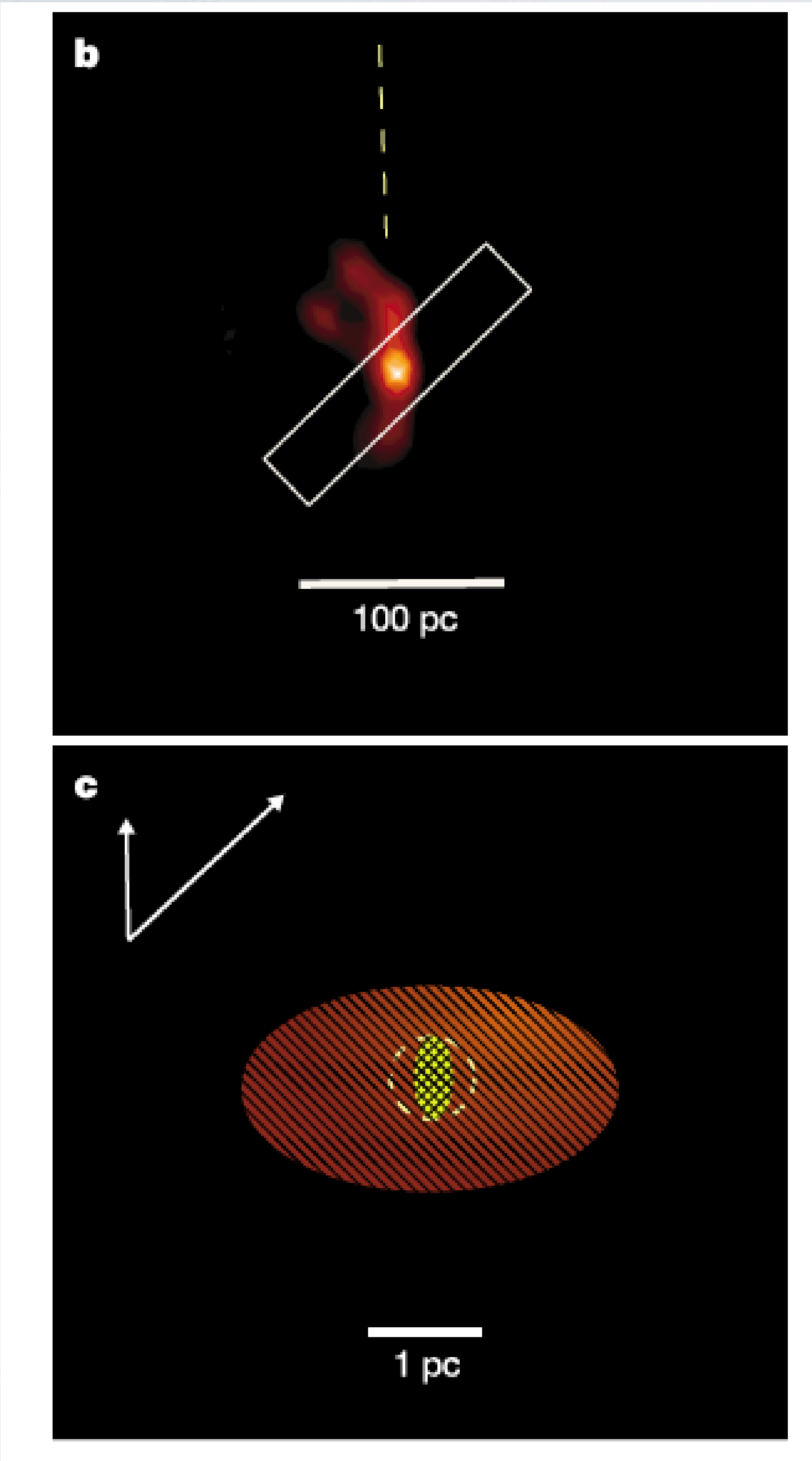
POSSIBLE CONNECTION WITH BLR



ALTERNATIVES FOR THE OBSCURATION

- Warps in accretion disk at a pc scale
- Clumps/clouds
- Winds from short distance from the BH
  - Radiation-driven winds
  - MHD (Blandford-Payne -type) flows
- IR-driven

DIRECT OBSERVATIONS OF THE TORUS



Jaffe et al. Nature, 2004

- Orientation effects play a major role in explaining many of the energetic phenomena in AGN
- Dusty clouds form a torus - like structure of the 1 parsec size
- Interferometric mid -infrared observations of NGC 1068 (Seyfert 2) reveals multi-component structure
- Warm (320K) - 2.1 parsec thick and 3.4 parsec in

One of the major problems which should be addressed by a theory of AGN obscuration is how the torus resists collapse into a geometrically thin disk. If the torus is supported by rotation and gas pressure then the temperature of such gas should be of the order of the virial temperature:

$$T_{\rm vir,g} = 2.6 \times 10^5 \, M_6 / r_{\rm pc} \, {\rm K}$$

Clearly, such temperatures cannot be reconciled with the existence of dust.

Comparing the energy density of the X-ray and UV-photons,

$$3.44 \times 10^{-5}\, M_6/r_{\rm pc}^2\, {\rm erg\, cm^{-3}}$$

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with the energy density of infrared radiation, we obtain that a gas-dust temperature of a few x 100K is required if all these X-ray and UV photons are converted to the infrared. A more elaborate treatment shows that if the temperature of the torus is a fraction of

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$$\beta = P_{\rm g}/P \simeq \left(10^3\, \frac{T_3^3}{n_7} + 1\right)^{-1}$$

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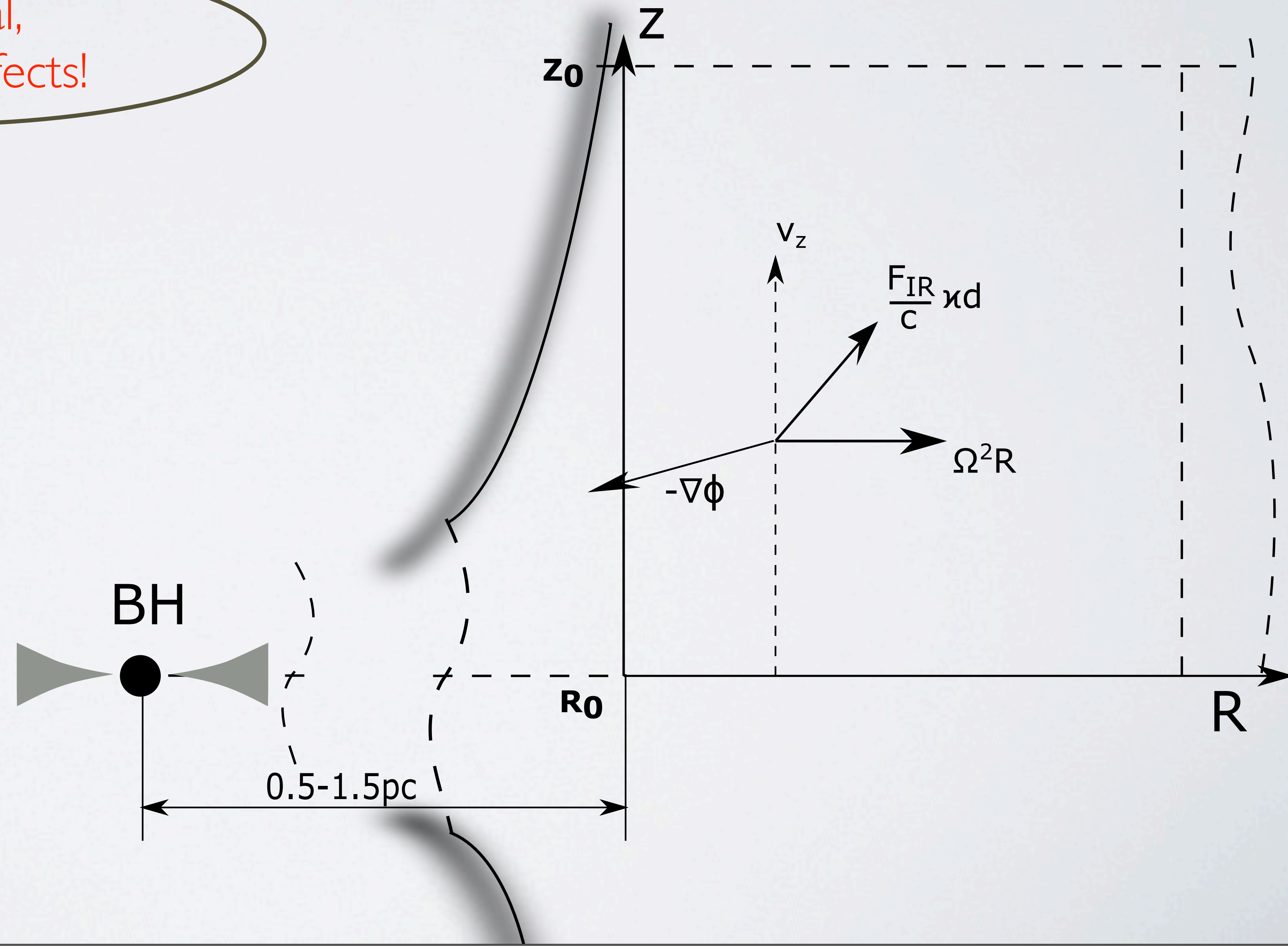

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UV is absorbed in a layer

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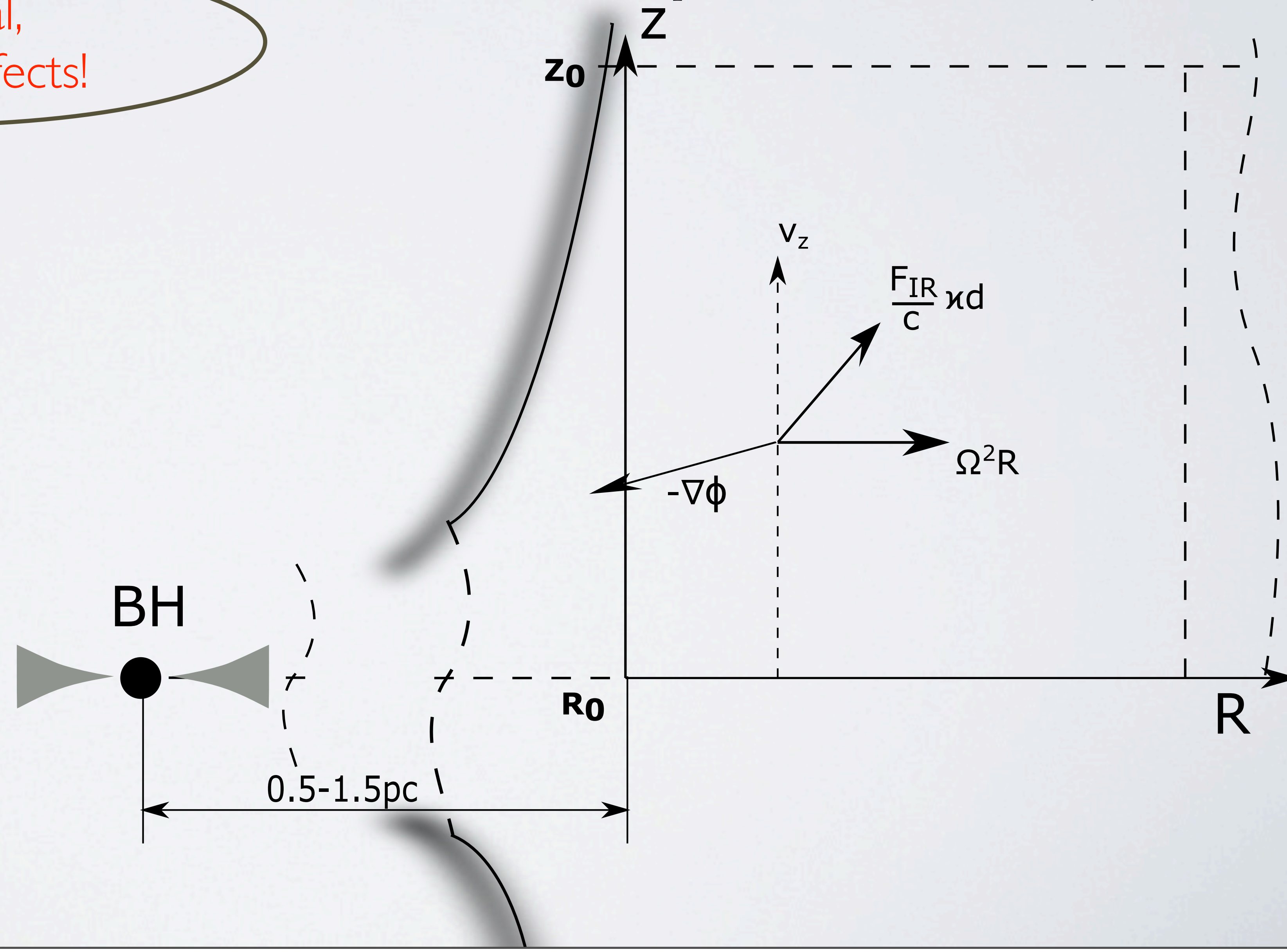

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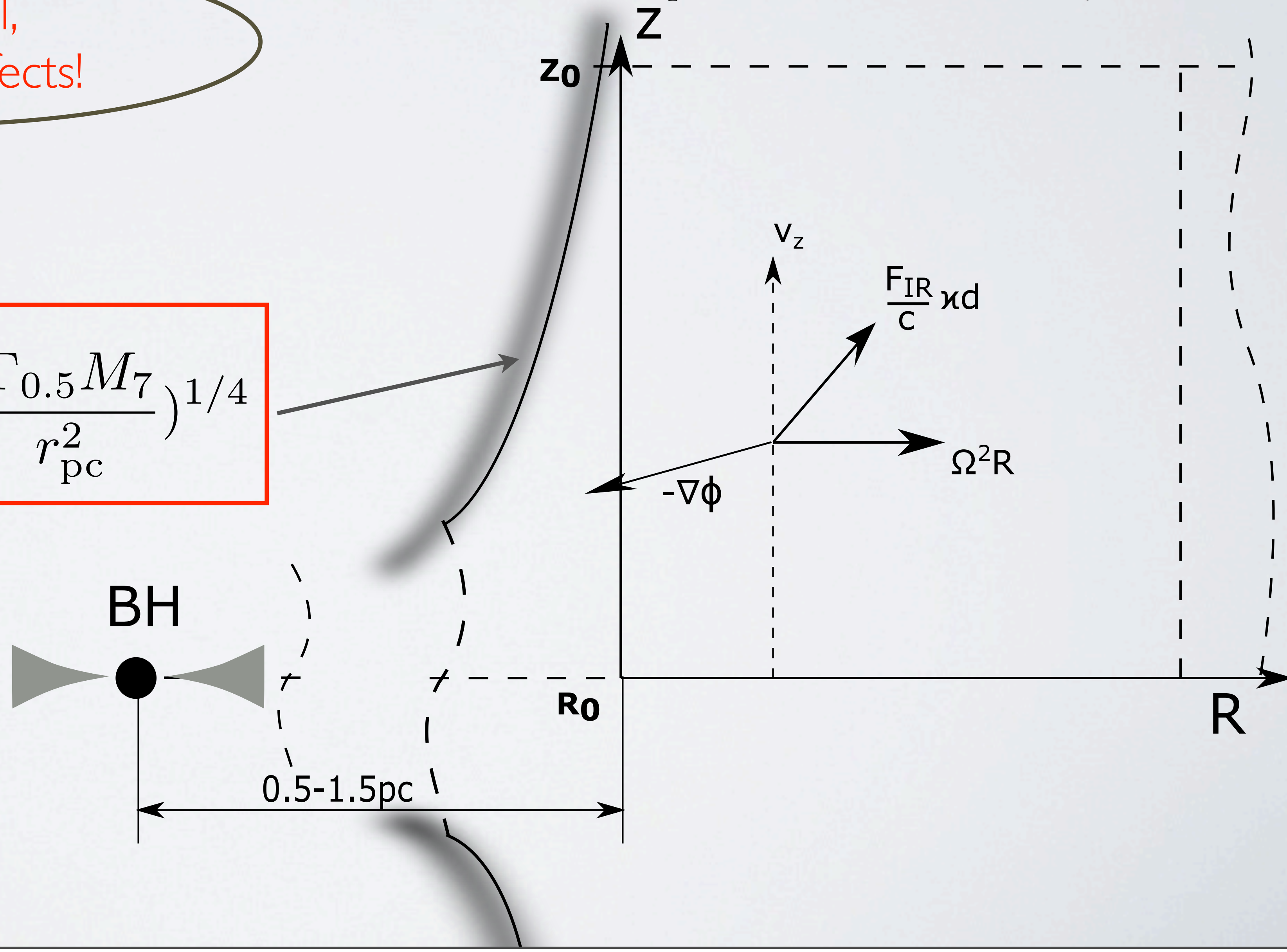
$$T_{\rm eff} = \left(4\alpha\Gamma \frac{GM}{\kappa_{\rm T} a r^2}\right)^{1/4} \simeq 463\, (\frac{\Gamma_{0.5} M_7}{r^2_{\rm pc}})^{1/4}$$



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- Mdot as an eigenvalue problem
- Mass of the “torus”
- Speed of an outflow
- AGN feedback

RADIATION HYDRODYNAMICS OF AGN OBSCURATION

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$$D_t\rho + \rho\,\nabla\cdot\mathbf{v} = 0,$$

$$D_t\mathbf{v} = -\frac{\mathbf{1}}{\rho}\,\nabla\mathbf{p} + \mathbf{g}_{\rm rad} - \nabla\boldsymbol{\Phi},$$

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Radiation Pressure Tensor

$$\mathbf{P}(\mathbf{r},t) = \frac{1}{c}\int_0^{\infty}\oint d\Omega\,\hat{\mathbf{n}}\hat{\mathbf{n}}\,I(\mathbf{r},\Omega,\nu,t)$$

Dorodnitsyn et al. , ApJ, 2011, 741, 29
Dorodnitsyn et al., ApJ, 2012, 747, 8

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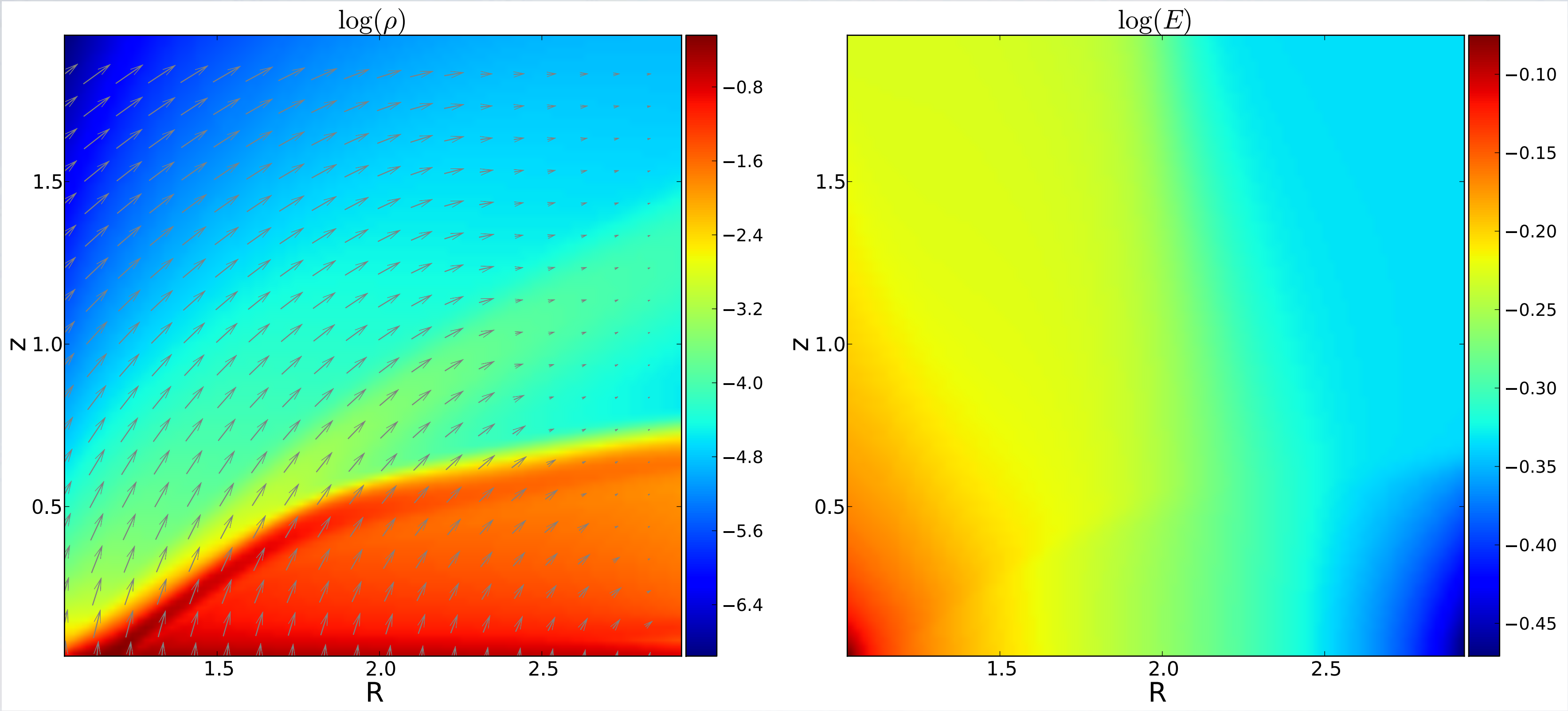
$$L = 0.5\, L_{\rm edd}$$

$$R = 1\, {\rm pc}$$

$$\tau_{\rm T} = 0.53$$



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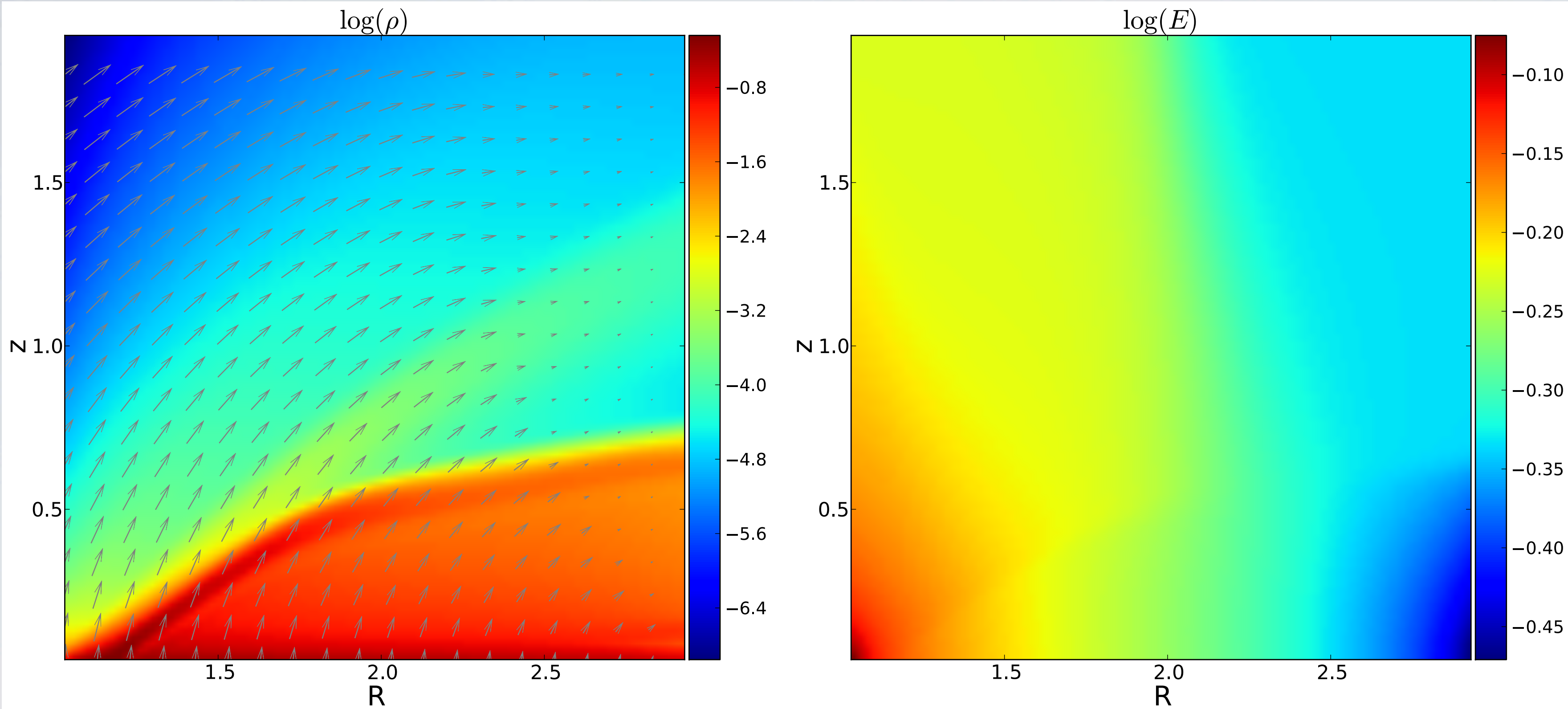

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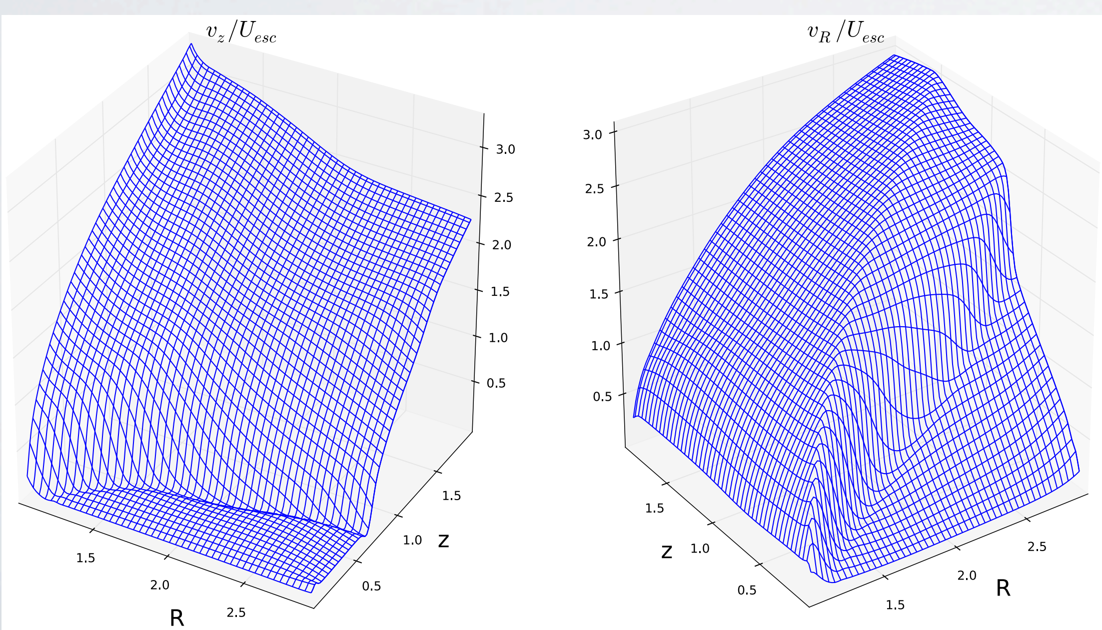

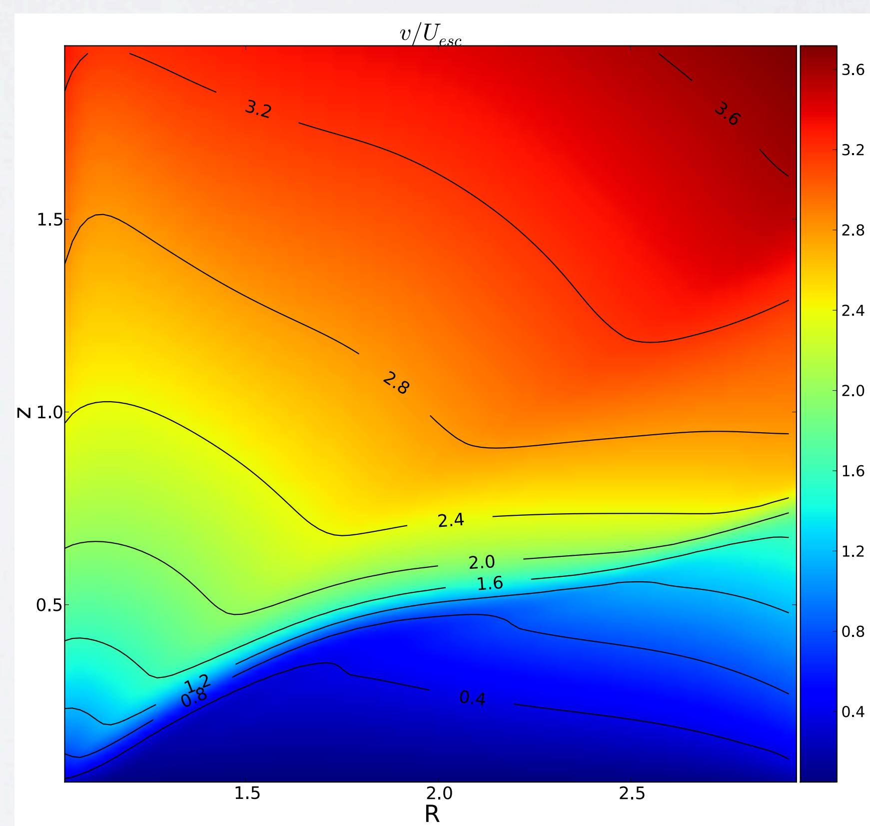

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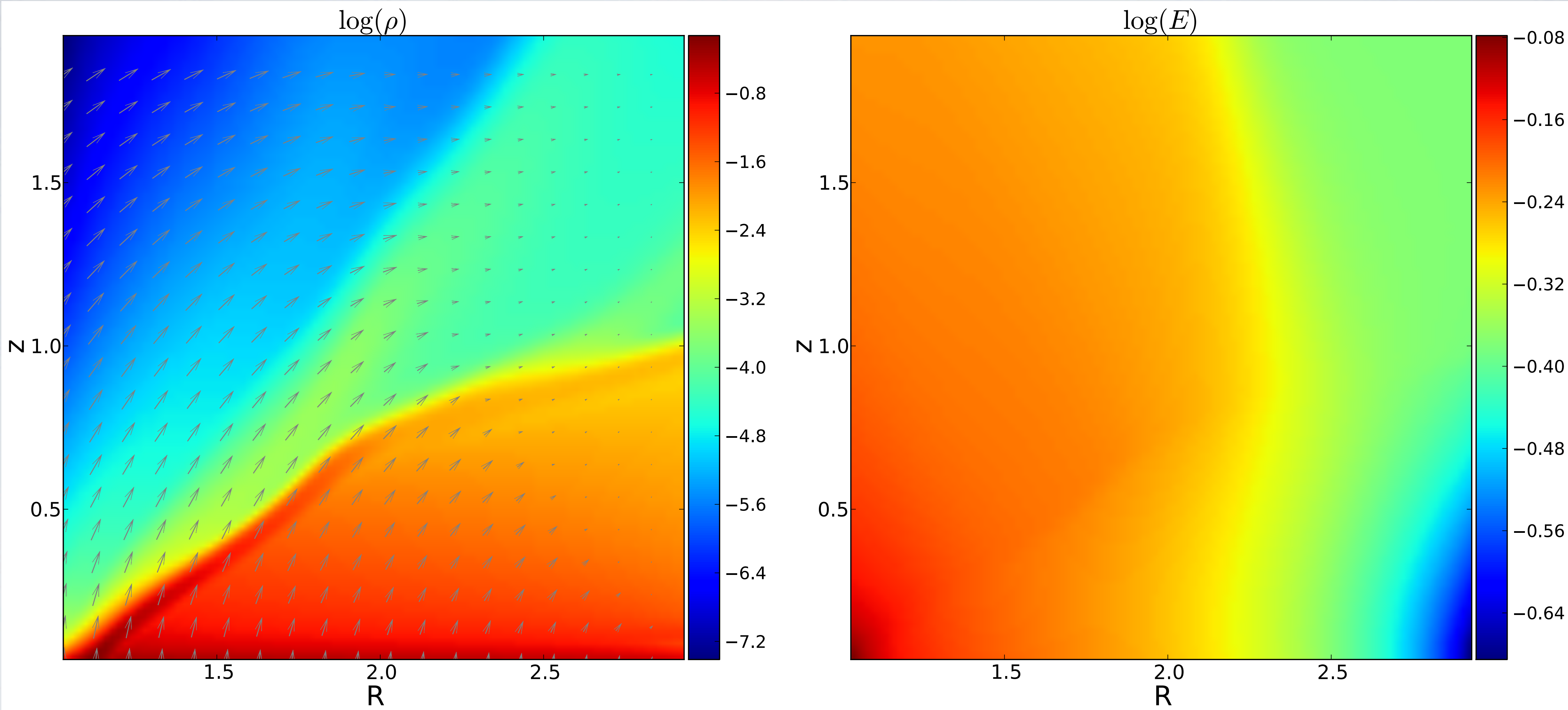

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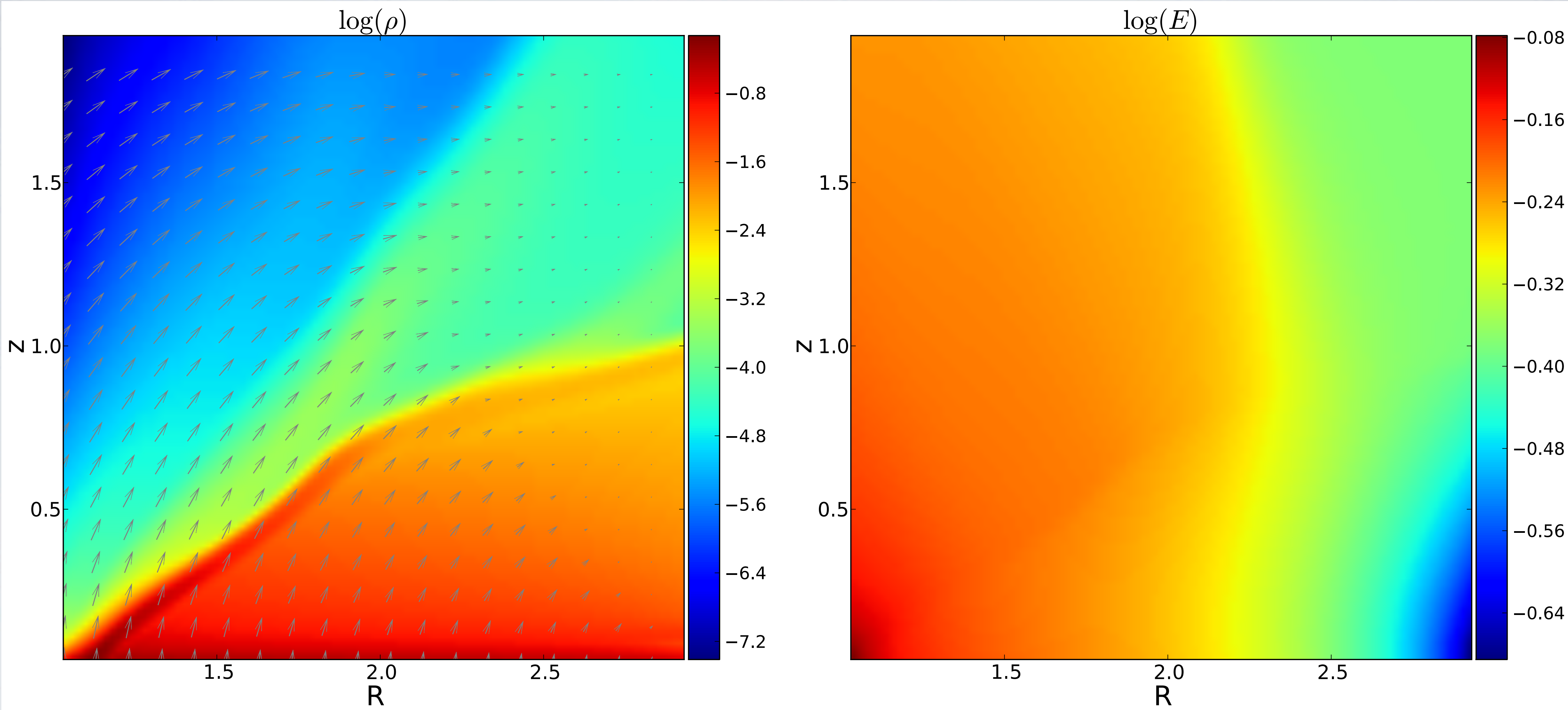
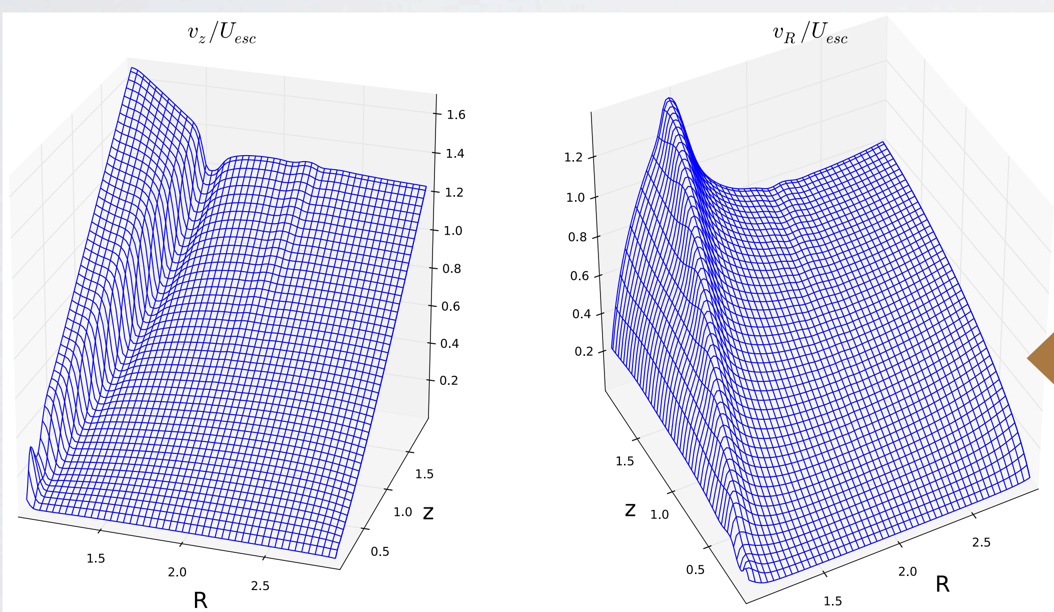
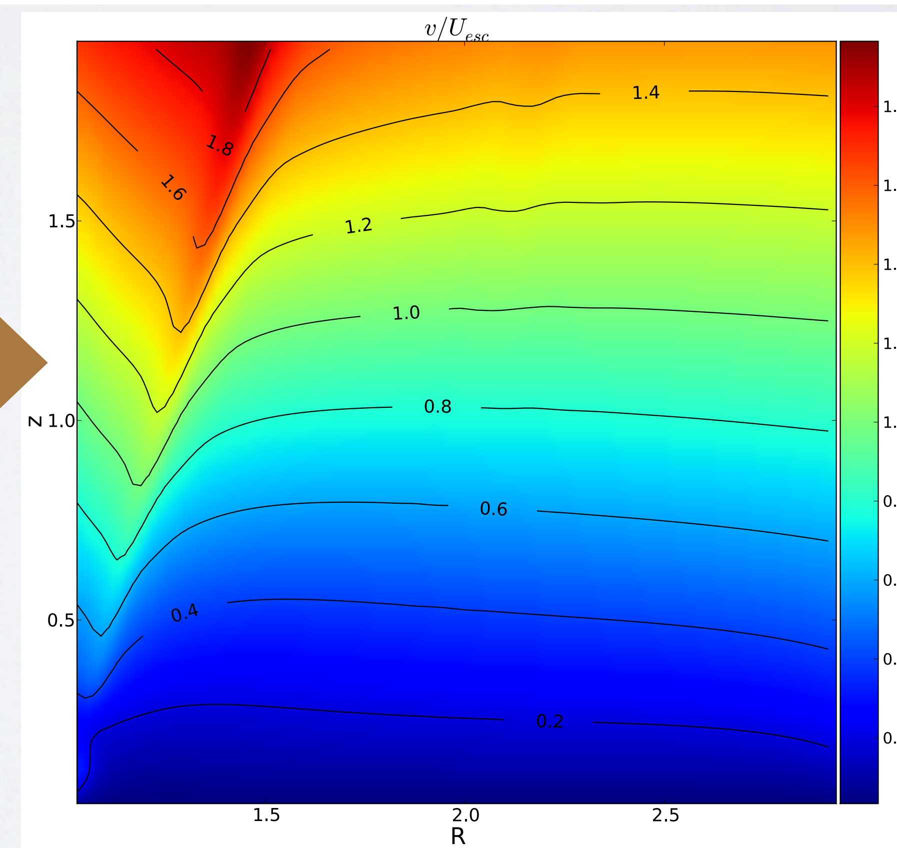
$$\tau_{\rm T} = 1.8$$







$$L = 0.05\, L_{\rm edd}$$

$$R = 1\,{\rm pc}$$

$$\tau_{\rm T} = 1.8$$

- As the luminosity of the central machine exceeds 0.1L_edd
- The geometrically thick wind is formed
- This "wind" is obscuring AGN at high inclinations

RHD, time-dependent 2.5D

Model	Γ	R_0	τ_T	n_0	$\langle v \rangle$	v^*_{max}	L_{kin}	L_{bol}	$\dot{M}$
1	0.5	1	0.53	$3 \cdot 10^5$	138.4	666.61	$1.23 \cdot 10^{41}$	$6.24 \cdot 10^{44}$	1.71
2	0.3	1	0.53	$3 \cdot 10^5$	104.87	560.27	$6.38 \cdot 10^{40}$	$3.74 \cdot 10^{44}$	1.38
3	0.1	1	0.53	$3 \cdot 10^5$	55.82	373.46	$1.48 \cdot 10^{40}$	$1.24 \cdot 10^{44}$	1.85
4	0.05	1	0.53	$3 \cdot 10^5$	36.63	282.23	$6 \cdot 10^{39}$	$6.25 \cdot 10^{43}$	0.64
5	0.8	1	1.8	$1 \cdot 10^6$	112.62	765	$4.11 \cdot 10^{41}$	$9.99 \cdot 10^{44}$	5
6	0.5	1	1.8	$1 \cdot 10^6$	90.55	513.42	$2.56 \cdot 10^{41}$	$6.24 \cdot 10^{44}$	4.18
7	0.3	1	1.8	$1 \cdot 10^6$	73.18	348.45	$1.37 \cdot 10^{41}$	$3.74 \cdot 10^{44}$	3.37
8	0.1	1	1.8	$1 \cdot 10^6$	59.73	159.74	$3.09 \cdot 10^{40}$	$1.24 \cdot 10^{44}$	1.88
9	0.05	1	1.8	$1 \cdot 10^6$	42.8	129.39	$1.31 \cdot 10^{40}$	$6.25 \cdot 10^{43}$	1.39

STATIC TORUS

CONCLUSIONS

CONCLUSIONS

“Dynamic Torus”

CONCLUSIONS

- Active Galactic Nuclei (AGN), Seyfert galaxies and quasars, are powered by luminous accretion and often accompanied by winds which are powerful enough to affect the AGN mass budget, and whose observational appearance bears an imprint of processes which are happening within the central parsec around the black hole (BH).

- Our results demonstrate that for AGN luminosities greater than $0.1\,L_{\rm edd}$ external illumination can support a geometrically thick obscuration via outflows driven by the infrared radiation pressure.

- The terminal velocity of marginally Compton-thin models $0.2 < \tau_{\rm T} < 0.6$ is comparable or greater than the escape velocity.

- In Compton thick models the maximum value of the vertical component of the velocity is lower than the escape velocity suggesting that a significant part of our torus is in the form of failed

Pressure of the infrared radiation on dust is crucial. Dusty winds may or may not be failed, i.e. returning. This flow is known aka "AGN torus"