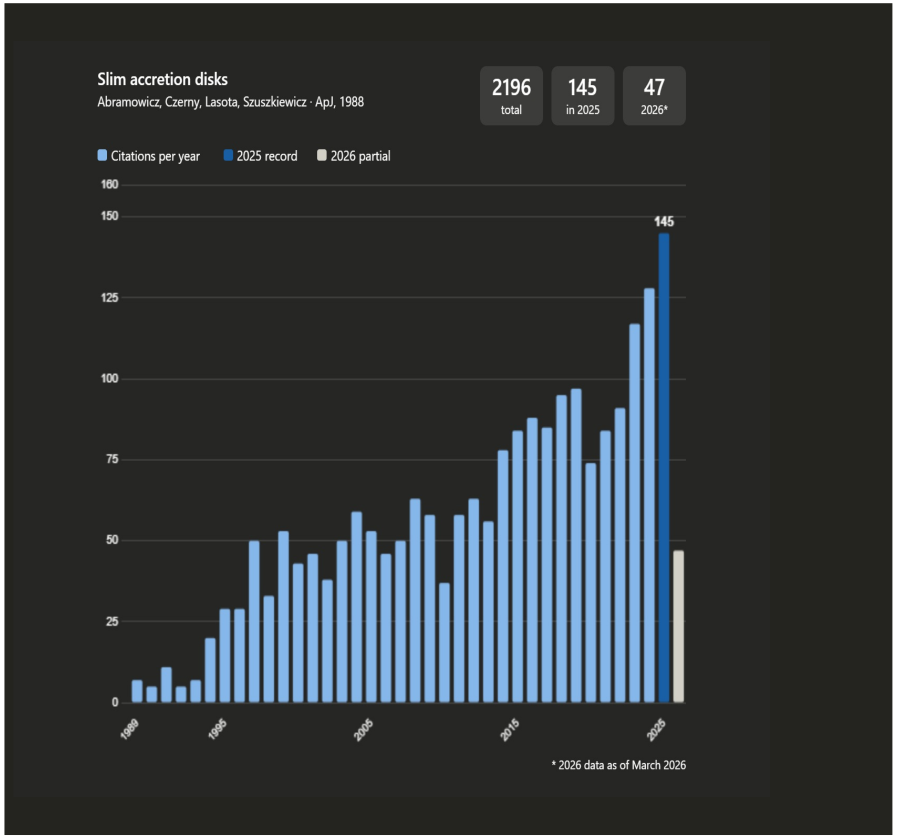
THE “CLASSIC” 1988 SLIM DISC MODELS



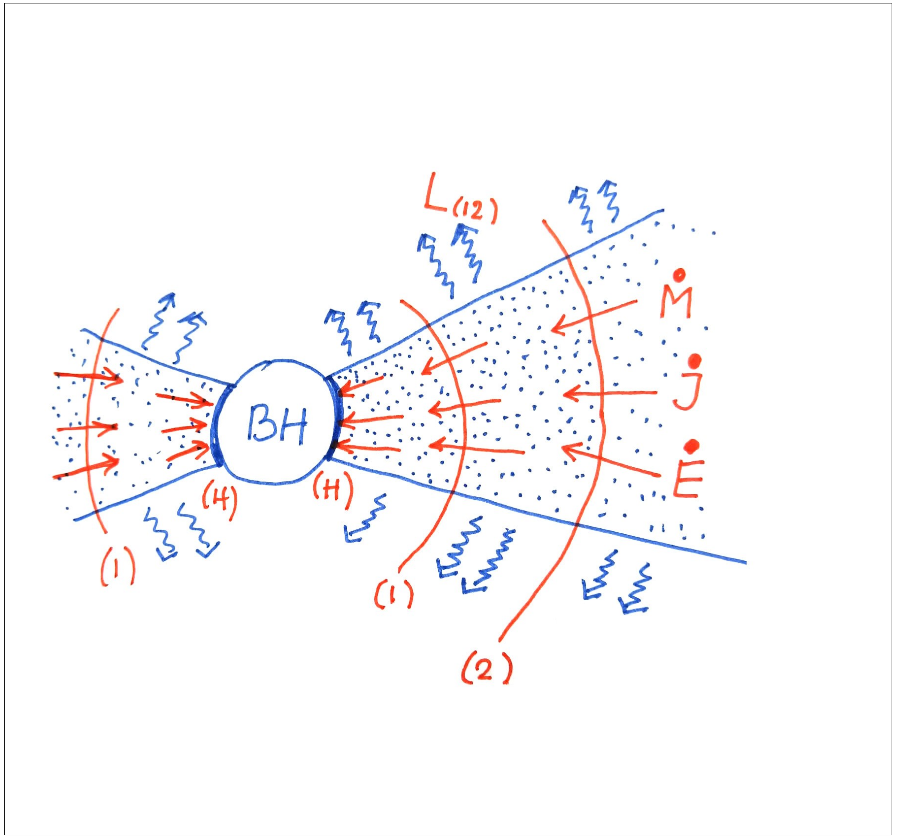
Bożena Czerny, Universe 2019, 5, 131
Slim Accretion Disks:
Theory and Observational Consequences

Slim accretion disc models describe an optically thick, geometrically not very thin quasi-Keplerian accretion flow onto a black hole. A considerable part of the energy dissipated in the disc interior is carried radially with the flow instead of being reemitted at the same radius, as in the standard Shakura and Sunyaev thin accretion disc model. Slim discs apply to sub-Eddington, and nearly (or slightly above) Eddington sources: active galactic nuclei and galactic X-ray binaries.

They use the $\alpha =$ const viscosity prescription.

Although nowadays we model the black hole accretion flows by super computer GRMHD simulations, slim discs are still very useful because they are semi-analytic: they provide more physical insight and are much easier to calculate.

HOW DOES ACCRETION WORK?



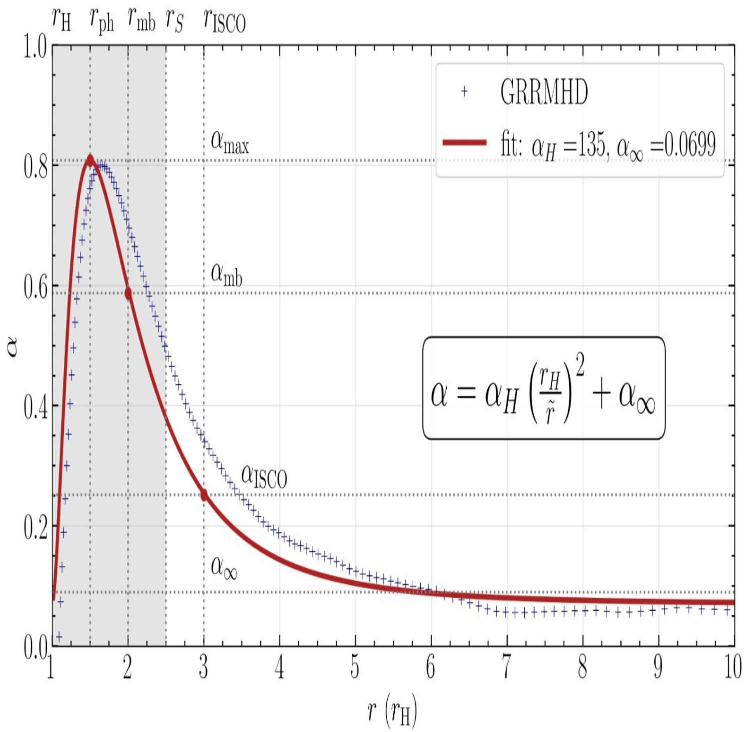
$$(\dot{M})_1 - (\dot{M})_2 = 0$$
$$(\dot{J})_1 - (\dot{J})_2 = 0$$
$$(\dot{E})_1 - (\dot{E})_2 = L_{12}$$
$$\dot{J} = \dot{M}\, j + \mathcal{T}$$
$$\dot{E} = \dot{M}\, e + \Omega\, \mathcal{T}$$
$$L_{12} = \int_1^2 \left(\frac{d\Omega}{dr}\right) \mathcal{T} ds$$

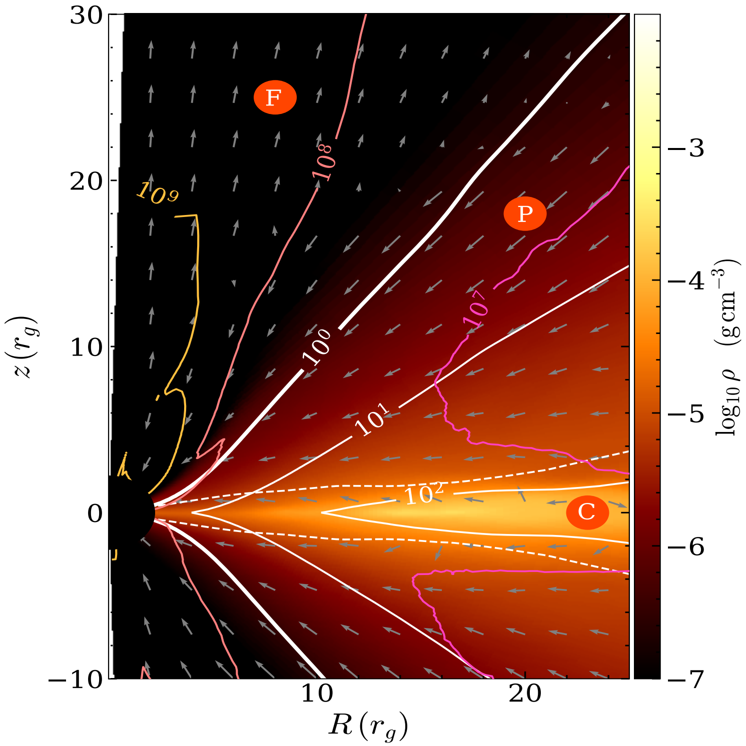
Shakura-Sunyaev:

$$\mathcal{T} = \alpha\, P, \quad \alpha = \text{const}$$

Slim discs equations are split into radial and vertical ODEs. The radial ones express conservation of mass, energy, angular momentum.

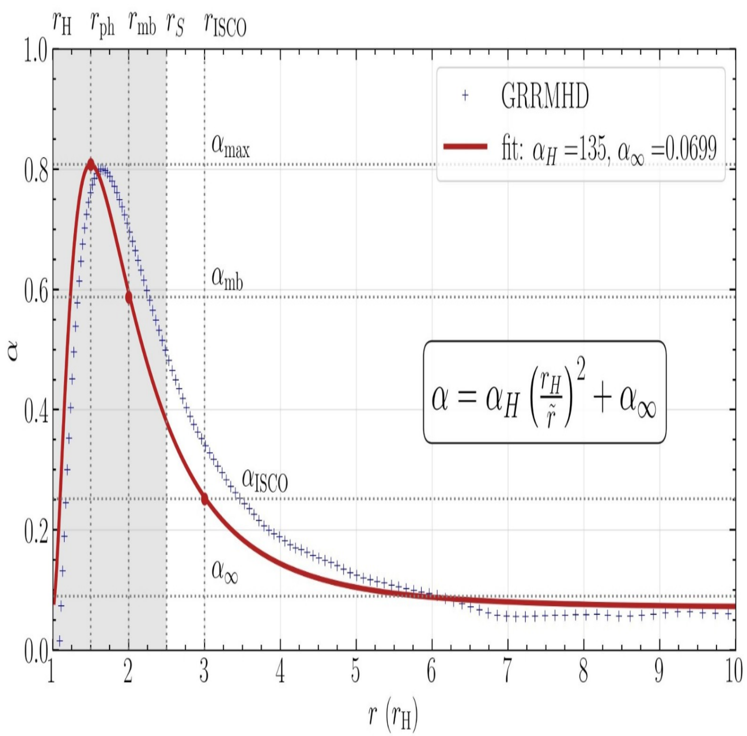
STRESS FROM GRMHD SIMULATIONS





State of art GRMHD simulations show that the Shakura-Sunyaev alpha is not constant.

NEW ALPHA VISCOSITY PRESCRIPTION



Marek Abramowicz
(Opava, Göteborg, Warsaw)

Axel Brandenburg
(Stockholm)

Debora Lančová
(Opava, Warsaw)

Jíři Horák
(Prague)

John Miller
(Oxford, Trieste)

Ewa Szuszkiewicz
(Szczecin)

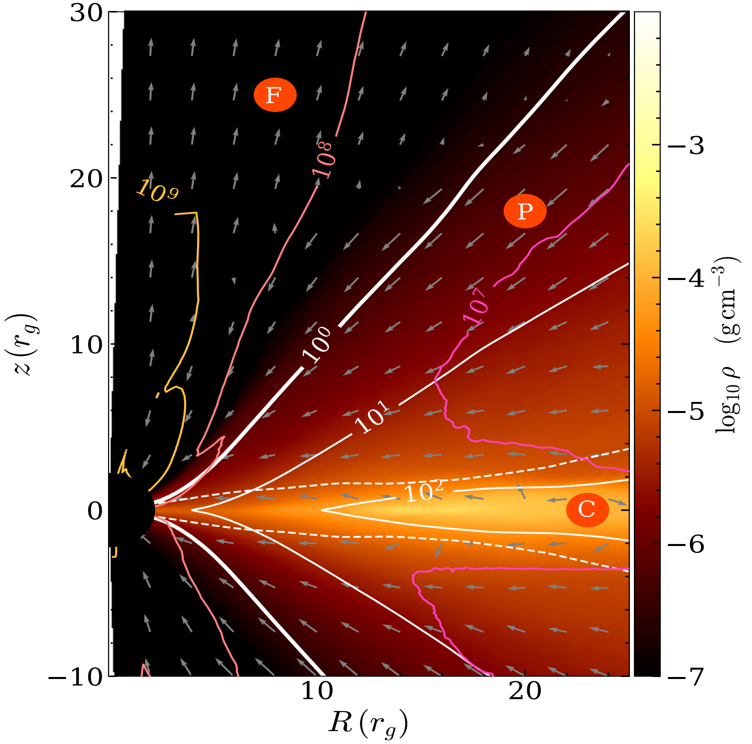
Maciej Wielgus
(Granada,Harvard)

They are likely collaborators of the Ph.D. student

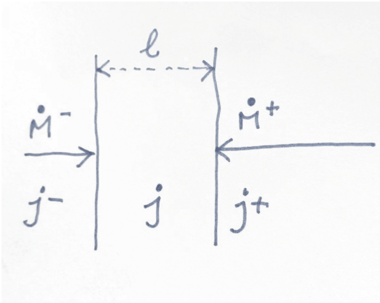
THE GRMHD SIMULATIONS TEAM

Debora Lančová,
David Abraca,
Włodek Kluźniak,
Maciek Wielgus,
Aleksander Sądowski,
Ramesh Narayan, Jan Shee,
Gabriel Török,
Marek Abramowicz,
Odele Straub, Agata Różańska,
Frederic Vincet

Opava, Harvard, Warsaw, Paris, Munich, Granada



NO STRESS AT THE HORIZON



$$\mathcal{T} = \dot{J} - \dot{M} j$$

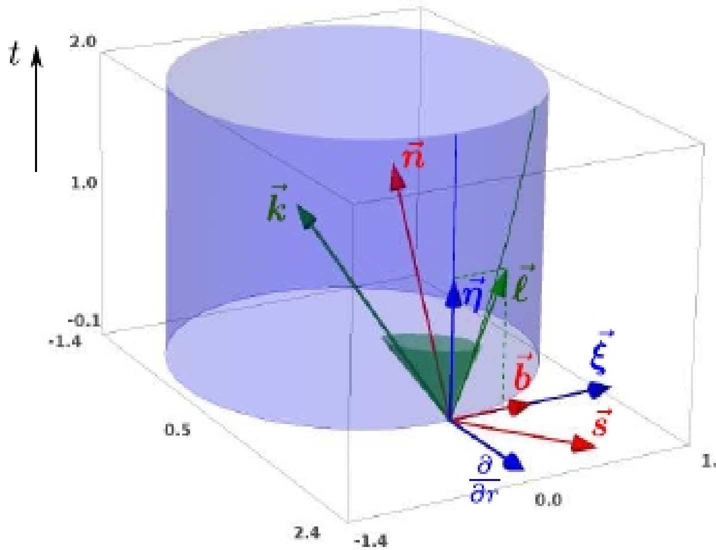
$$\dot{M} = (\dot{M}^+ - \dot{M}^-); \quad \dot{J} = (j^+\dot{M}^+ - j^-\dot{M}^-)$$

$$j = \frac{j^+ \dot{M}^+ + j^- \dot{M}^-}{\dot{M}^+ + \dot{M}^-}$$

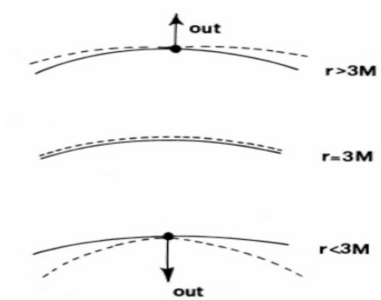
$$\mathcal{T} = 2\,\frac{\dot{M}^+ \dot{M}^- (j^+ - j^-)}{\dot{M}^+ + \dot{M}^-}$$

Abramowicz, Jaroszyński, Kato,
Lasota, Różańska, Sądowski
Astr. Ap., 521, A15, (2010)

Lasota, Gourgoulhon
Abramowicz, Tchekhovskoy, Narayan
Phys. Rev. D, 89, 024041 (2014)



INSIDE — OUTSIDE REVERSAL



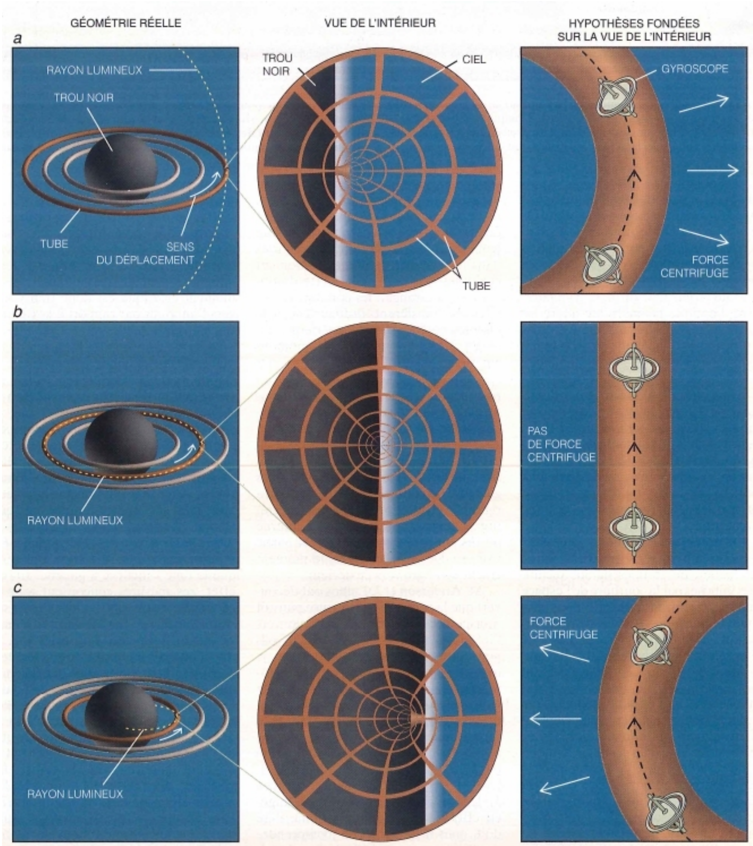
Abramowicz, Carter, Lasota (1988):
♣ **Optical Geometry**

Abramowicz, Prasanna (1990):
♣ **Reversal of centrifugal force** ♣ **Reversal of gyroscope precession** ♣ **Reversal of Rayleigh criterion: $dj/dr < 0$ for stability**

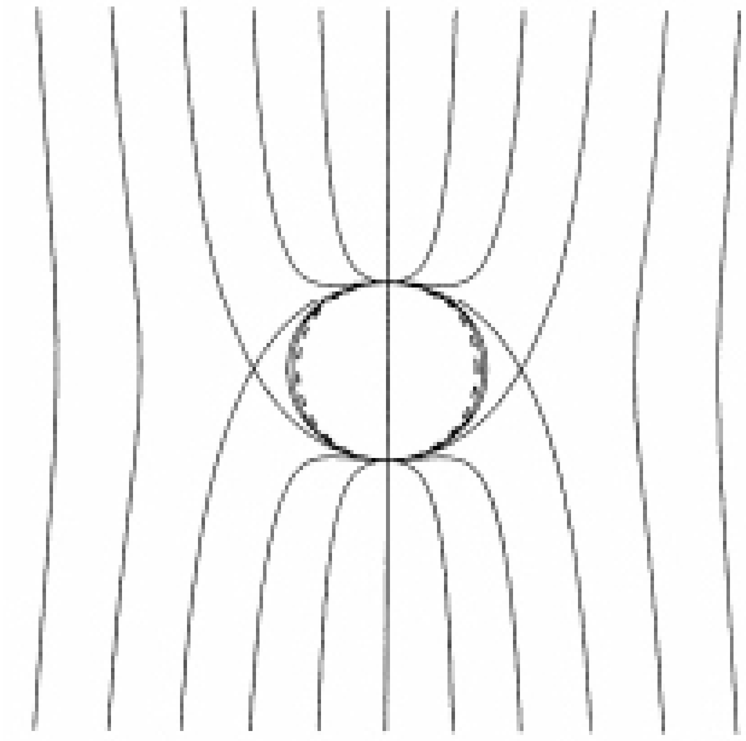
Anderson, Lemos (1988):
♣ **Reversal of the direction of angular momentum transport**

Chandrasekhar, Miller (1974); Abramowicz, Miller (1990)
♣ **Reversal of the ellipticity behaviour of collapsing Maclaurin spheroids**

Abramowicz, Scientific American, March 1994



RADIUS OF GYRATION



Abramowicz, Miller, Stuchlík (1993)
Phys. Rev. D 47, 1440

Abramowicz, Nurowski, Wex, (1995)
Class. Quantum Grav. 12, 1467

$$\eta^i = \text{time Killing}$$
$$\xi^i = \text{axial Killing}$$

$$n^i = \frac{\eta^i}{(\eta\eta)^{1/2}} \quad \tau^i = \frac{\xi^i}{(-\xi\xi)^{1/2}}$$

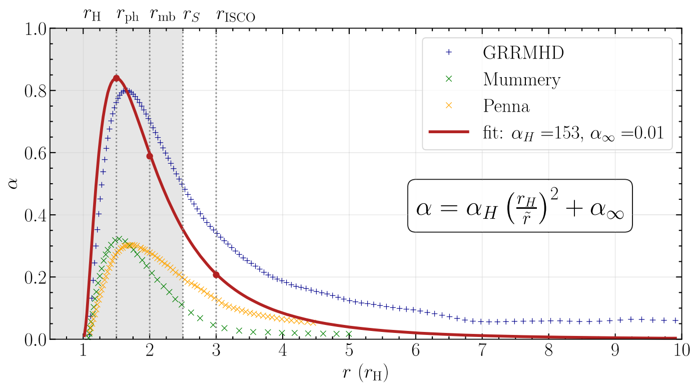
$$\Phi = -\frac{1}{2}\ln(\eta\eta) \quad \tilde{r}^2 = -\frac{(\xi\xi)}{(\eta\eta)}$$

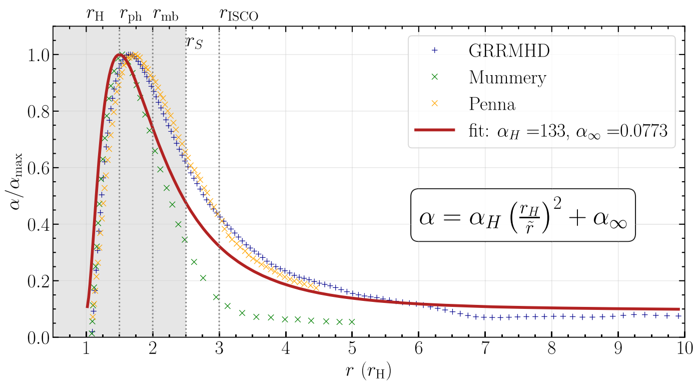
$$u^i = \gamma(n^i + v\tau^i) \quad a_k = u^i \nabla_i u_k$$

$$a_k = \nabla_k \Phi + \frac{(\gamma v)^2}{\tilde{r}} \nabla_k \tilde{r}$$

$$v = \tilde{r}\Omega \quad j = \tilde{r}^2\Omega$$

OUR ALPHA PRESCRIPTION





Abramowicz, Brandenburg, Horák, Lančová, Miller, Szuszkiewicz Wielgus

$$\boldsymbol{\alpha = \alpha_H \left(\frac{1}{\tilde r^2}\right) + (\eta\eta)\,\alpha_\infty}$$

THE END