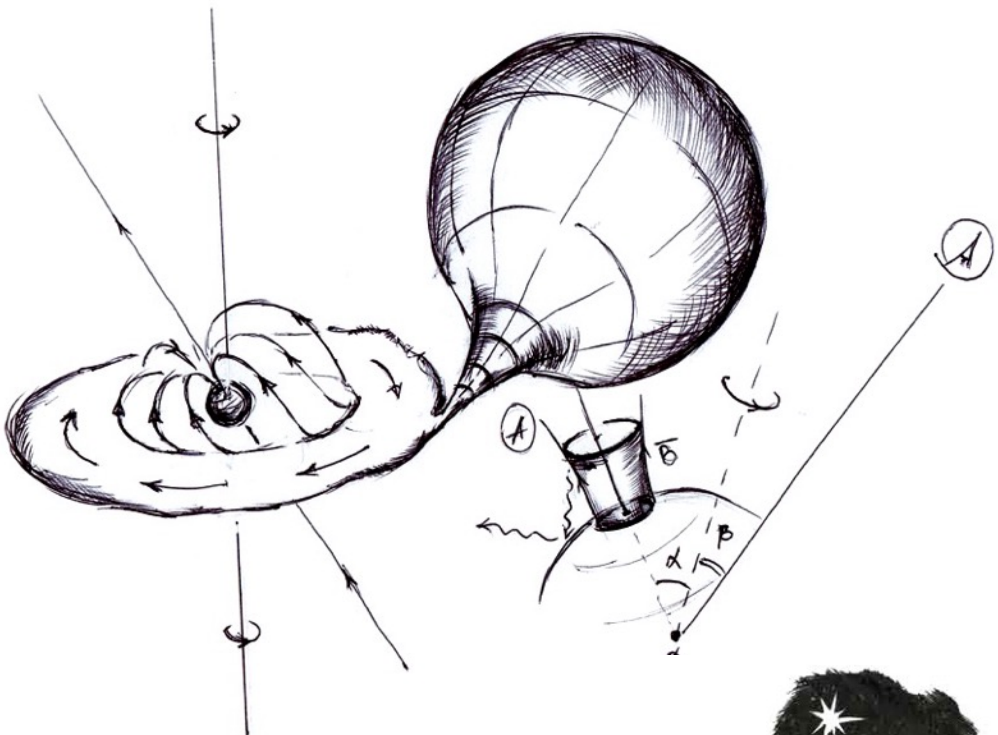


Accretion geometry of ULX pulsars

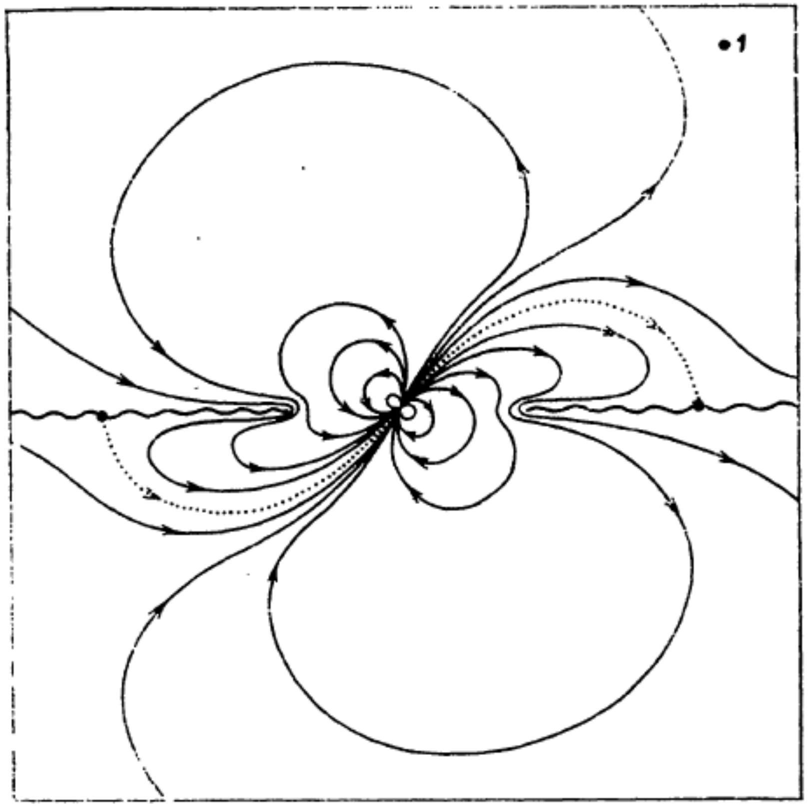
Alexander A. Mushtukov

8 June 2018
Madrid

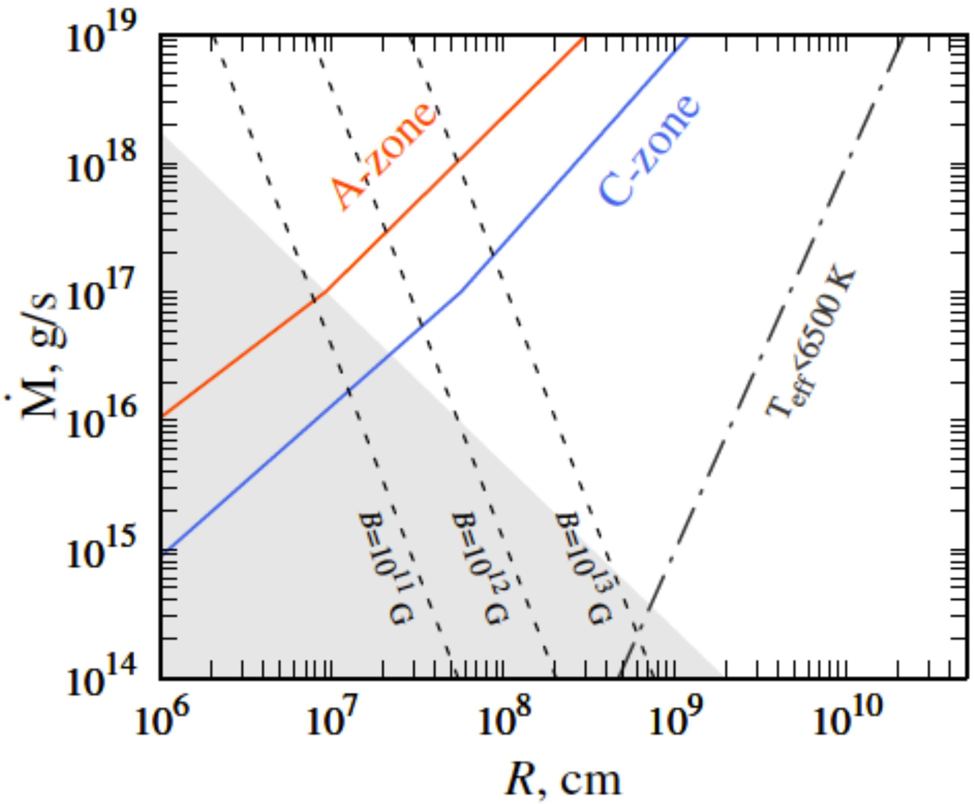
UNIVERSITY OF AMSTERDAM

ANTON PANNEKOEK INSTITUTE

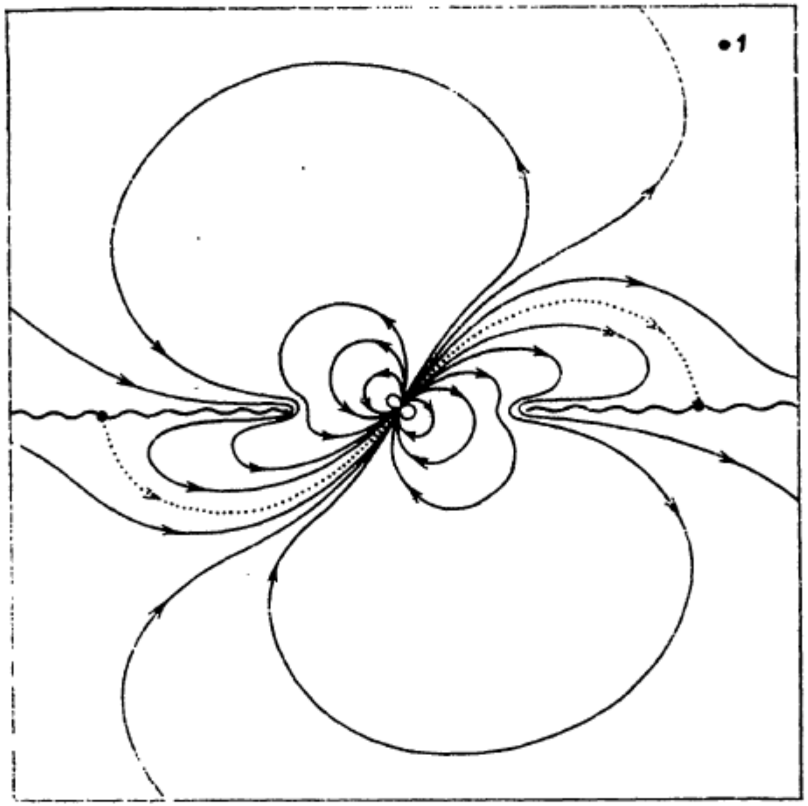
Accreating magnetized neutron stars: X-ray pulsars



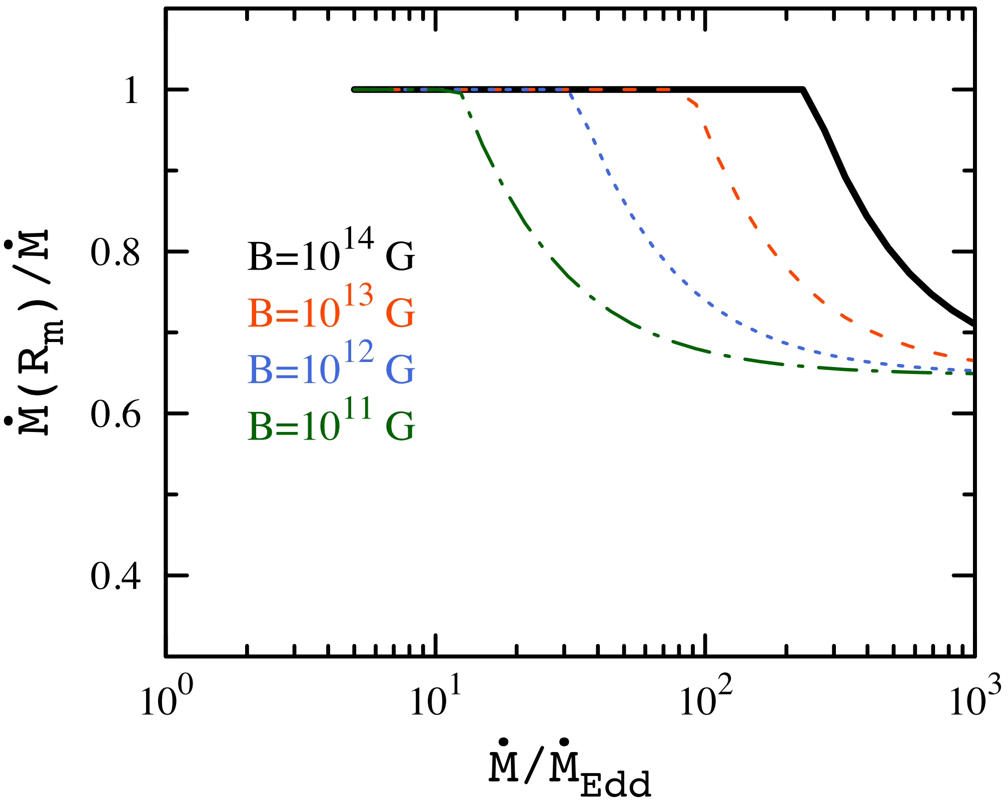
Accretion discs in XRPs



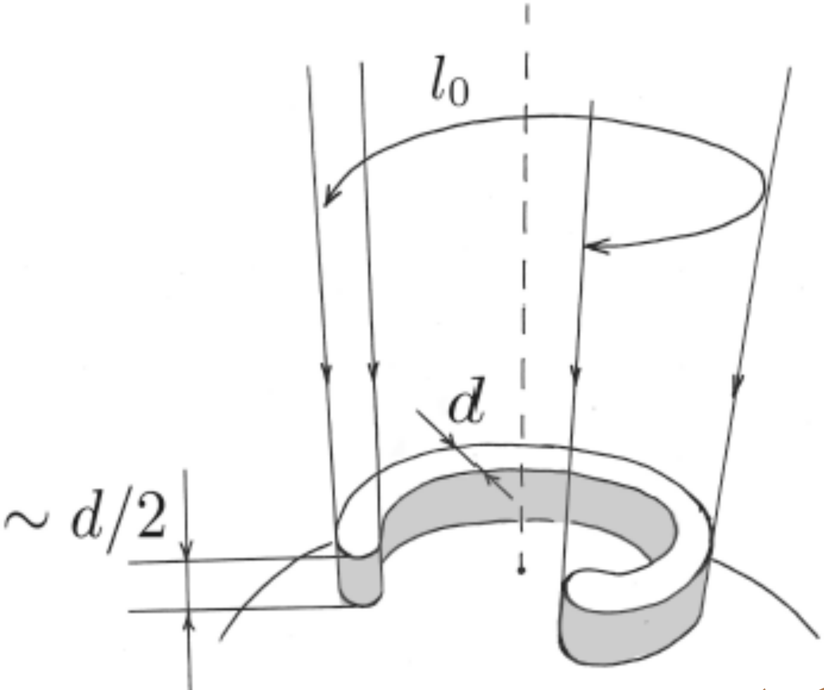
Accreating magnetized neutron stars: X-ray pulsars

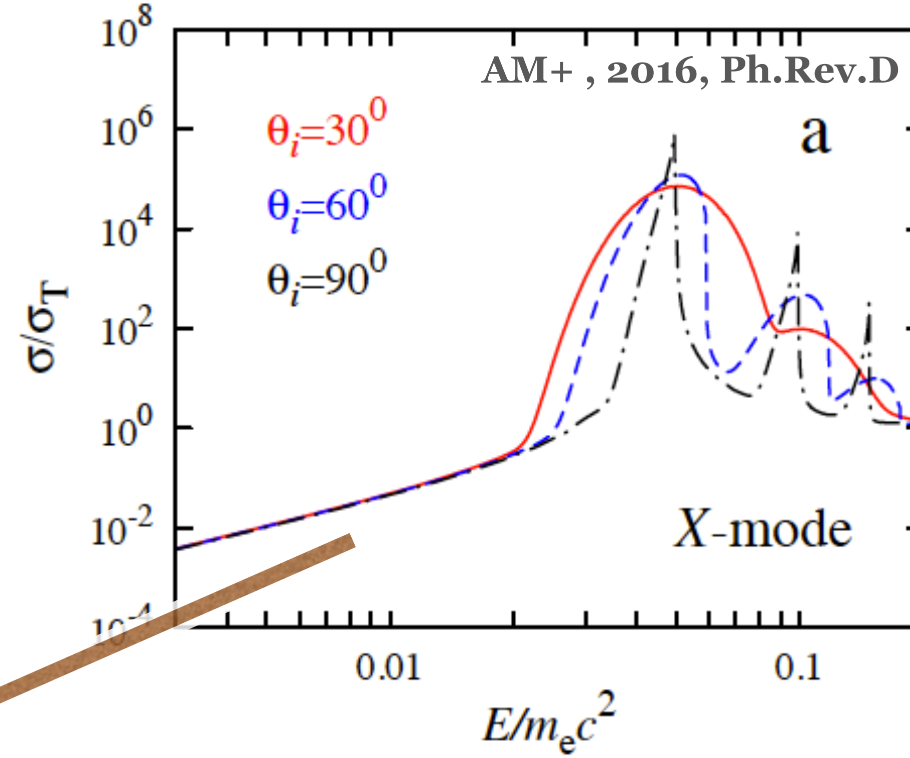


Mass outflow and mass accretion rates at the magnetosphere



Critical luminosity: matter is stopped by radiation



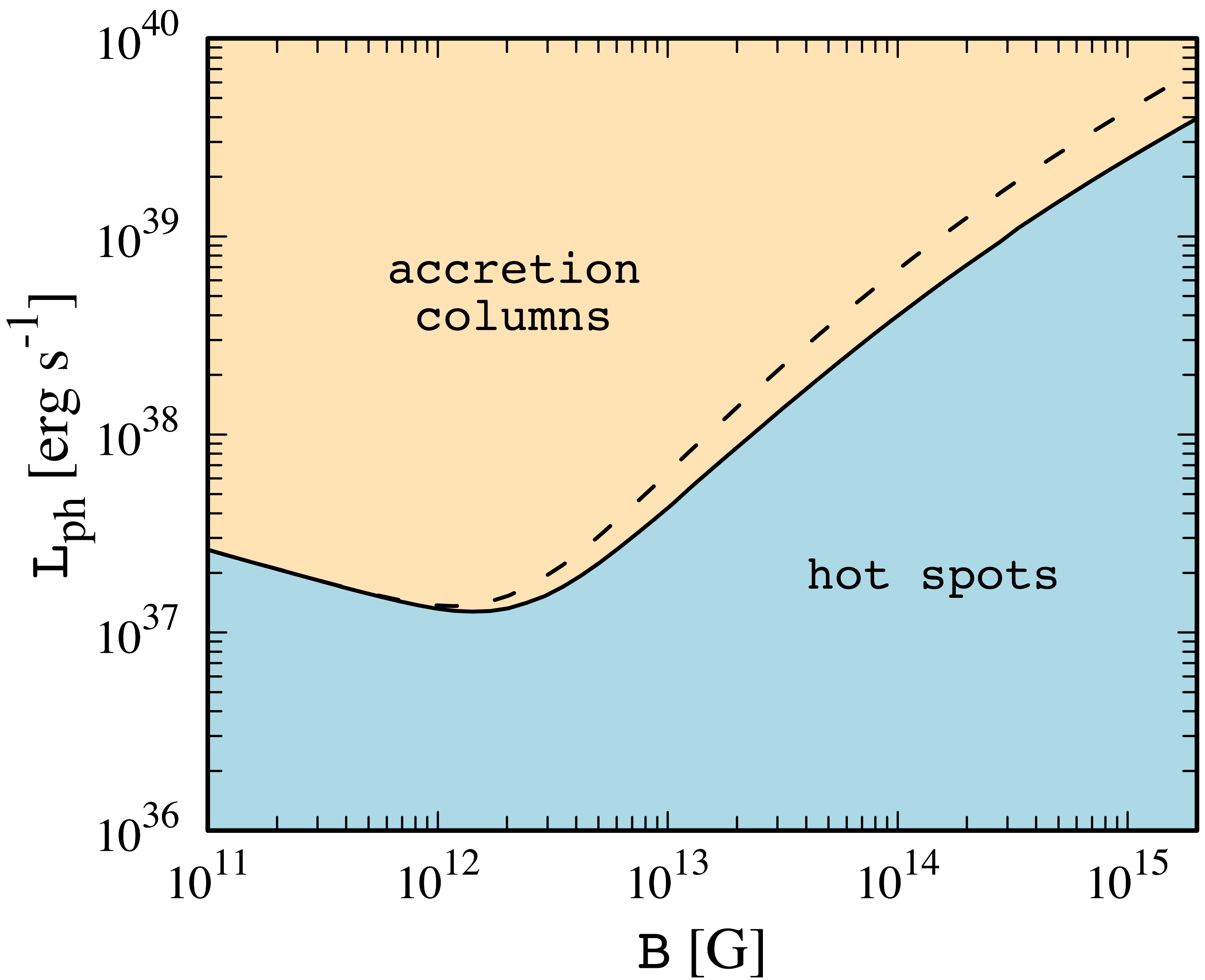


$$L^* = 4\times10^{36}\left(\frac{\sigma_T}{\sigma_{eff}}\right)\left(\frac{l_0}{2\times10^5[cm]}\right)\frac{1}{R_6}\frac{M}{M_\odot}\quad[\mathrm{erg\ s^{-1}}]$$

$$L_{\mathrm{Edd}} = \frac{4\pi G M m_{\mathrm{p}} c}{\sigma_{\mathrm{T}}} \approx 1.3\times10^{38}\frac{M}{M_\odot}\ \mathrm{erg\ s^{-1}}$$

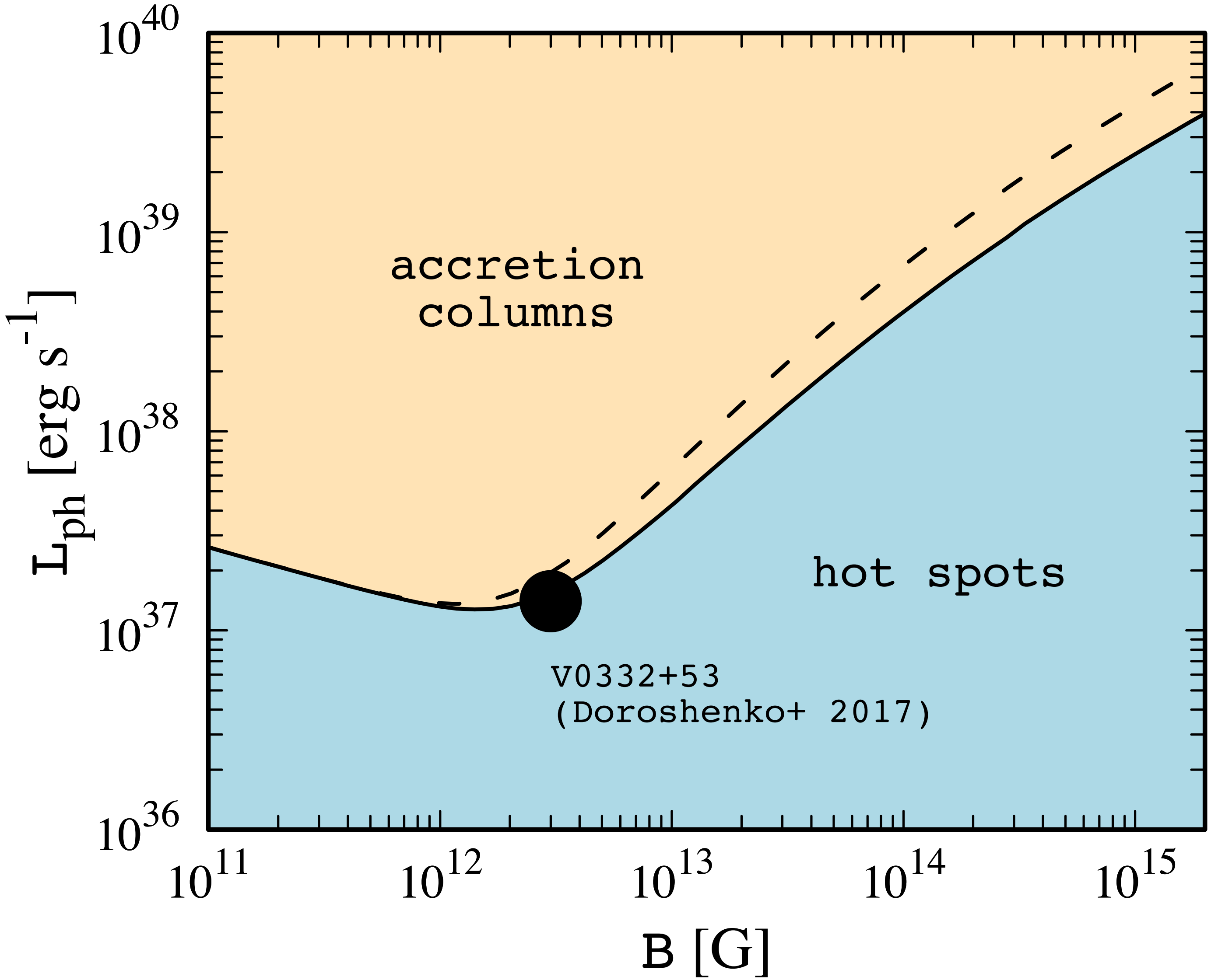
Basko & Sunyaev, 1976, MNRAS, 175
AM+, 2015, MNRAS, 447

Critical luminosity



AM+ 2015, MNRAS, 447

Critical luminosity



AM+ 2015, MNRAS, 447

Above the critical luminosity: accretion column

Dipole magnetic field.

*

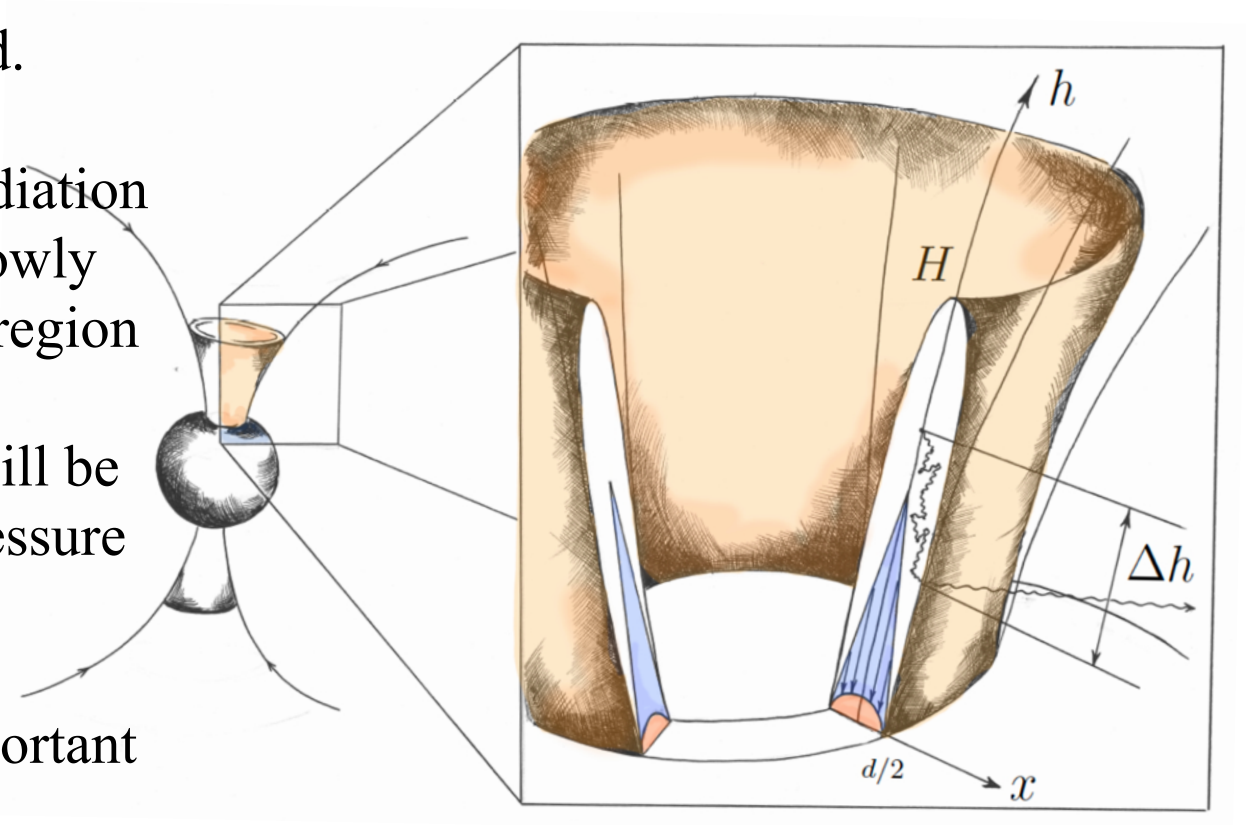
Accretion flow stops at radiation dominated shock and slowly settles in inside a sinking region

*

The gravitational force will be offset by the radiation pressure gradient only

*

The gas pressure is unimportant



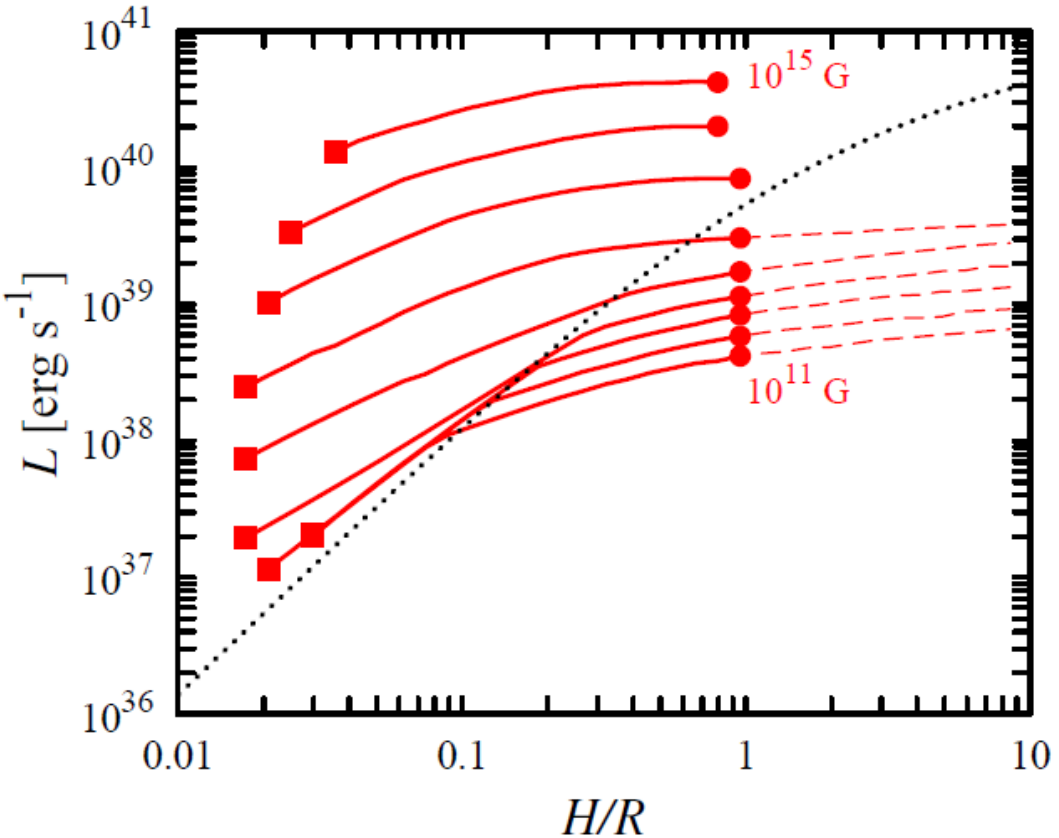
Analytical estimation:

$$L(H=R) \approx 1.8 \times 10^{39} \left(\frac{l_0/d_0}{50}\right) \left(\frac{\kappa_T}{\kappa_\perp}\right) \frac{M}{M_\odot} \mathrm{erg\,s^{-1}}$$

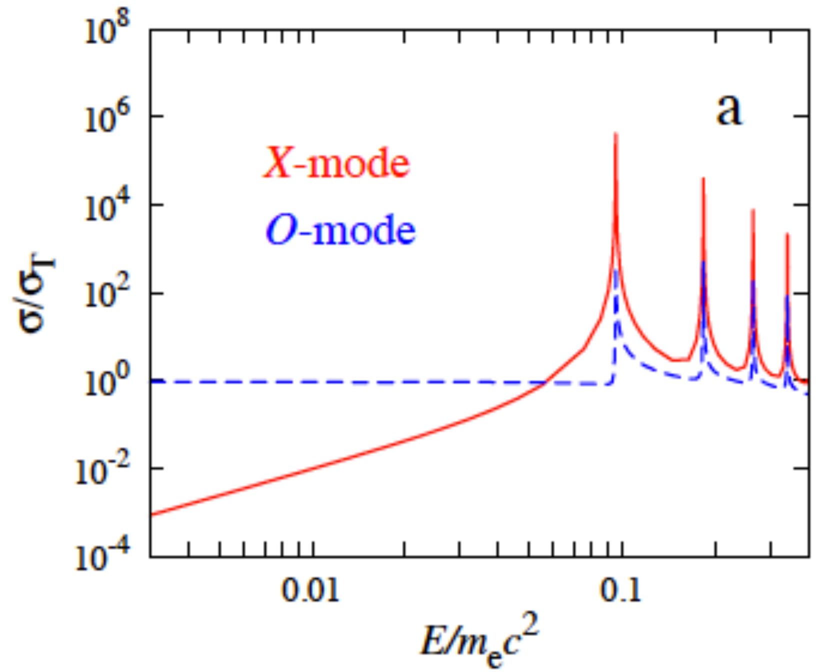
AM+ 2015, MNRAS, 454

Accretion column: height and luminosity

Luminosity of accretion column as a function of column height



Scattering cross-section:
The higher the mass accretion rate
=> the higher the temperature
=> the higher photon energy
=> the higher the cross-sections

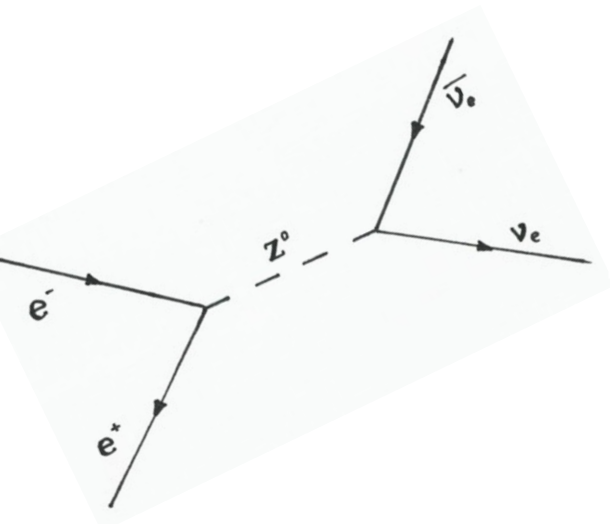


AM+ 2015, MNRAS, 454

Neutrino pulsars

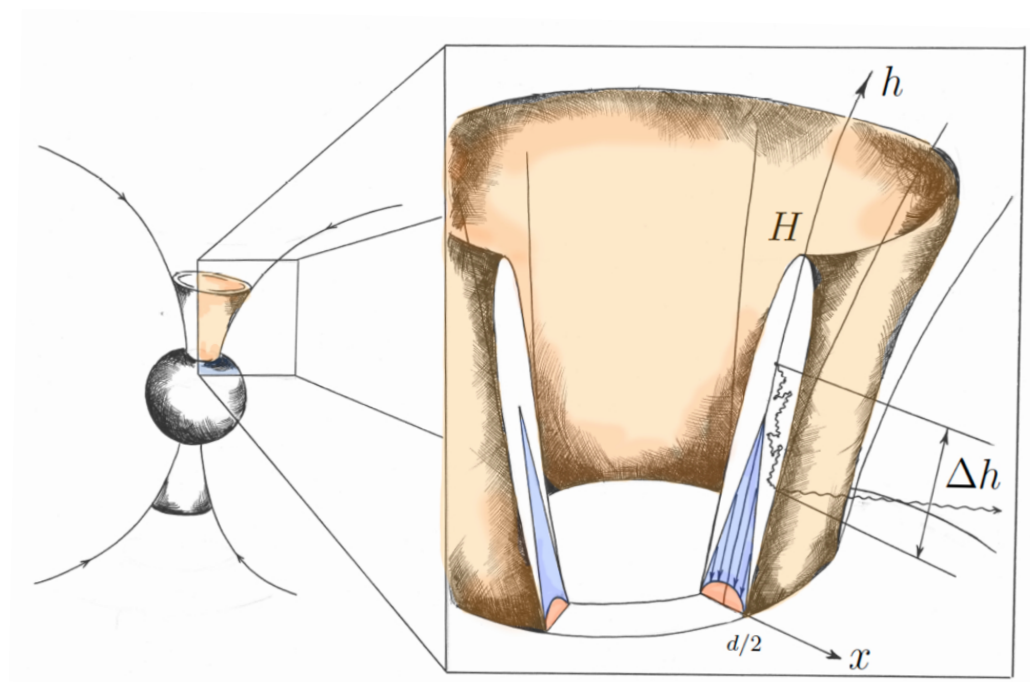
Typical time of photon escape:

$$t_{\rm diff} = \frac{\tau d}{2c} \approx 5 \times 10^{-4} \, \frac{\dot{m}_{10} d_4^2 \kappa_{\rm e}}{\beta} \;\; {\rm s}$$



$$\frac{\partial}{\partial h}\left[\left(-\frac{\rho G M}{R+h} + \frac{\rho v^2}{2} + \varepsilon_{\rm tot} + P_{\rm tot} + 2 n_+ m_{\rm e} c^2\right) v\right] = Q^-$$

$$e^- + e^+ \longrightarrow \nu + \overline{\nu}$$



The total accretion luminosity:

$$L_{\rm tot} = \frac{GM\dot{M}}{R} = L_{\rm ph} + L_\nu$$

AM+ 2018, MNRAS,476

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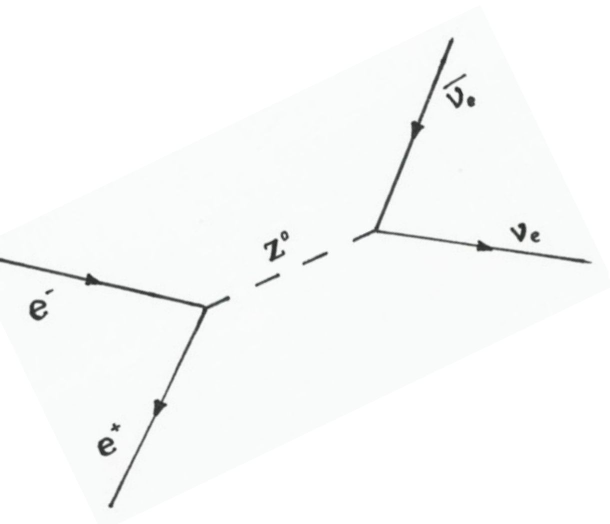

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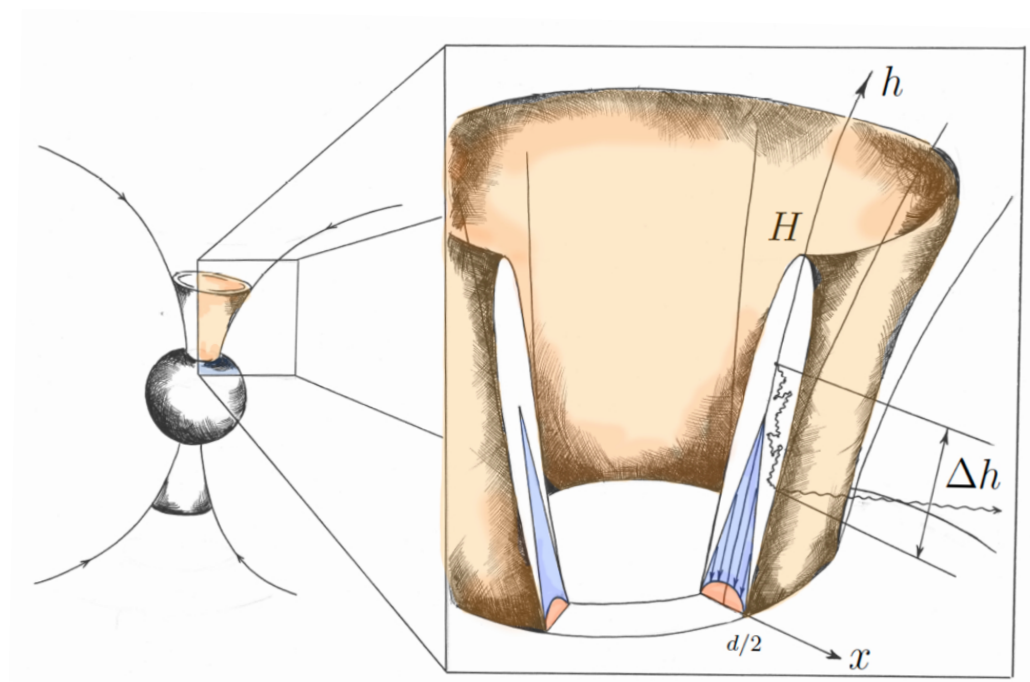

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AM+ 2018, MNRAS,476

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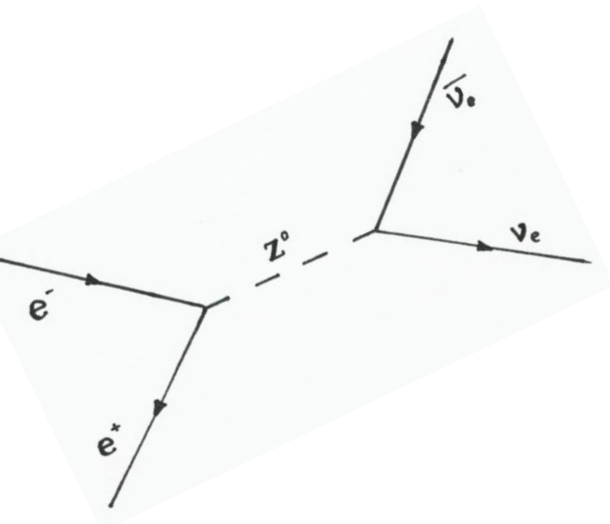

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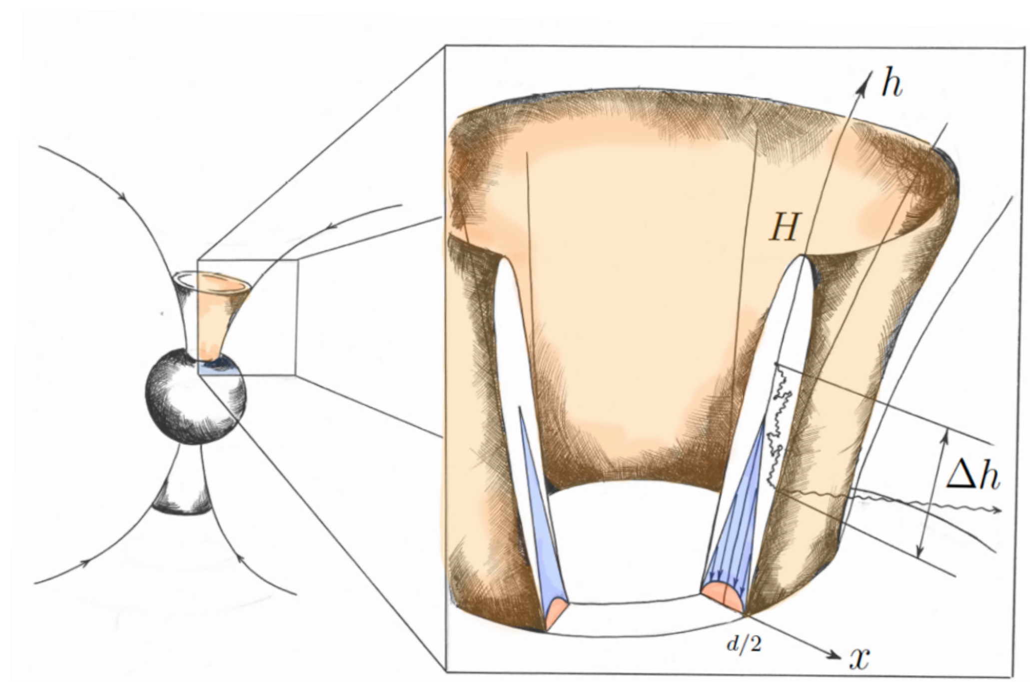

AM+ 2018, MNRAS,476

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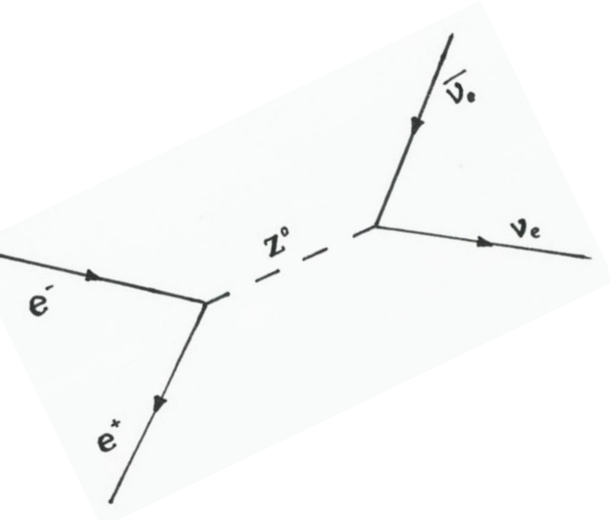

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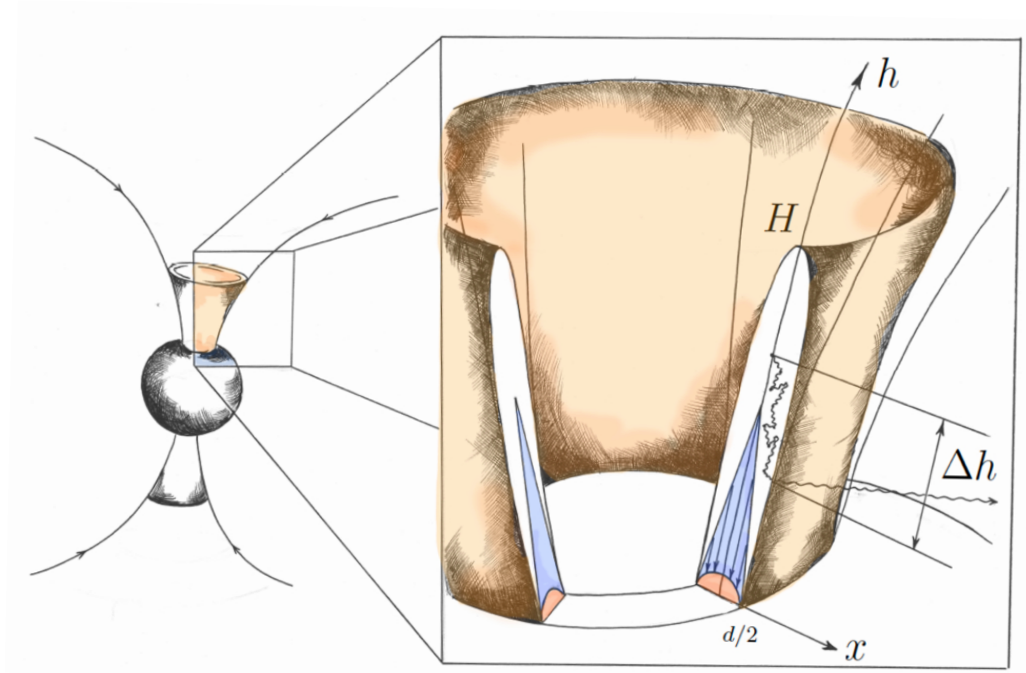

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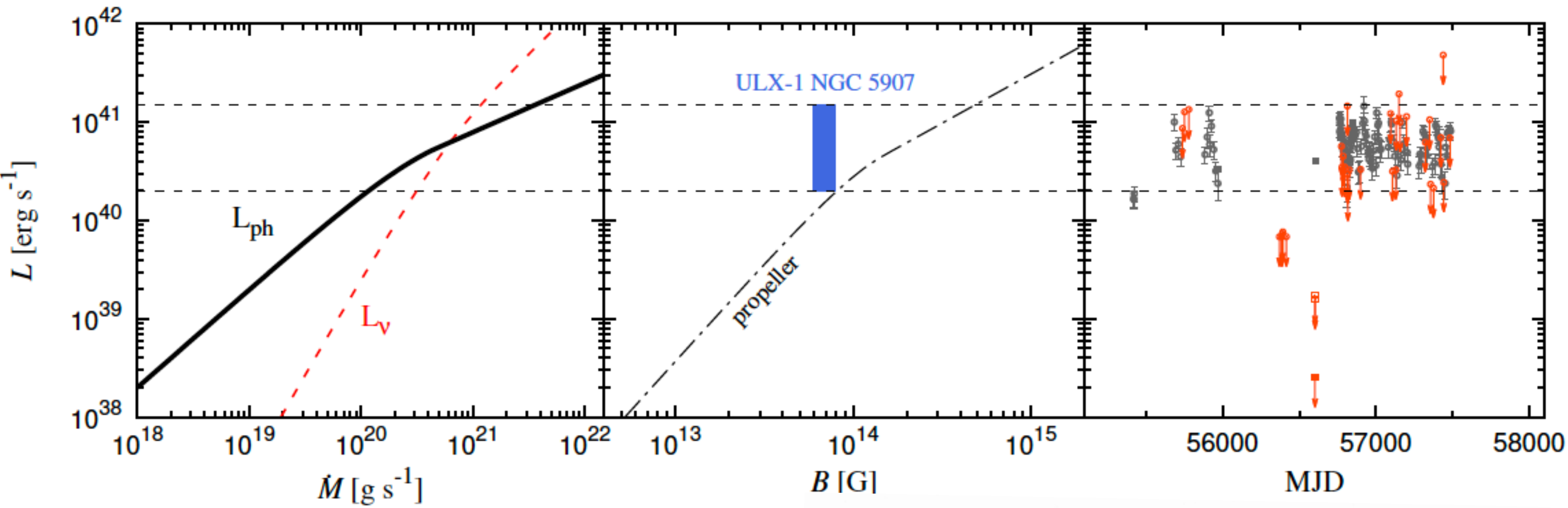
AM+ 2018, MNRAS,476

Neutrino pulsars



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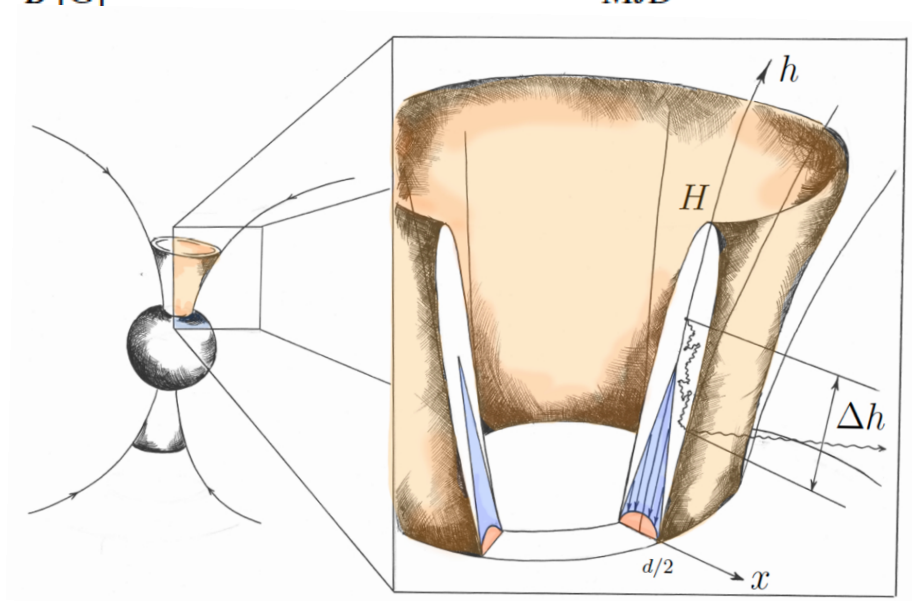
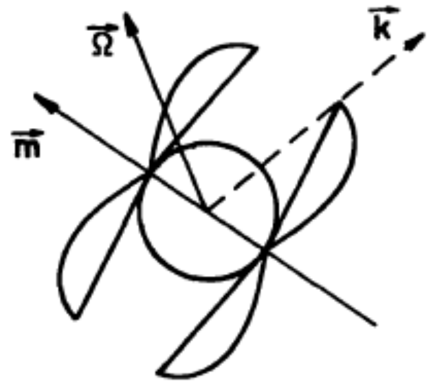


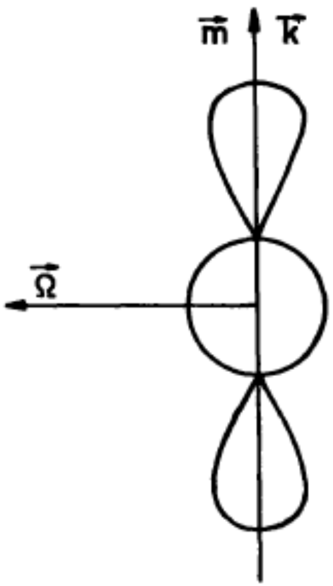
AM+ 2018, MNRAS,476

Accretion column: radiation beaming

Accretion column case

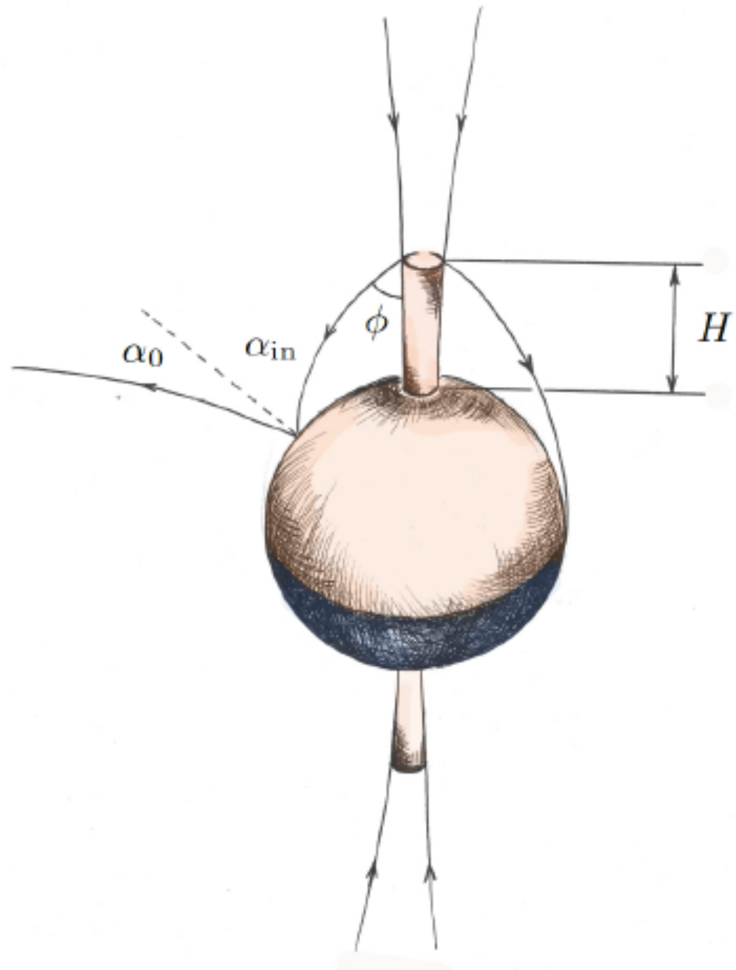


Hot spots case



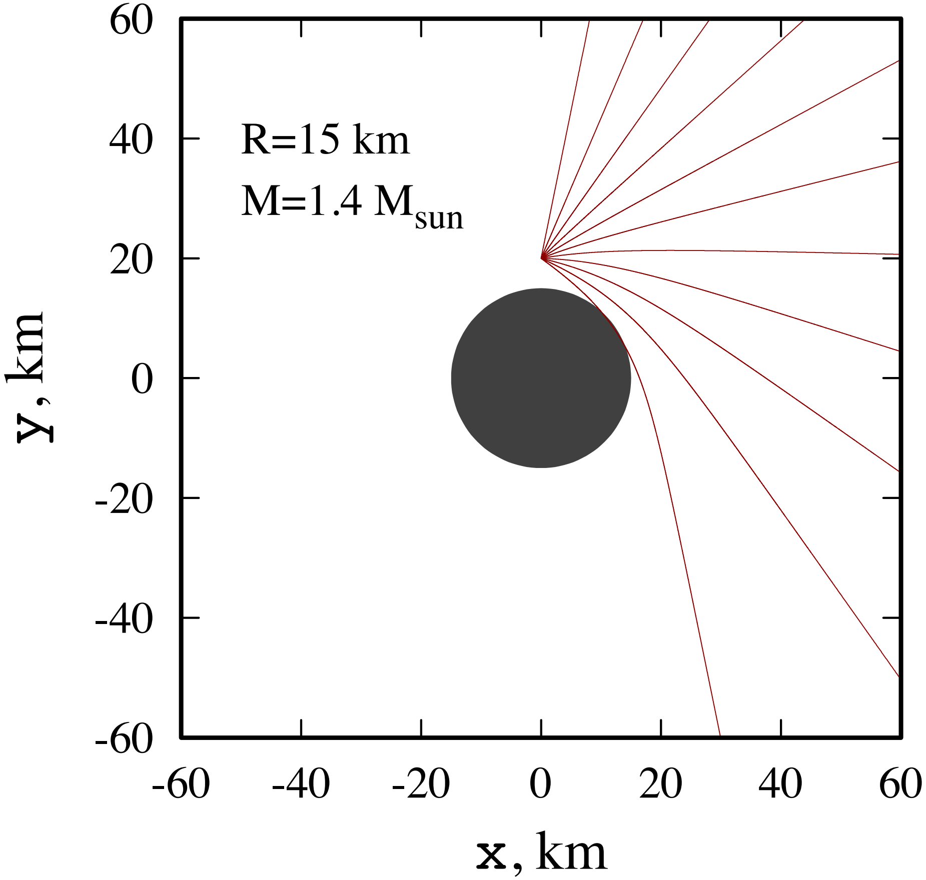
Gnedin, Sunyaev 1973, A&A,25

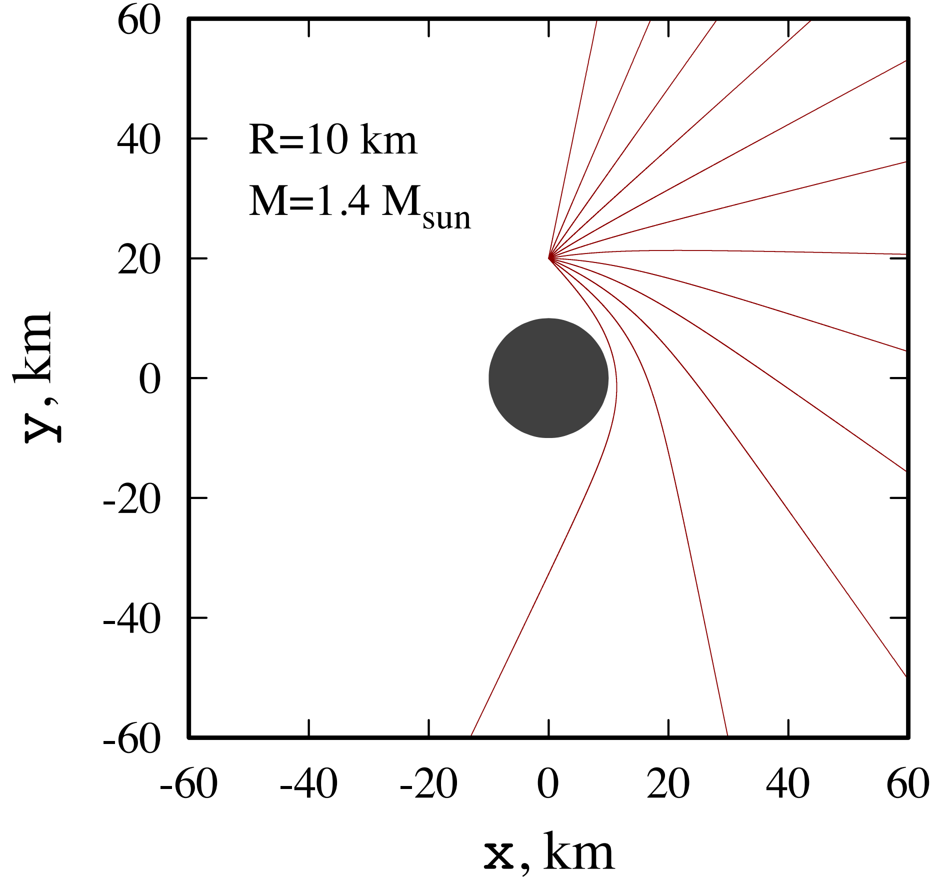
Accretion column: radiation beaming



AM+ 2018, MNRAS, 747, 5425

Accretion column: radiation beaming





AM+ 2018, MNRAS, 747, 5425

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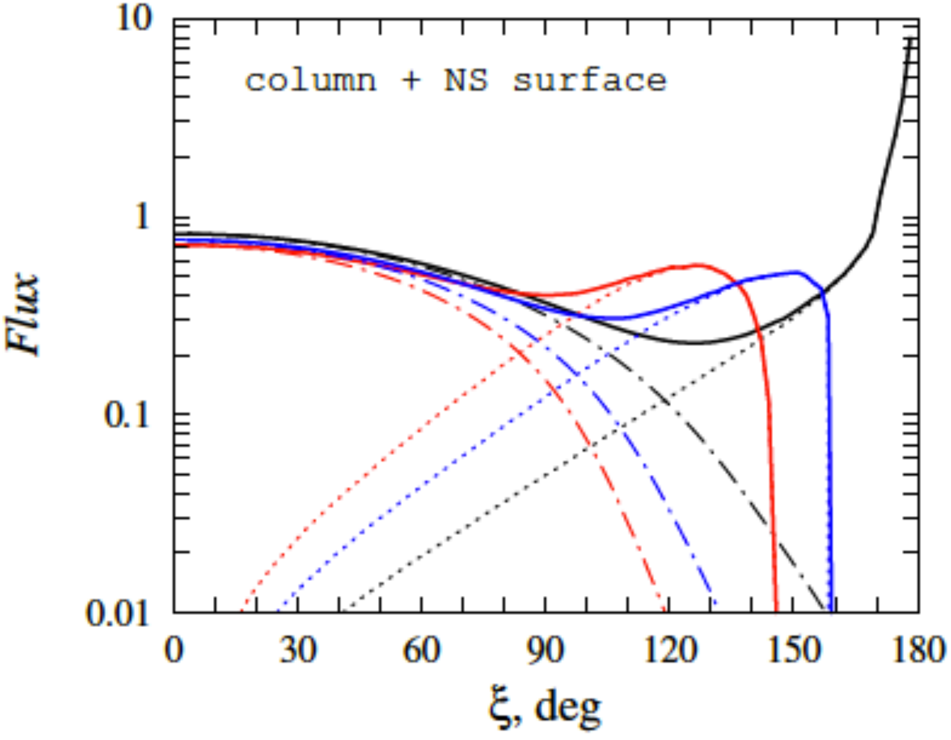

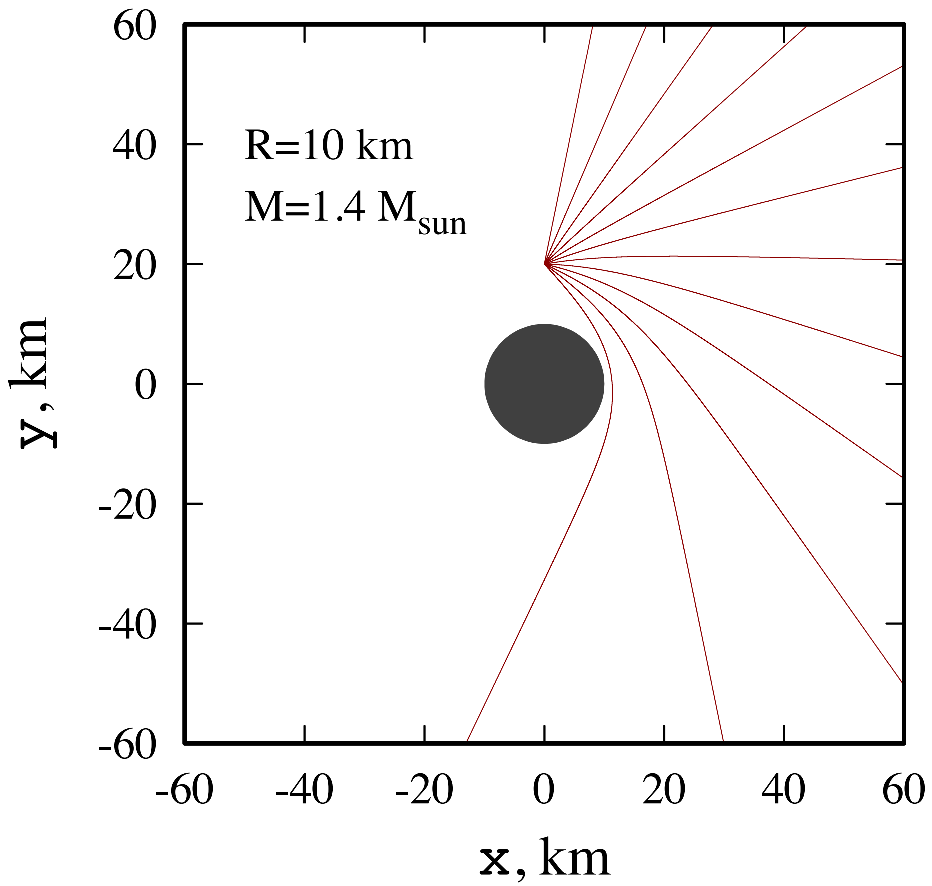

AM+ 2018, MNRAS, 747, 5425

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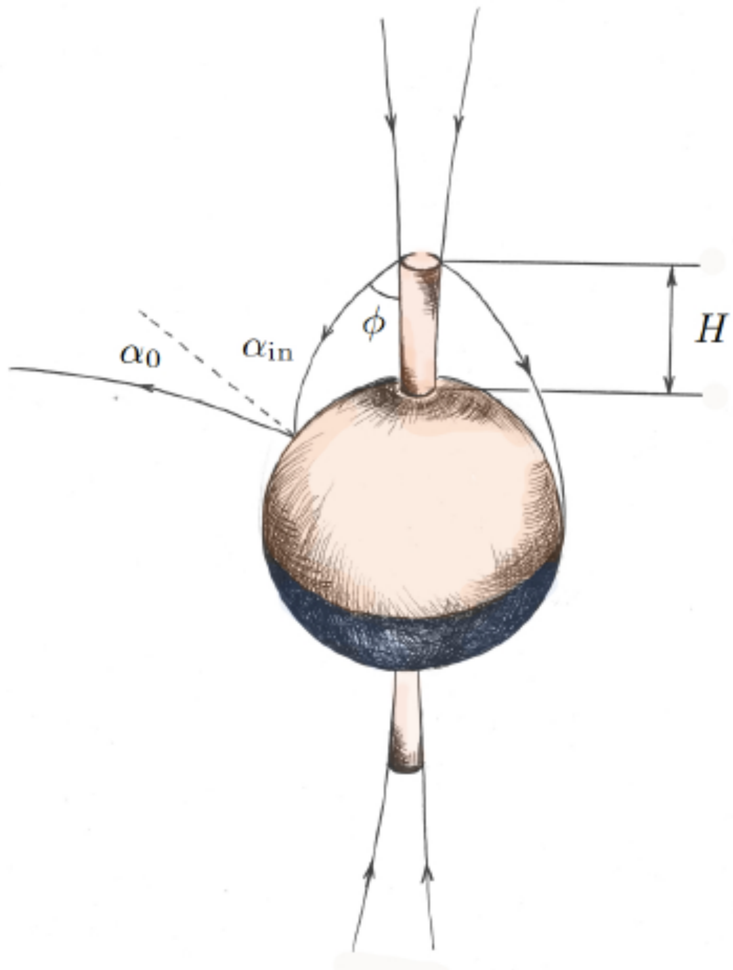
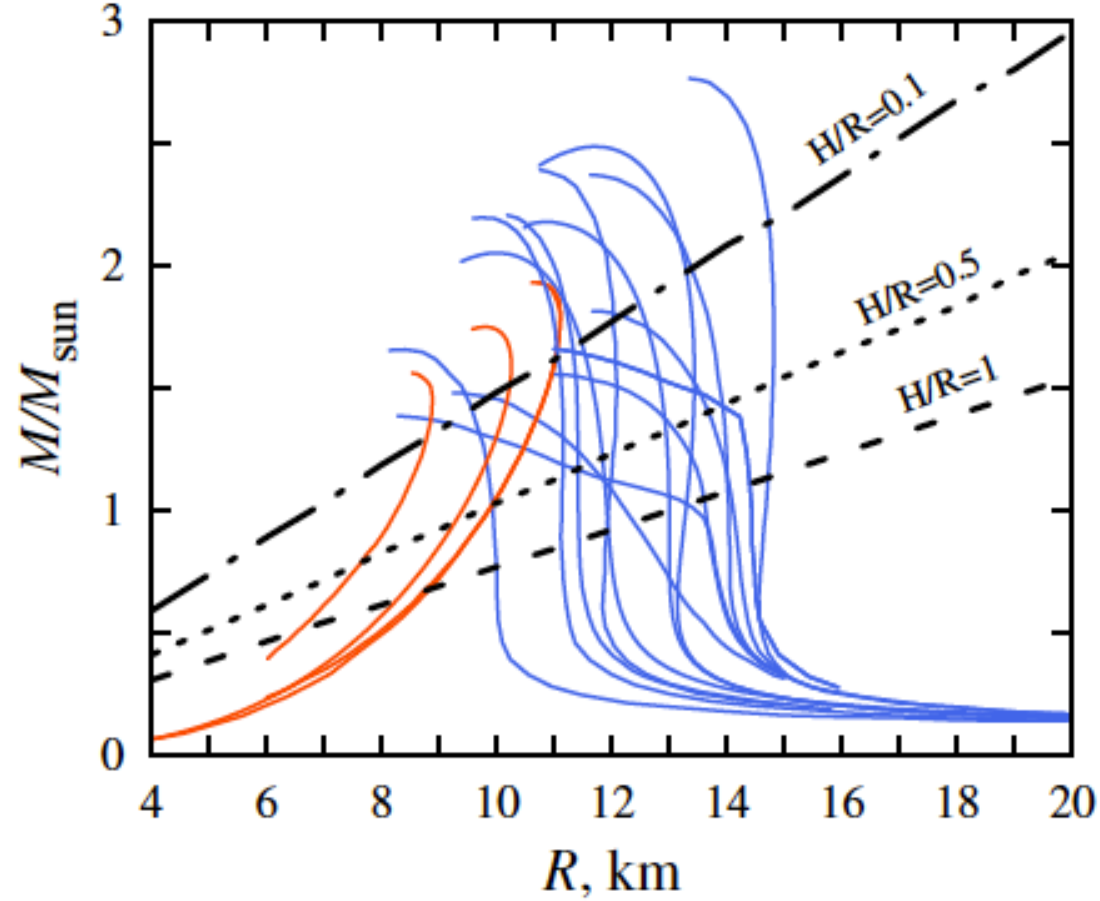
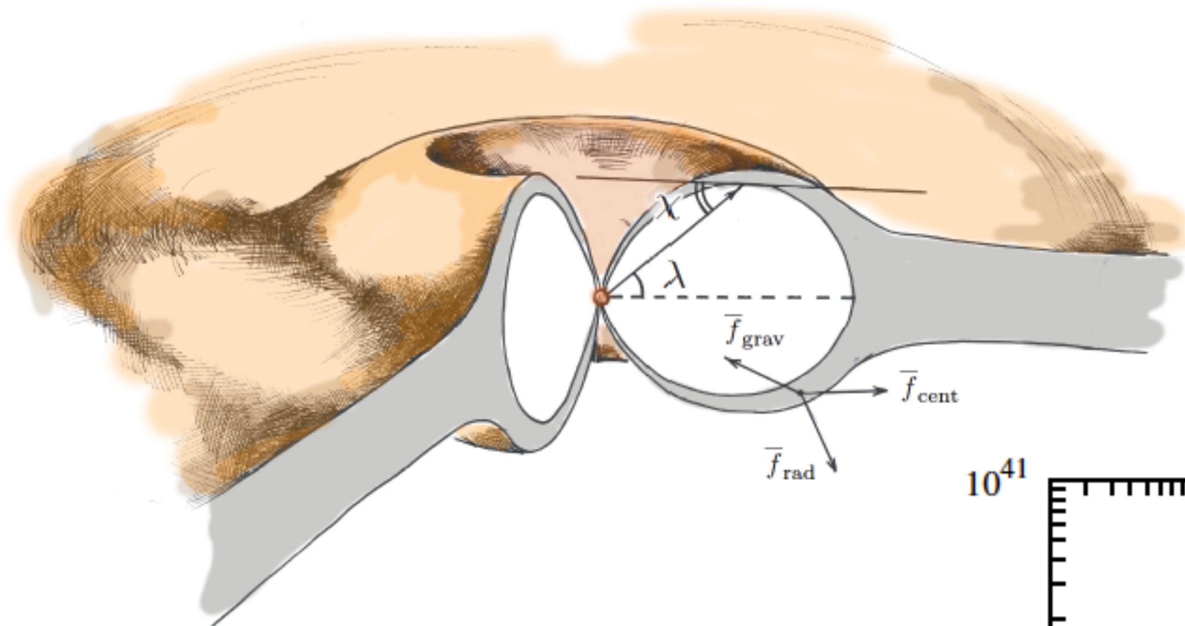


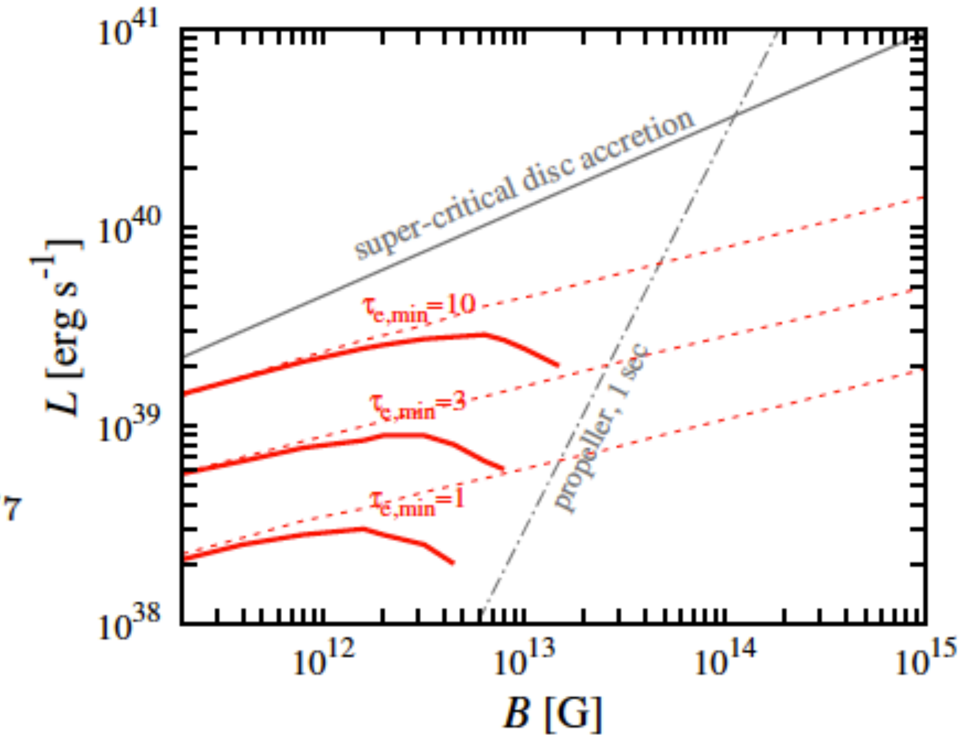
Accretion column eclipses
and
neutron star mass-radius relation



AM+ 2018, MNRAS, 747, 5425

Accretion envelope





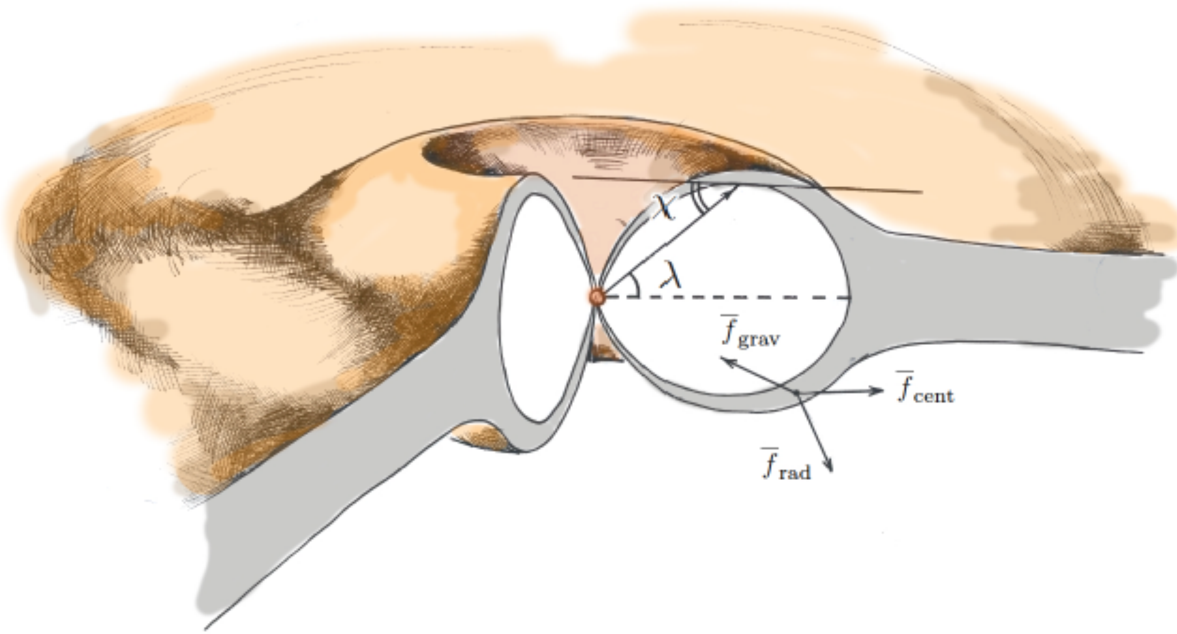
Stability

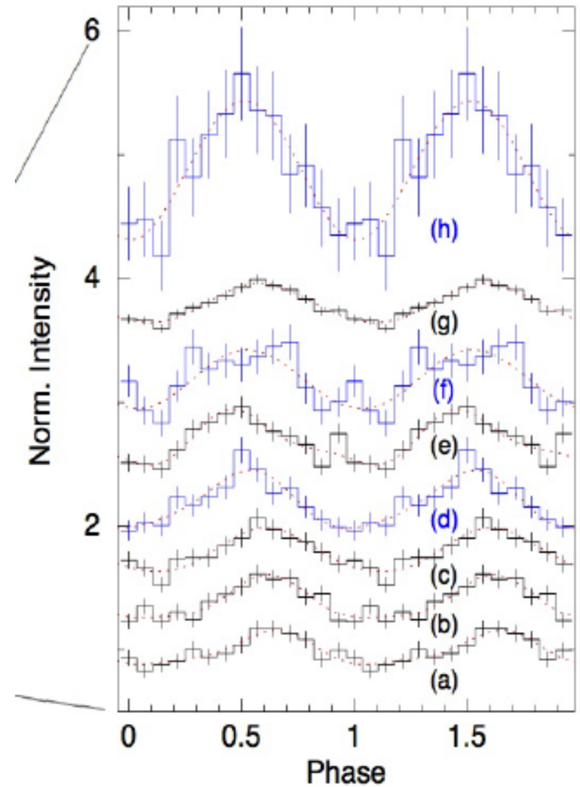
$$P_{\rm mag}(\lambda = 0) \propto L^{12/7} B^{-10/7}$$

$$\frac{P_{\rm rad}}{P_{\rm mag}} \lesssim 7 \times 10^{-2} \tau L_{39}^{-1/7} B_{12}^{2/7} m^{2/7} R_6^{-2/7}$$

AM+ 2017, MNRAS, 467

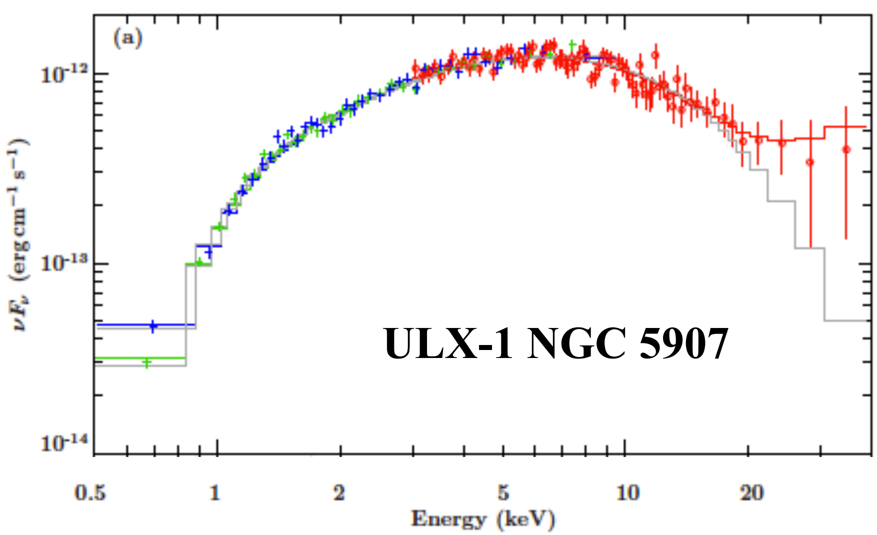
Accretion envelope





Israel+, Science, 2017

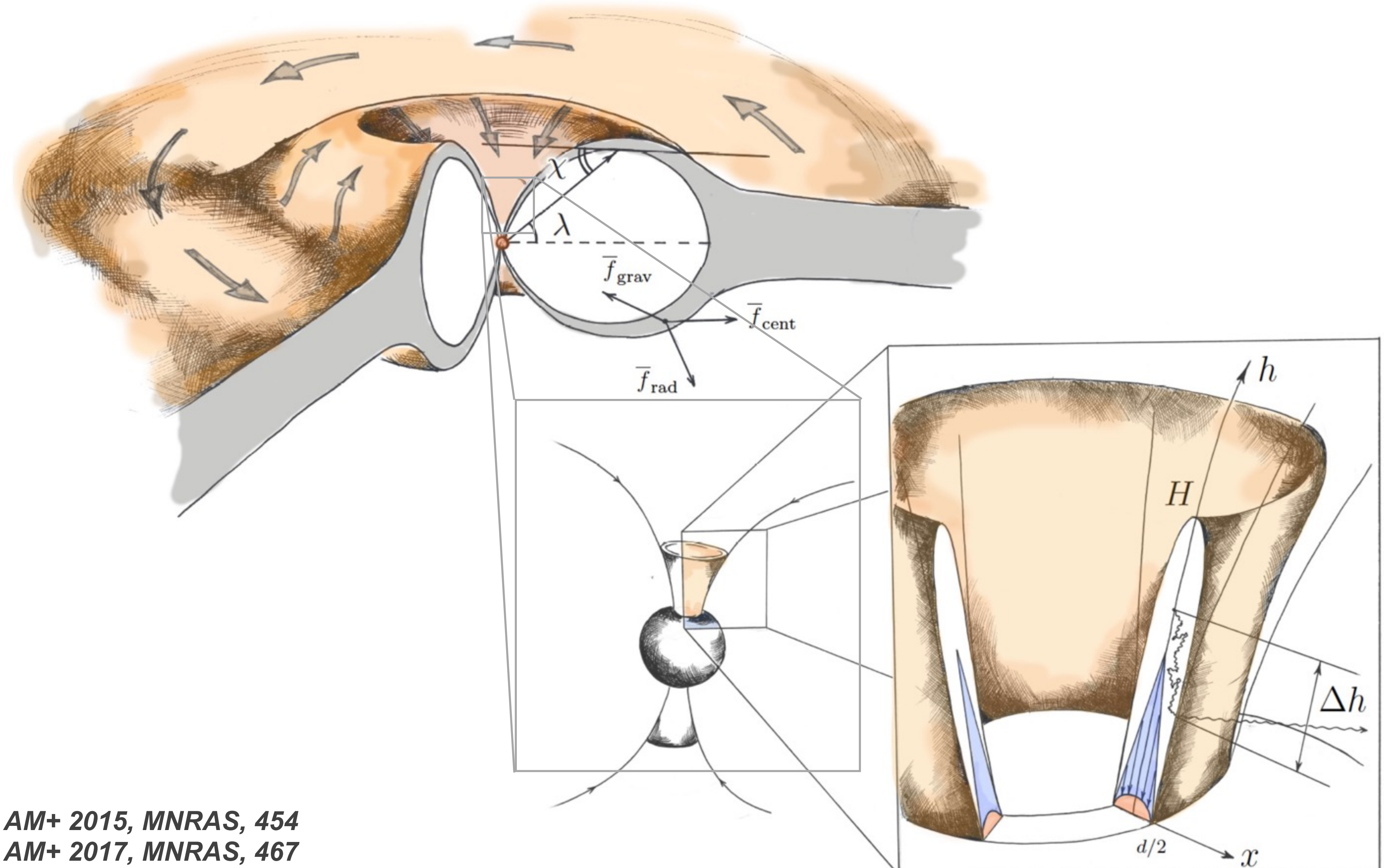
Some consequences:
- we hardly see the central NS directly
- multicolour black-body spectrum
- smooth pulse profiles
- super-orbital variability because of precession of magnetic dipole



AM+ 2017, MNRAS, 467

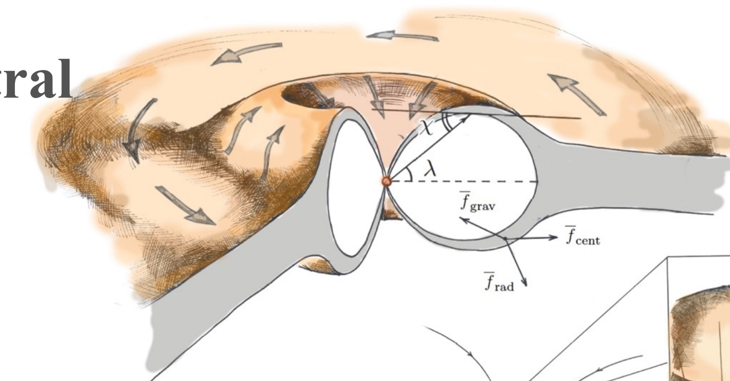
Fuerst+ 2016

Geometry of ULXPs

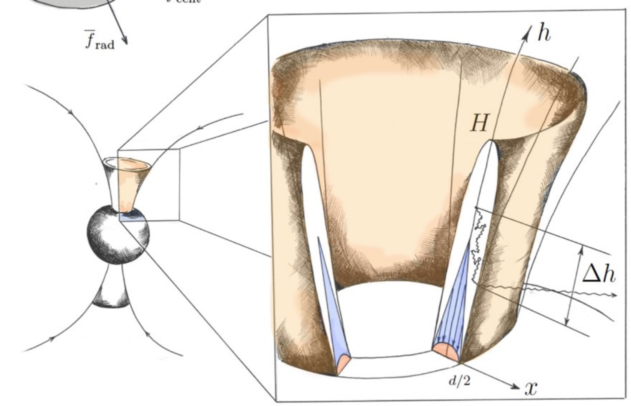


AM+ 2015, MNRAS, 454
AM+ 2017, MNRAS, 467
AM+ 2018, MNRAS, 476

Conclusions



(1) Accretion columns are the central engines in ULXs;
their luminosity is strongly affected by geometry (!)



(2) Advective accretion columns can produce strong neutrino emission

(3) The X-ray flux from accretion column is strongly lensed by NS gravitational field

(4) Bright ULXPs are surrounded by optically thick envelopes
- observational manifestation
- principal possibility of accretion

(5) We have to track bright transients to verify the theory of ULXPs