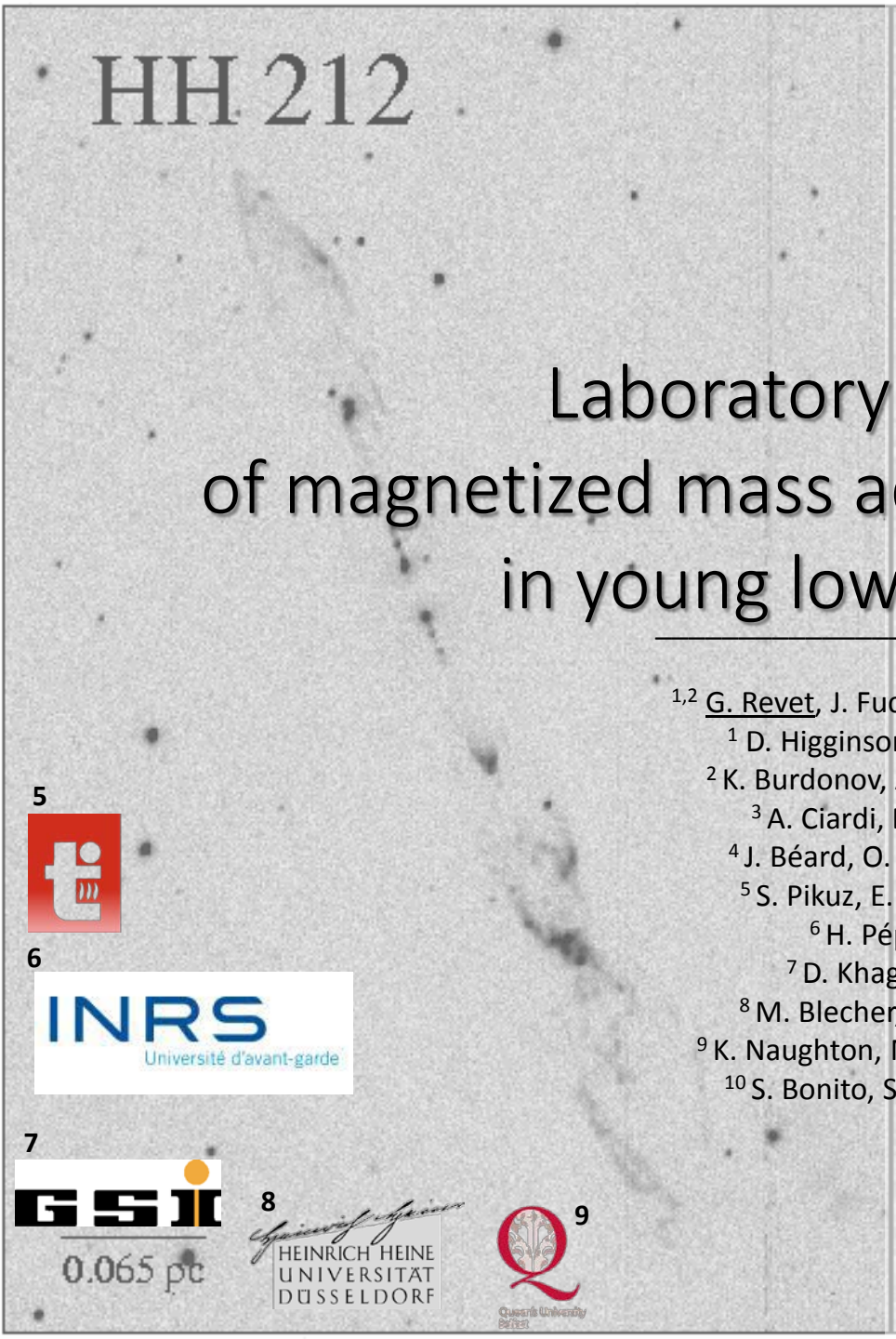
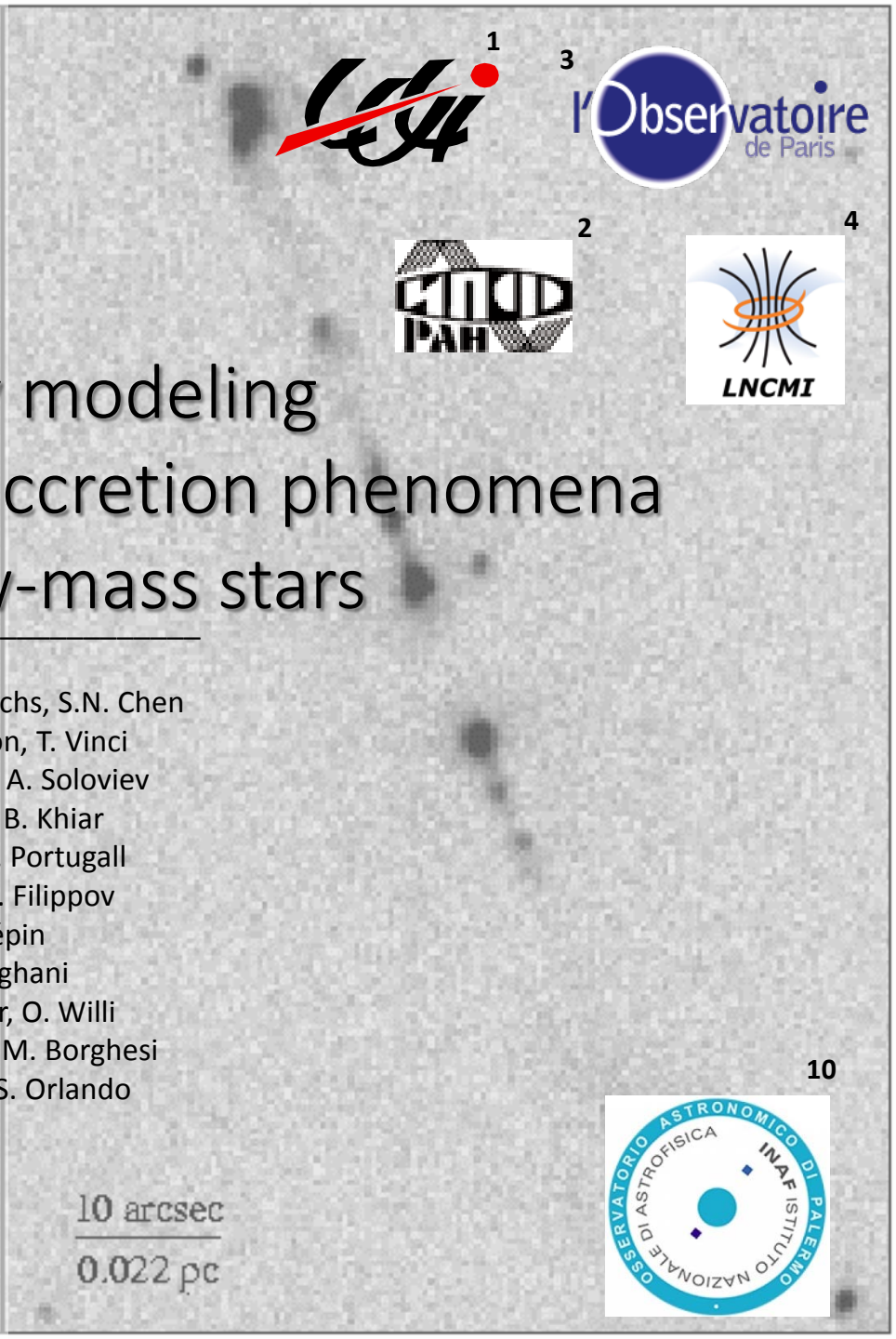
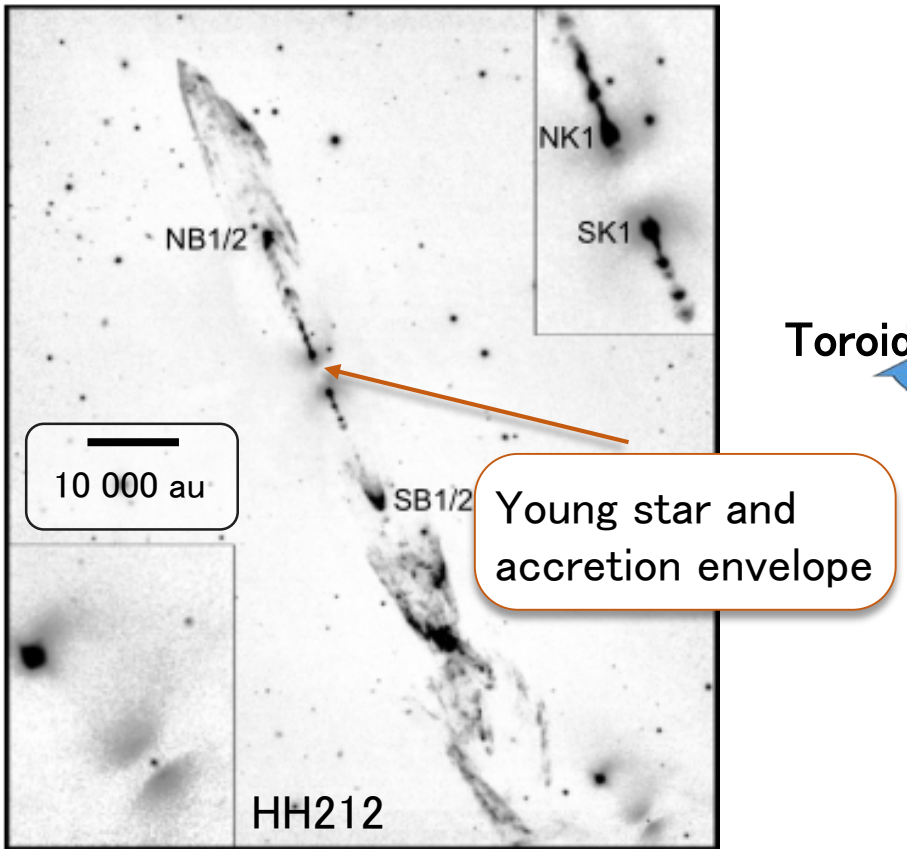


Laboratory modeling of magnetized mass accretion phenomena in young low-mass stars

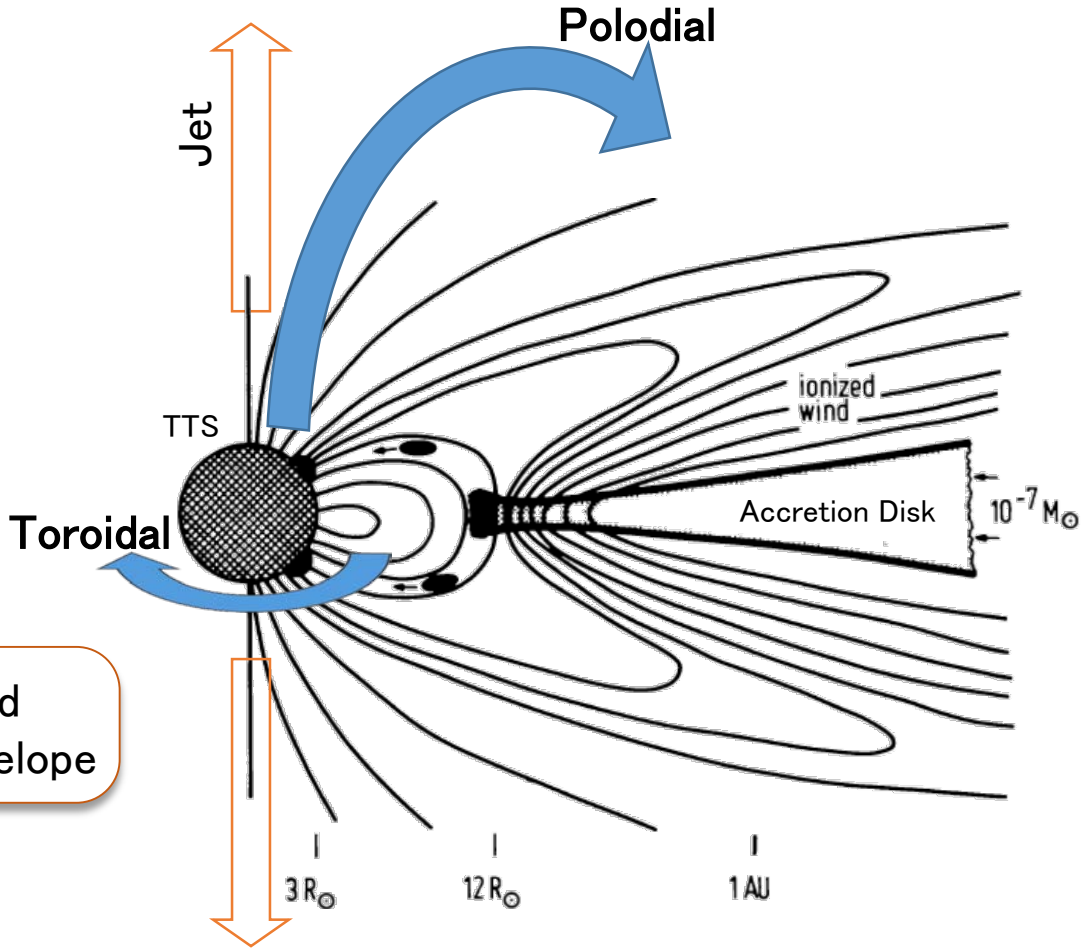
[1,2] G. Revet, J. Fuchs, S.N. Chen
[1] D. Higginson, T. Vinci
[2] K. Burdonov, A. Soloviev
[3] A. Ciardi, B. Khiar
[4] J. Béard, O. Portugall
[5] S. Pikuz, E. Filippov
[6] H. Pépin
[7] D. Khaghani
[8] M. Blecher, O. Willi
[9] K. Naughton, M. Borghesi
[10] S. Bonito, S. Orlando



Young Star object



McCaughrean, *et al.,* The Messenger **109**, 28 (2002).



Adapted from Bouvier, J., *et al.*, arXiv preprint, (2006).

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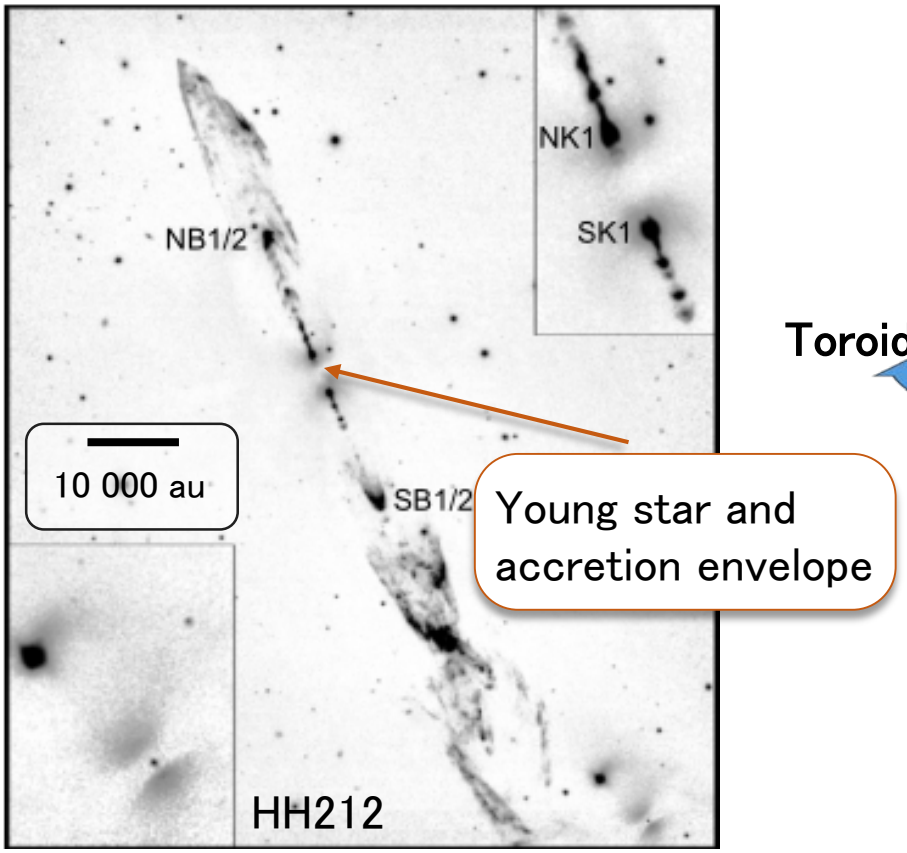

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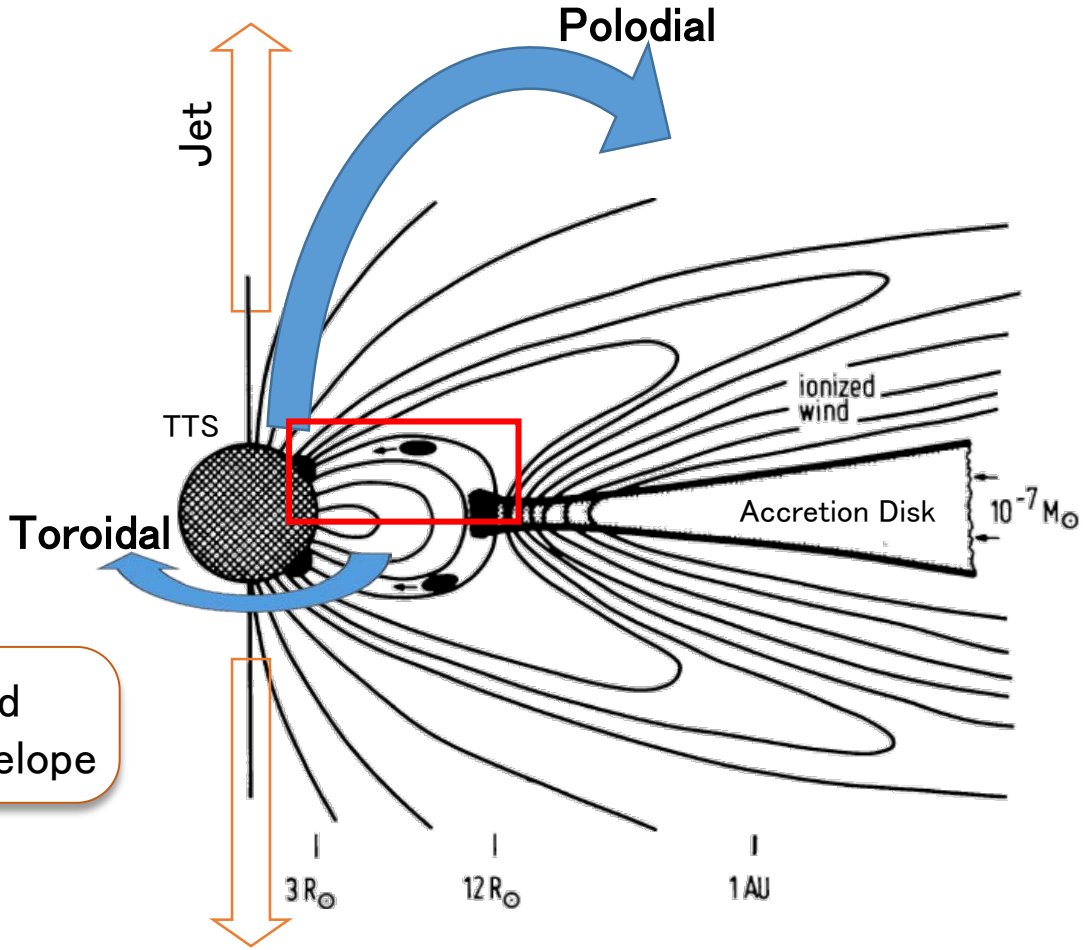

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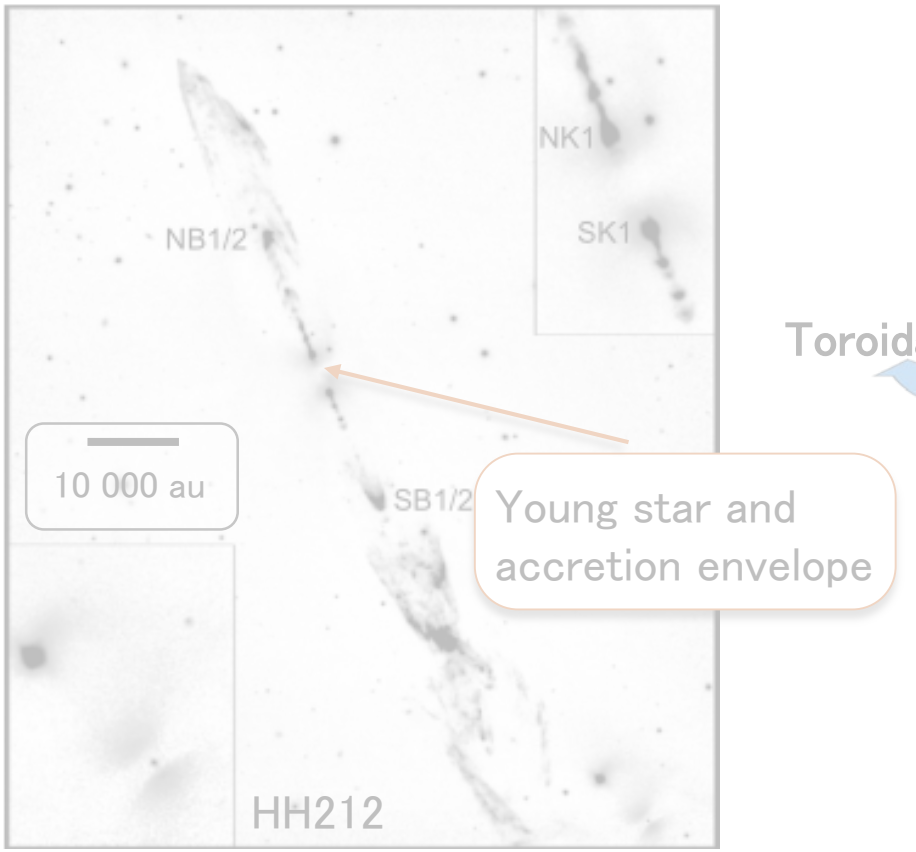

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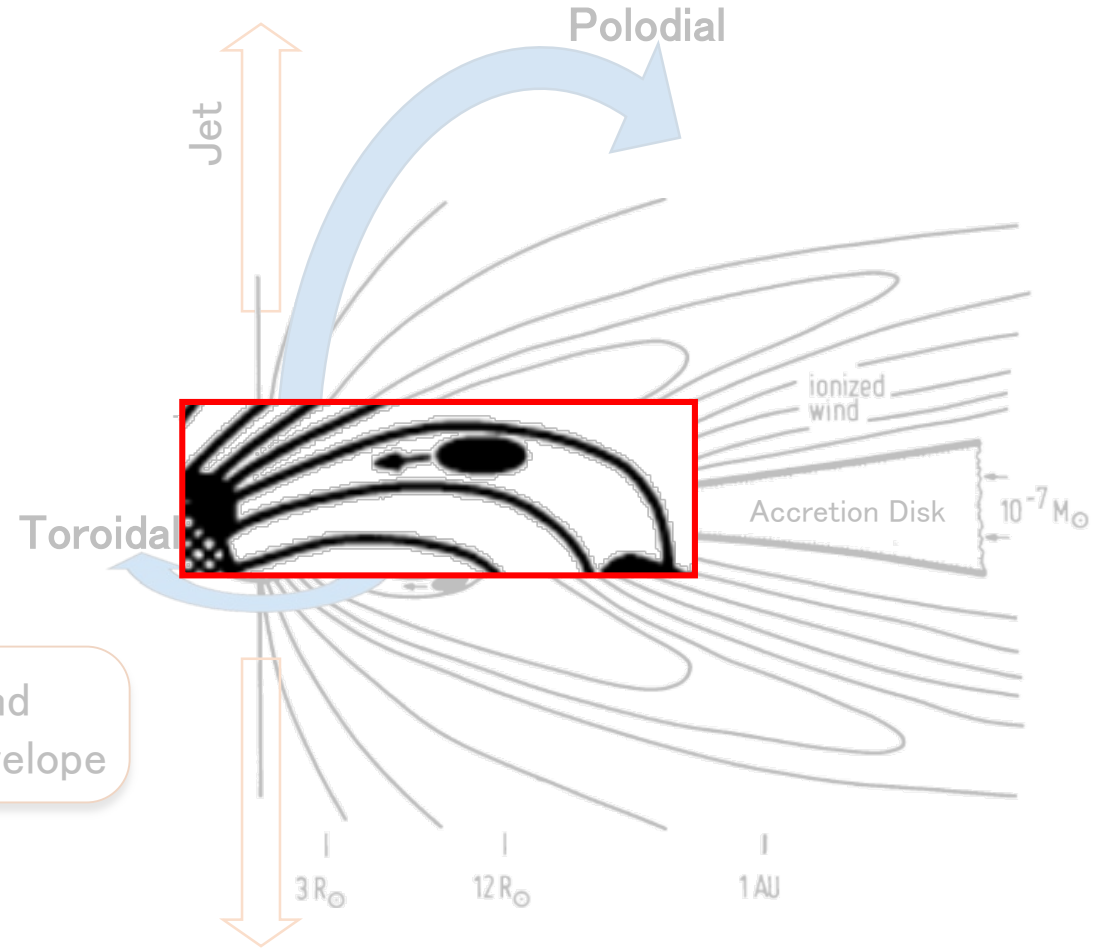

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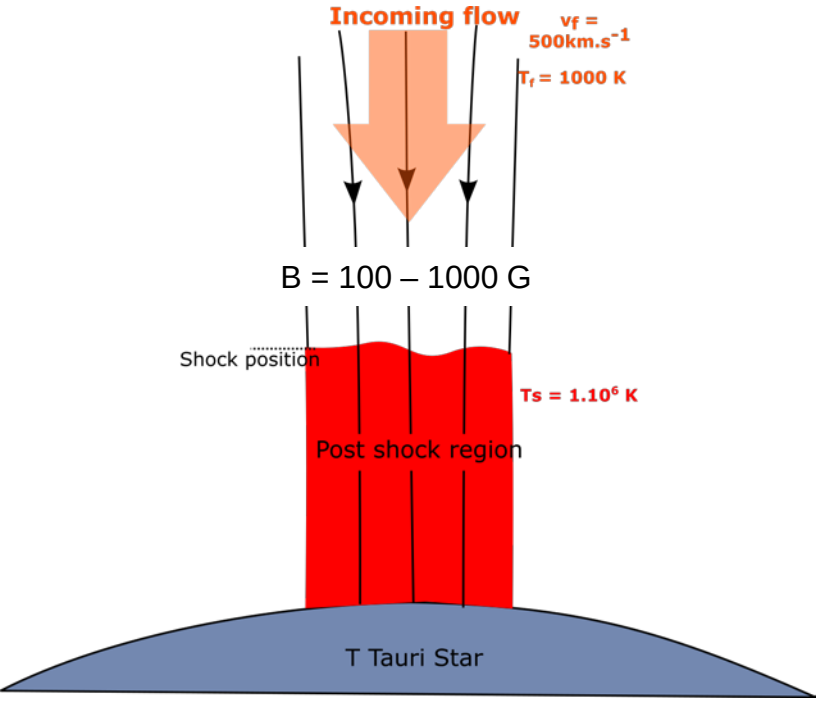
Accretion dynamics : current issues



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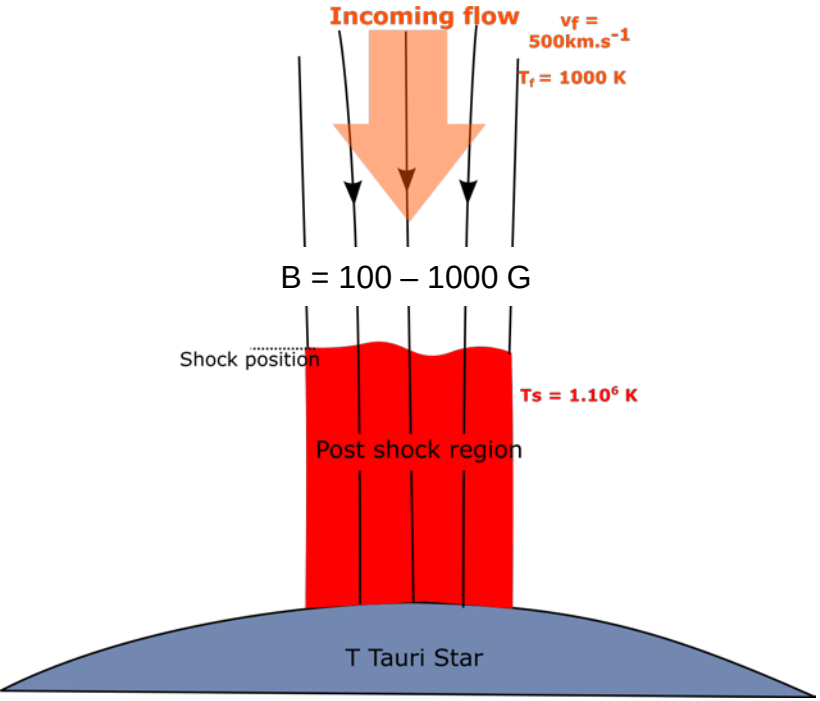

Observed X-ray luminosity is below the predicted value inferred from optical/UV emissions

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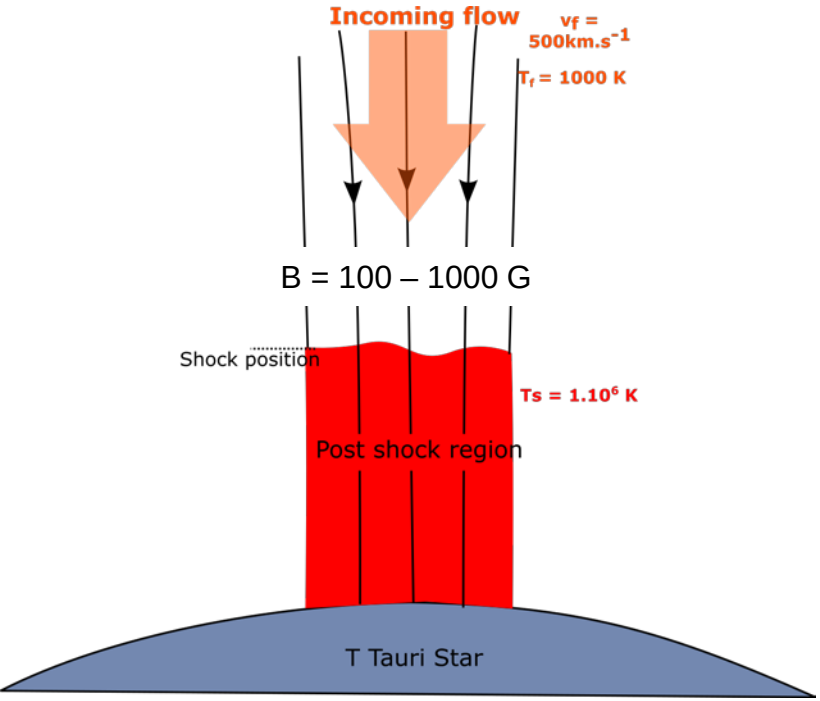

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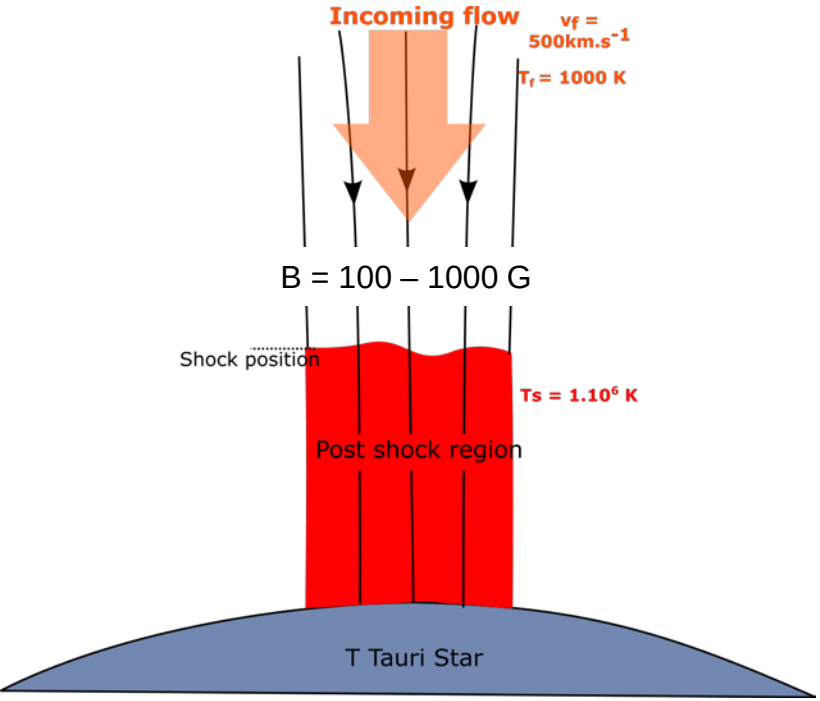

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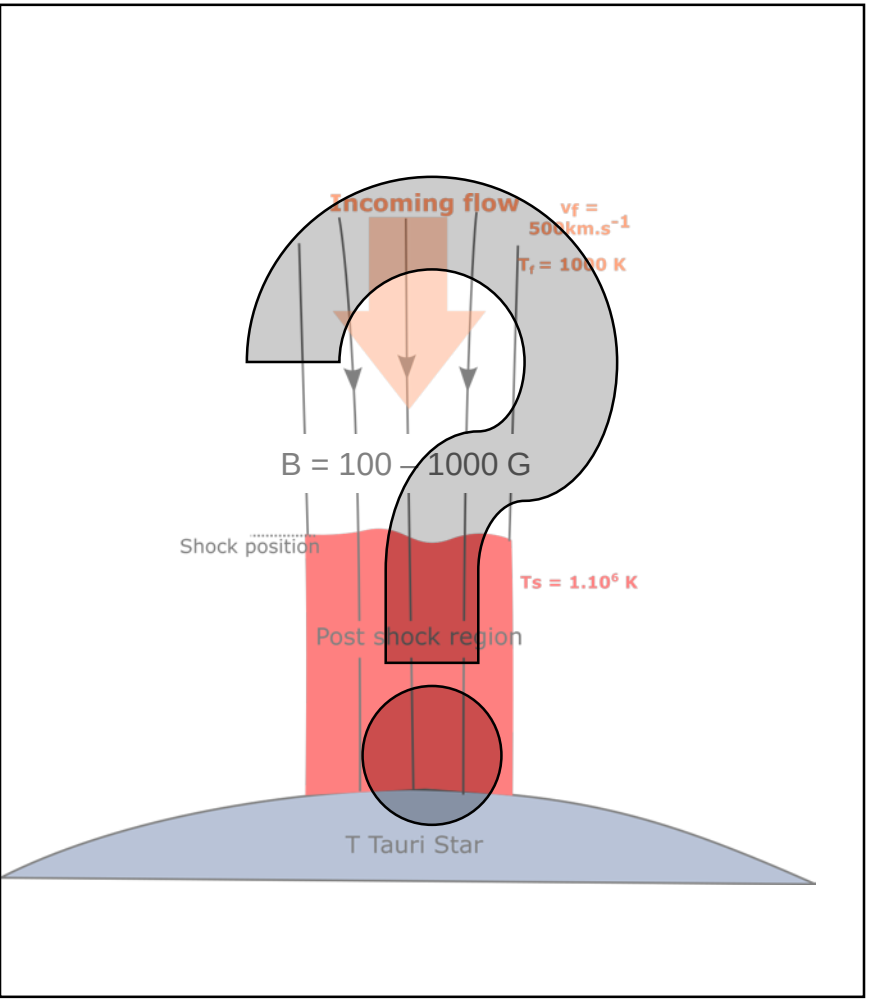

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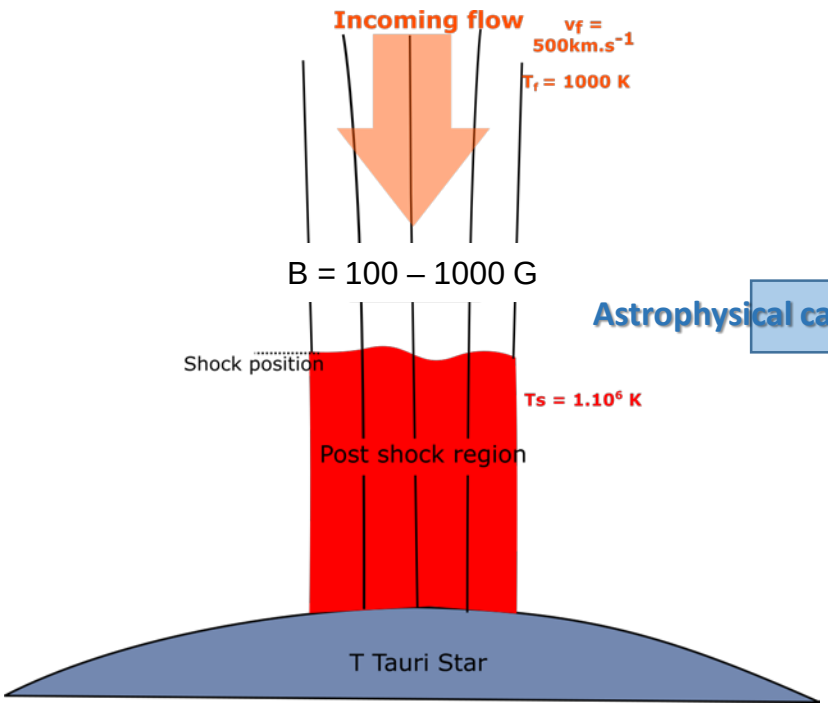
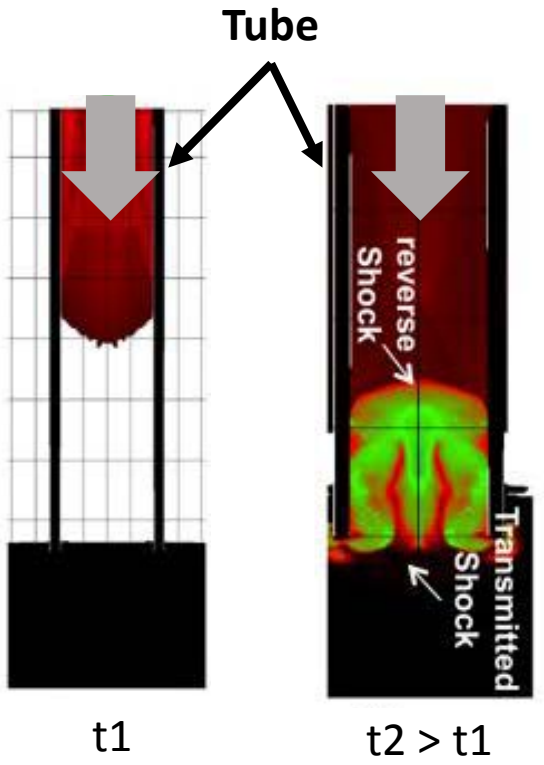
How can we check this ?

Accretion dynamics in the laboratory





E. Falize et al., HEDP 8, 1 (2012)

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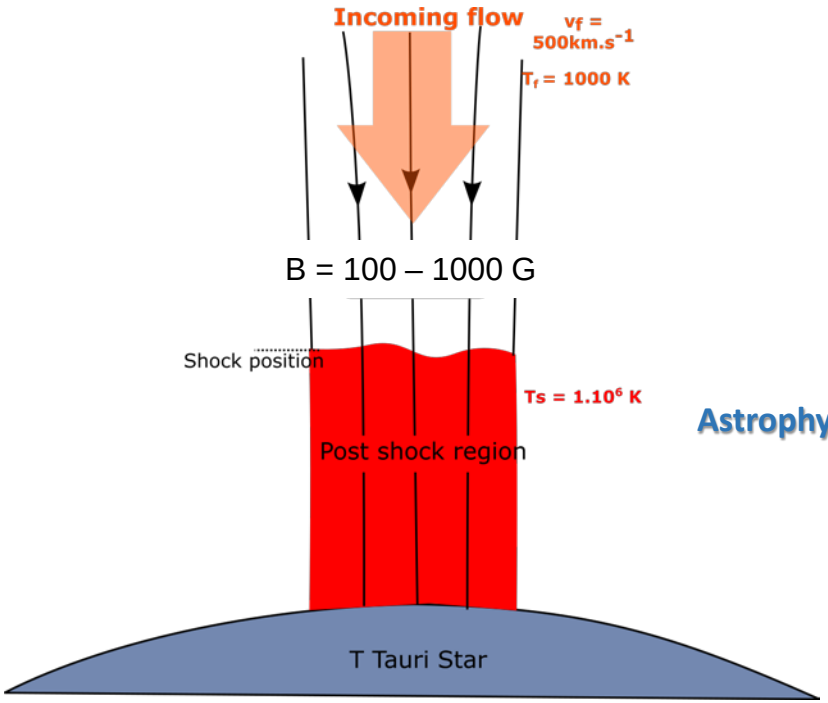
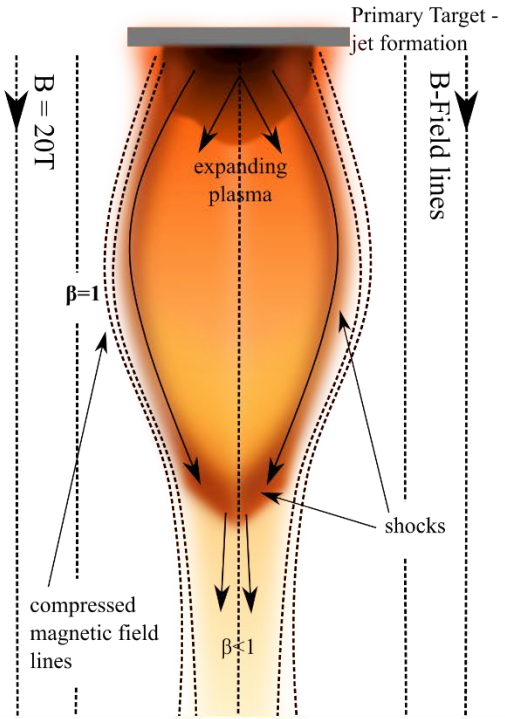
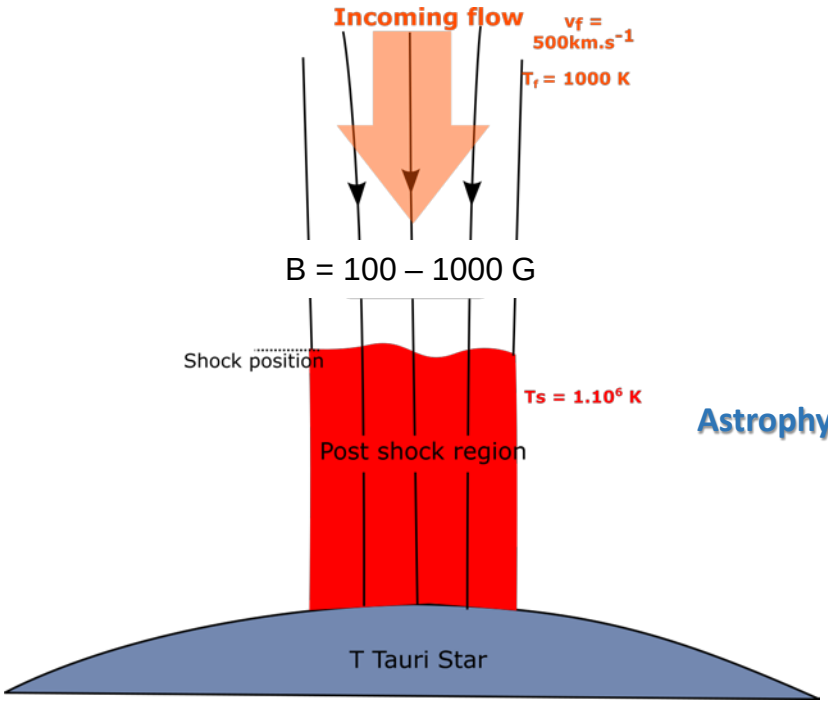


Astrophysical case → Laboratory case



Our new experimental approach:

Accretion dynamics in the laboratory



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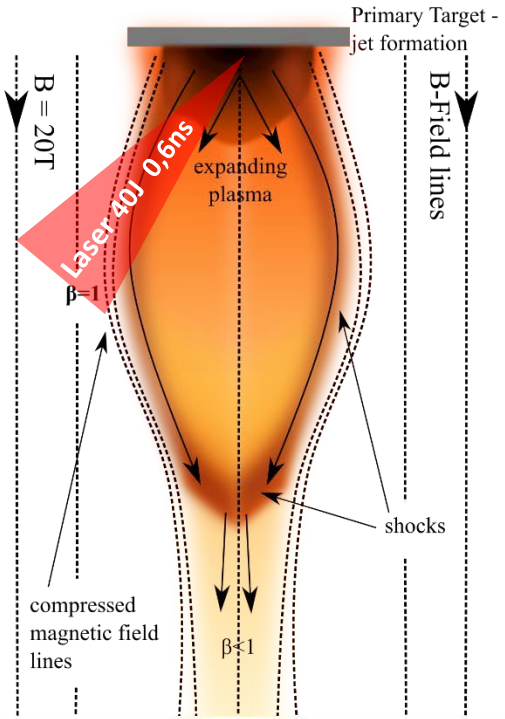

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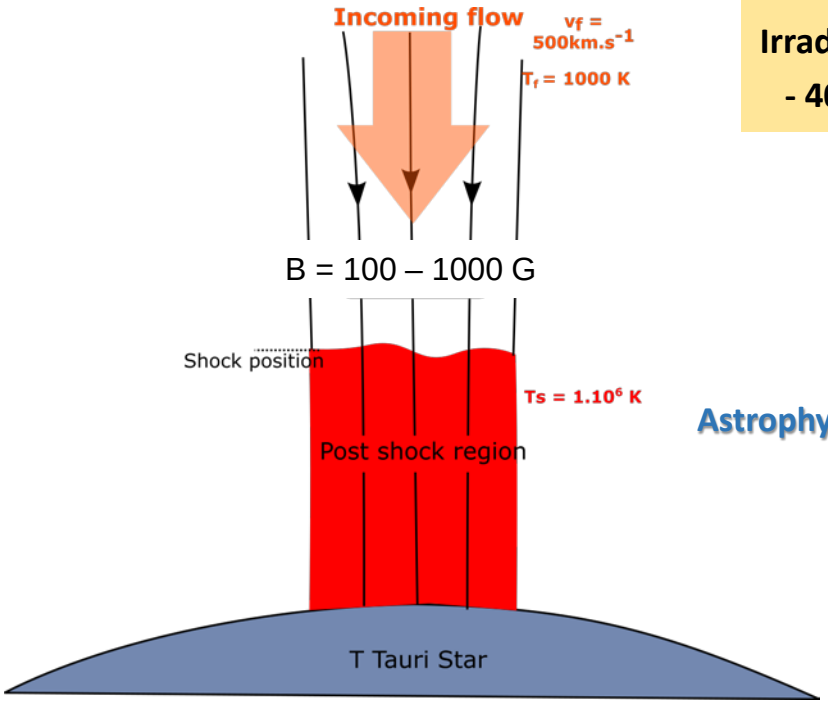
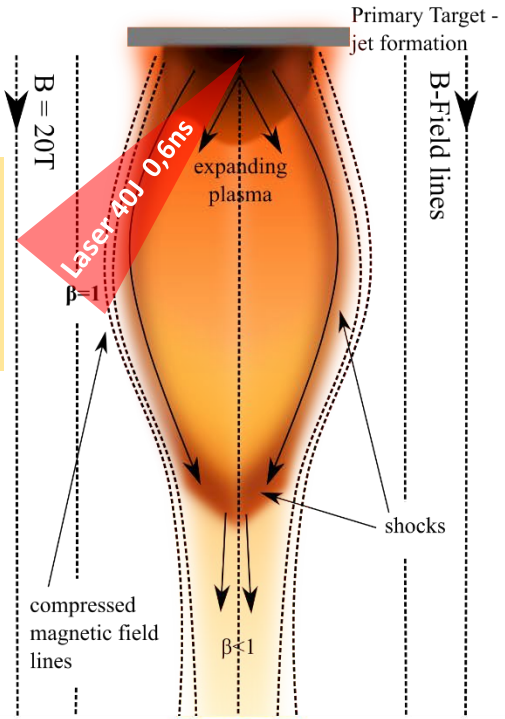


ELFIE facility (LULI, France)

Irradiation Laser : 1ω (λ = 1057 nm)
- 40 J/0.6 ns (1.6.10^{13} W.cm^{-2})



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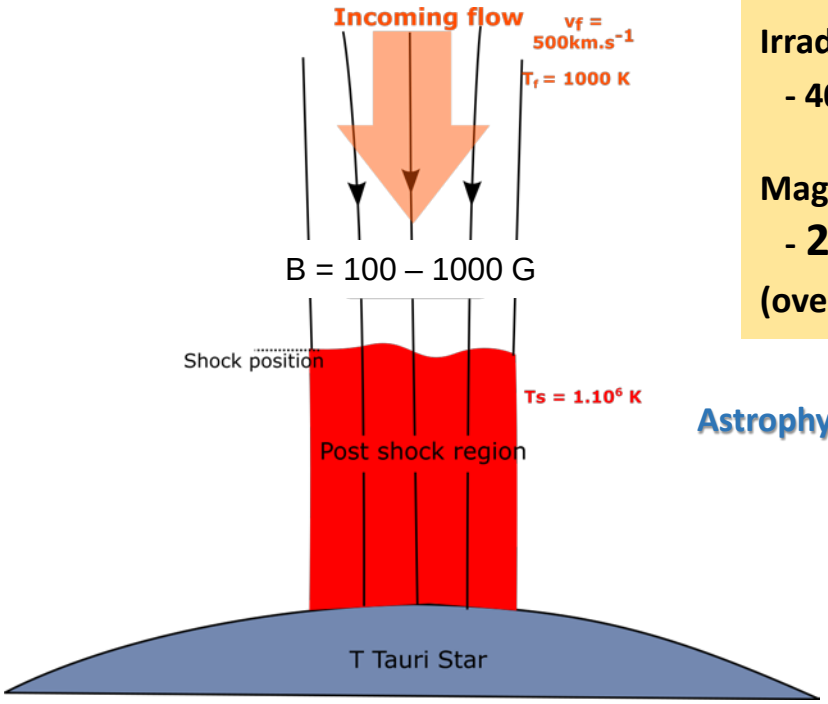

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- 20T pulsed

(over few µs and few cm scales)

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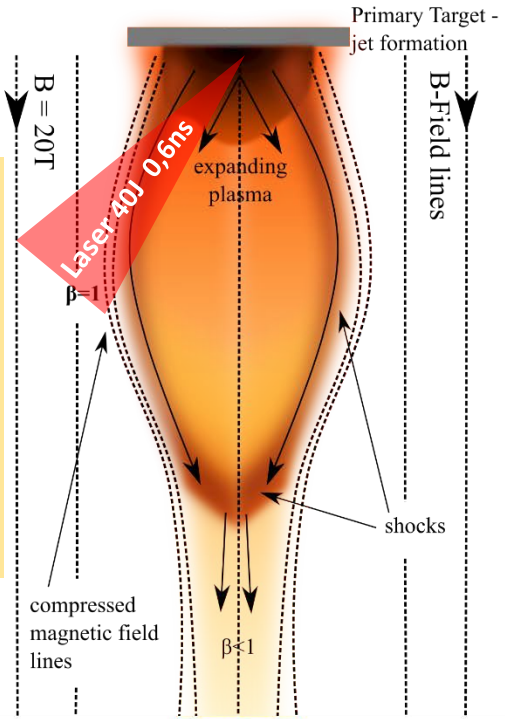

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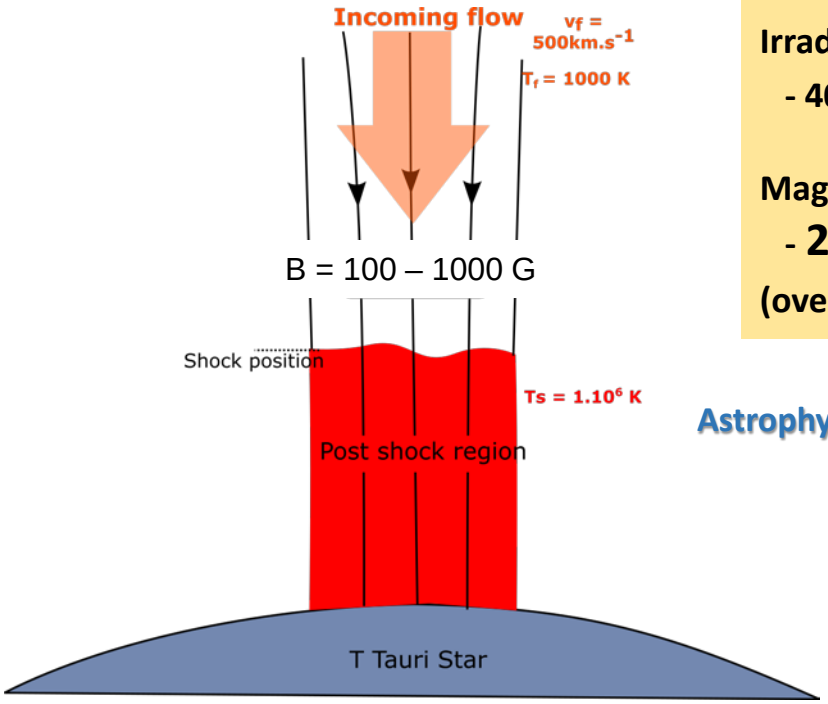

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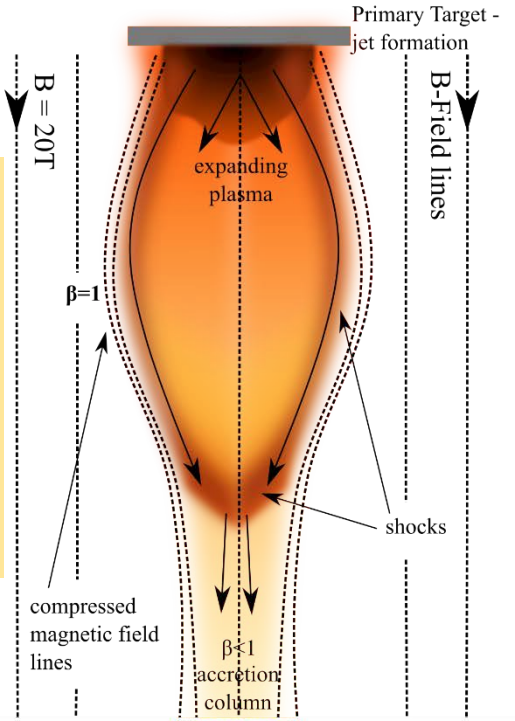
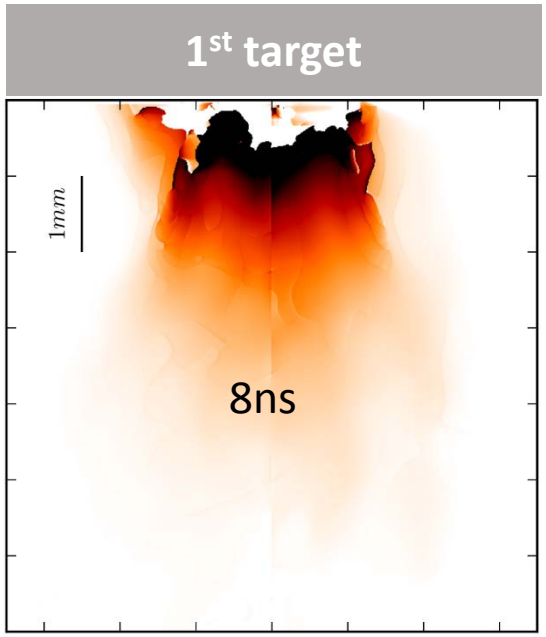


Our new experimental approach:

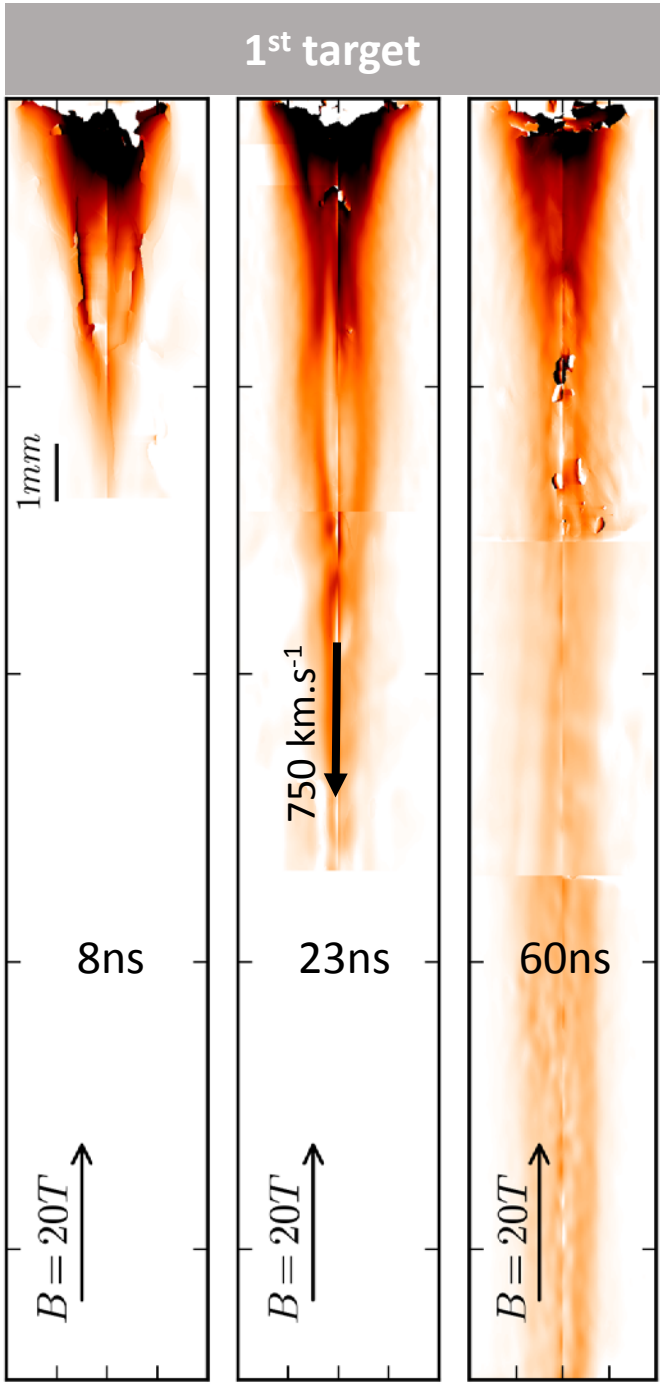
- **The magnetized collimated laser-produced plasma jet acts as the accretion column**

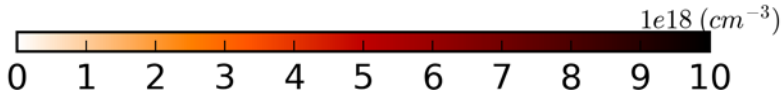
Jet collimation by poloidal magnetic field

Without B



B = 20T



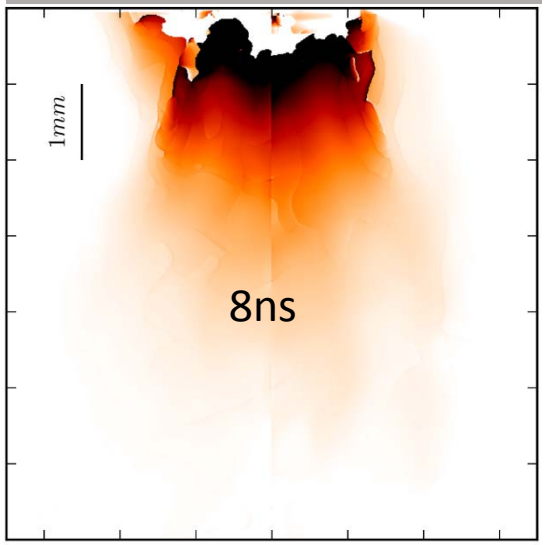


B. Albertazzi *et al.*, Science 346, 325 (2014)
D. P. Higginson et *al.*, HEDP 23, 48-59 (2017)
A. Ciardi et *al.*, PRL 110, 025002 (2013)

Jet collimation by poloidal magnetic field

Without B

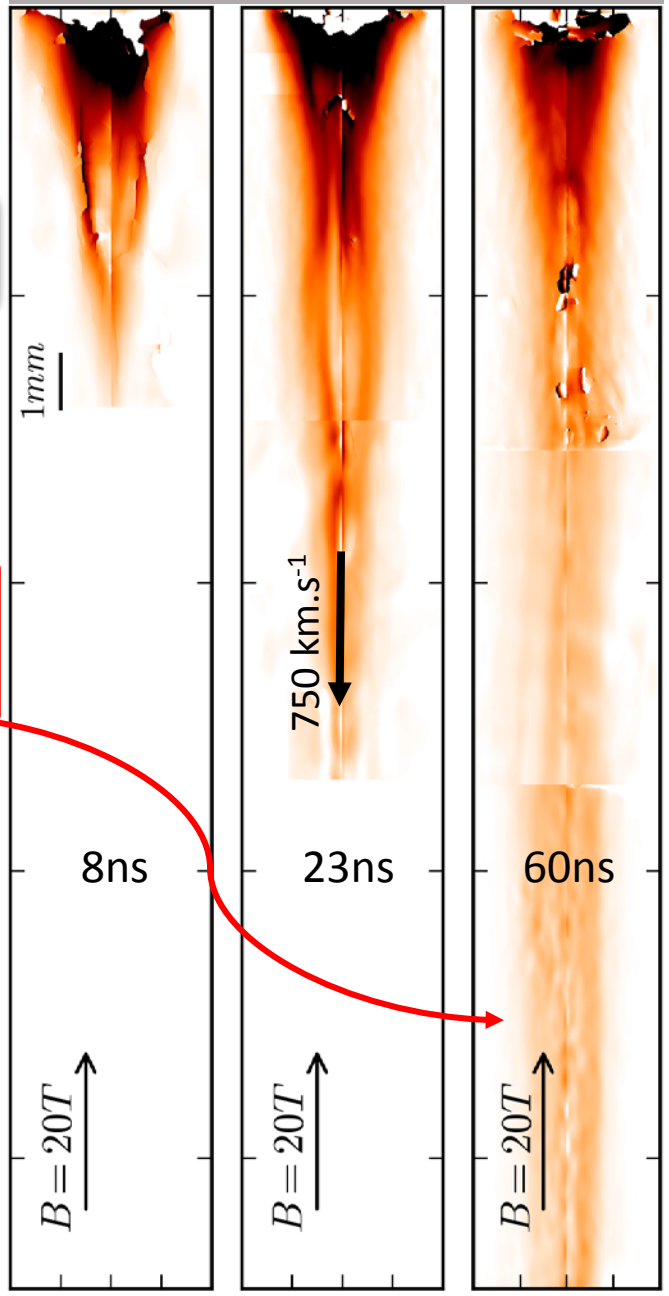
1st target

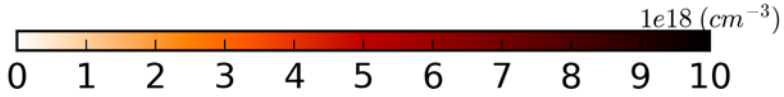


B = 20T

$n_e = 1.5 \times 10^{18} cm^{-3}$
$T_e = 10 - 15eV$

1st target





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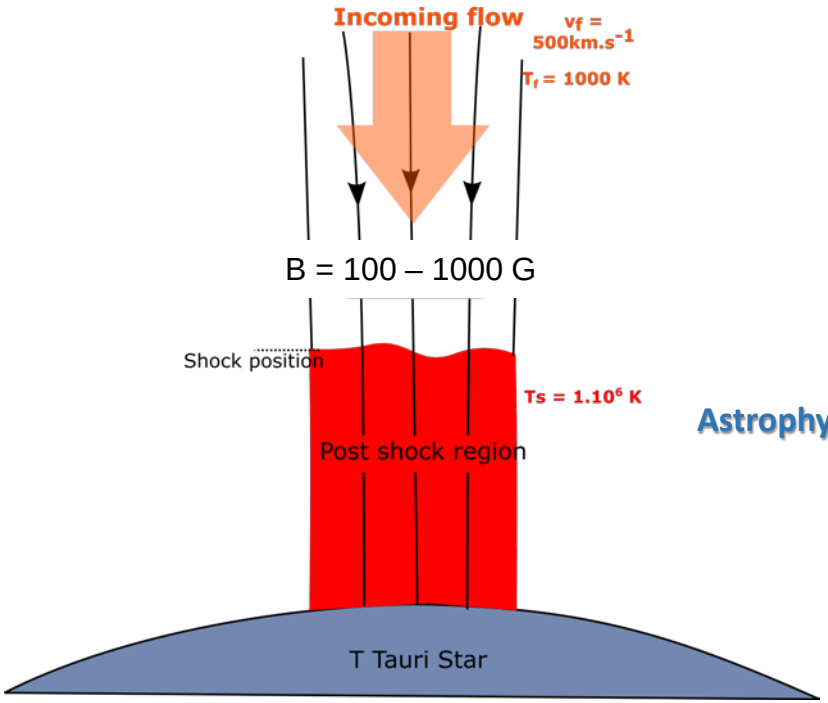

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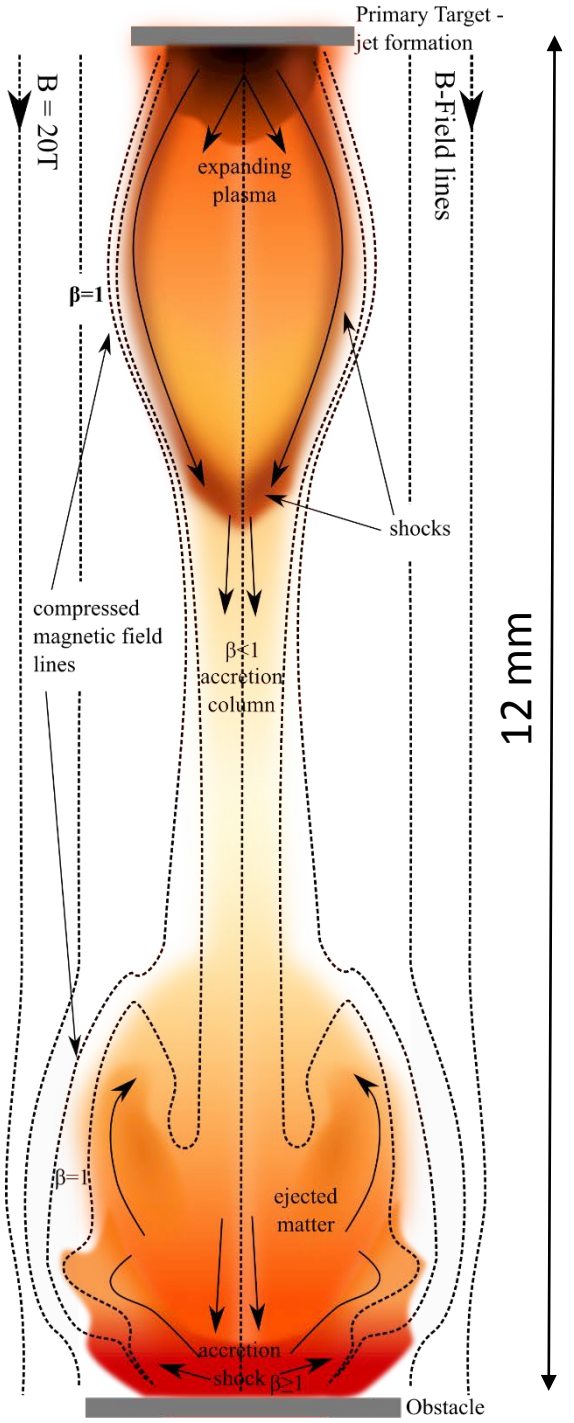

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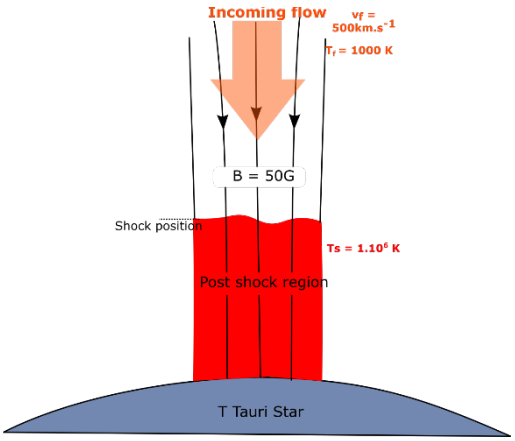
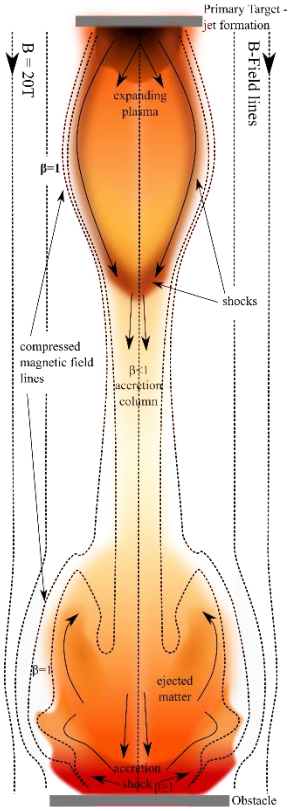
- **The magnetized collimated laser-produced plasma jet acts as the accretion column**
- **A secondary target located on the jet propagation acts as the stellar surface**

Scalability of the lab experiment



	CTTS	Laboratory
Incident stream	B-Field = $7 \times 10^{-4} T$	B-Field = $20T$
Material	H	C_2H_3Cl
Electronic density $[n.cm^{-3}]$	1×10^{11}	1.5×10^{18}
Te $[eV]$	0,22	10
Density $[g.cm^{-3}]$	1.7×10^{-13}	$9{,}7 \times 10^{-6}$
Speed accretion flow $[km.s^{-1}]$	500	$100 - 1000$
Sound speed $[km.s^{-1}]$	7.4	24
Mach number	67	32
Reynolds	2.6×10^{11}	$4{,}6 \times 10^{5}$
Peclet number	8.2×10^{8}	10
Magnetic Reynolds	3.5×10^{9}	34
β_{ther}	1.7×10^{-2}	2×10^{-2}
β_{dyn}	128	34
Euler number $(v\sqrt{\rho/p})$	87	40,8
Alfven number $(B/\sqrt{\rho})$	1.2×10^{-2}	1.1×10^{-2}



D. D. Ryutov et al.,
The Astrophysical J. Suppl. 127, 465 (2000)

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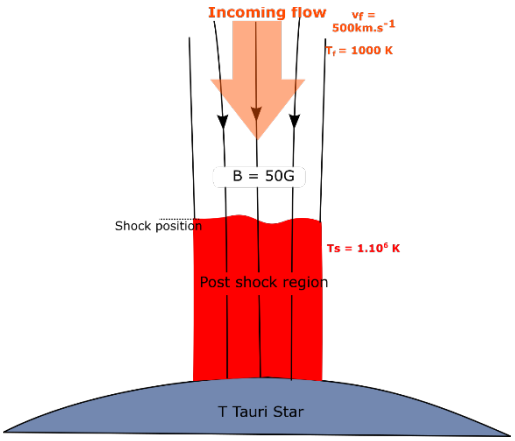

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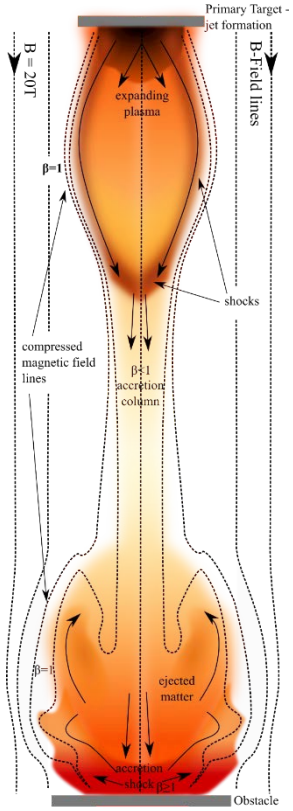
Both are ideal MHD plasmas



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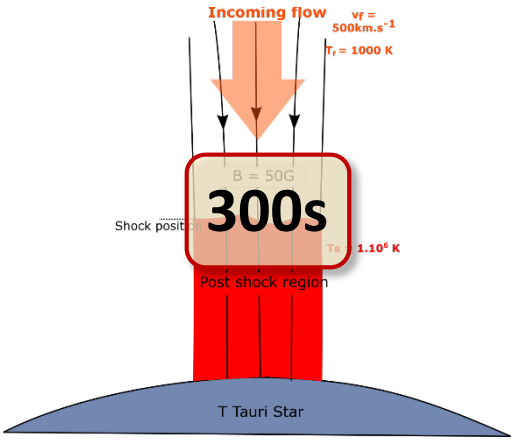

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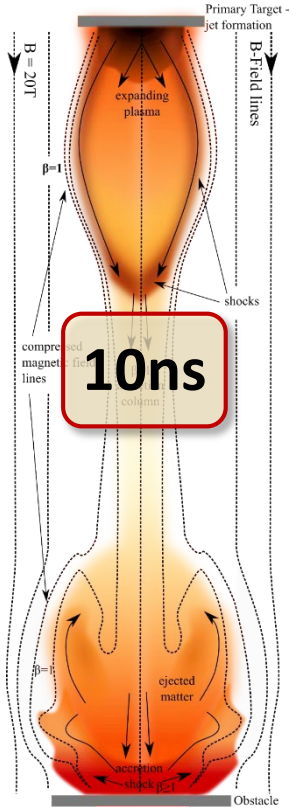
Both are ideal MHD plasmas

Both MHD systems should evolve in a similar way



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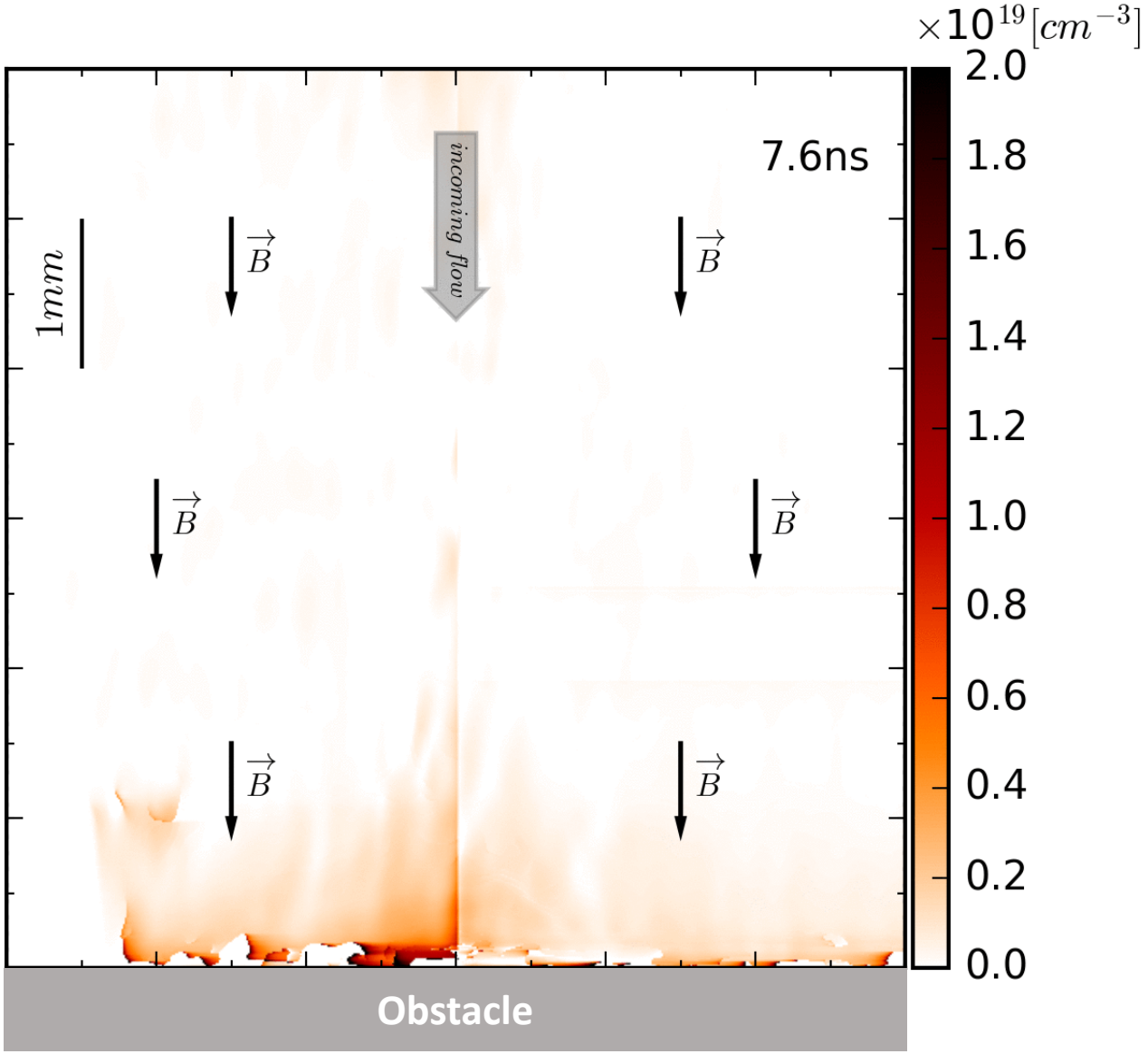
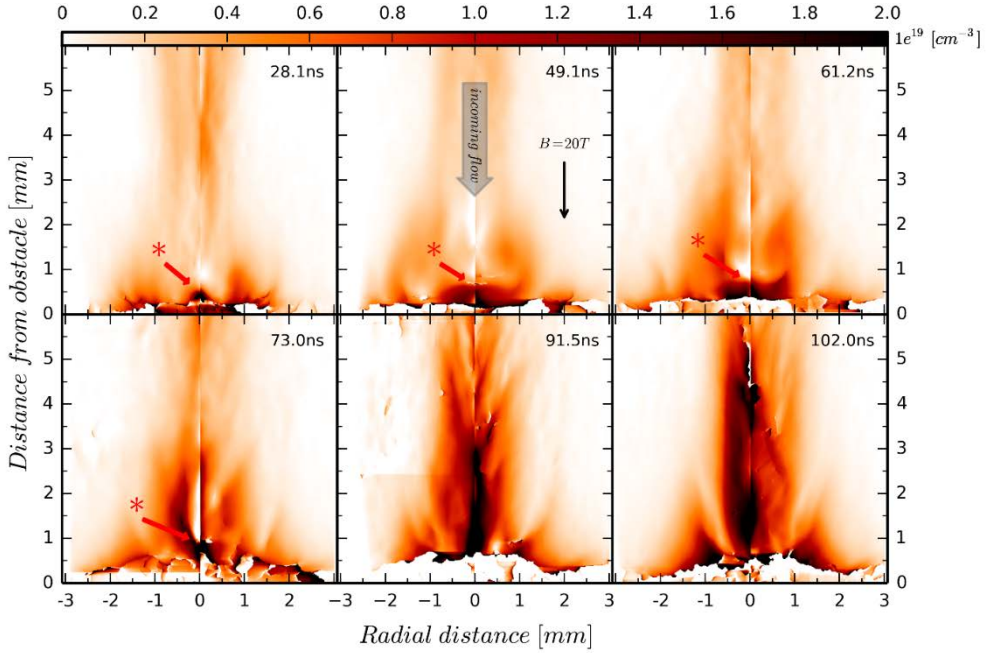
Experimental accretion dynamics



Comparison with astrophysical simulation



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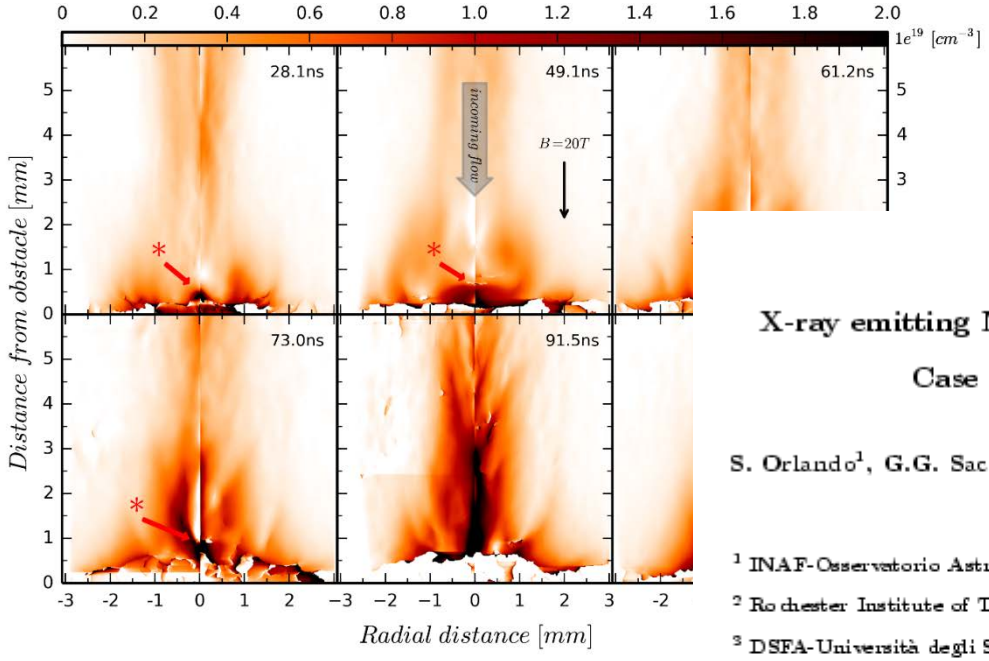

With gravity

X-ray emitting MHD accretion shocks in classical T Tauri stars.
Case for moderate to high plasma-β values

S. Orlando[1], G.G. Sacco[2,1], C. Argiroffi[3,1], F. Reale[3,1], G. Peres[3,1], and A. Maggio[1]

[1] INAF-Osservatorio Astronomico di Palermo, Piazza del Parlamento, 1 , 90134, Palermo, Italy
[2] Rochester Institute of Technology, 54 Lomb Memorial Dr., Rochester, NY, 14623, USA
[3] DSFA-Università degli Studi di Palermo, Piazza del Parlamento, 1, 90134, Palermo, Italy

Run By-10

S. Orlando *et al.*, A&A 510, A71 (2010)

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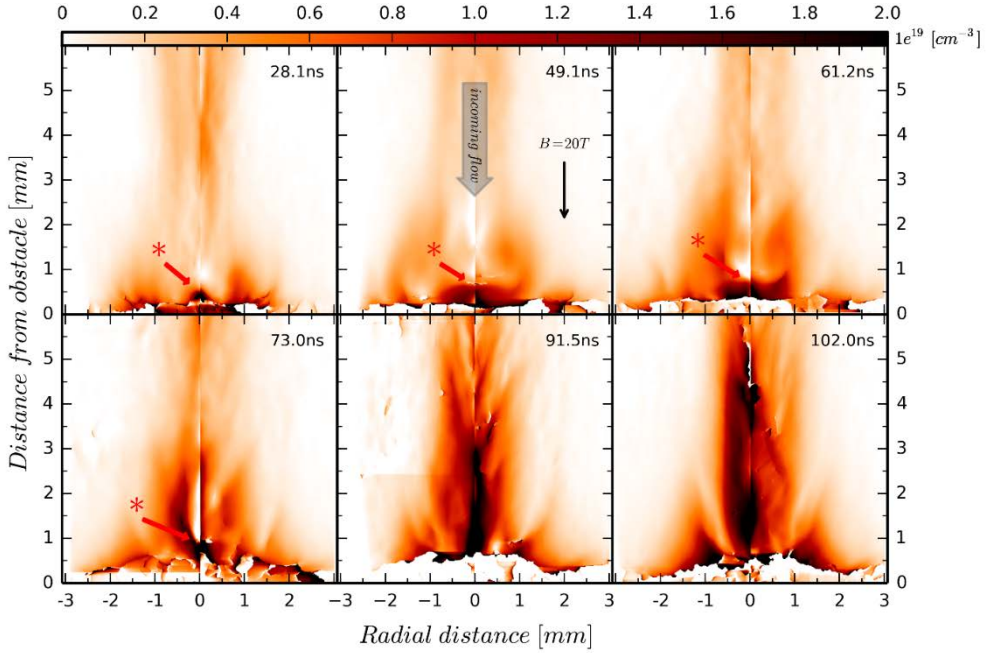

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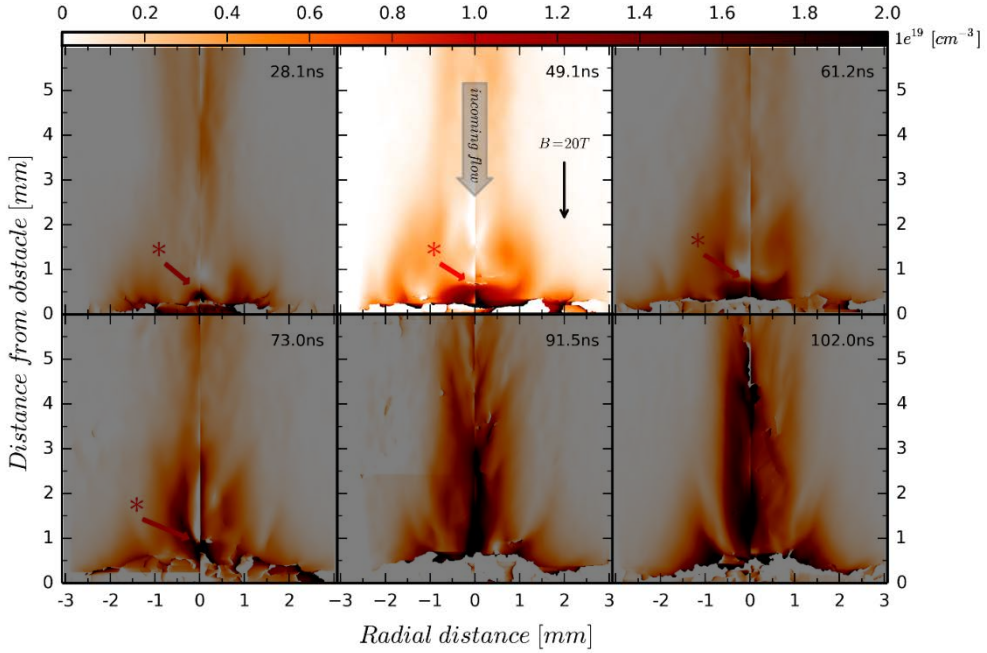
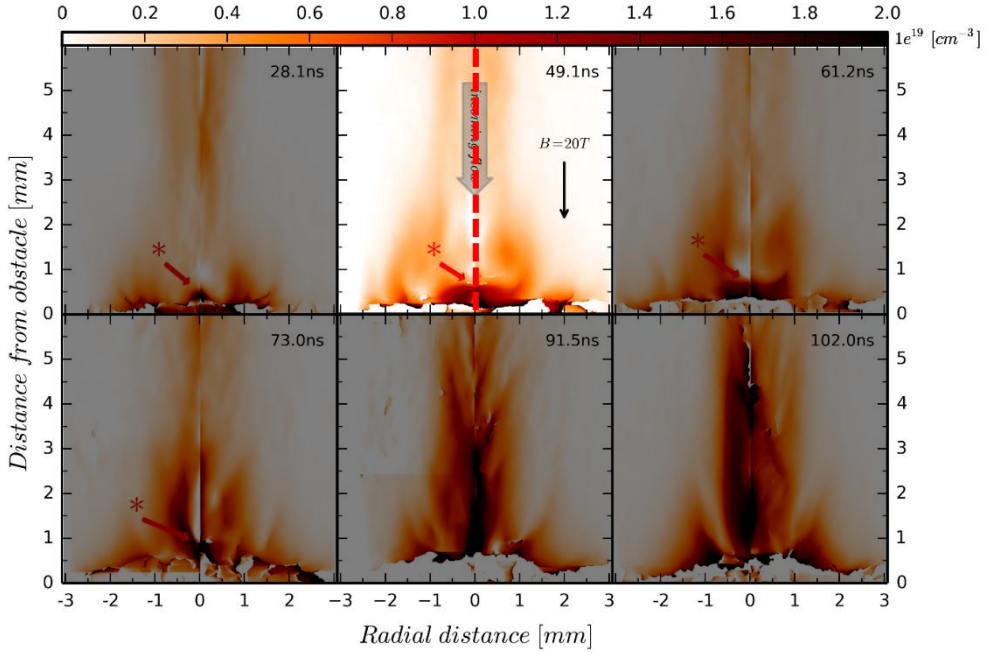
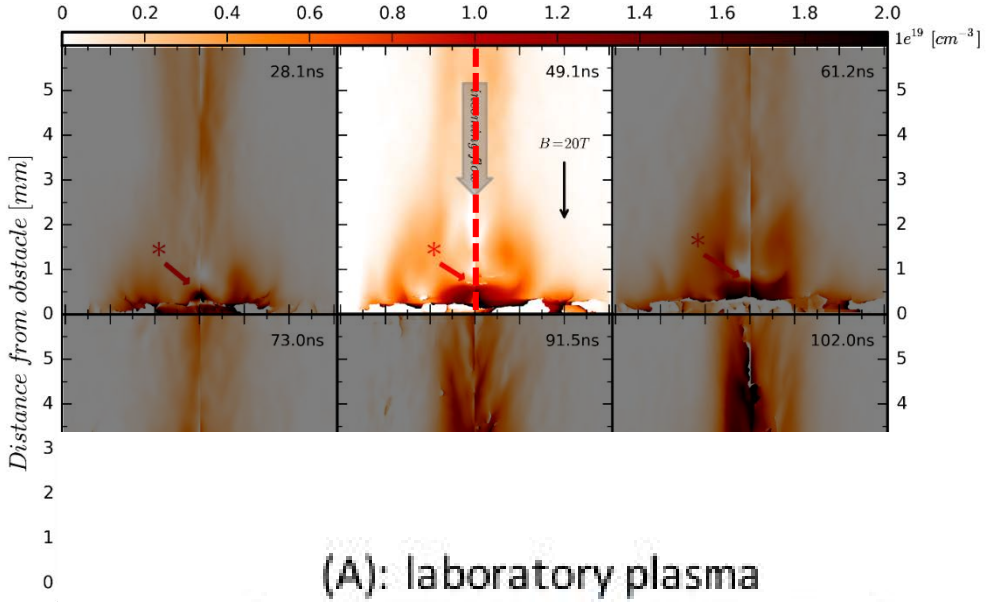
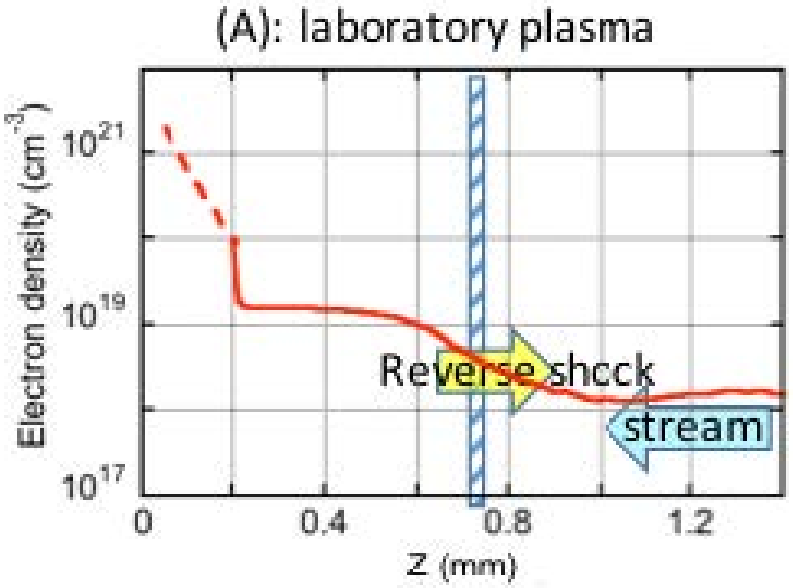


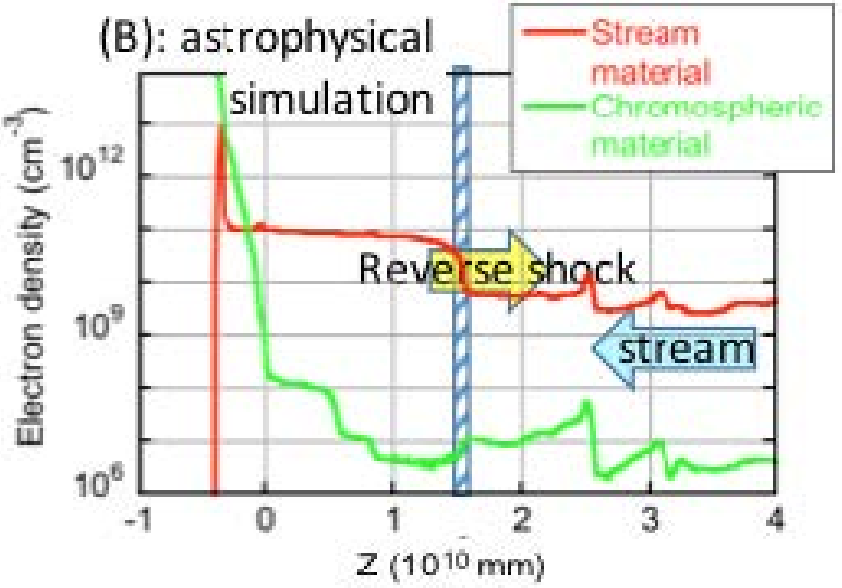
Comparison with astrophysical simulation



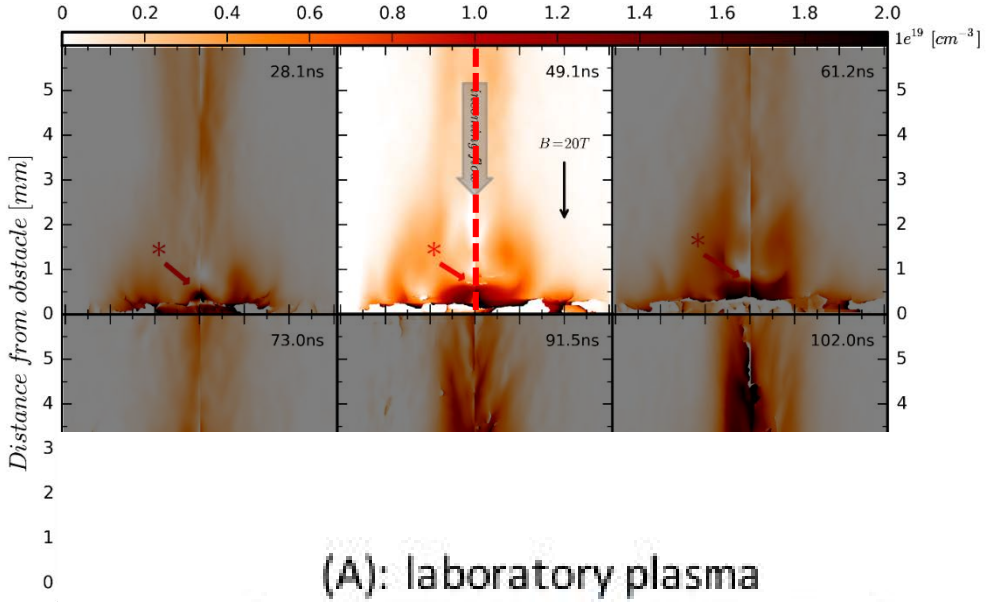
Comparison with astrophysical simulation





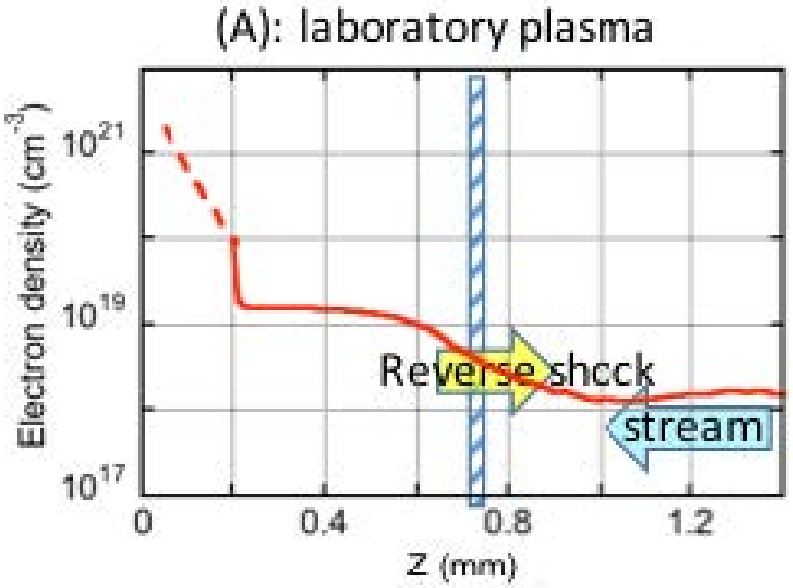


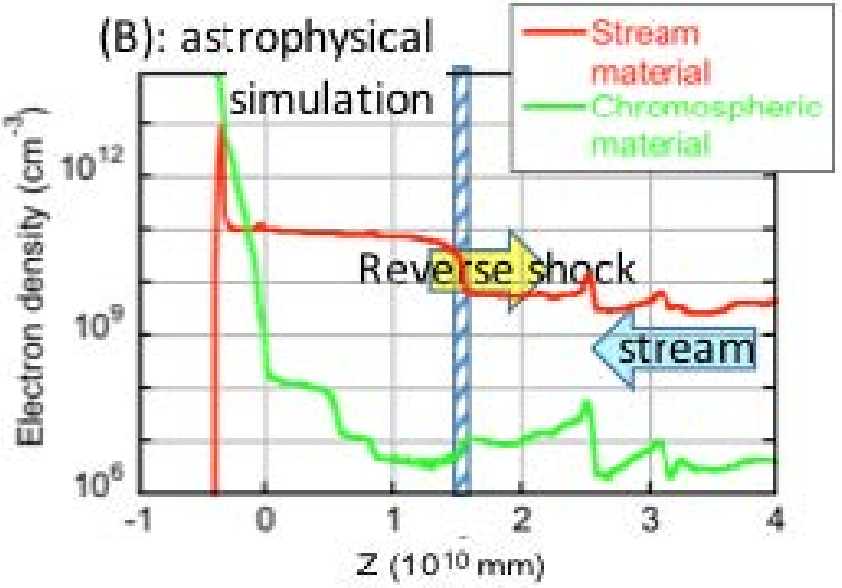
Comparison with astrophysical simulation



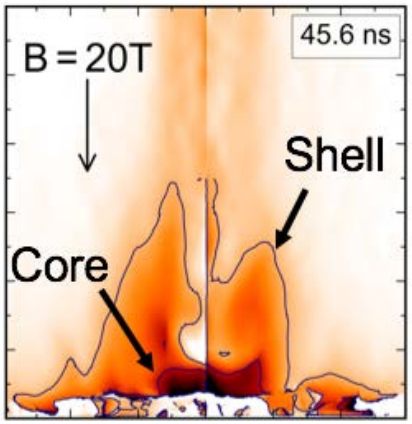
Experimentally :

95 % of plasma
seen through x-ray spectrometer
is composed by **stream plasma**

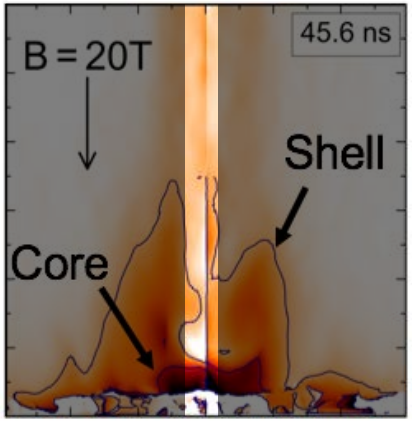




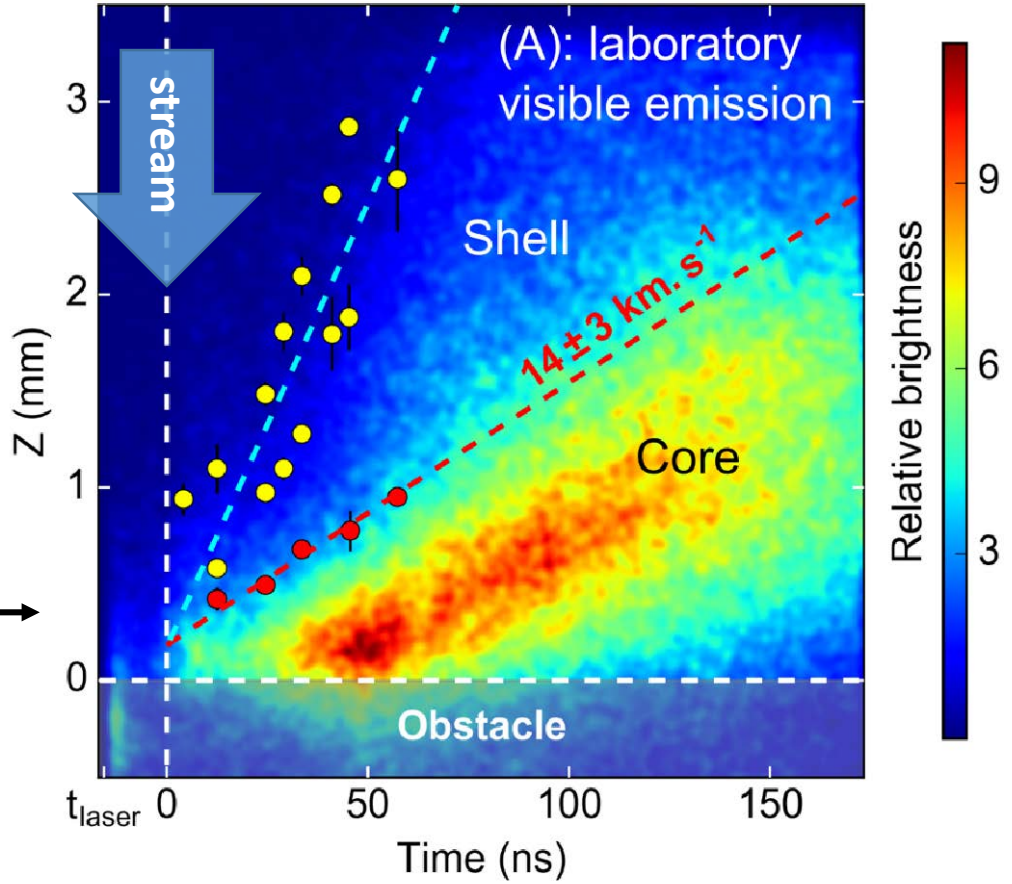
Shocked core and shell have not only different densities but also different temperatures



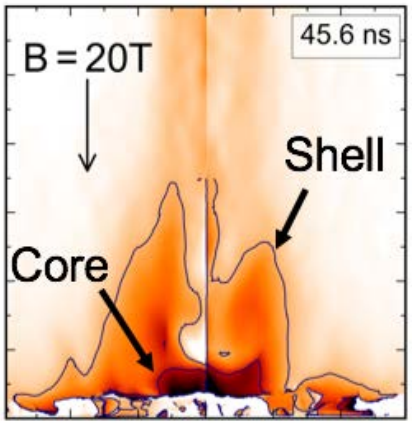
Shocked core and shell have not only different densities but also different temperatures

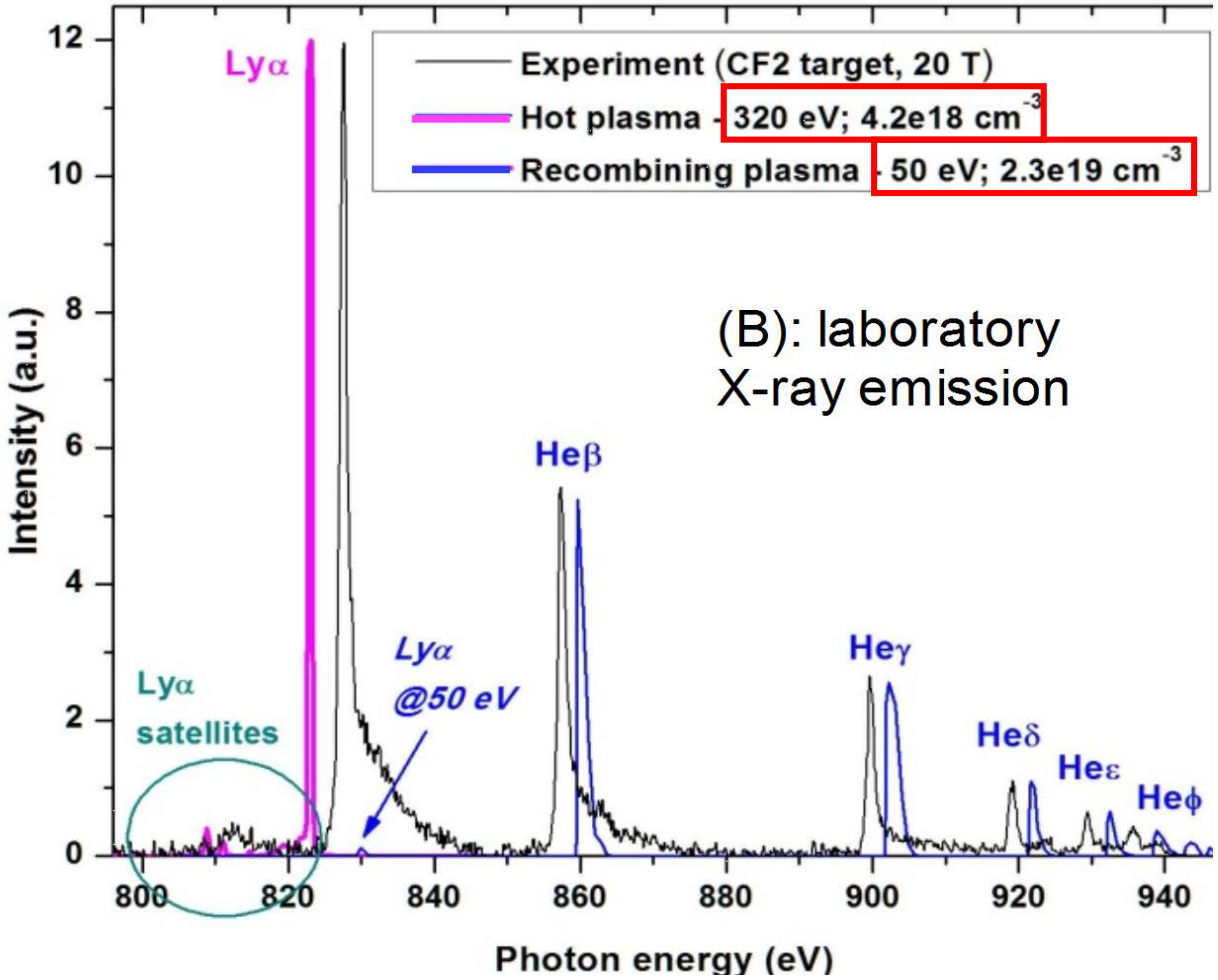


Streaked visible emission



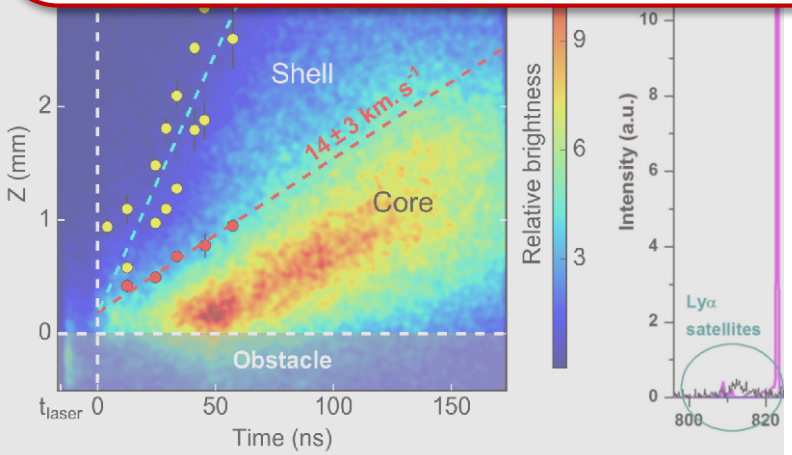
Shocked core and shell have not only different densities but also different temperatures

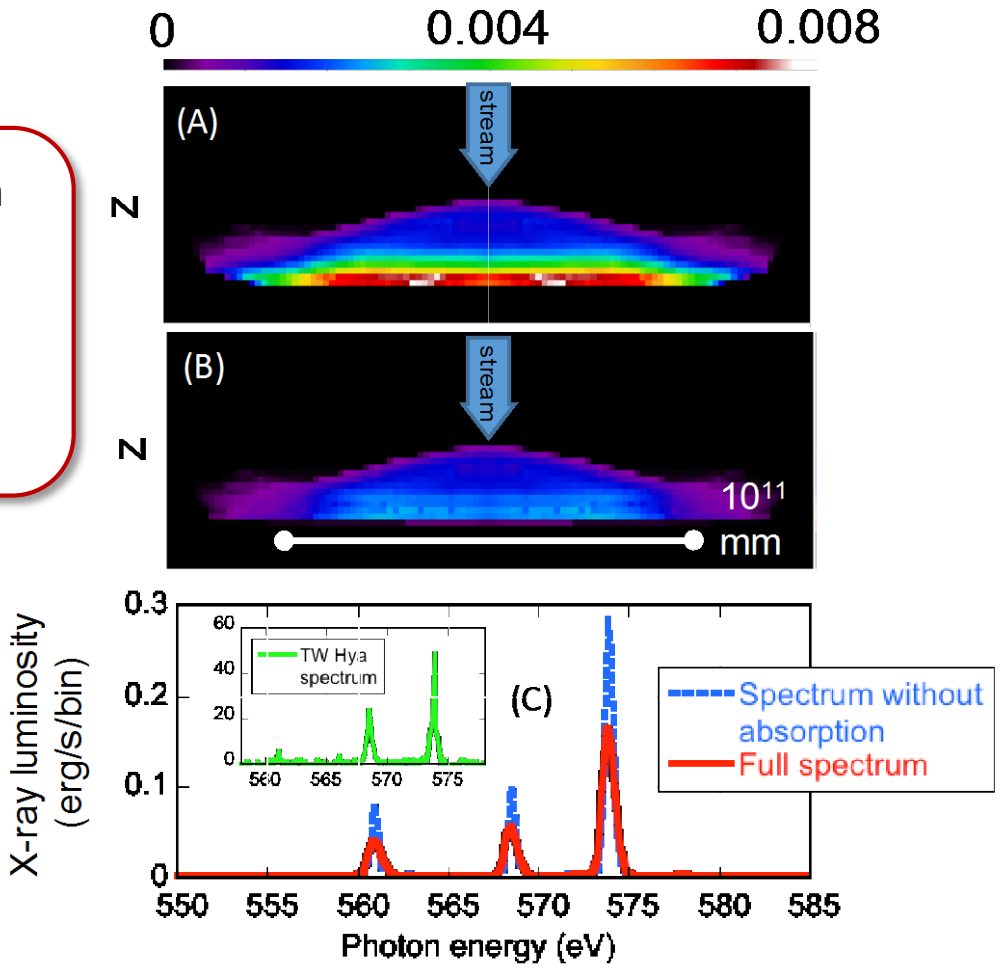




The shell plasma is seen to have an absorptive effect on the X-ray emission of the core, in the astrophysical simulated situation

These more complex dynamics have an impact on the way x-rays are emitted/absorbed, and might lead to underestimation of the mass accretion rate if not taken into account.





Overview

- Accretion dynamics can be studied in details in the **laboratory**. Experimental results reproduce important features seen in astrophysical simulations.

- The clear evidence of a **shell** forming around the shocked plasma was shown in the laboratory, corroborating features from 2D astro simulations.

- This shell has an impact on the **absorption** of the X-ray exiting the shocked region, and should be taken into account in order to correctly interpret emission coming from that accretion process.