Simulations of magnetized BHNSs in full general relativity

Zachariah Etienne*

Collaborators:

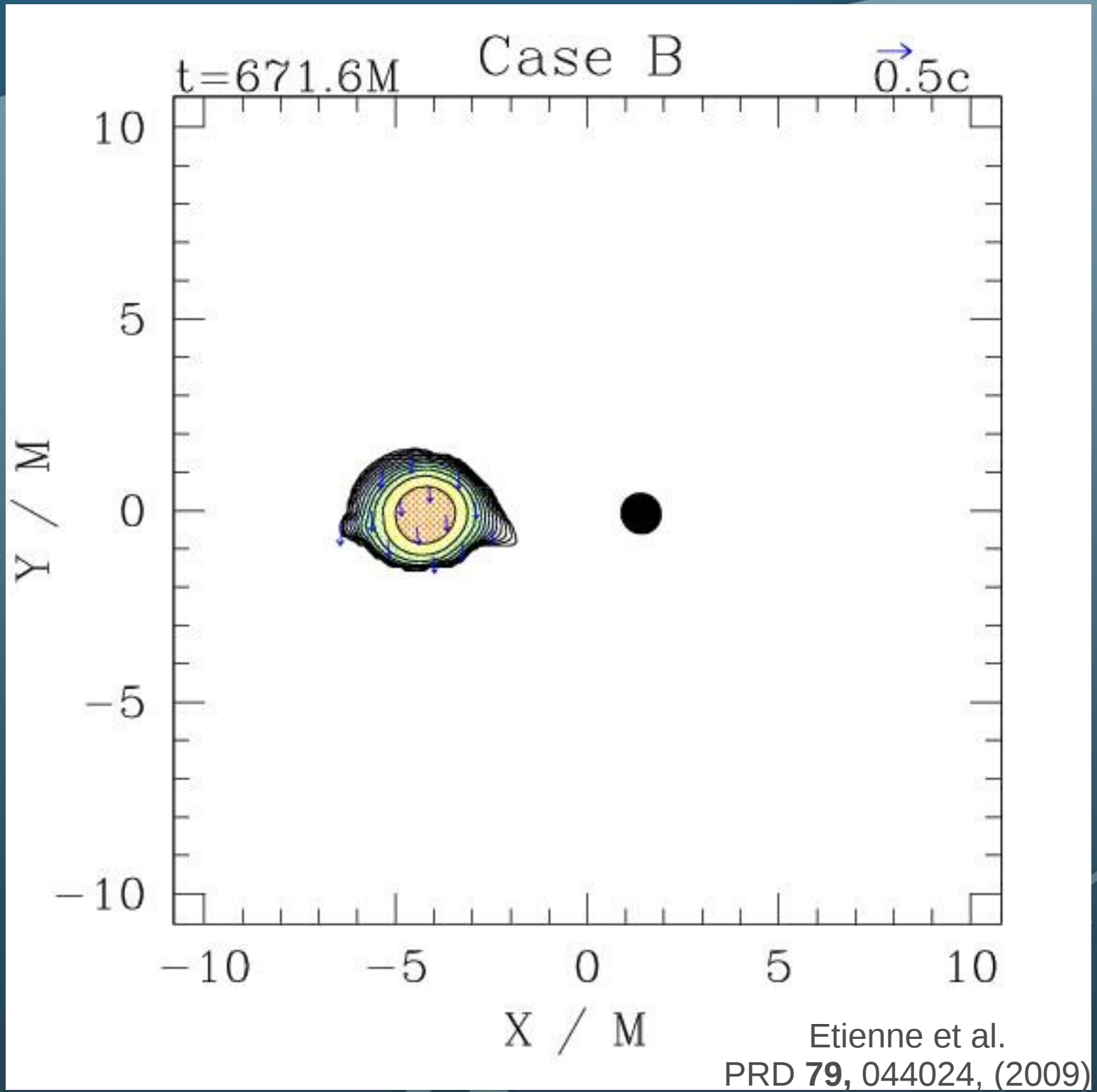
Yuk Tung Liu
Vasileios Paschalidis
Stu Shapiro

References:

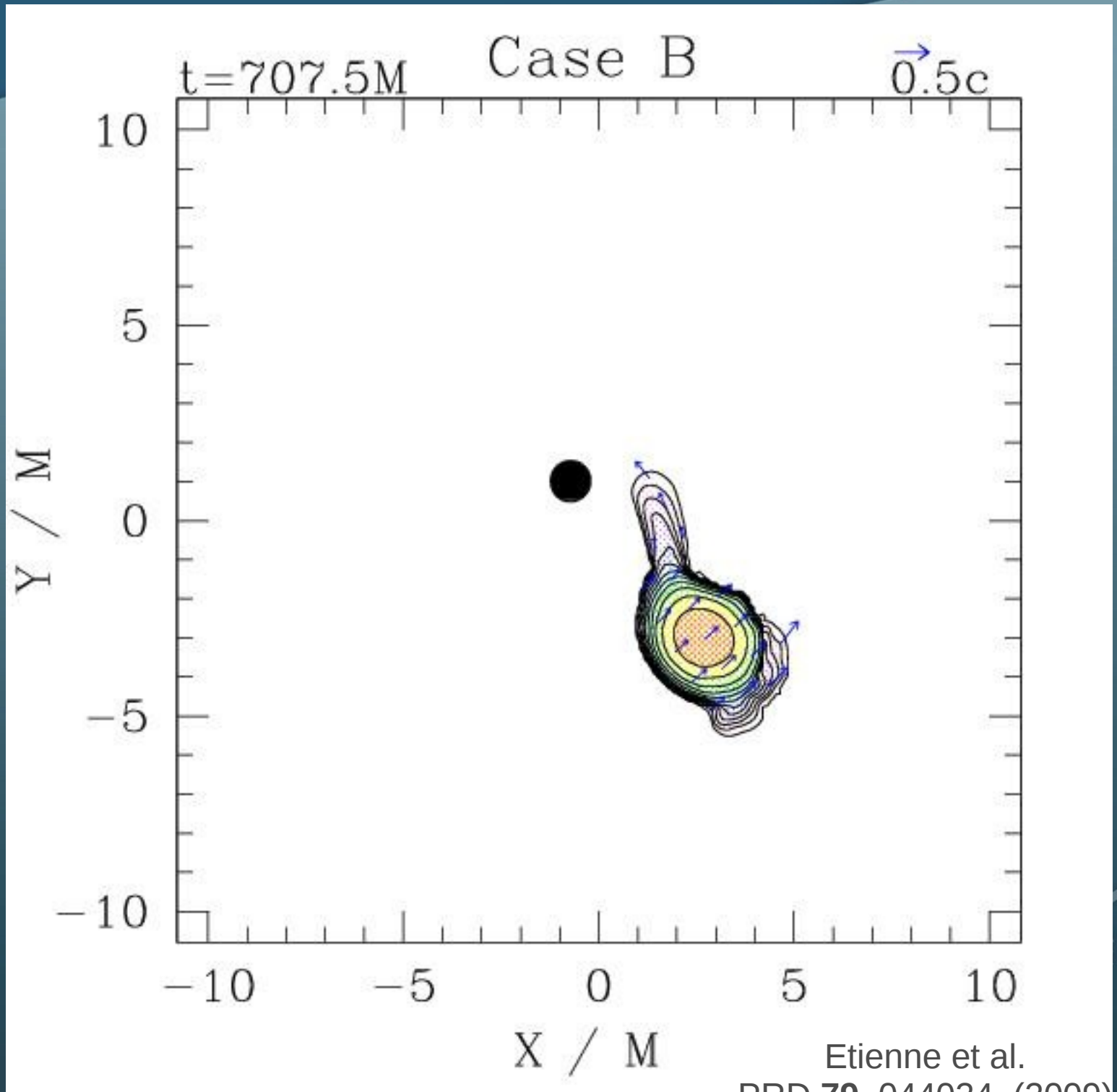
***Technique*: Etienne et al., PRD 85, 024013 (2012)**
***First Results*: Etienne et al., PRD 85, 064029 (2012)**
***Latest Results*: Etienne et al., *In preparation* (2012)**

3D Visualizations
by
Stu Shapiro's REU team:
G. Colten, M. Jin,
D. Kolschowsky, F. Walsh
tinyurl.com/mentormovies

**** NSF Astronomy & Astrophysics postdoc. fellow AST-1002667***



Etienne et al.
PRD **79,** 044024, (2009)



Etienne et al.
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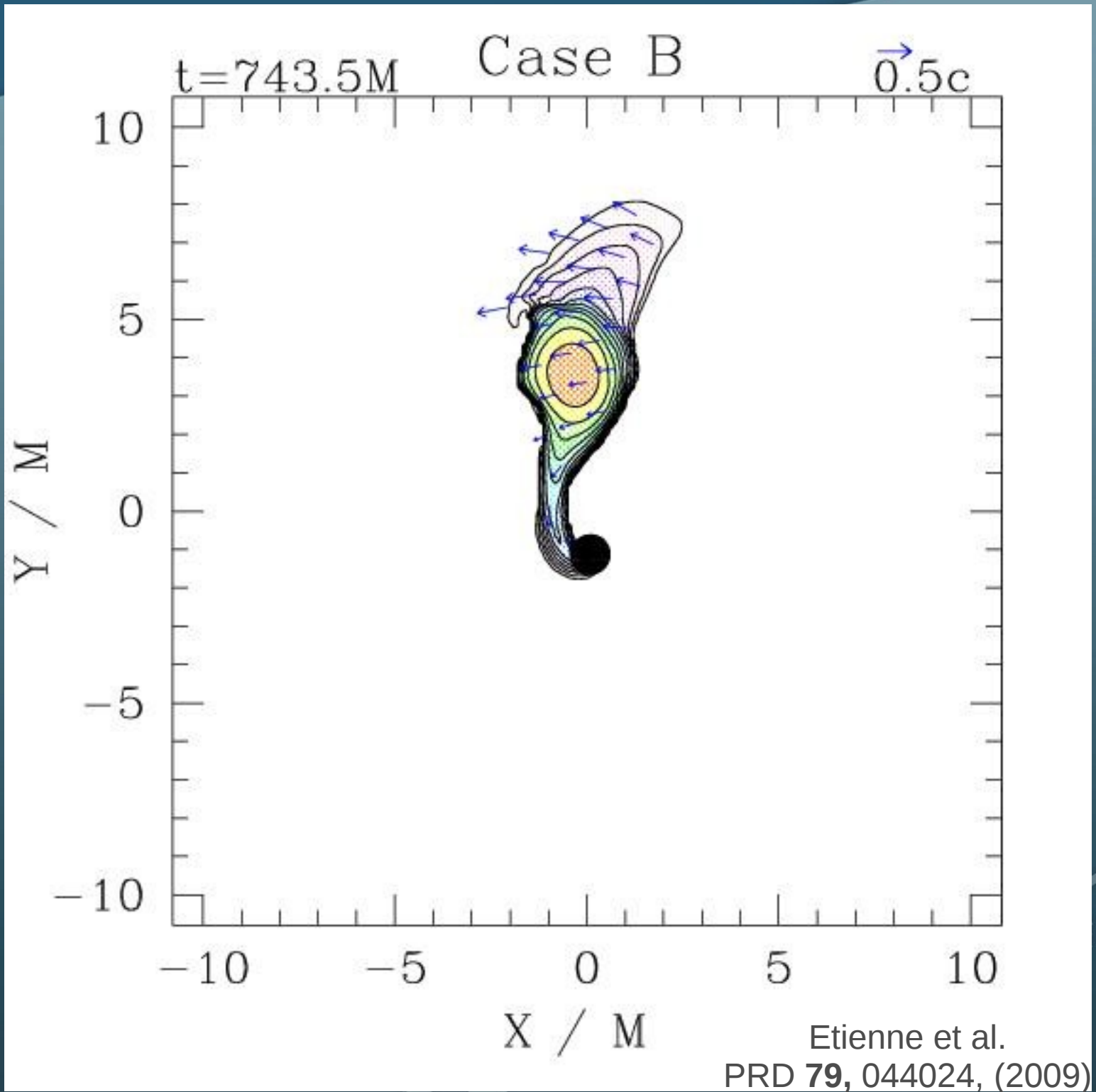

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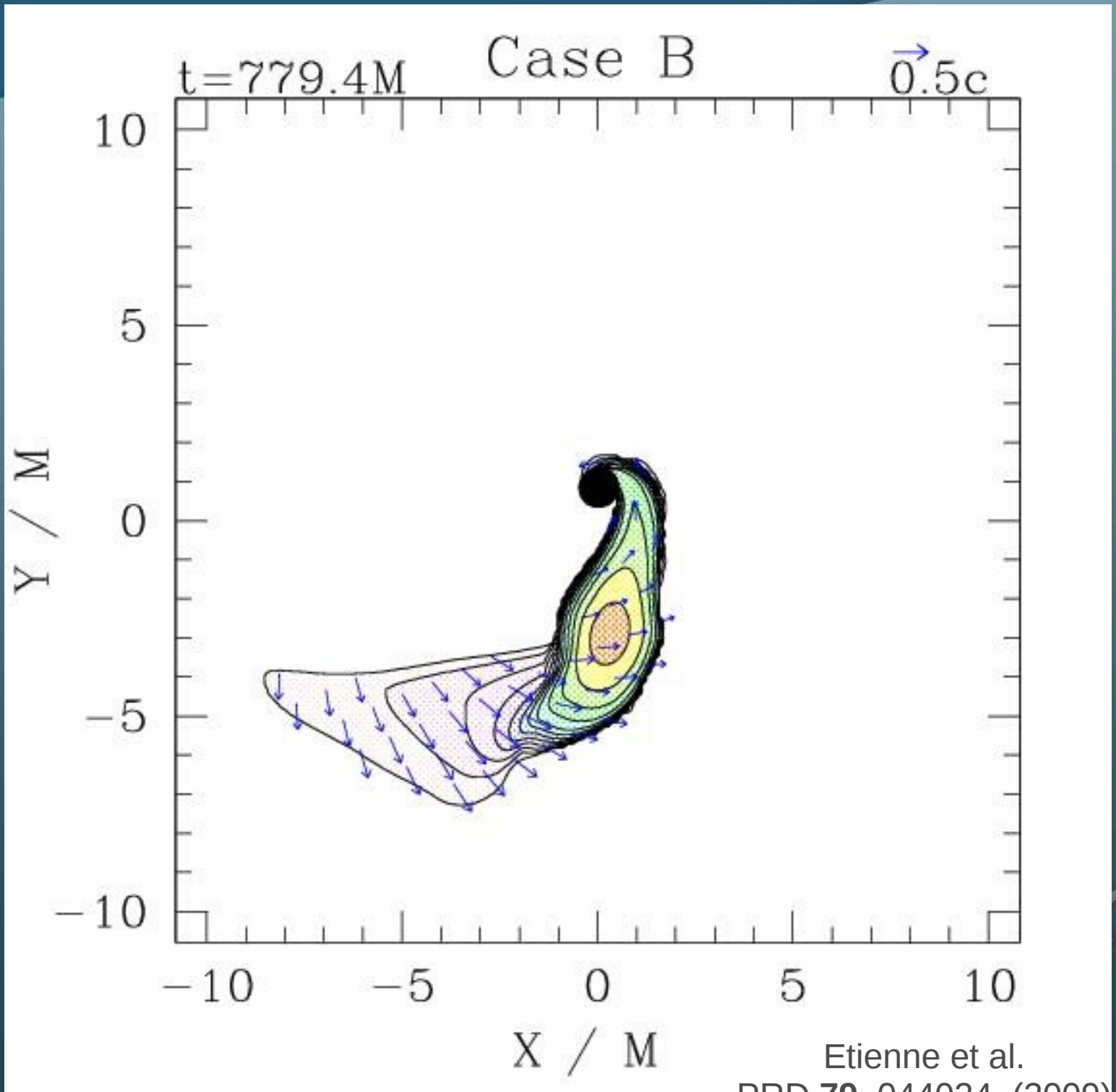

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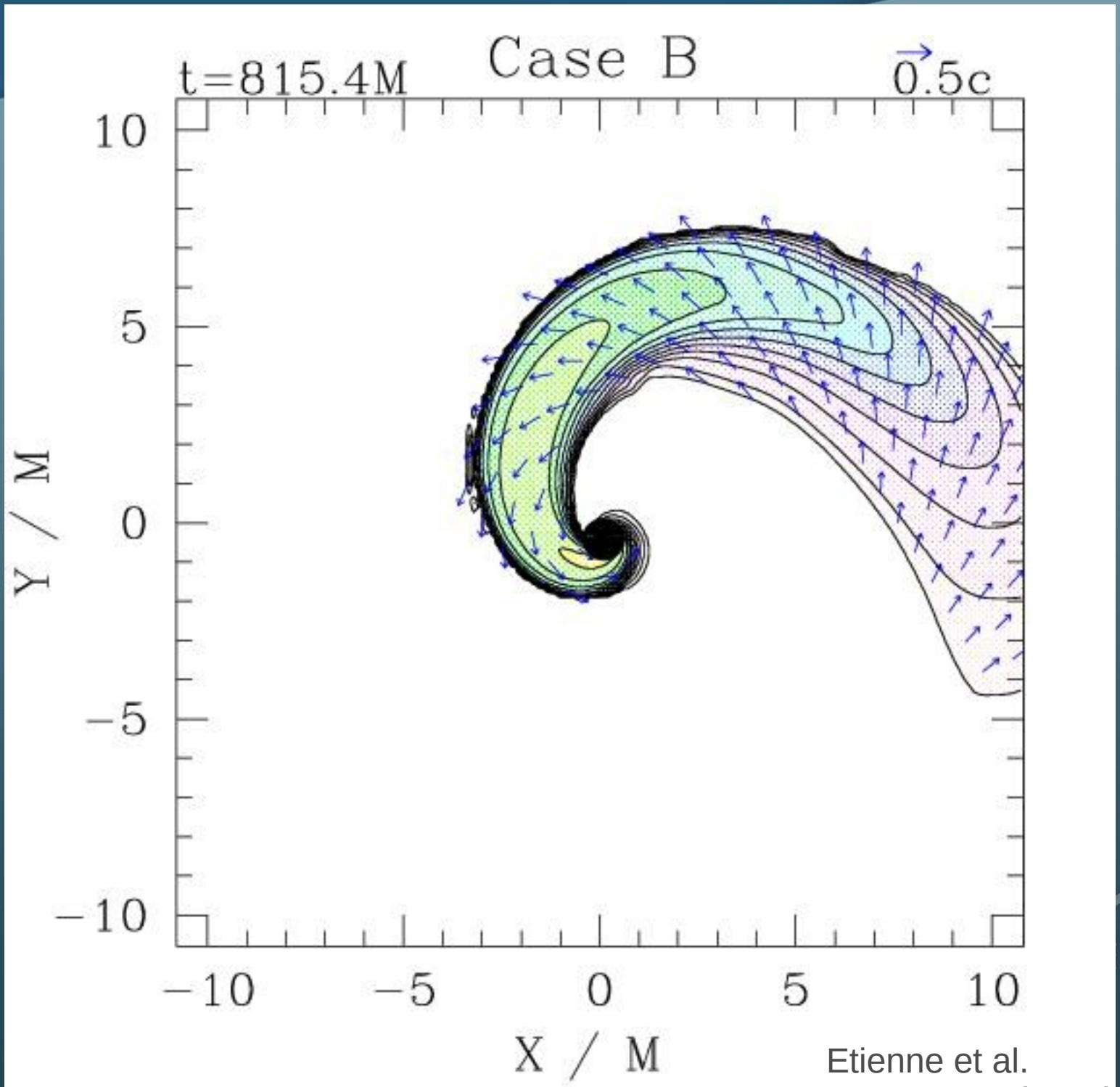
PRD **79,** 044024, (2009)



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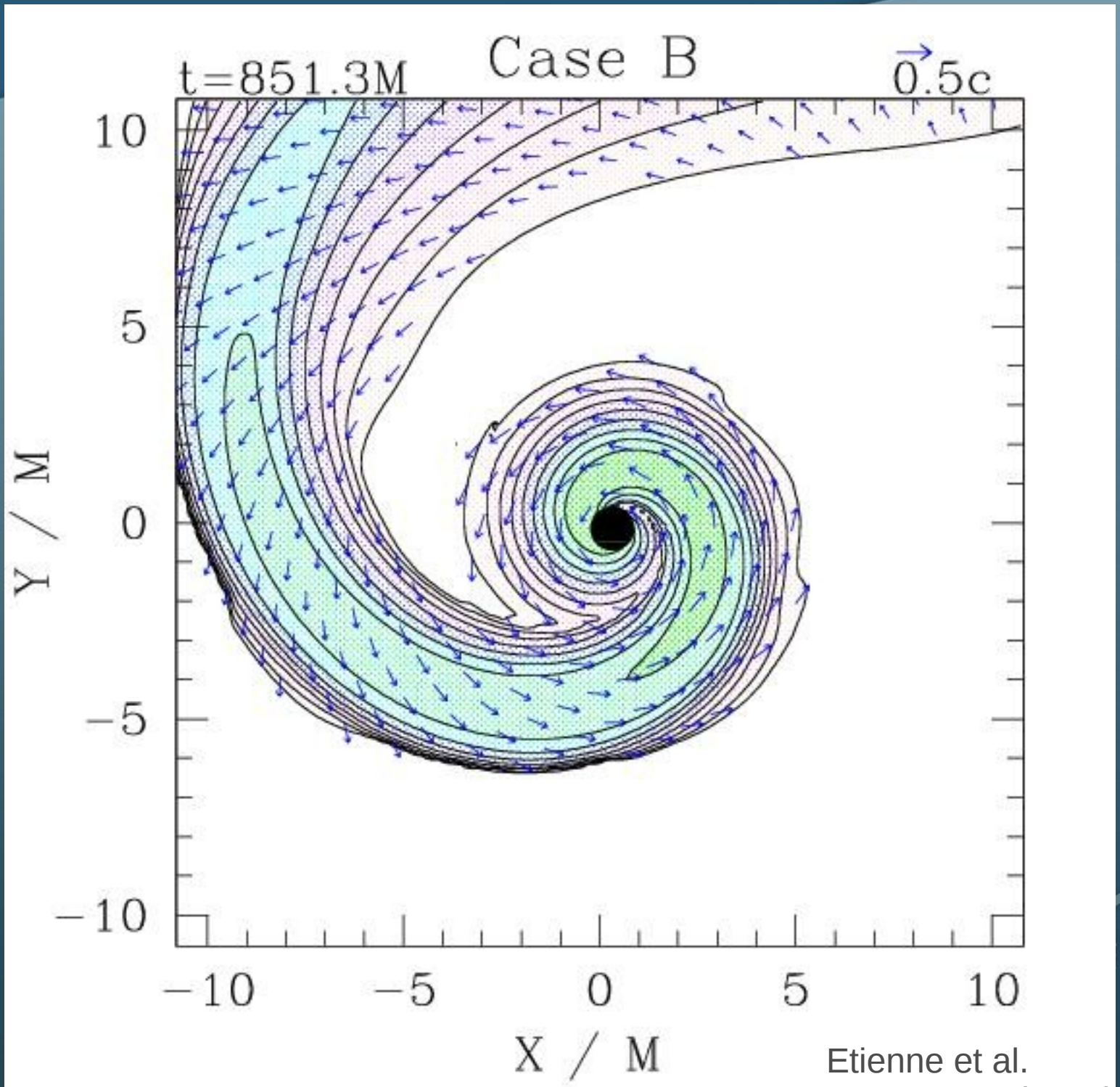

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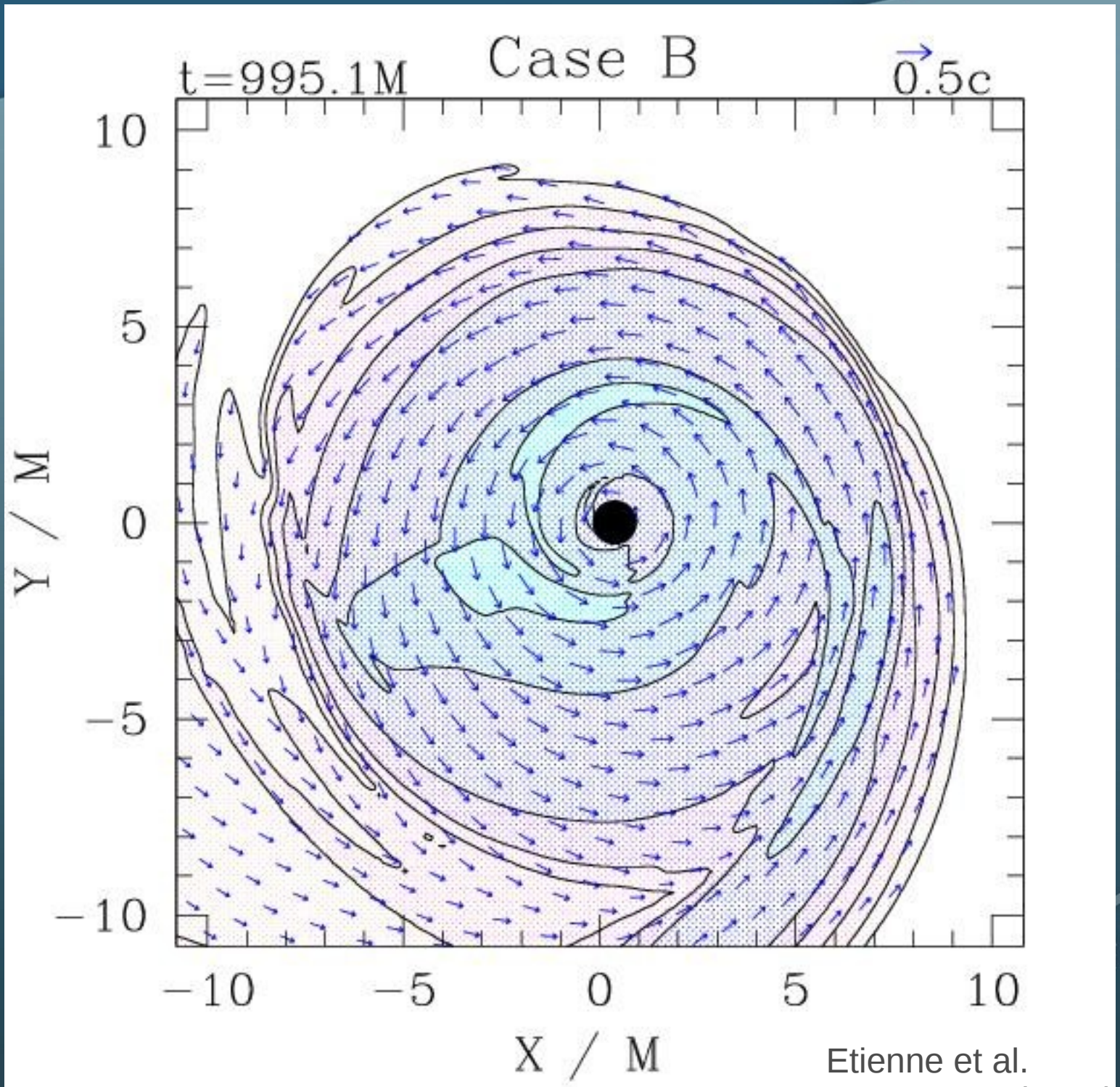

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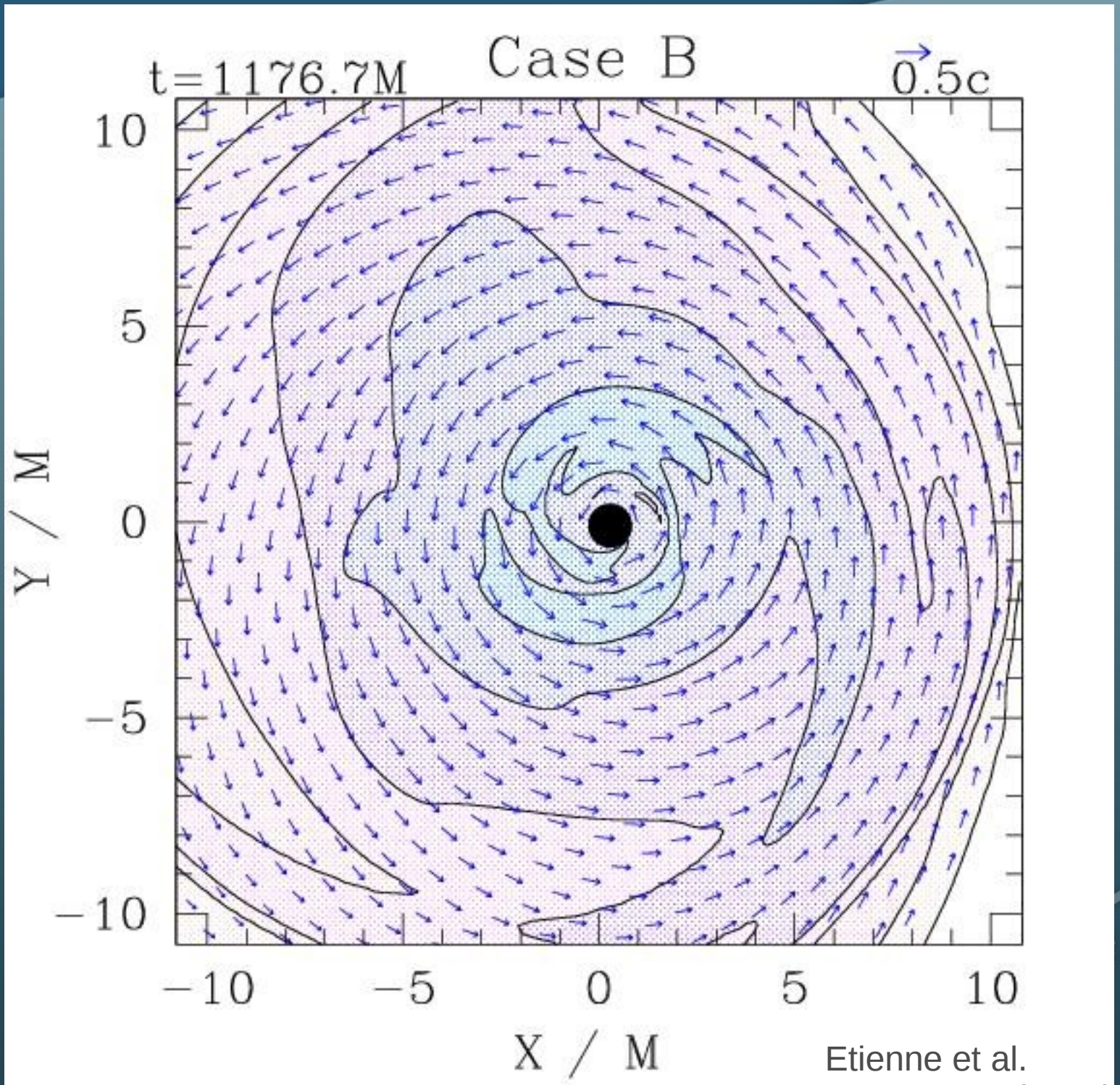
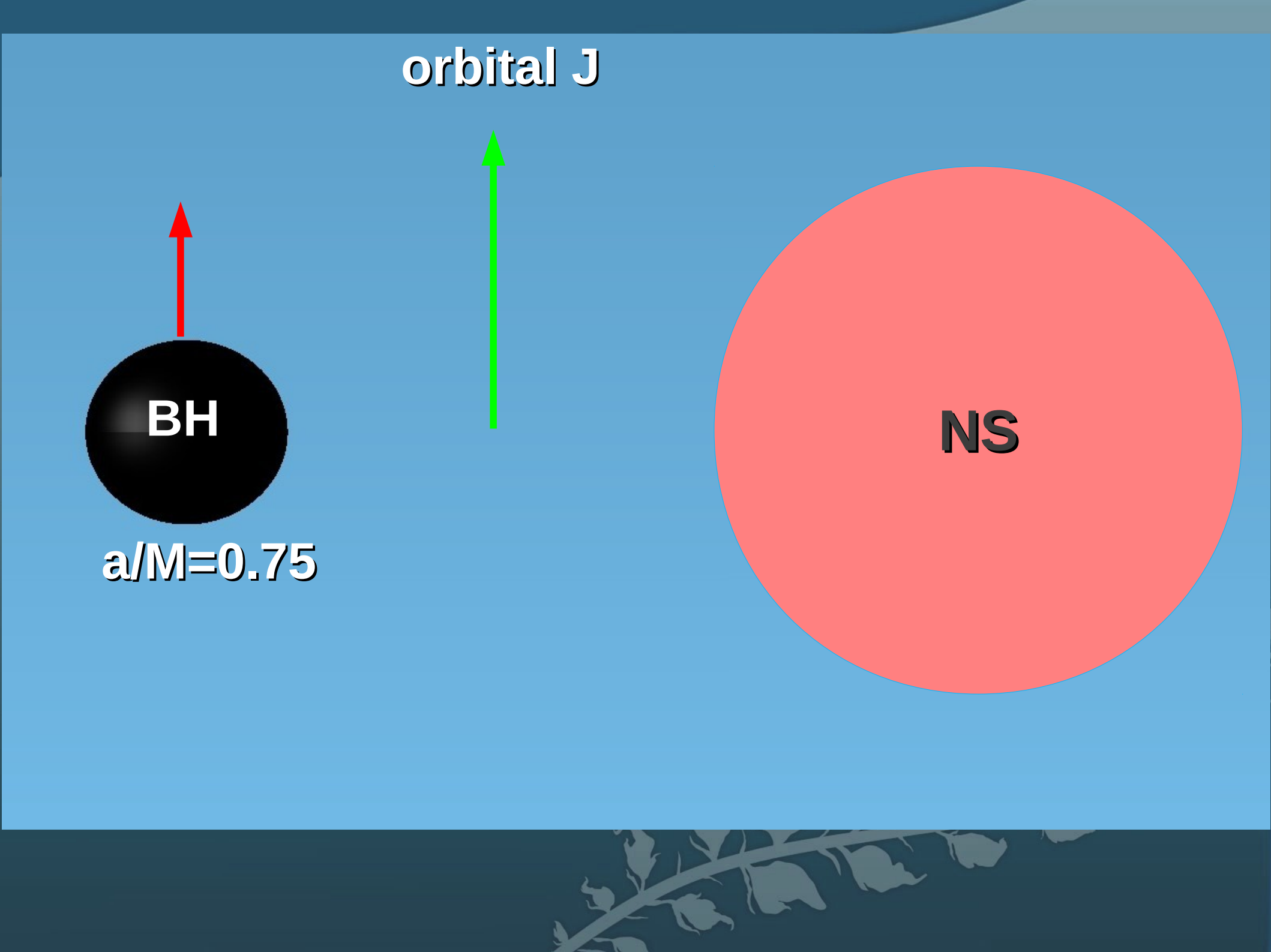
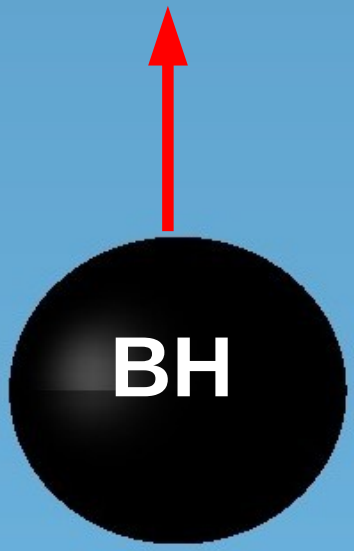


Etienne et al.
PRD **79,** 044024, (2009)


SGRB!
Reuters


orbital J
BH
a/M=0.75
NS

orbital J



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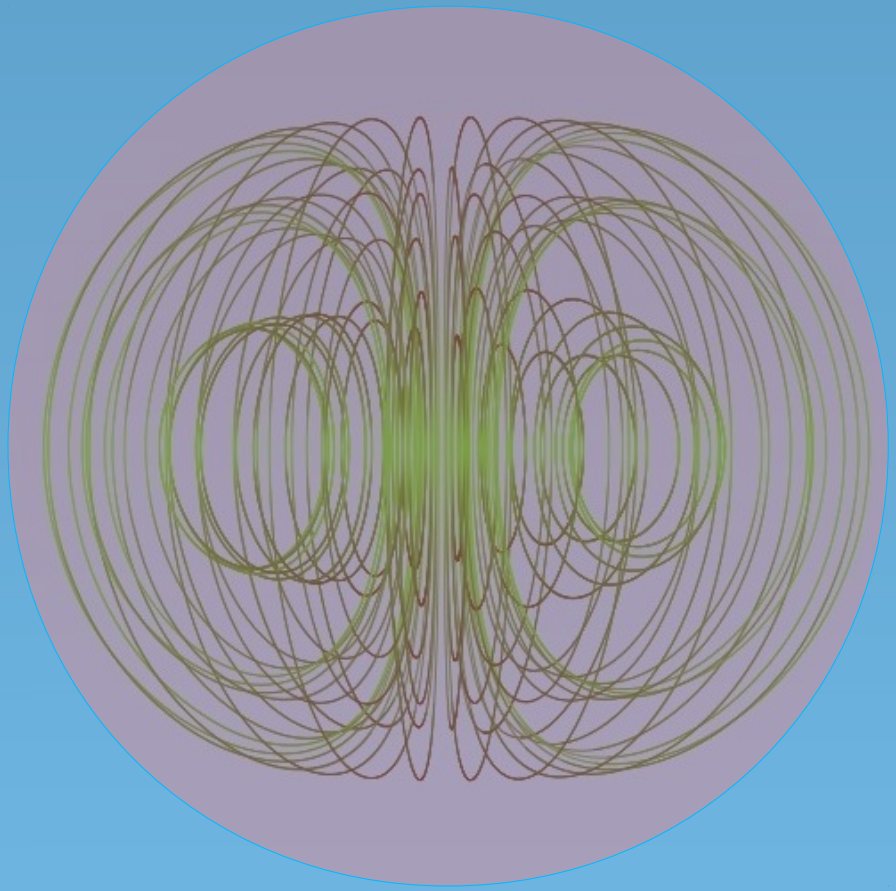

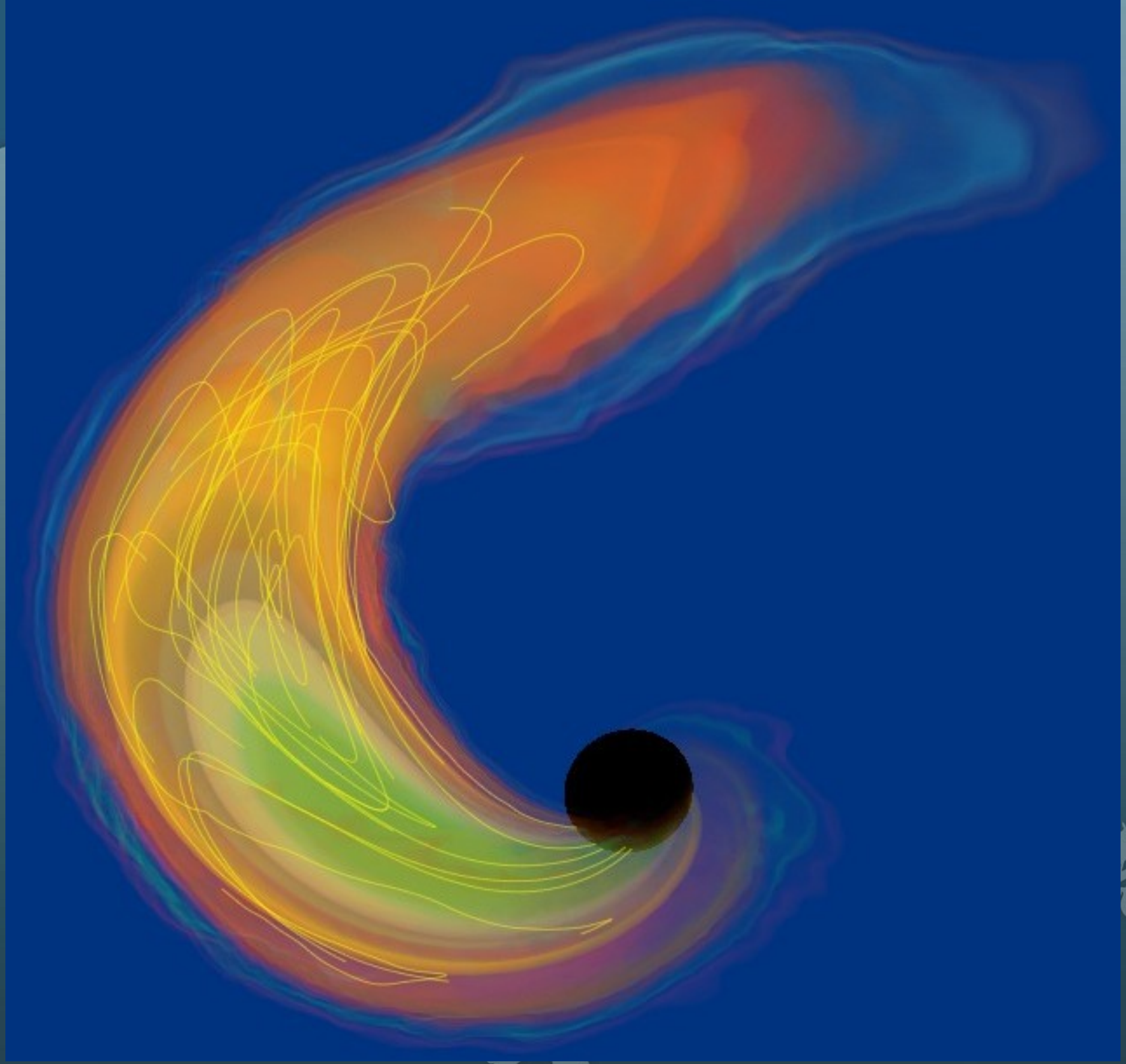

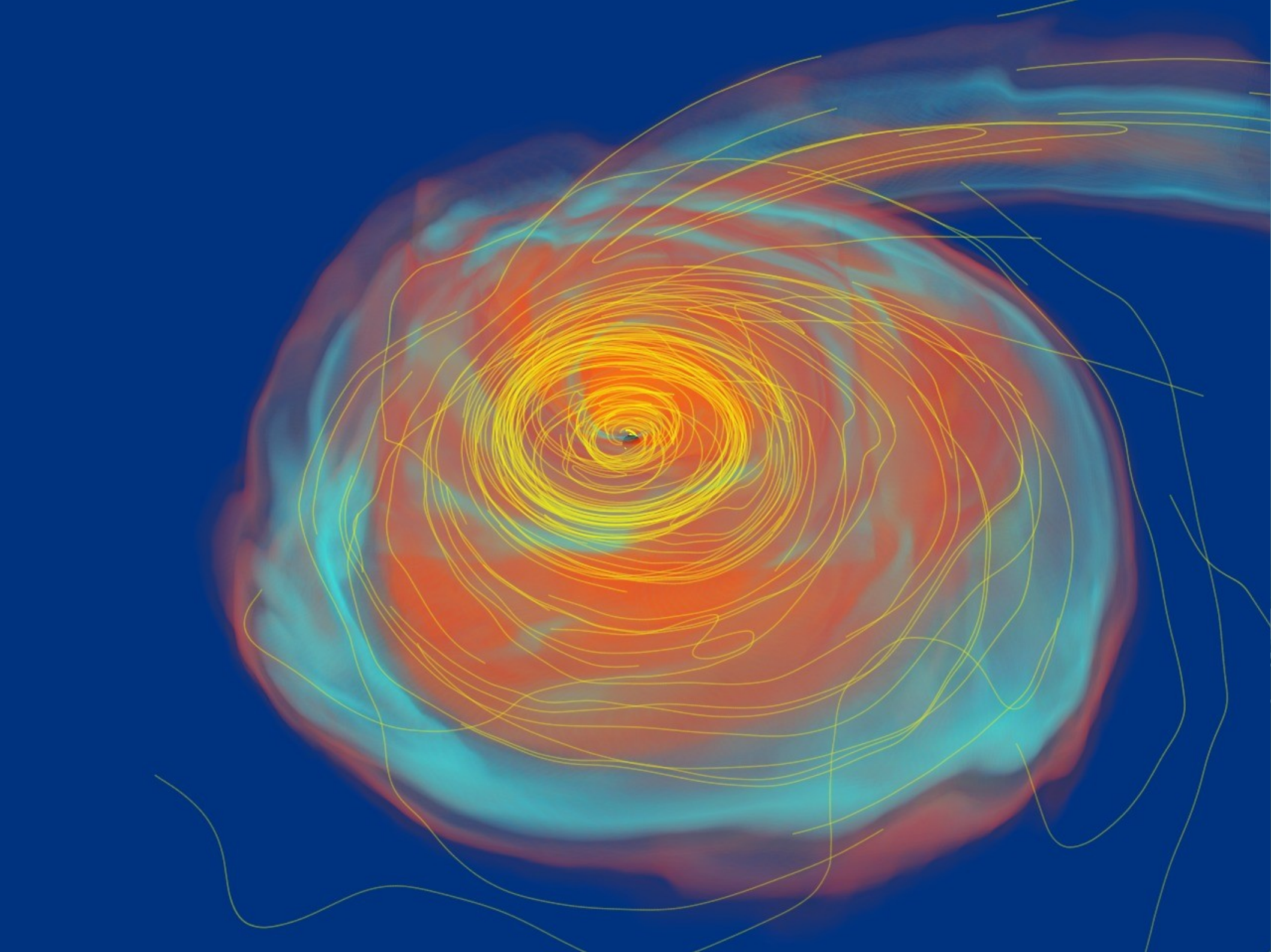

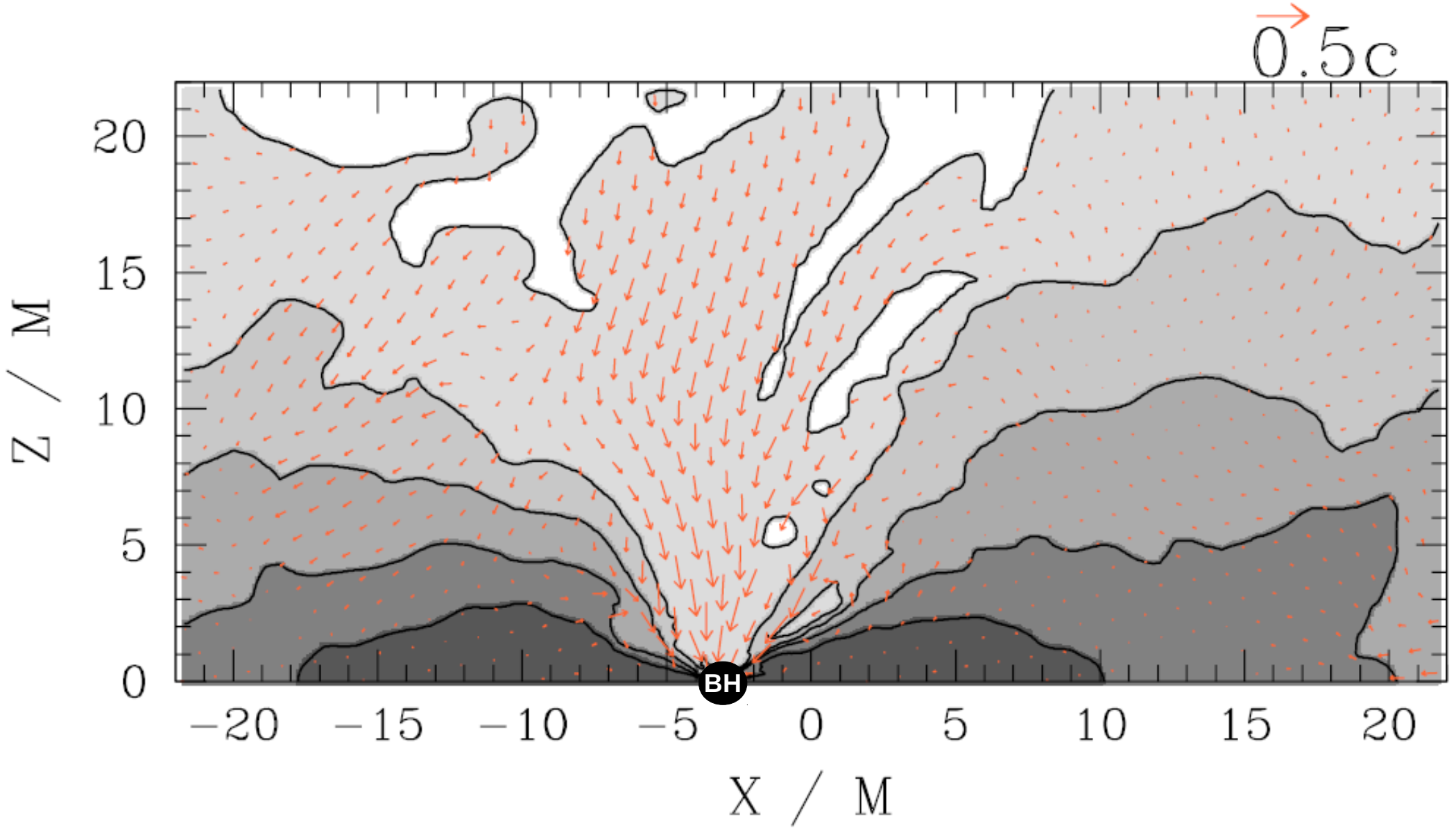

End of simulation

Maybe we didn't evolve long enough...

Etienne et al. (2012)
PRD 85, 064029

The Astrophysical Journal, 678:1180–1199, 2008 May 10

THE INFLUENCE OF MAGNETIC FIELD GEOMETRY ON THE EVOLUTION OF BLACK HOLE ACCRETION FLOWS: SIMILAR DISKS, DRASTICALLY DIFFERENT JETS

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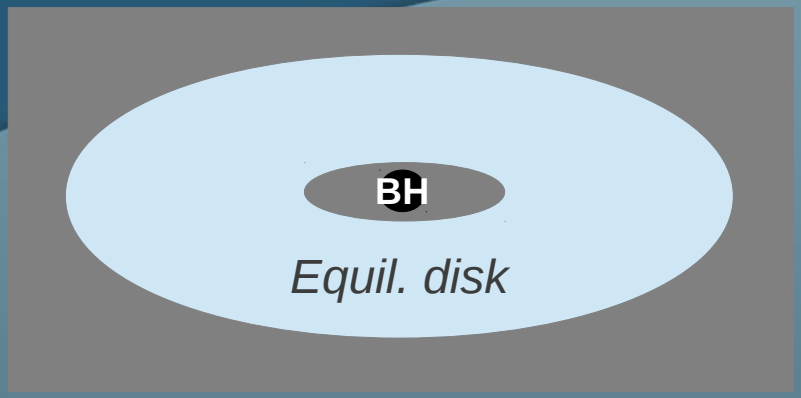
Received 2007 September 24; accepted 2008 January 10



Beckwith, Hawley, & Krolik
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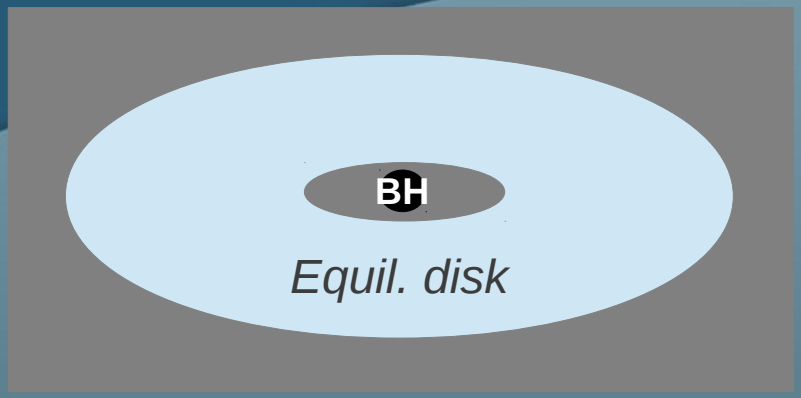
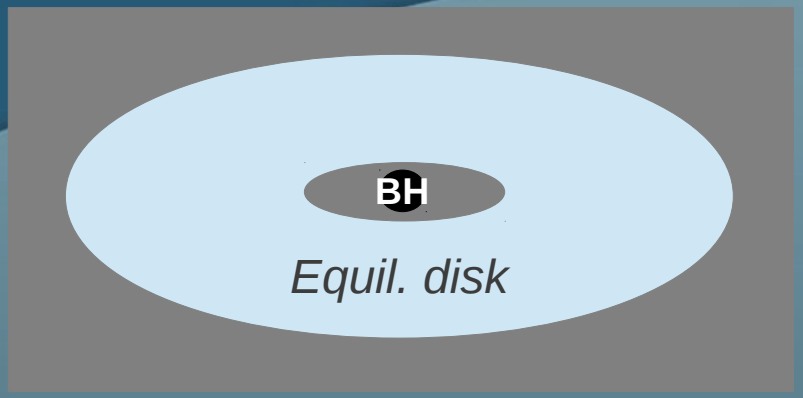


+ Toroidal magnetic fields

Beckwith, Hawley, & Krolik
ApJ 678:1180 (2012)



+ Toroidal magnetic fields → **NO JET**

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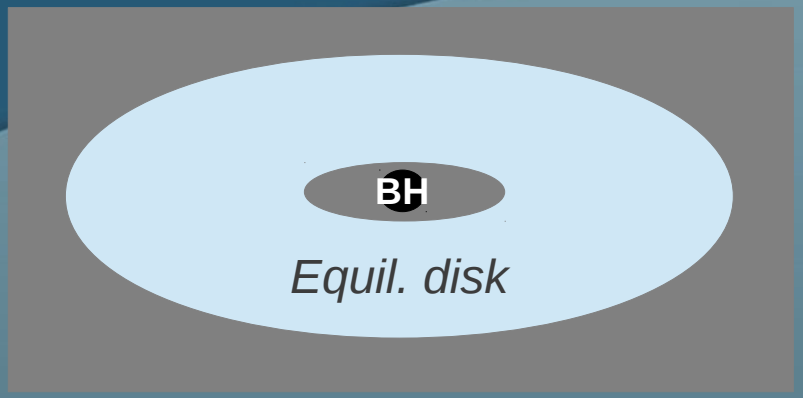


+ Toroidal magnetic fields → **NO JET**

Even after evolving the disk 20x longer than us...

Beckwith, Hawley, & Krolik
ApJ 678:1180 (2012)

Almost purely toroidal magnetic fields

NO JET?
NO SGRB?

Etienne et al. (2012)
PRD 85, 064029

Almost purely toroidal magnetic fields

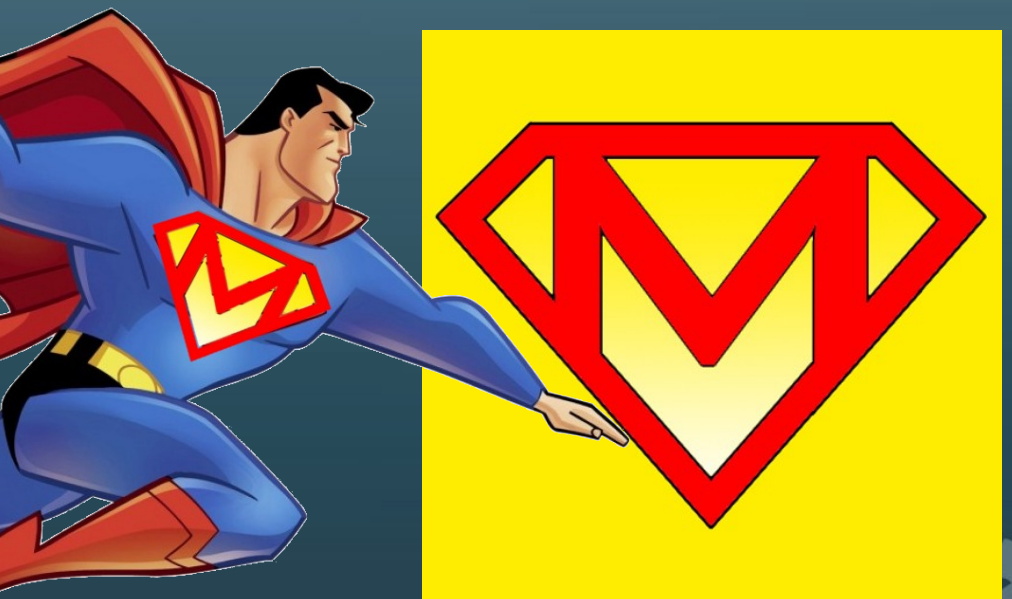
NO JET?
NO SGRB?

Etienne et al. (2012)
PRD 85, 064029

Almost purely toroidal magnetic fields

MRI

Almost purely toroidal magnetic fields



MRI

MRI

Exponentially amplified *poloidal* fields

MHD turbulence = eff. viscosity, drives accretion

Jet formation

SGRB?

MRI

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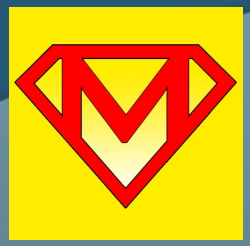

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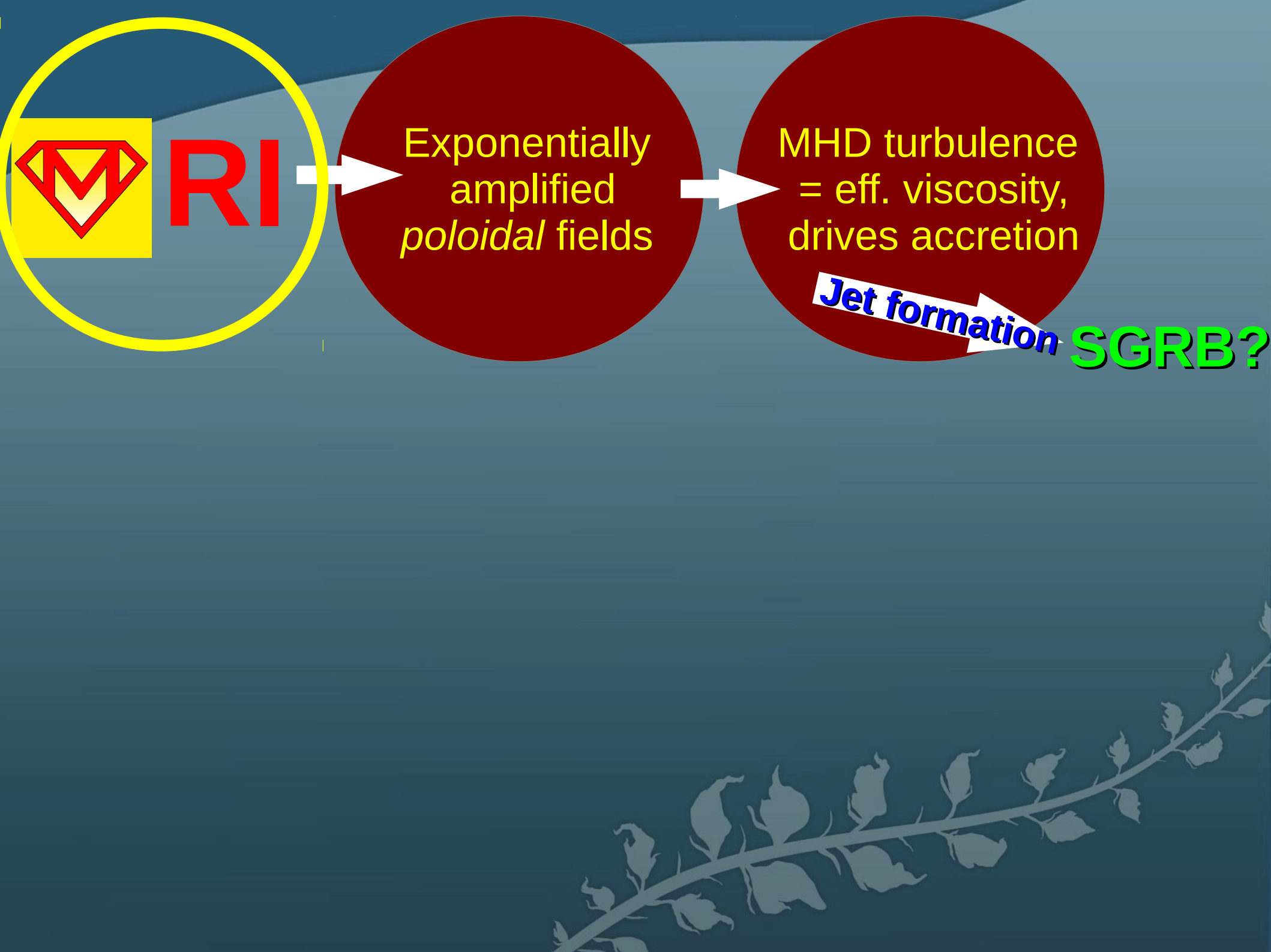
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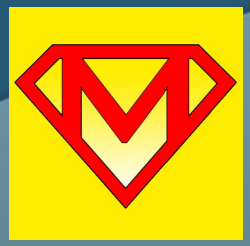

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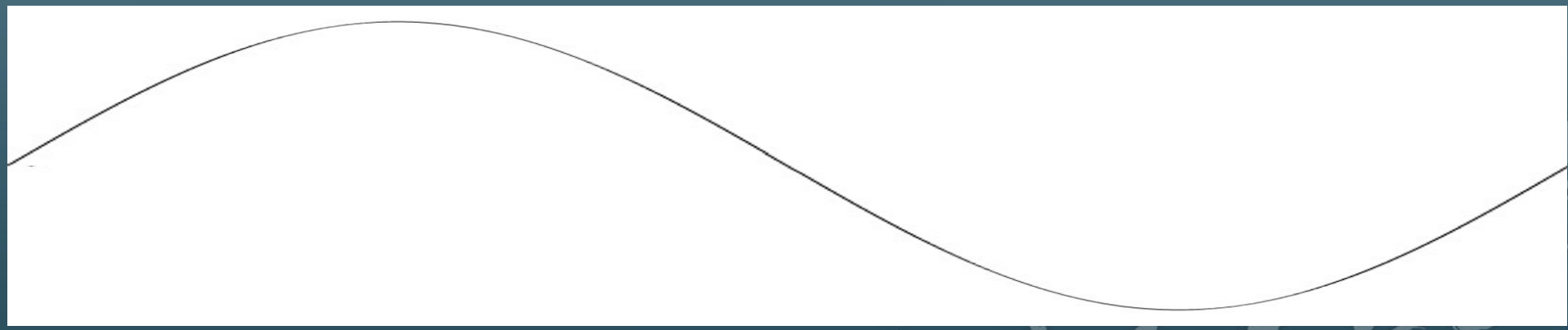

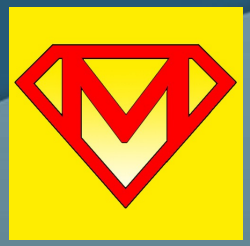

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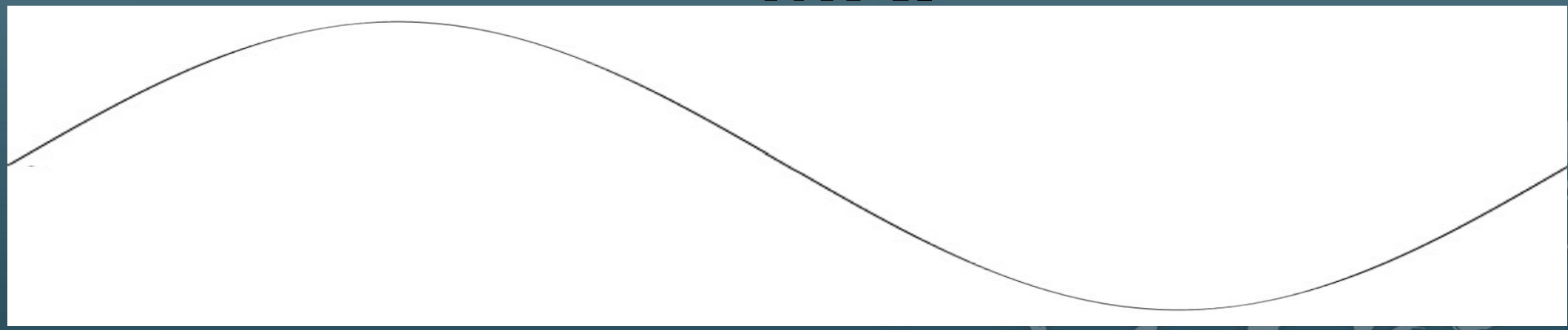
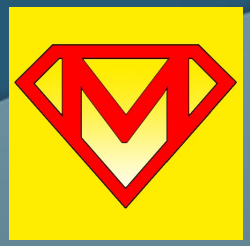
λ_{MRI}





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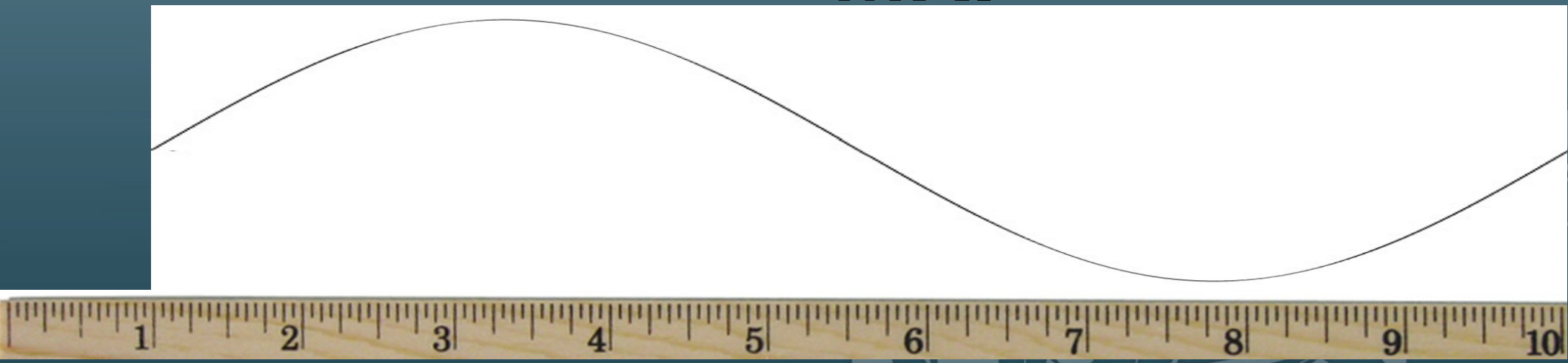

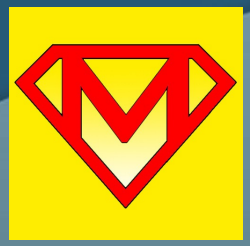

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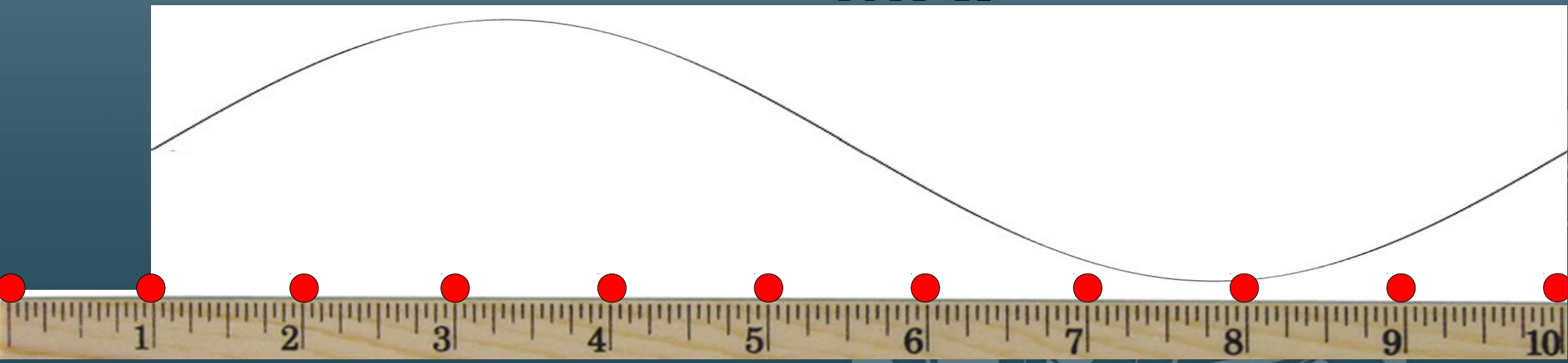

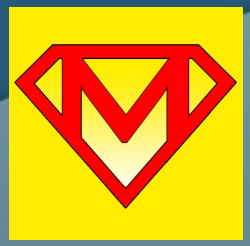

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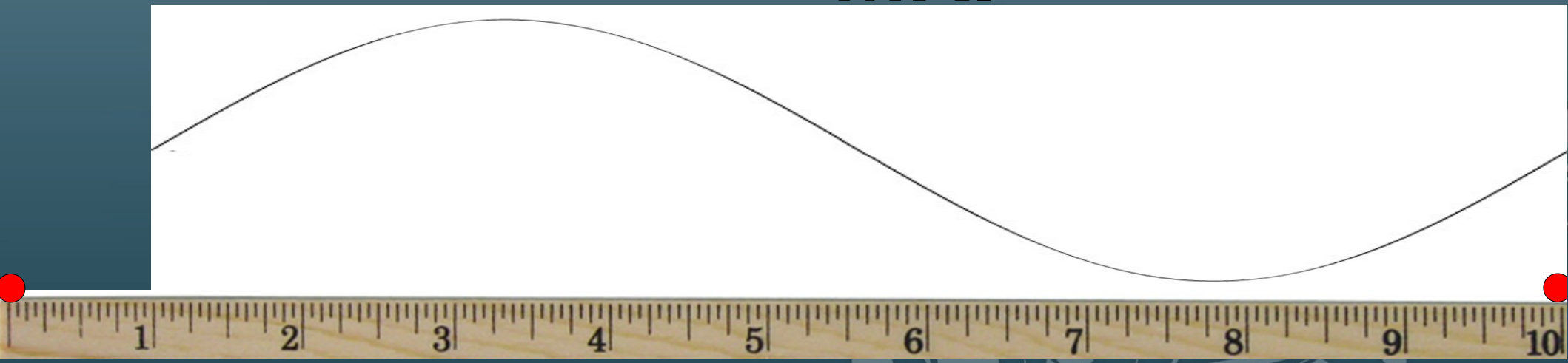
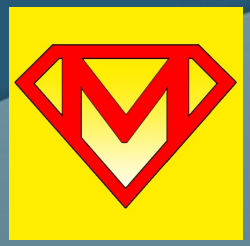


Under-resolve λ_{MRI} by factor of ~10



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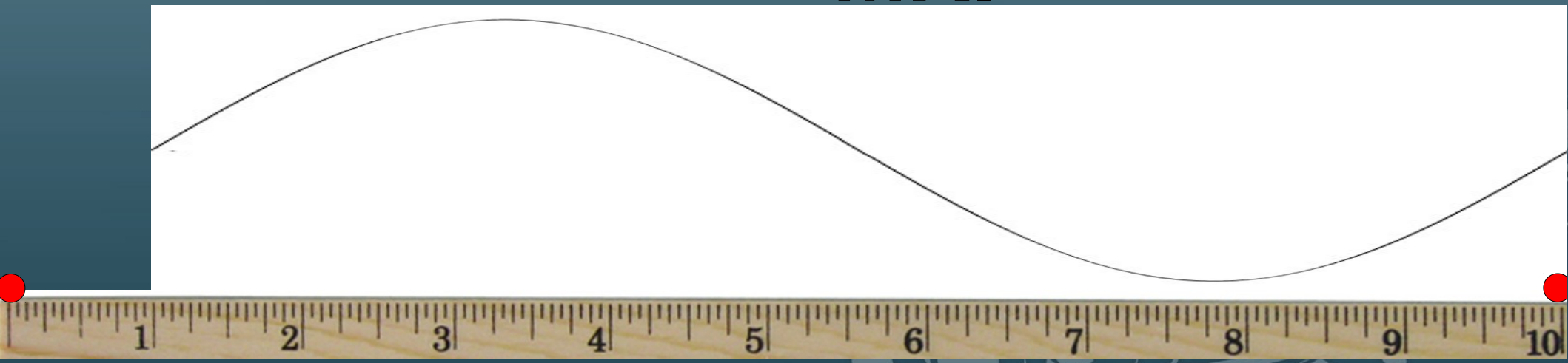

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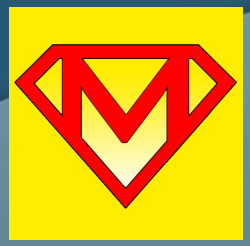

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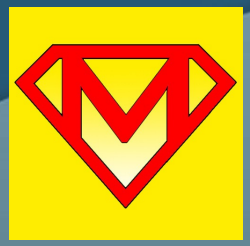

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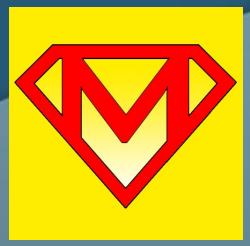
$$\lambda_{MRI} \sim |B^P|$$



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How to increase?

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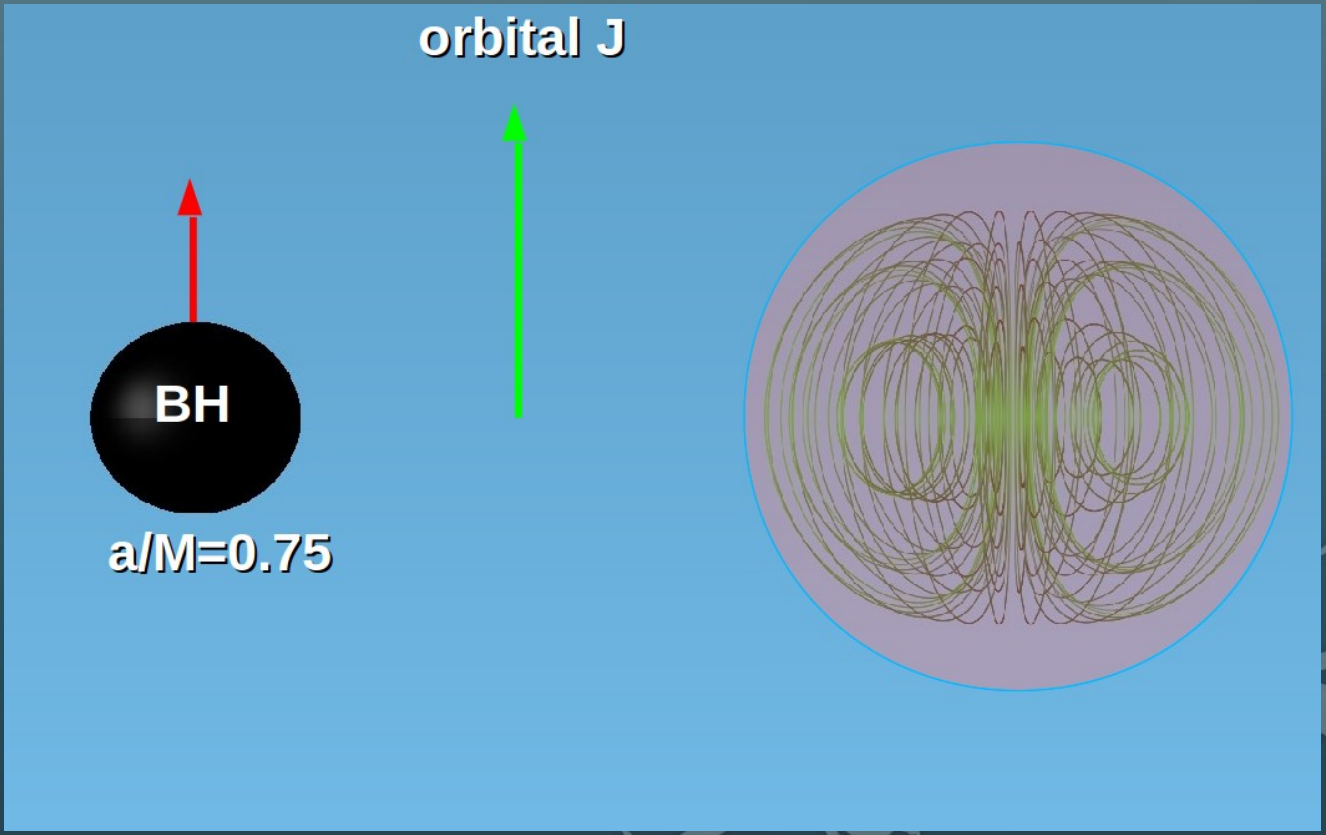
How to increase?



$$\lambda_{MRI} \sim |B^P|$$

How to increase?

Mirror symmetry imposed

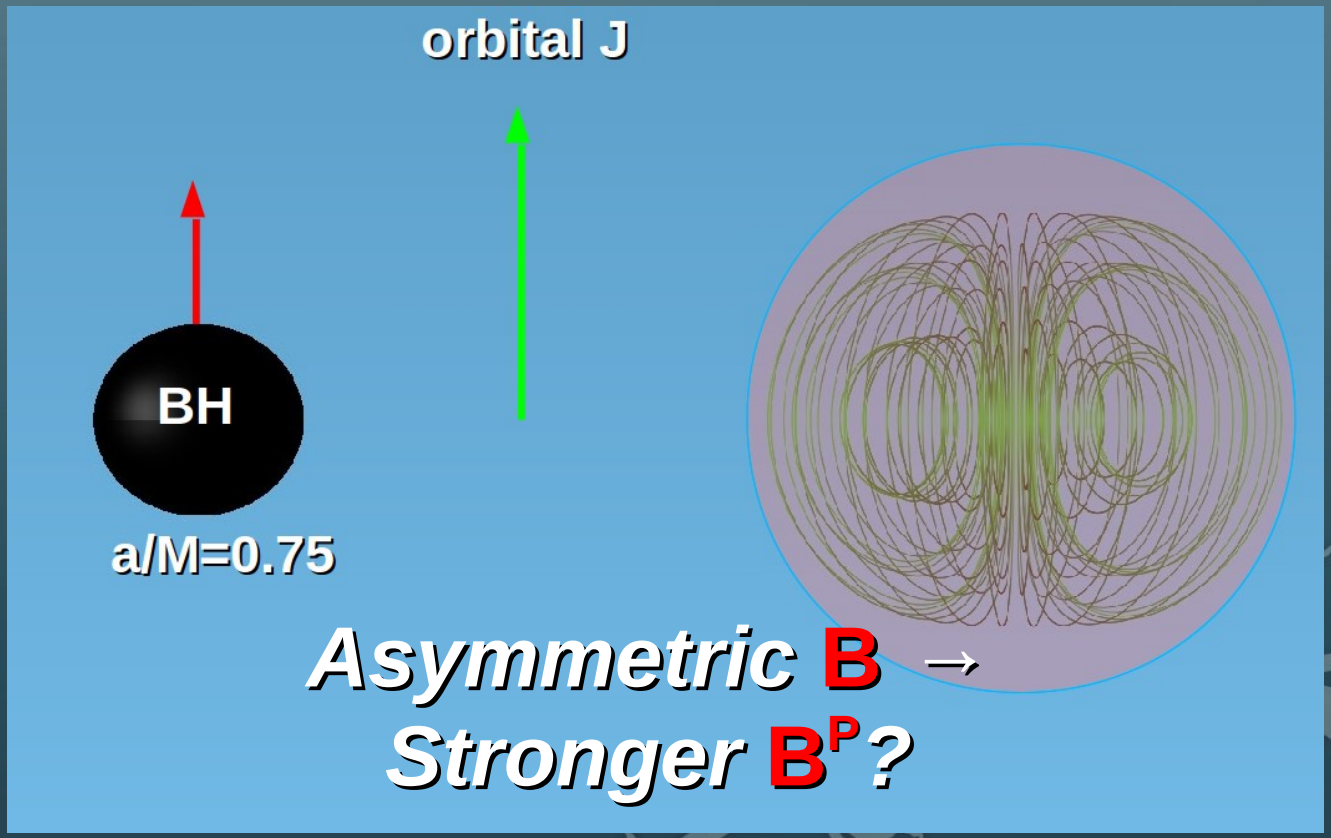
$$\lambda_{MRI} \sim |B^P|$$

How to increase?

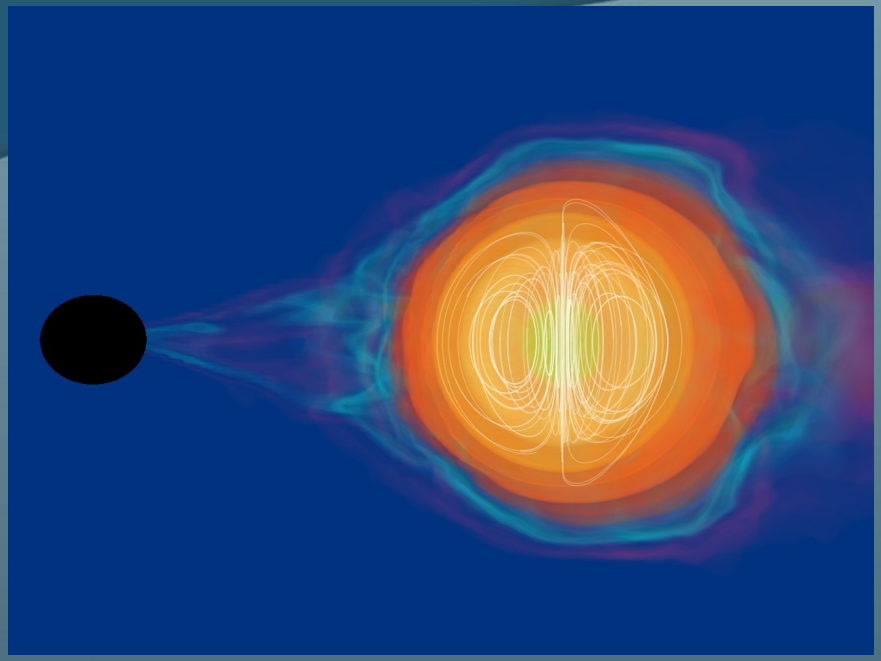
Mirror symmetry imposed →
Fluid can't cross

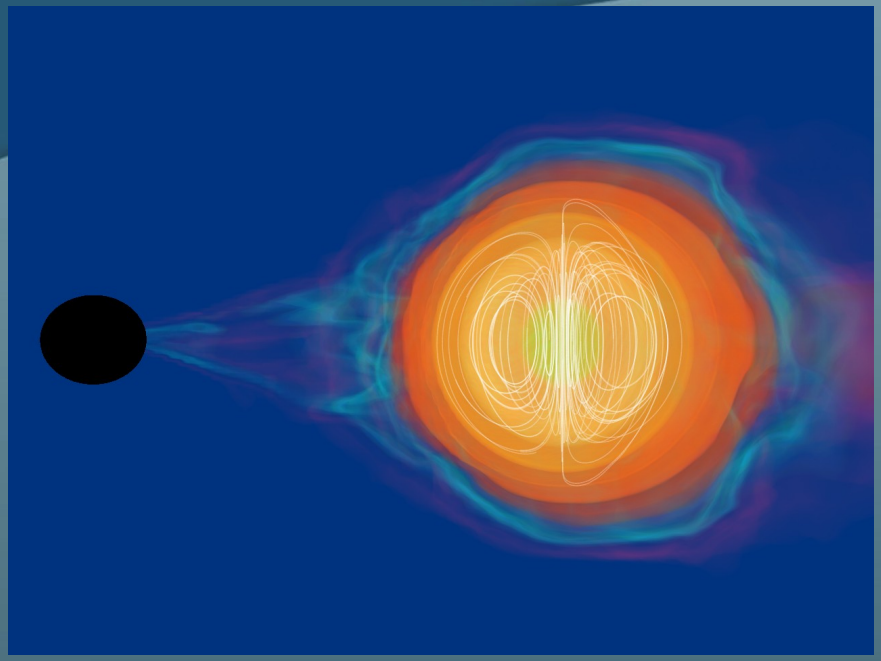
$$\lambda_{MRI} \sim |B^P|$$

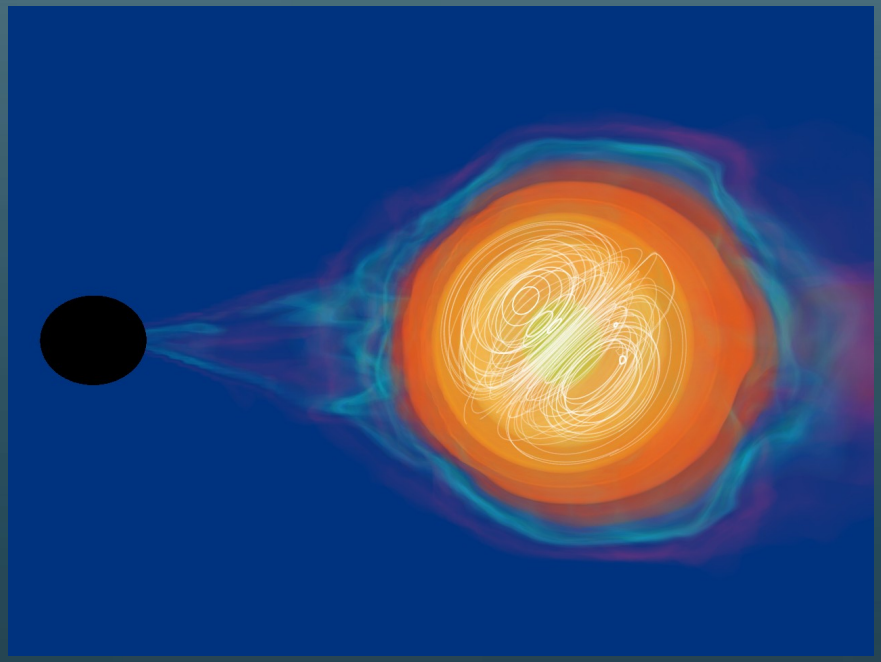
How to increase?

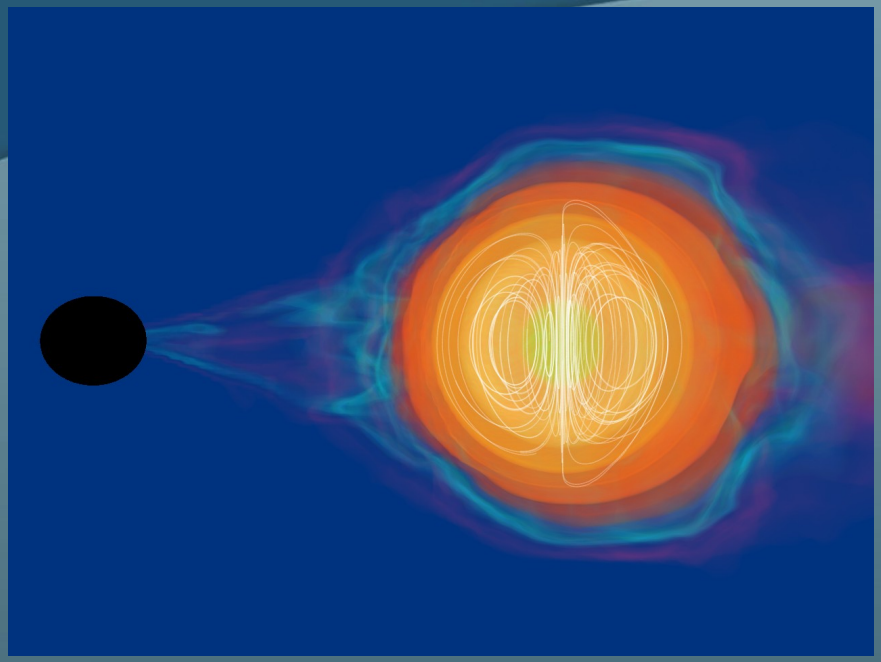


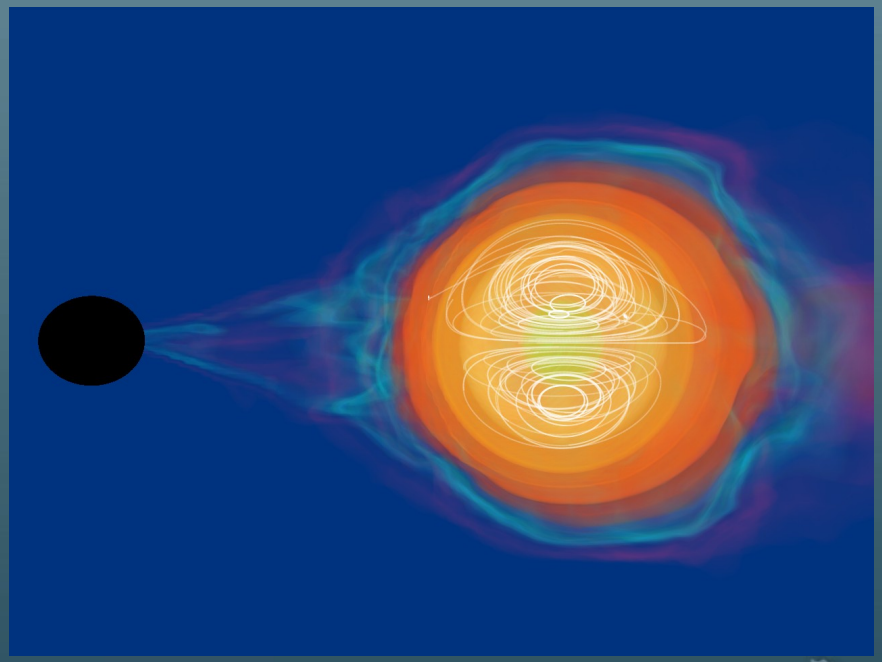
Asymmetric B →
Stronger B^P?

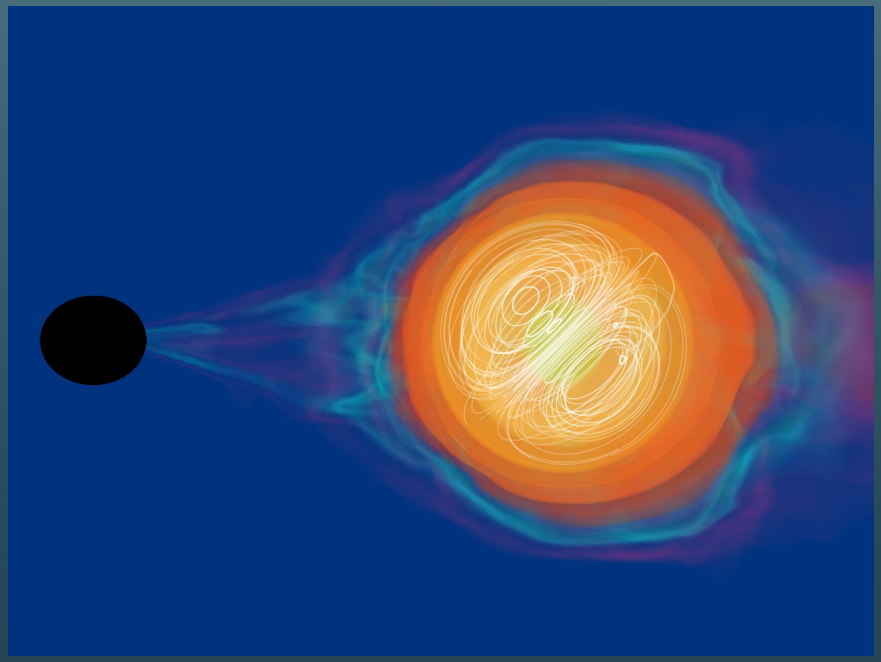


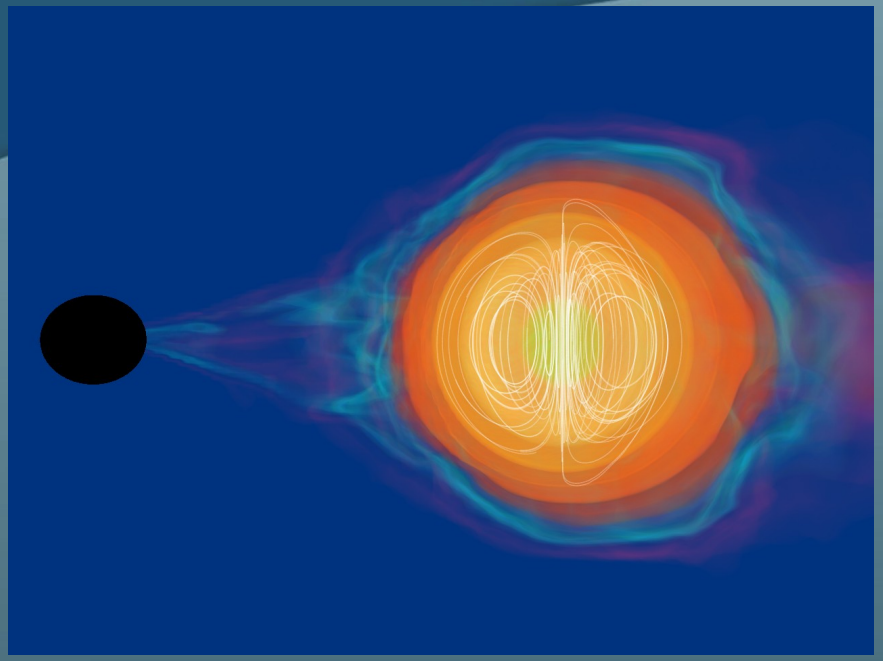


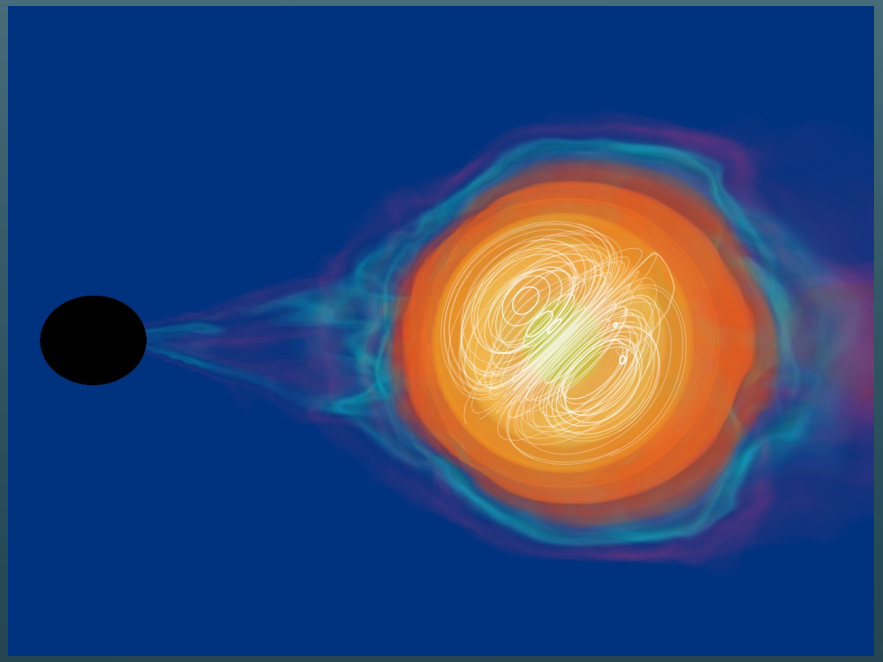


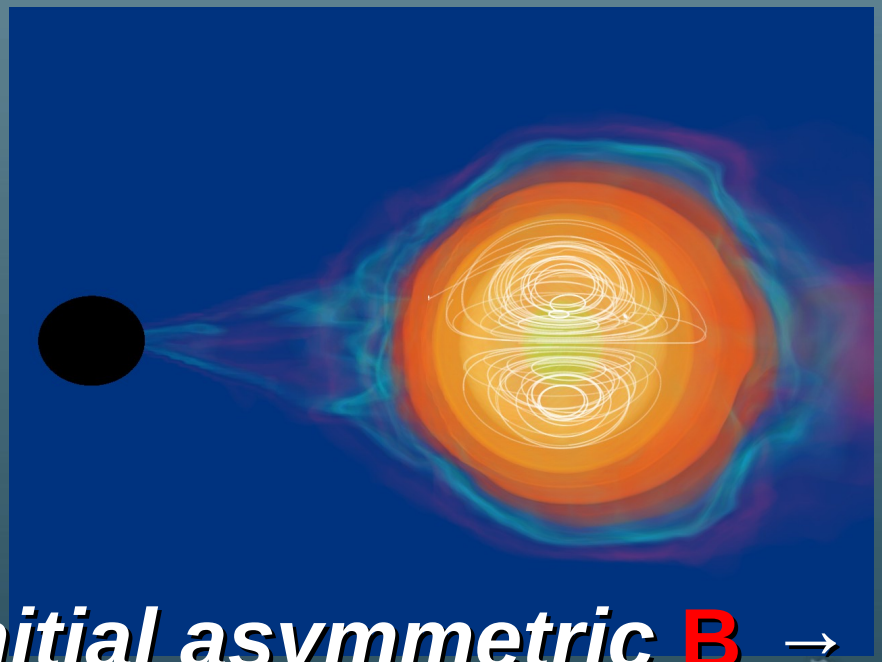




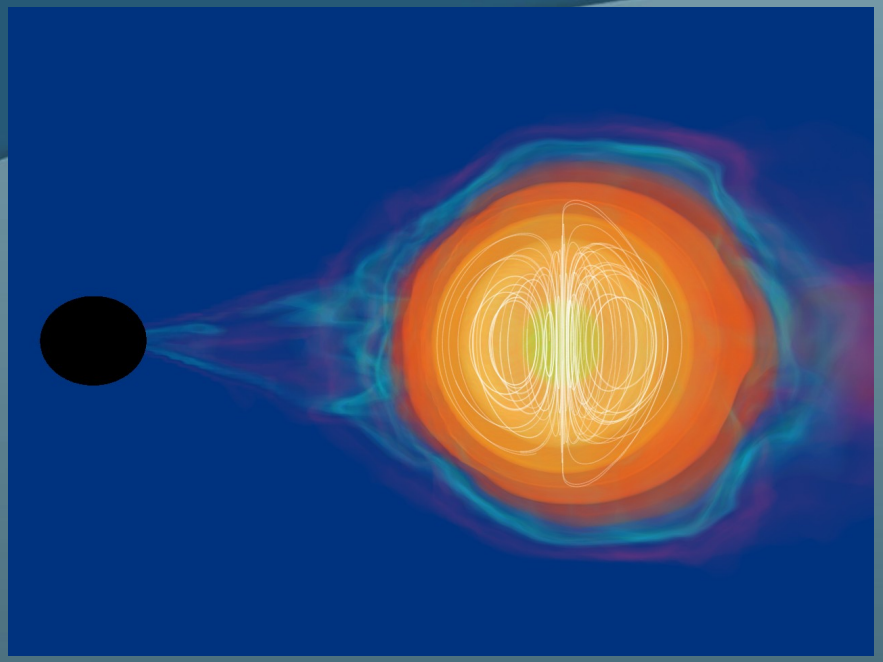


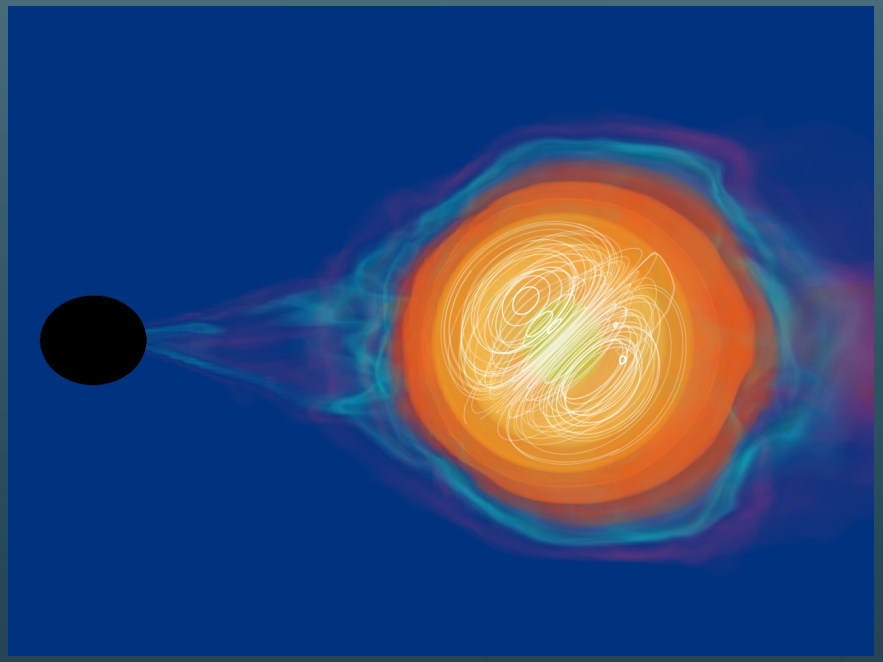


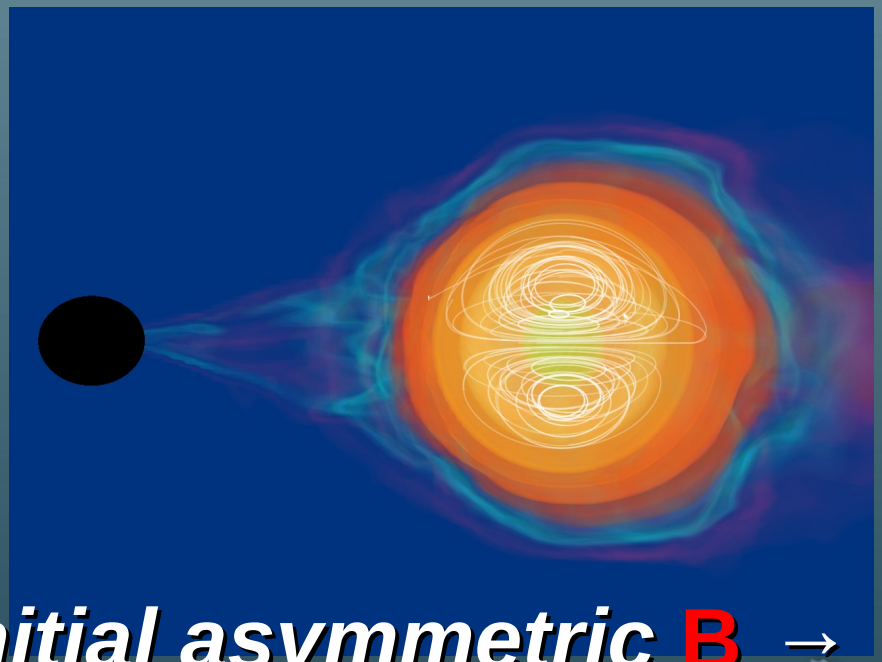




Initial asymmetric B →
Stronger B^P in the disk?



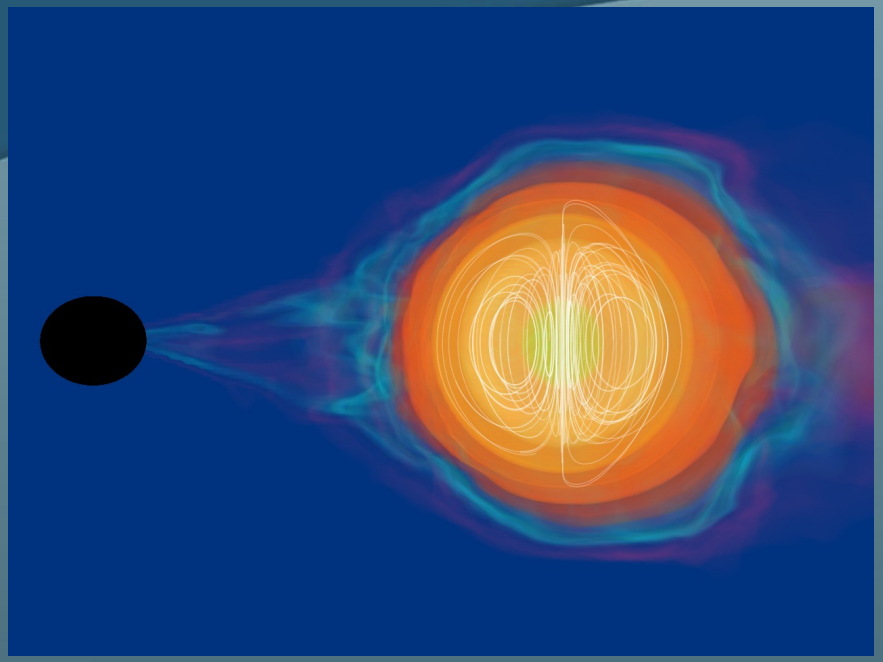


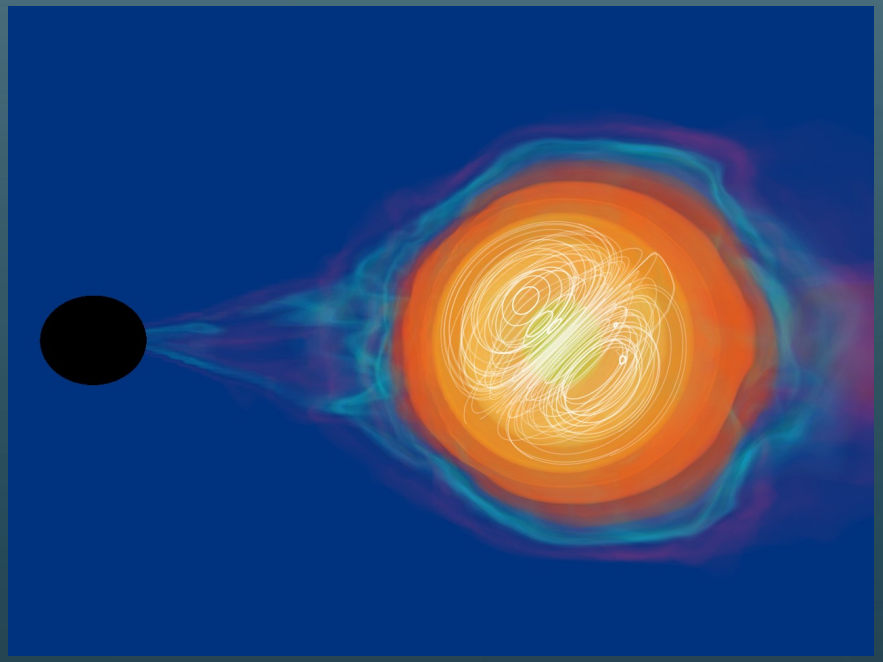


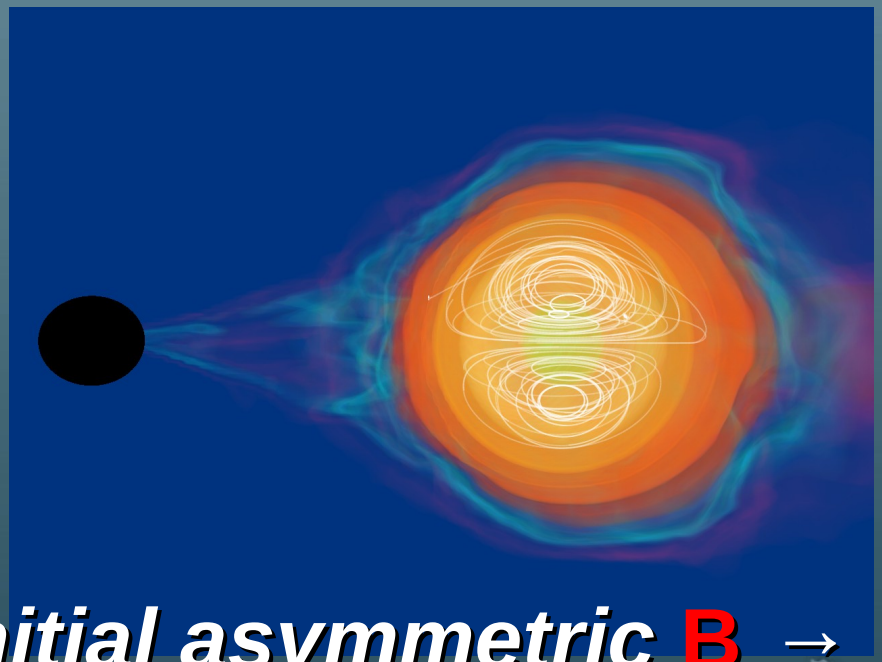
Initial asymmetric B →
Stronger B^P in the disk?

YES:

Stronger tilt →
Stronger B^P







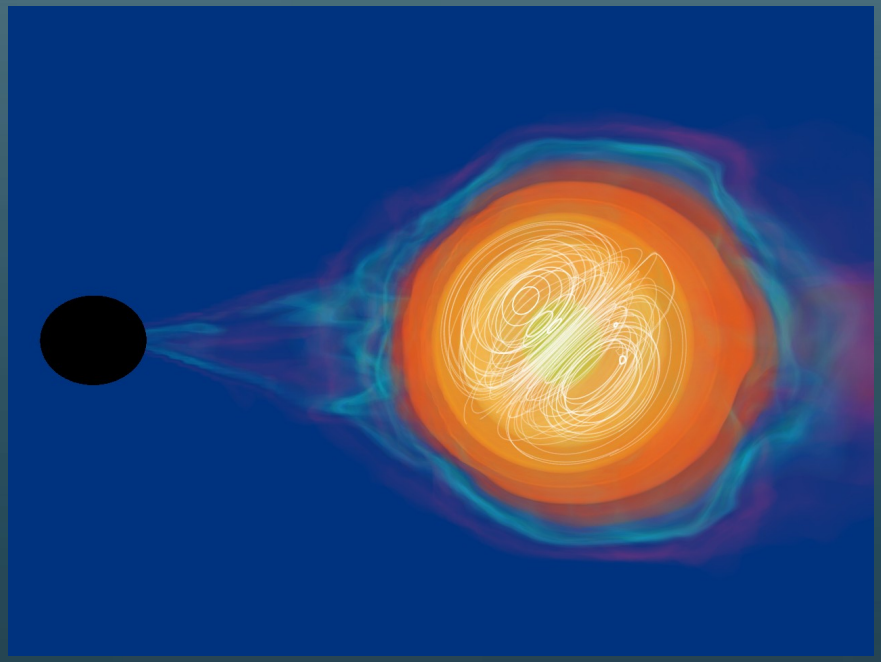
Initial asymmetric B →
Stronger B^P in the disk?

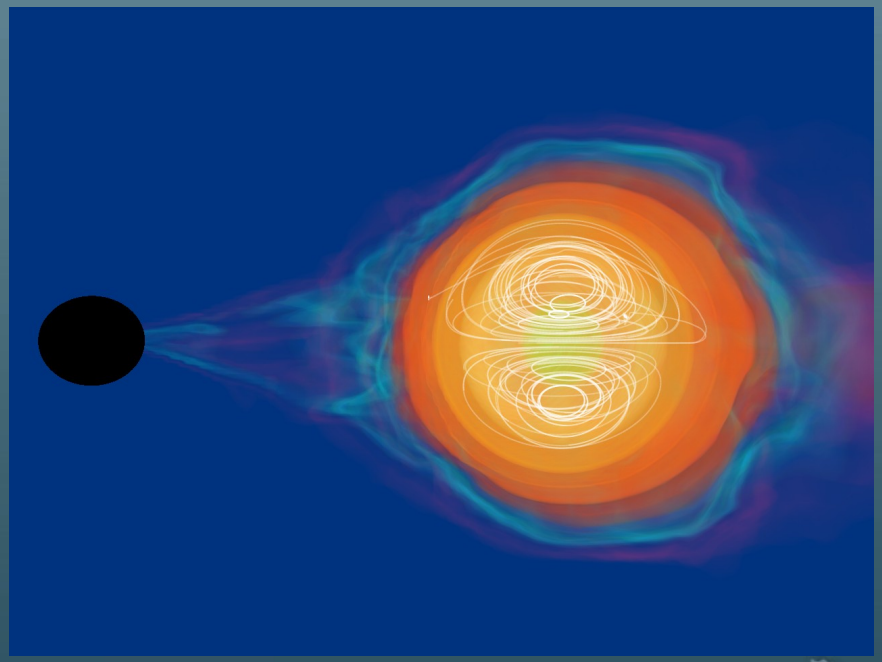
YES:

Stronger tilt →
Stronger B^P

$\lambda_{MRI}/\Delta X \approx 1$

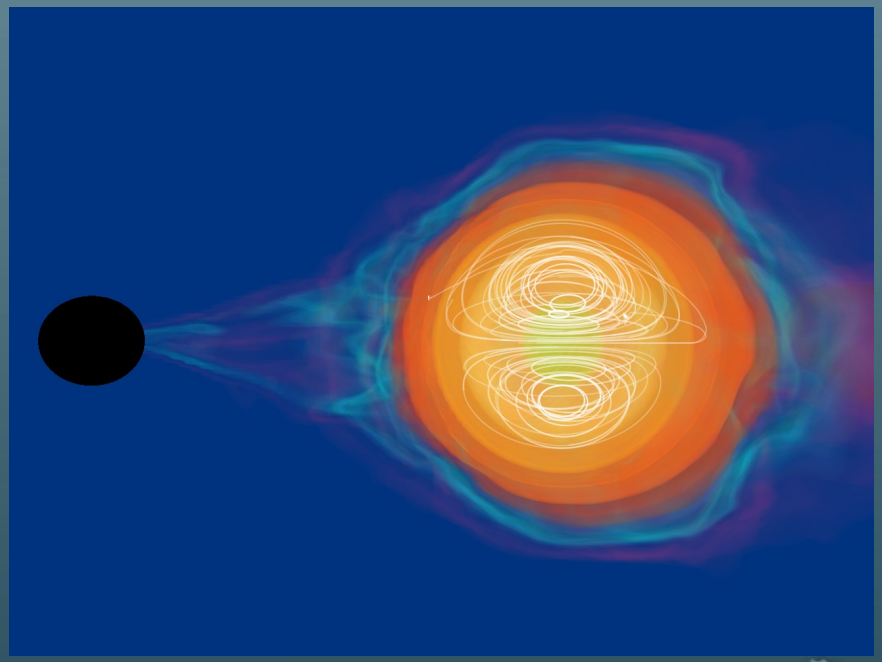
in remnant disk



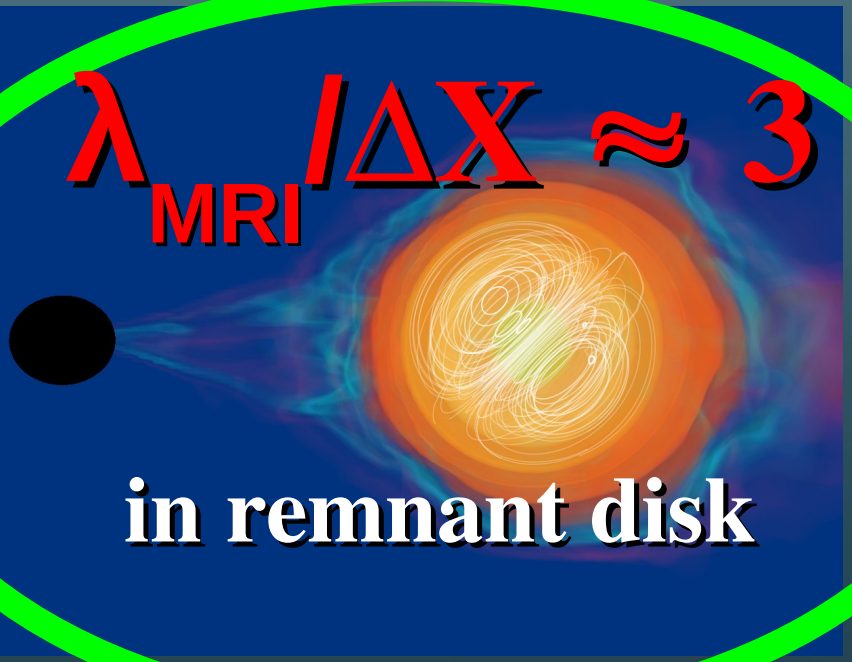


$\lambda_{MRI}/\Delta X \approx 1$

in remnant disk



$\lambda_{MRI}/\Delta X \approx 3$



in remnant disk

$\lambda_{MRI}/\Delta X \approx 1$

in remnant disk

$\lambda_{MRI}/\Delta X \approx 3$

in remnant disk

$\lambda_{MRI}/\Delta X \approx 8$

in remnant disk

$\lambda_{MRI}/\Delta X \approx 1$

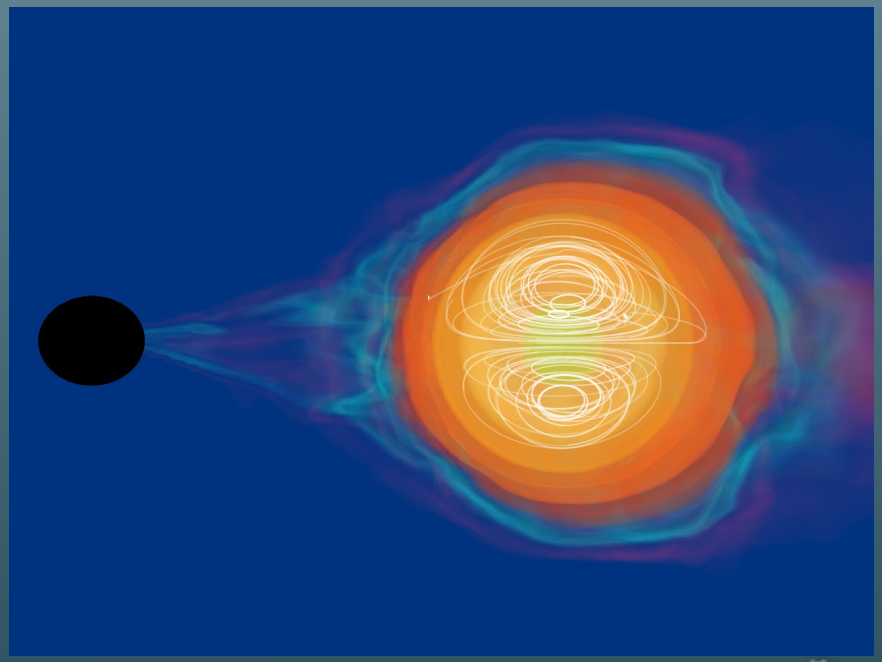
in remnant disk

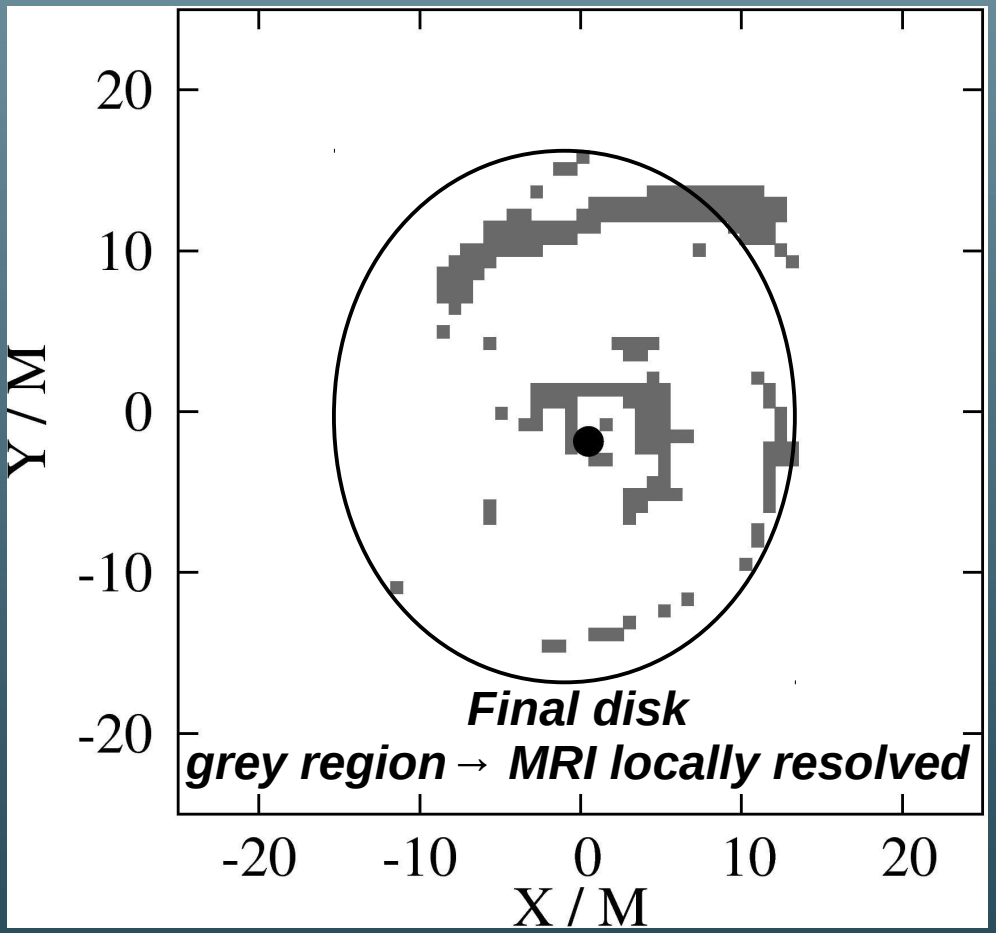
$\lambda_{MRI}/\Delta X \approx 3$

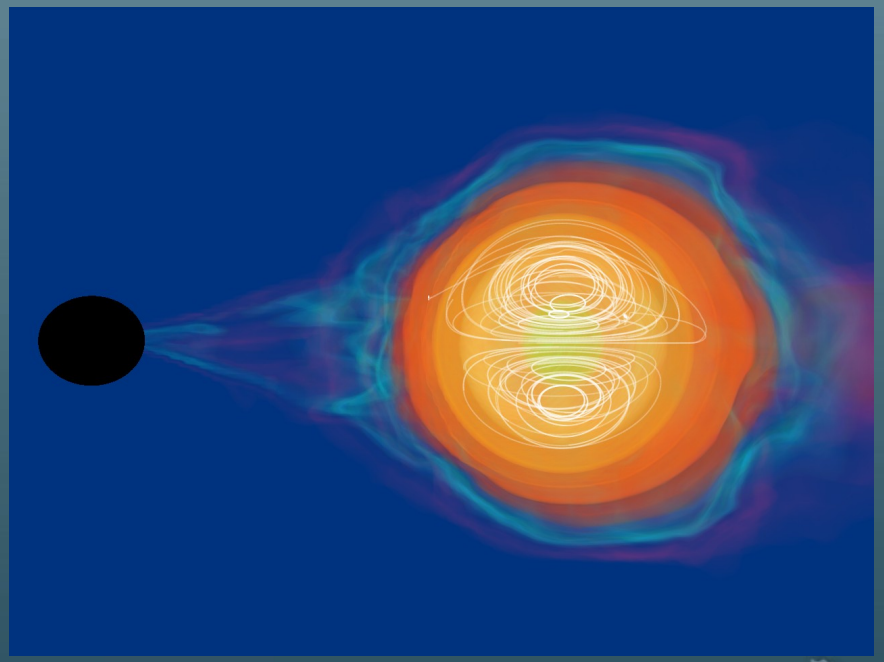
in remnant disk

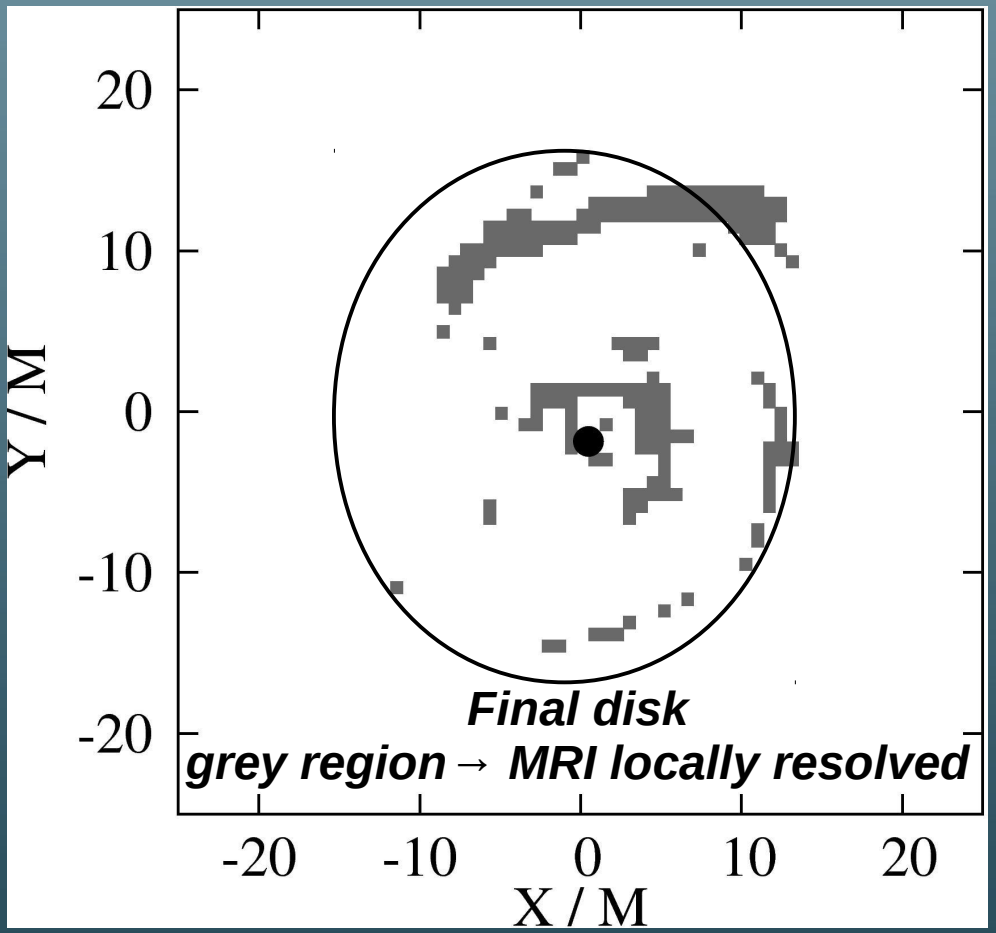
$\lambda_{MRI}/\Delta X \approx 8$

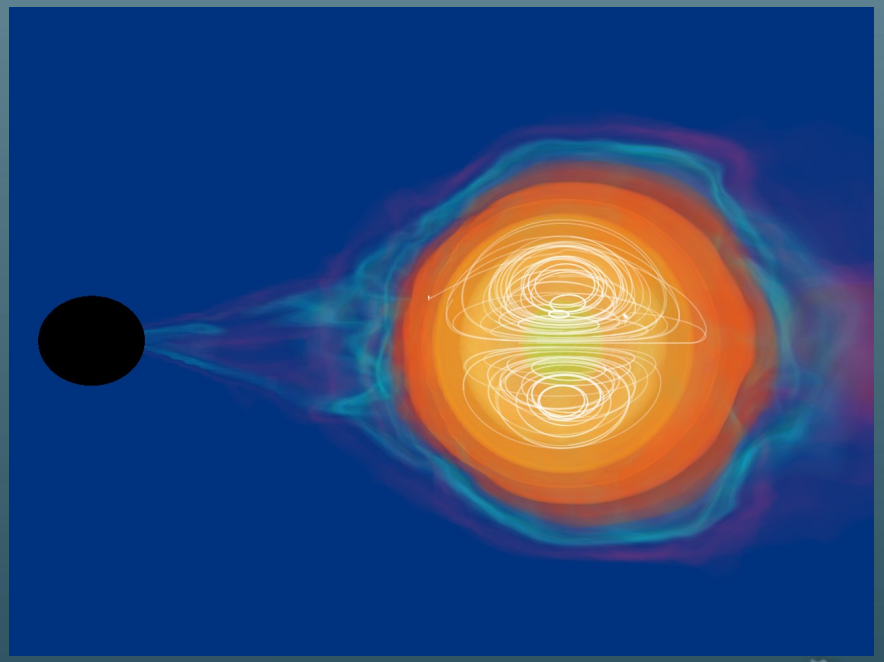
in remnant disk



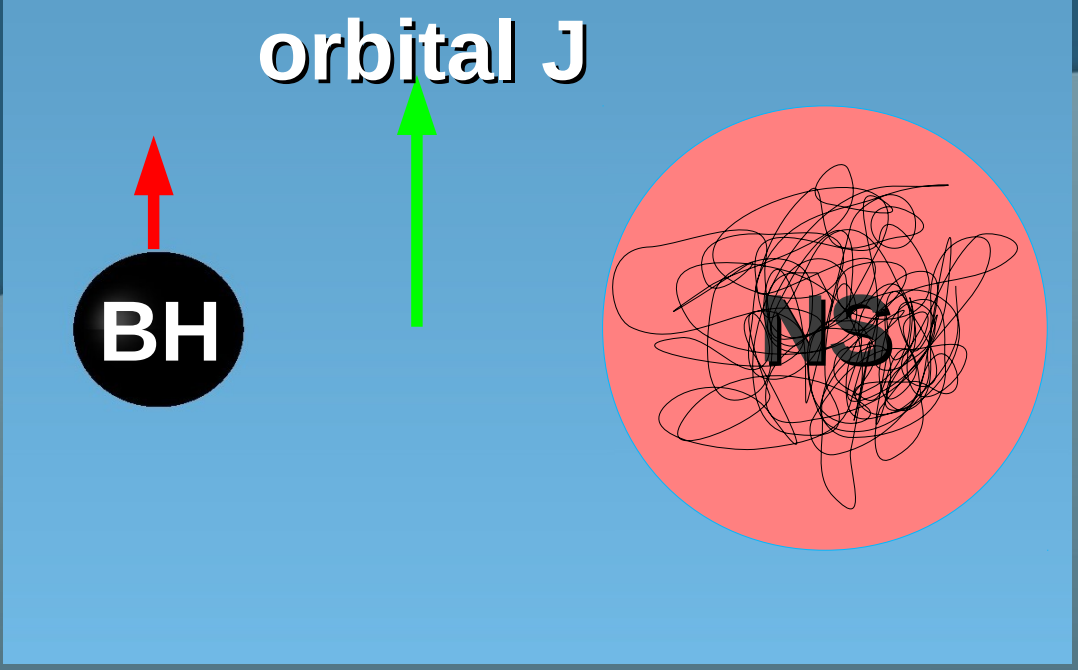

20
10
0
-10
-20
Y / M
-20
-10
0
10
20
X / M
Final disk
grey region → MRI locally resolved

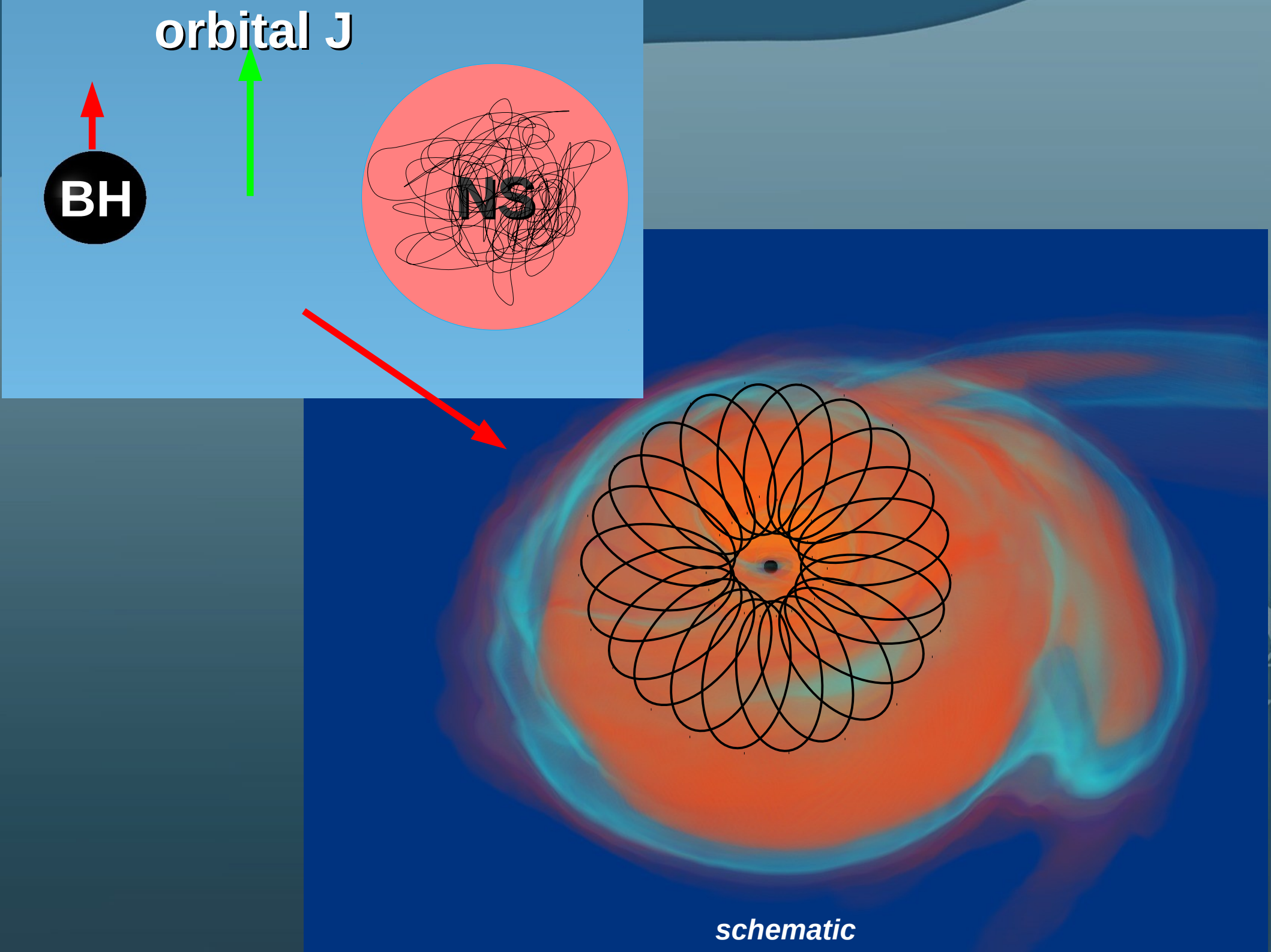


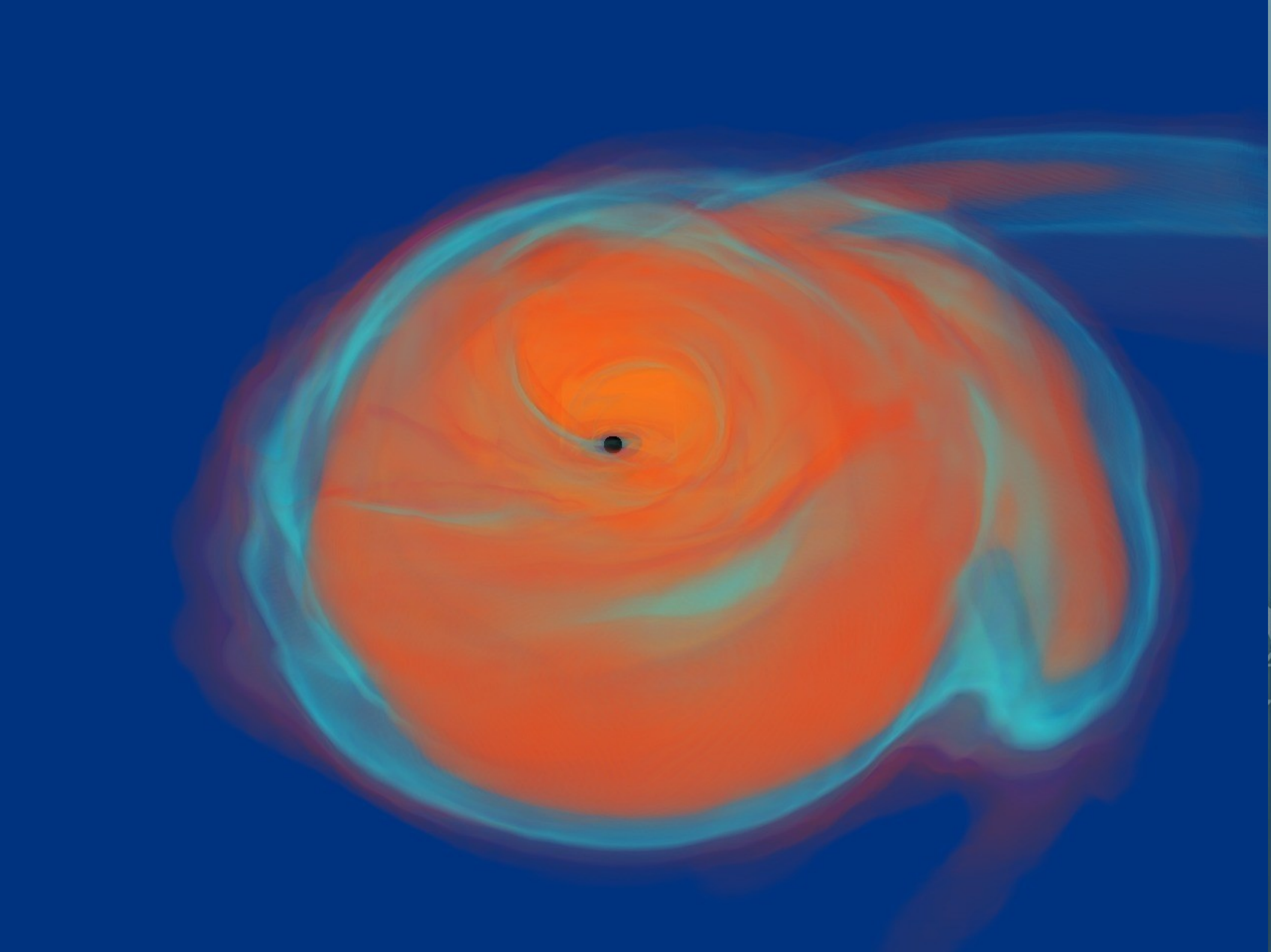

20
10
0
-10
-20
Y / M
-20
-10
0
10
20
X / M
Final disk
grey region → MRI locally resolved

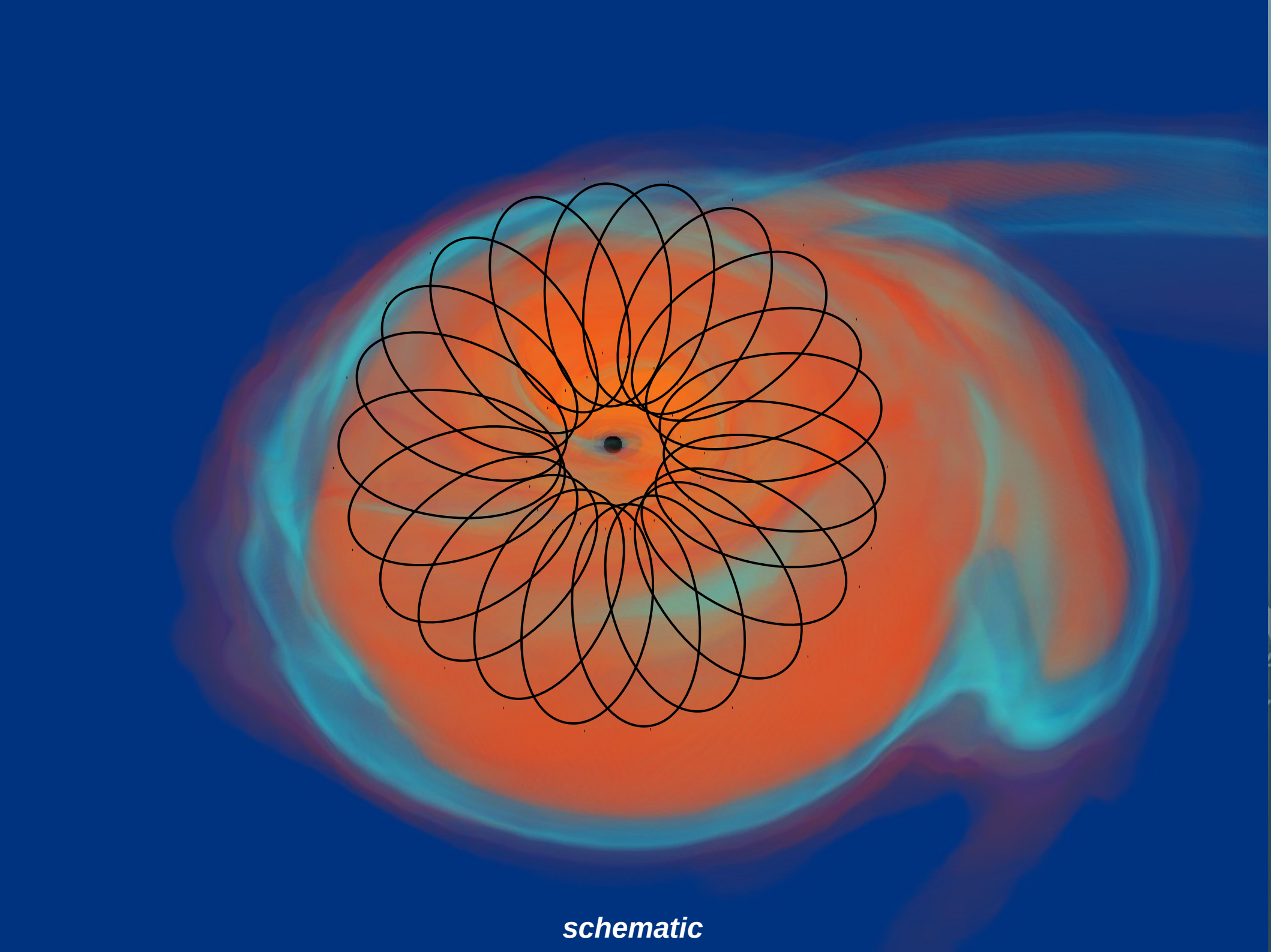


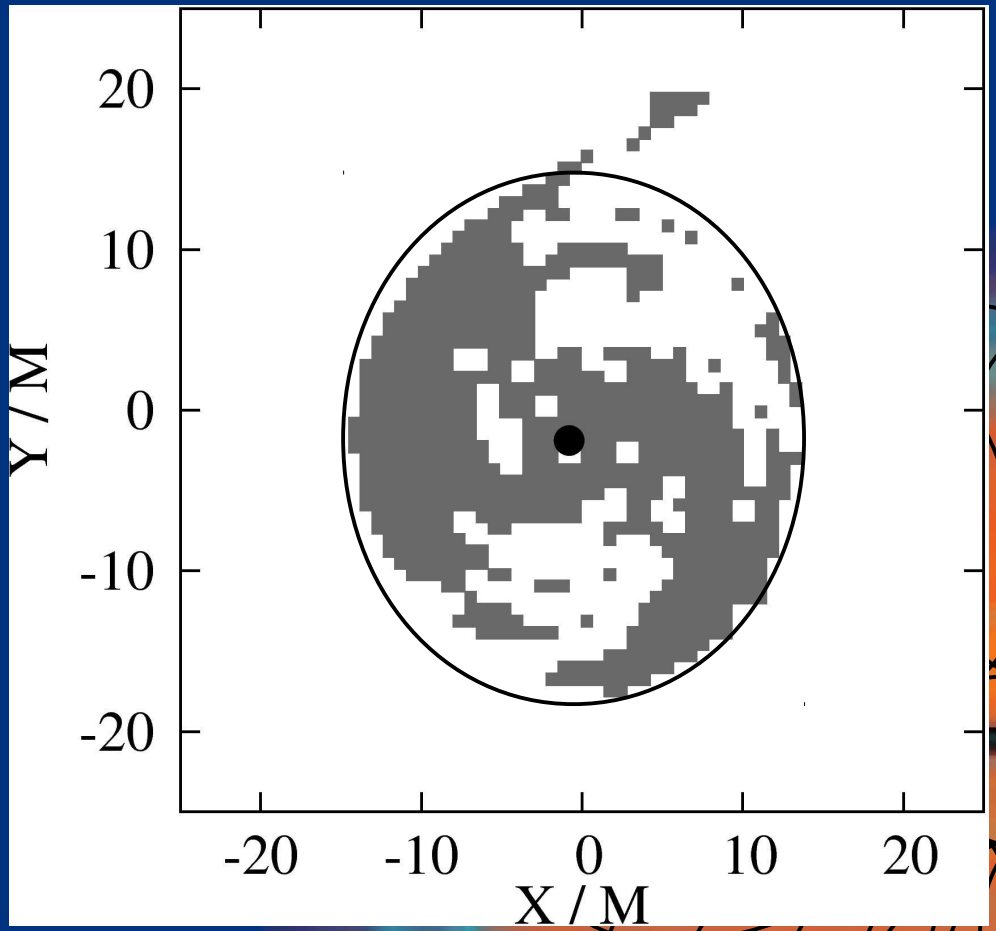

orbital J
BH
NS


orbital J
BH
NS


orbital J
BH
NS
schematic

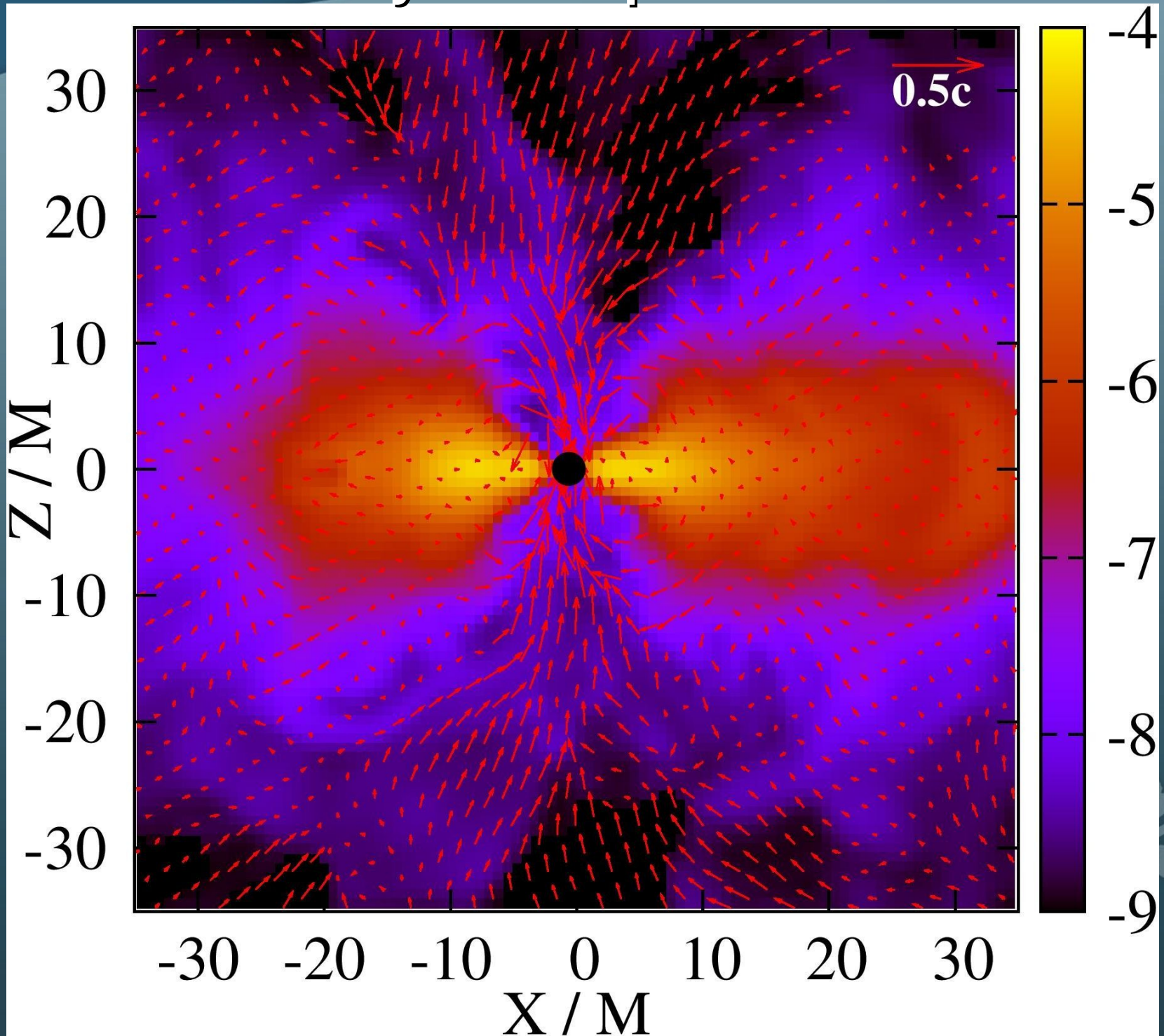



schematic

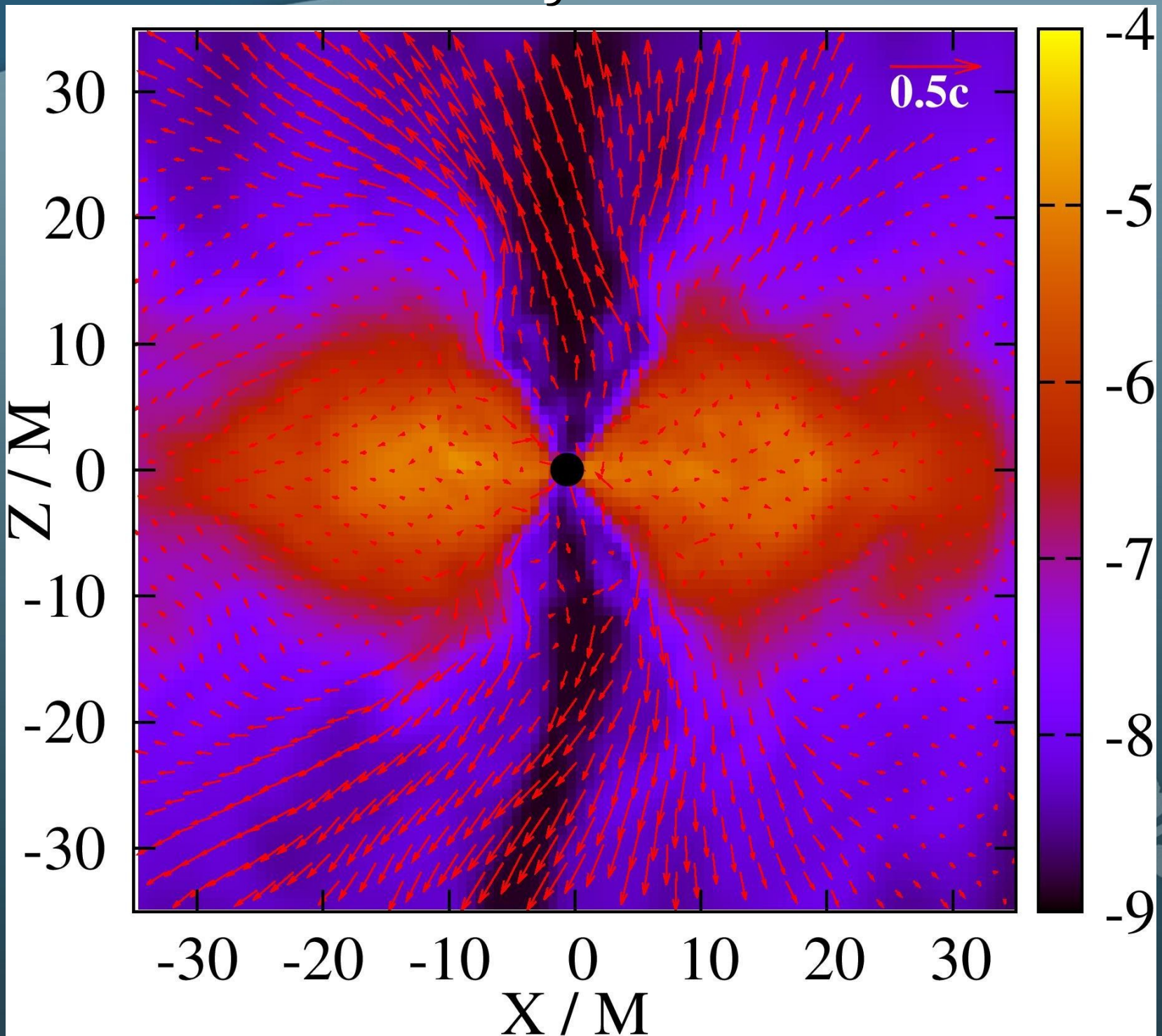


schematic

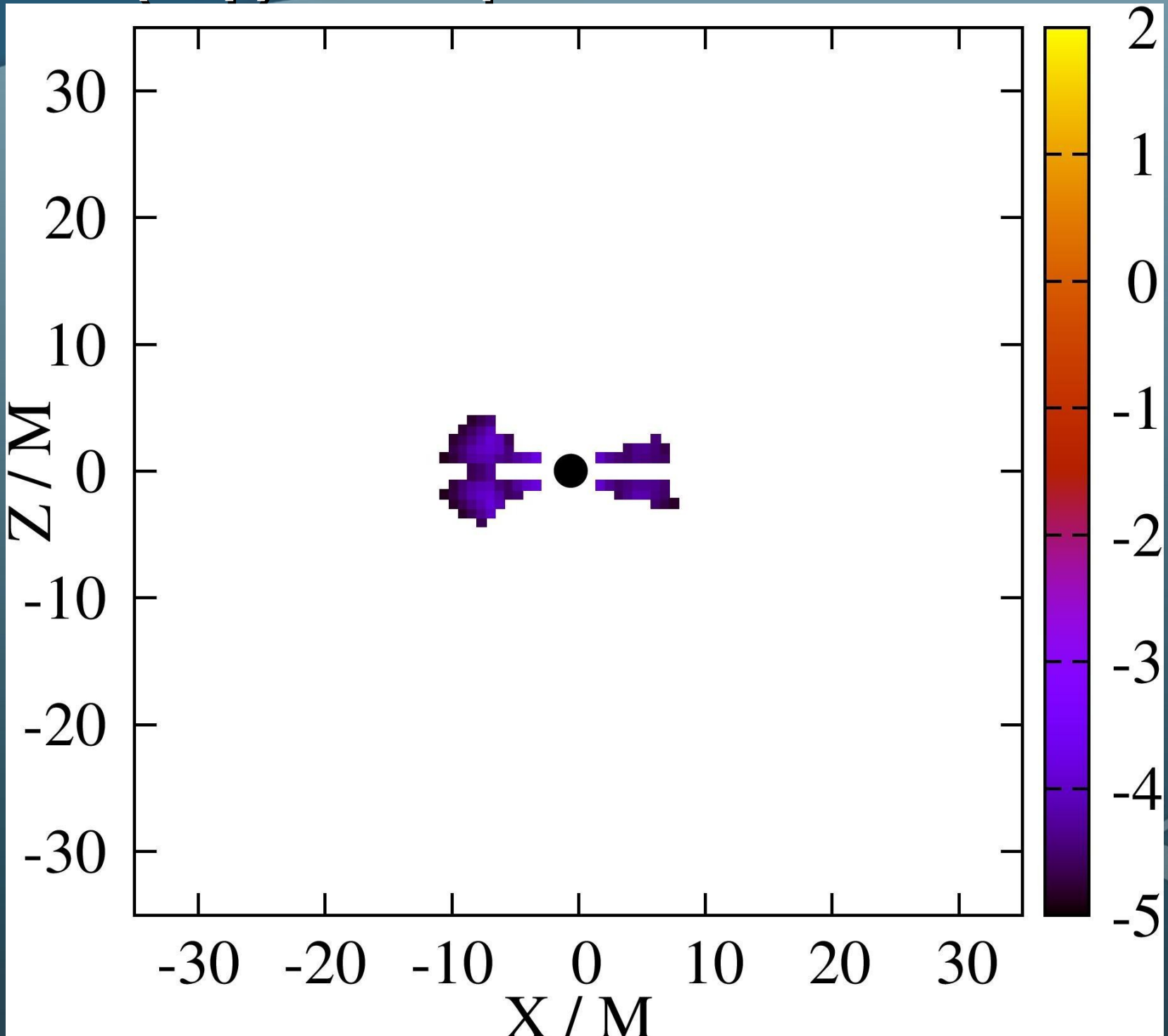
Rest-mass density: When poloidal fields inserted



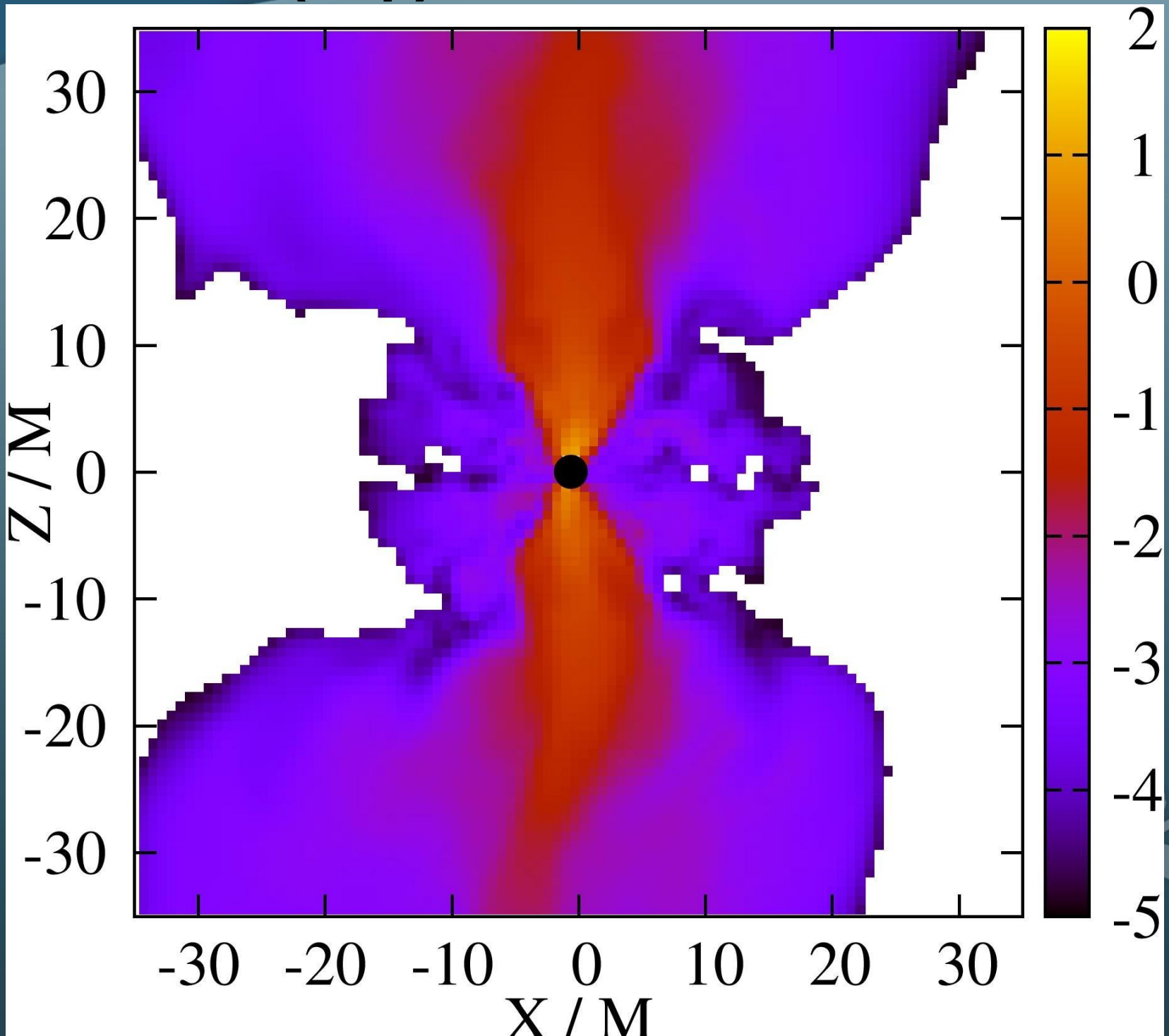
Rest-mass density: End of simulation

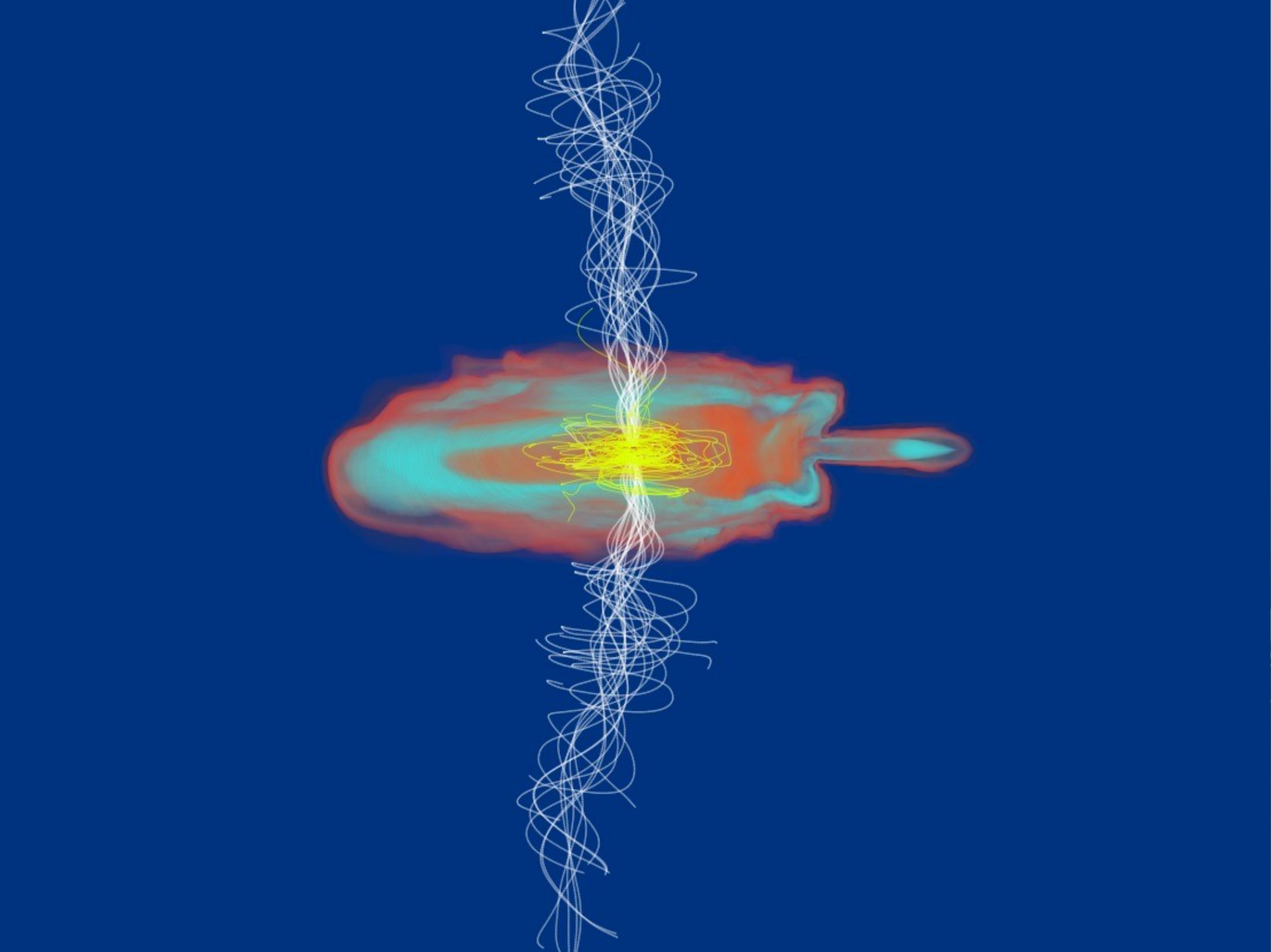


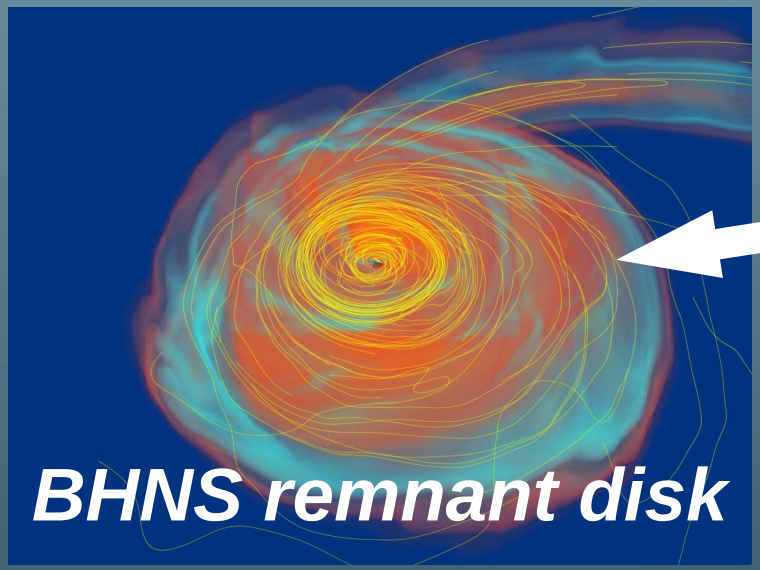
$B^2/(8\pi\rho)$: When poloidal fields inserted



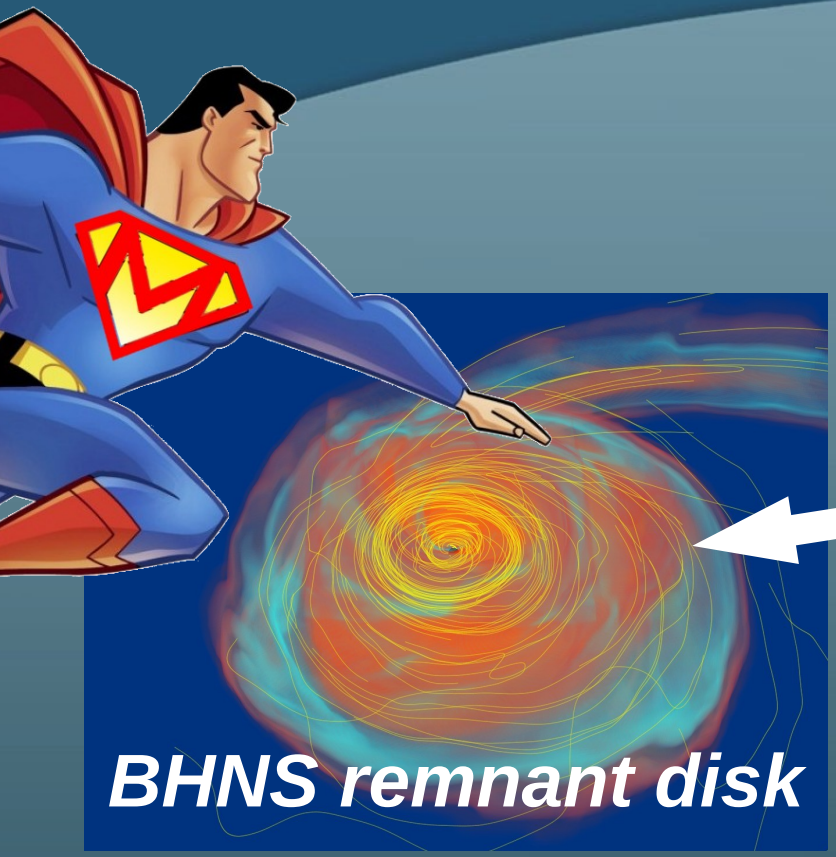
$B^2/(8\pi\rho)$: End of simulation





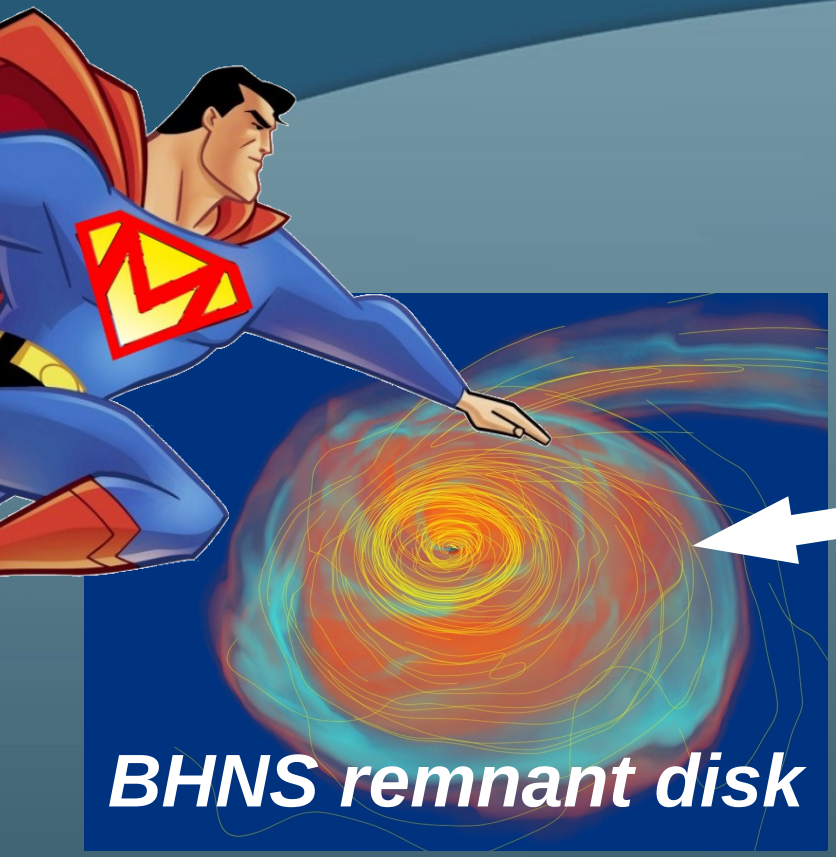


Almost purely toroidal magnetic fields



Almost purely toroidal magnetic fields

RI



Almost purely toroidal magnetic fields

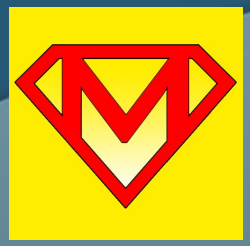
MRI

Exponentially amplified *poloidal* fields

MHD turbulence = eff. viscosity, drives accretion

Jet formation

SGRB?



RI

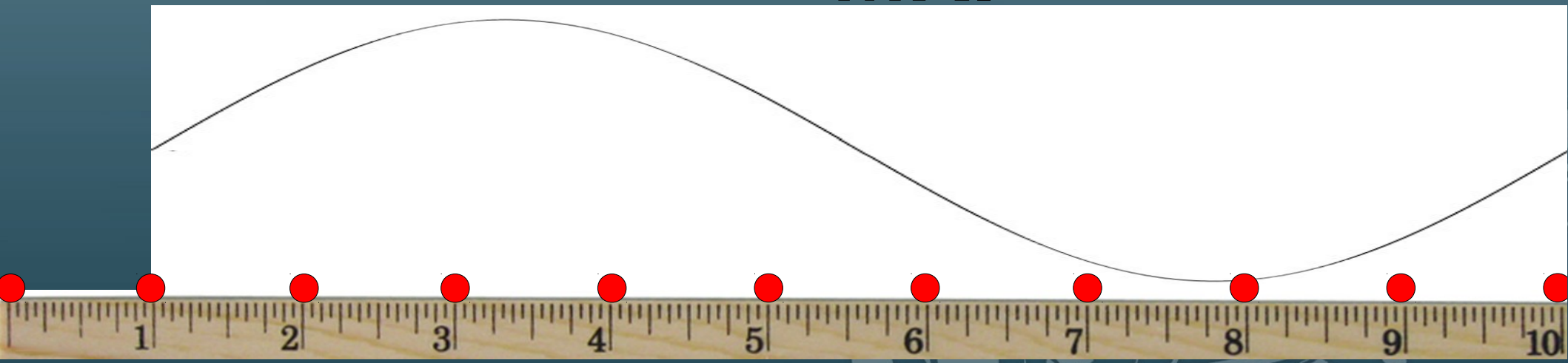
Exponentially amplified *poloidal* fields

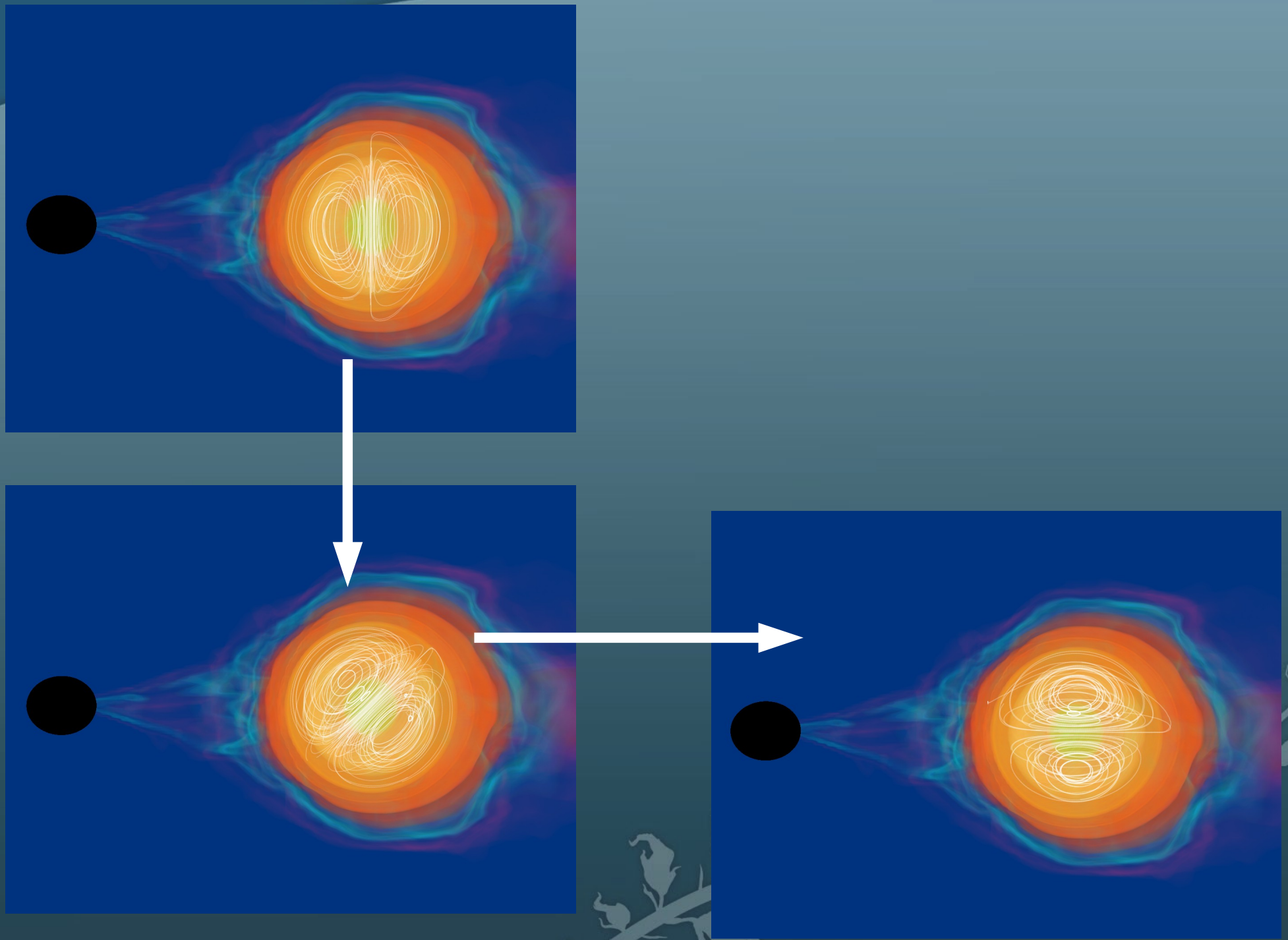
MHD turbulence = eff. viscosity, drives accretion

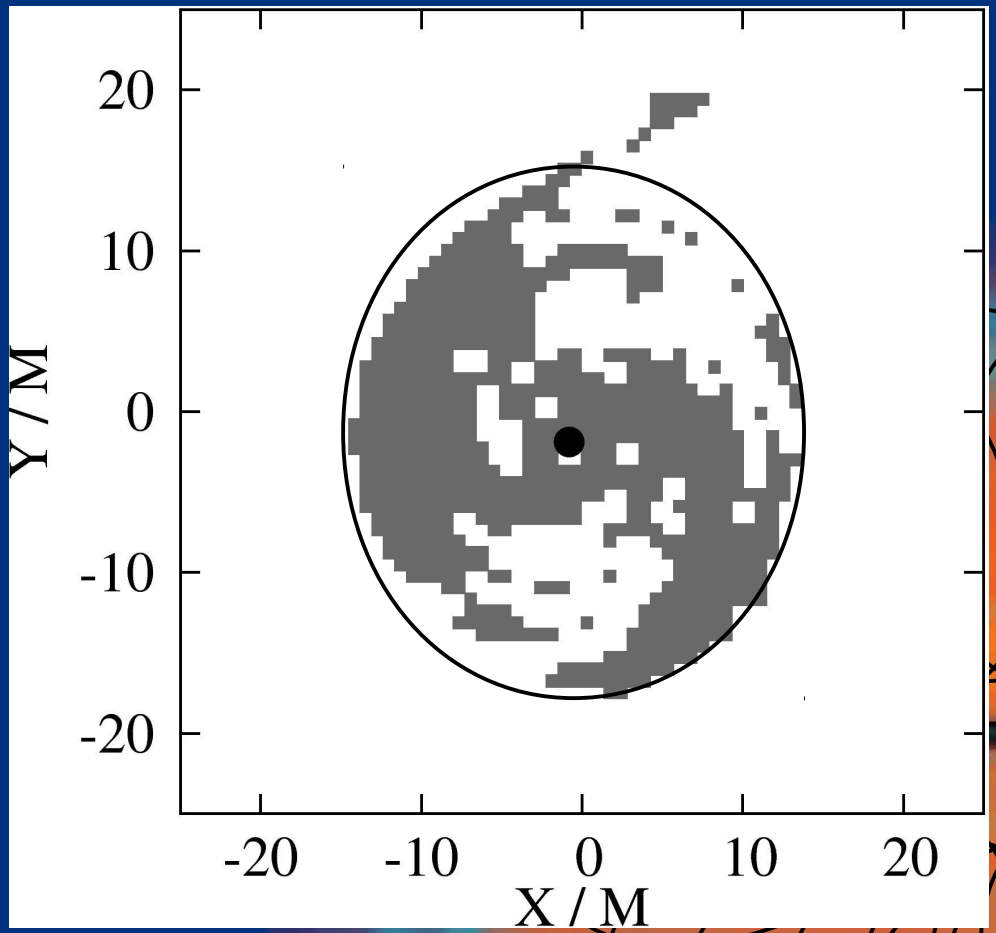
Jet formation

SGRB?

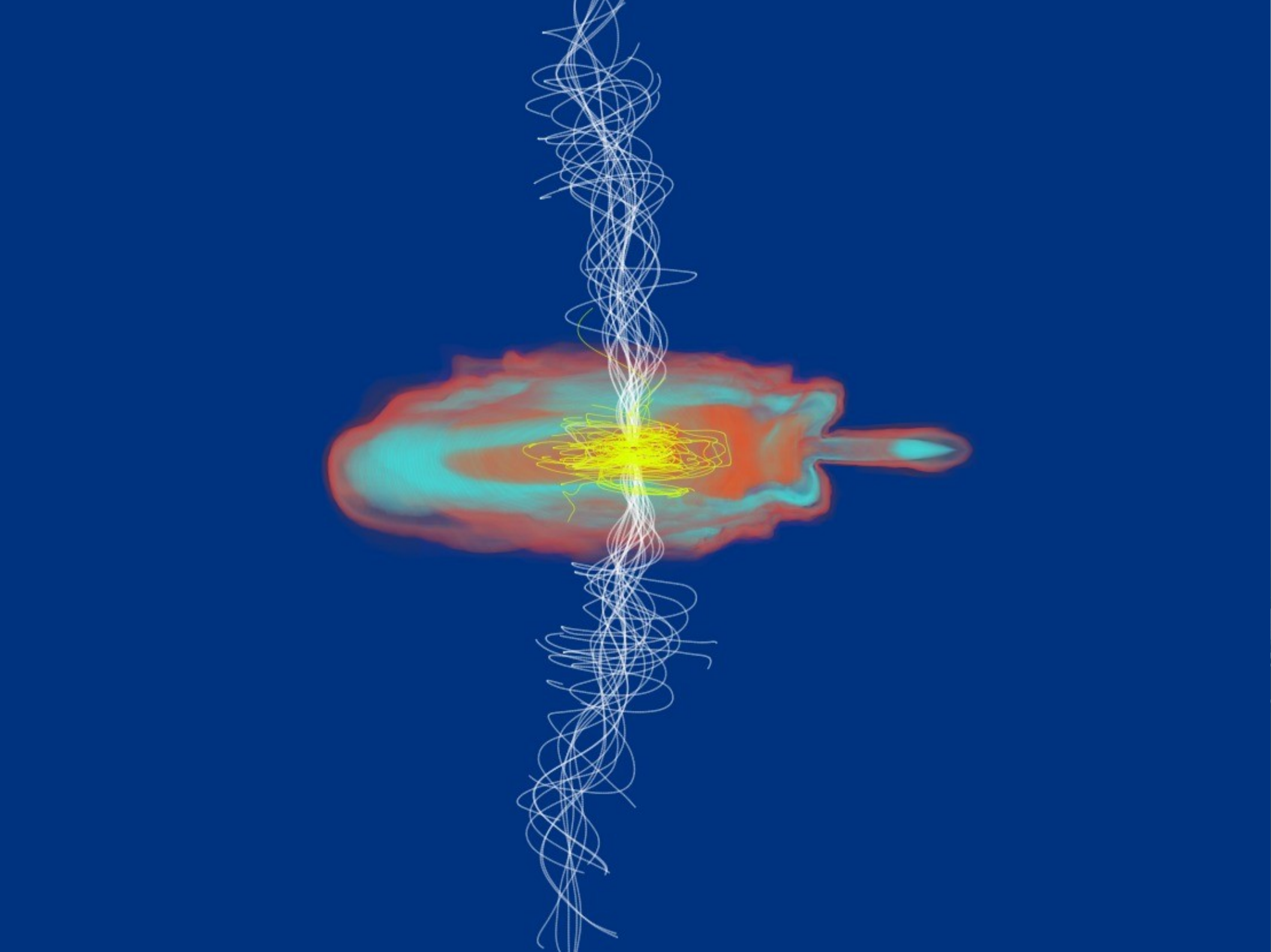
λ_{MRI}







schematic



The Bottom Line