

γ -ray obscuration in η Carinae

SCIENCE MEETING: 5 June 2023, Versoix

BALBO MATTEO

Where are the Galactic PeVatrons?



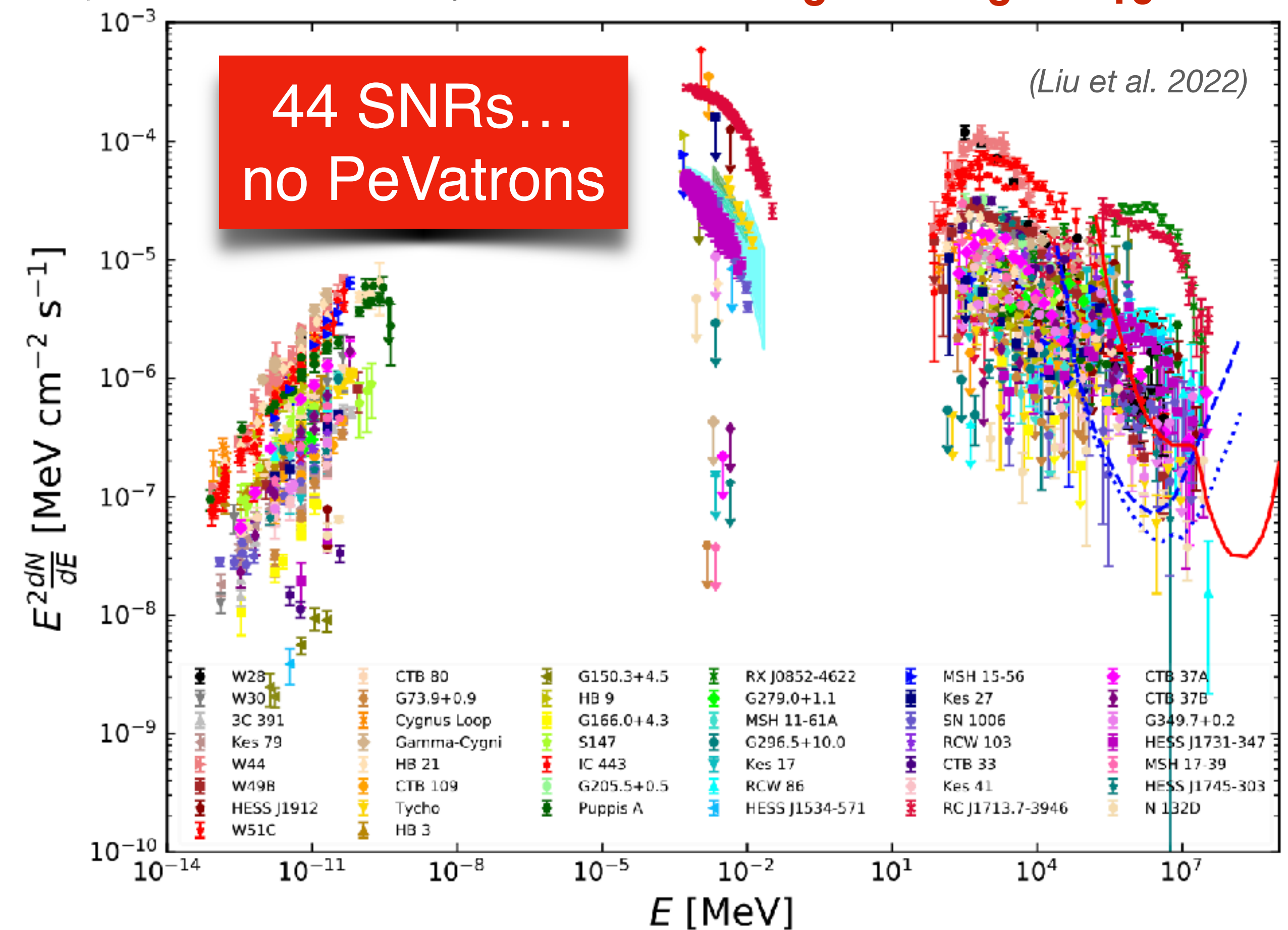
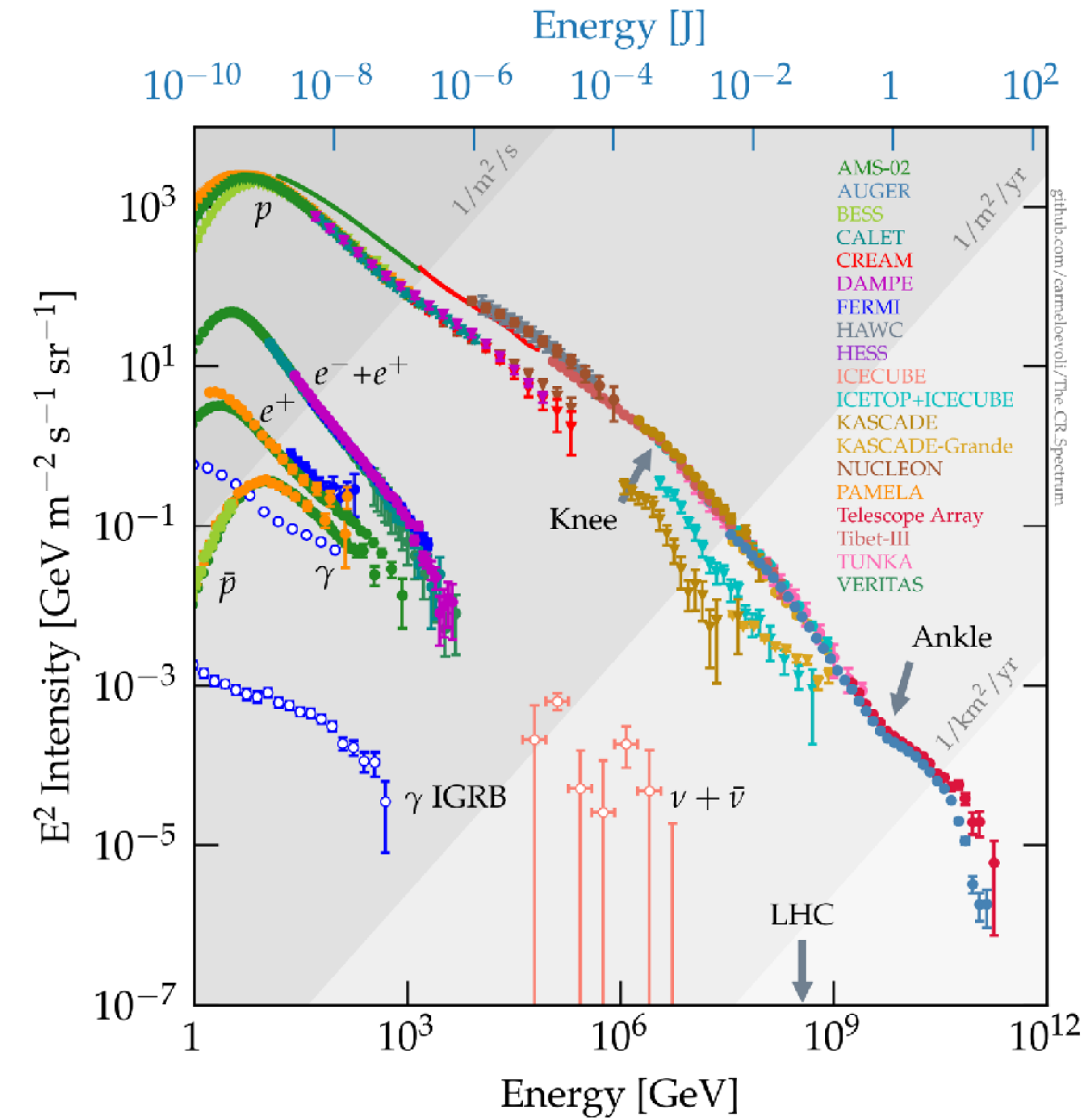
shock speed
radius
magnetic field

$$E_{max} \simeq v_s R B$$

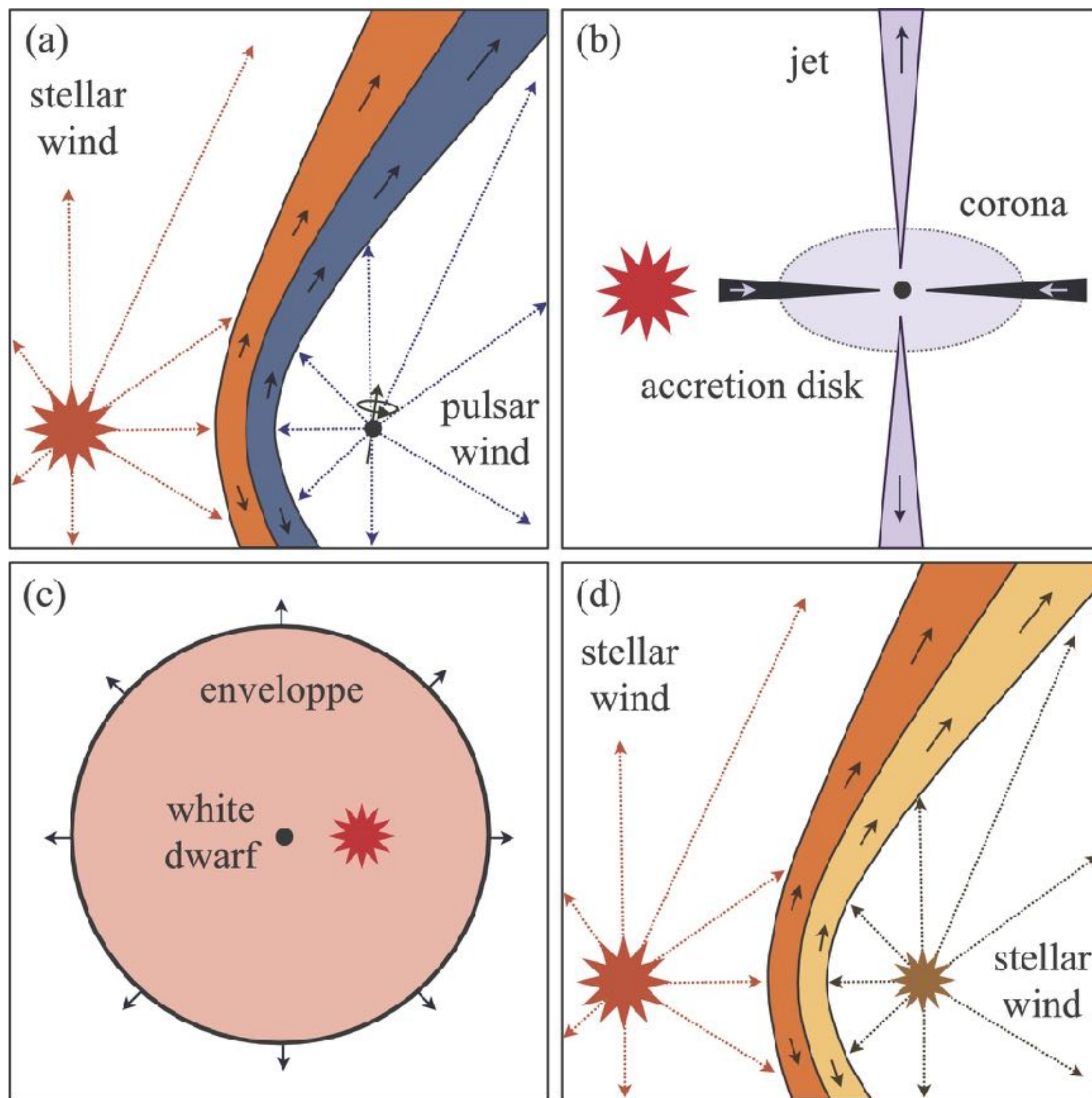
**Hillas
criterium:**

$$E_{max} \simeq 1 \left(\frac{v_s}{10^3 \text{ Km/s}} \right) \left(\frac{R}{\text{pc}} \right) \left(\frac{B}{\mu\text{G}} \right) \text{TeV}$$

3 3 10



γ -ray binaries



Types of γ -ray binaries:

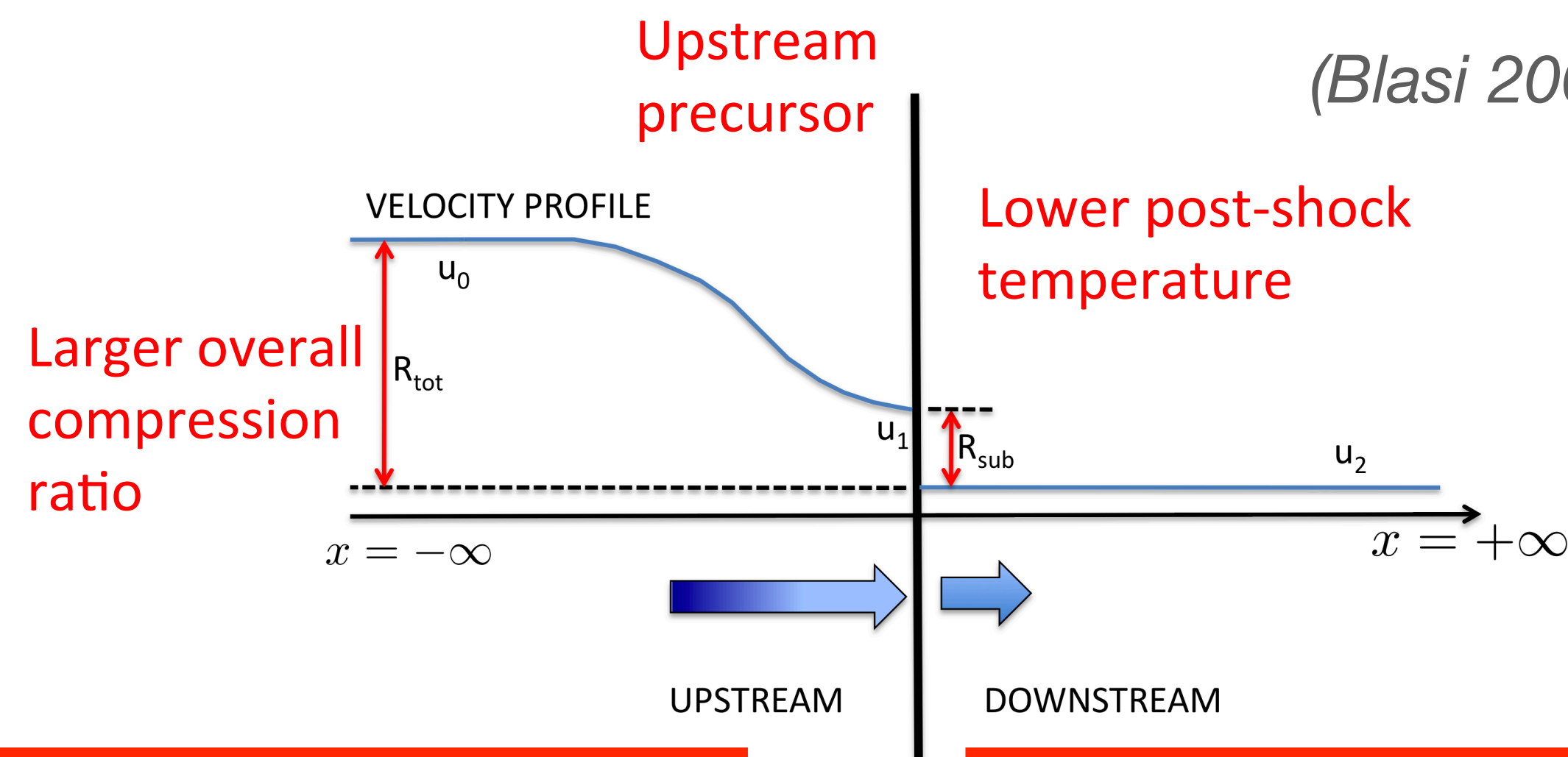
a) massive star + pulsar

c) Nova + WD

b) micro quasar

d) CWB

(Blasi 2005; 2013)

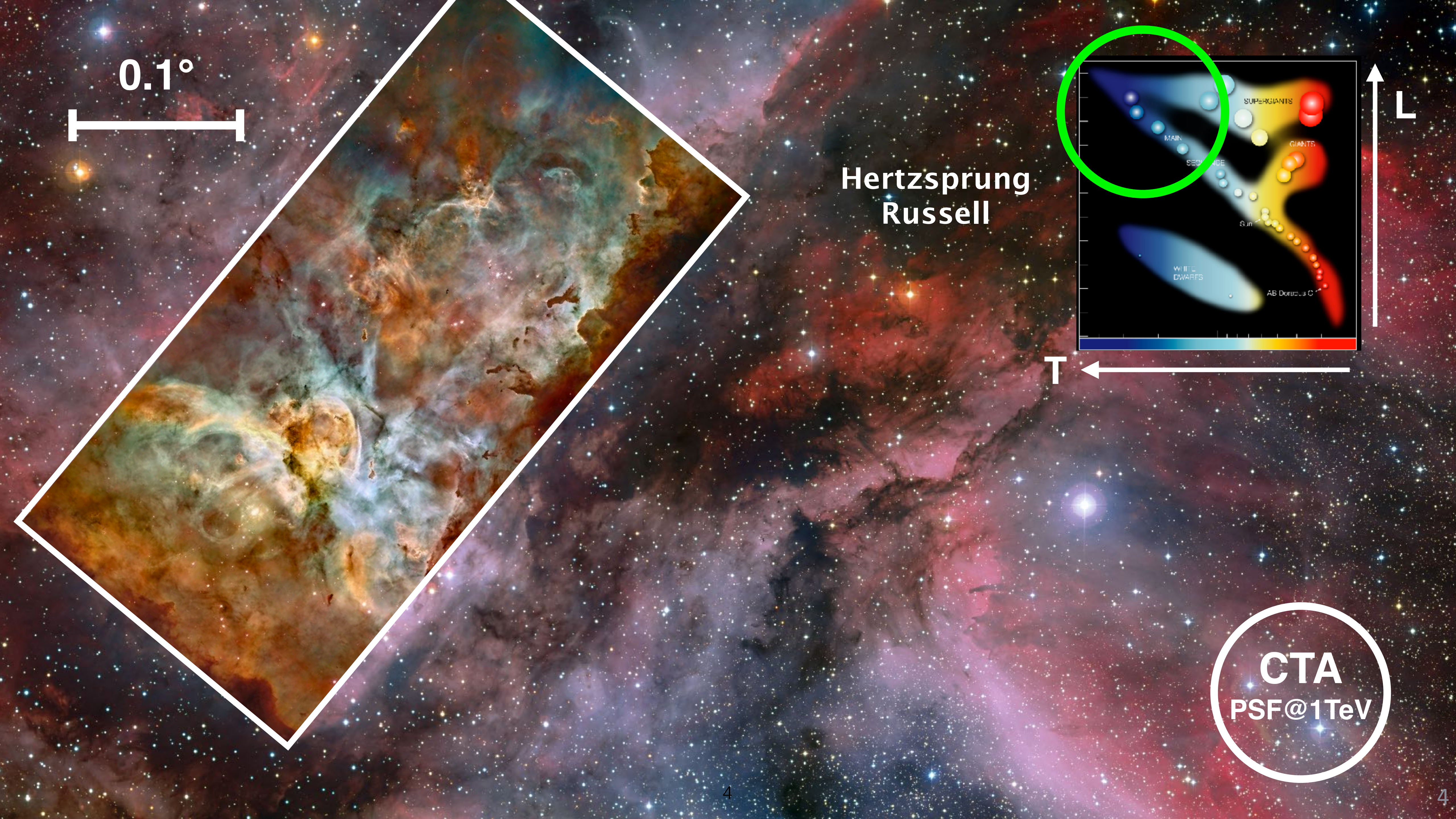


Leptonic
IC on UV/OPT
up to $\sim$ GeV

OR

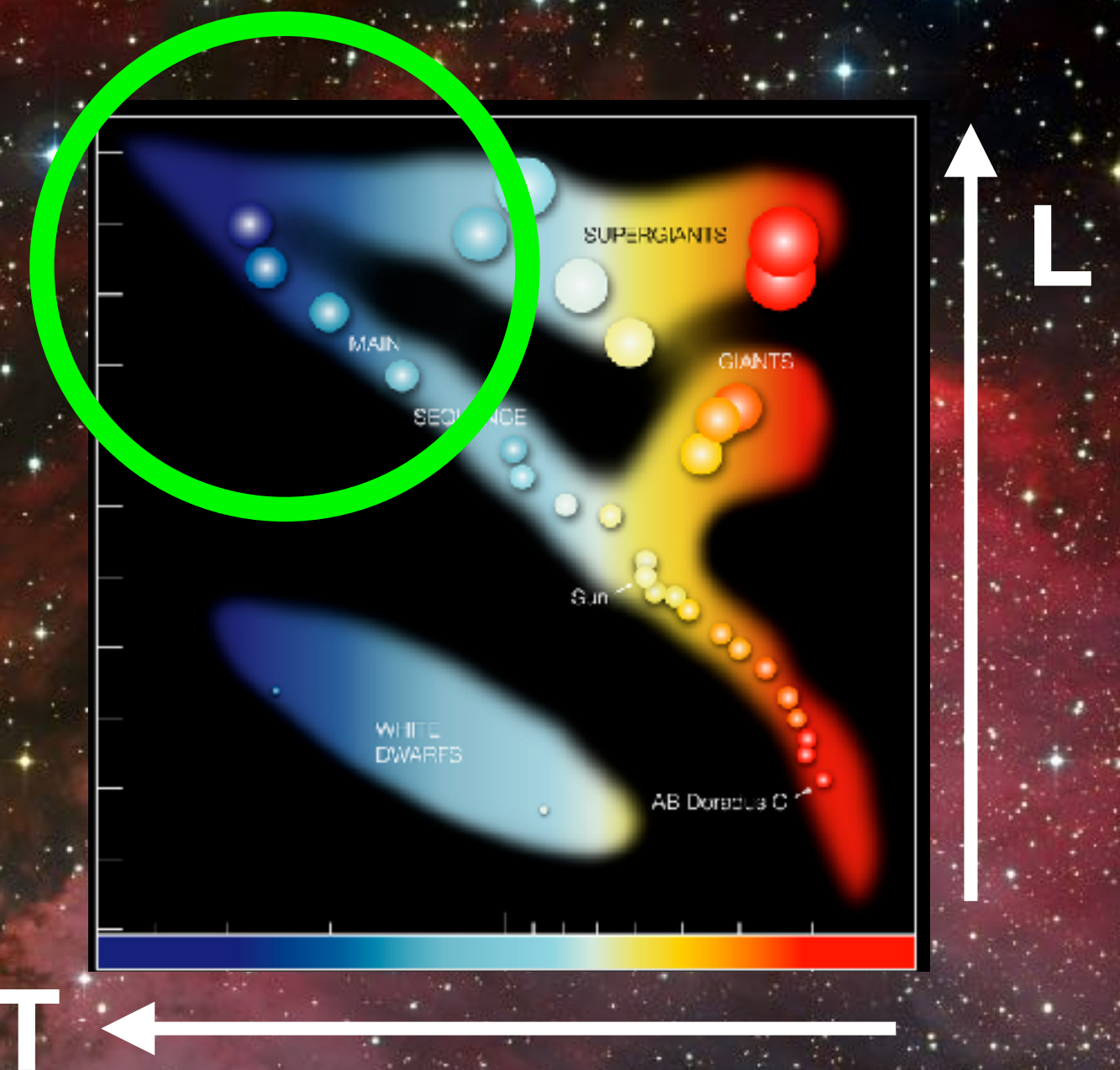
Hadronic
 $pp \rightarrow \pi_0$
higher energies





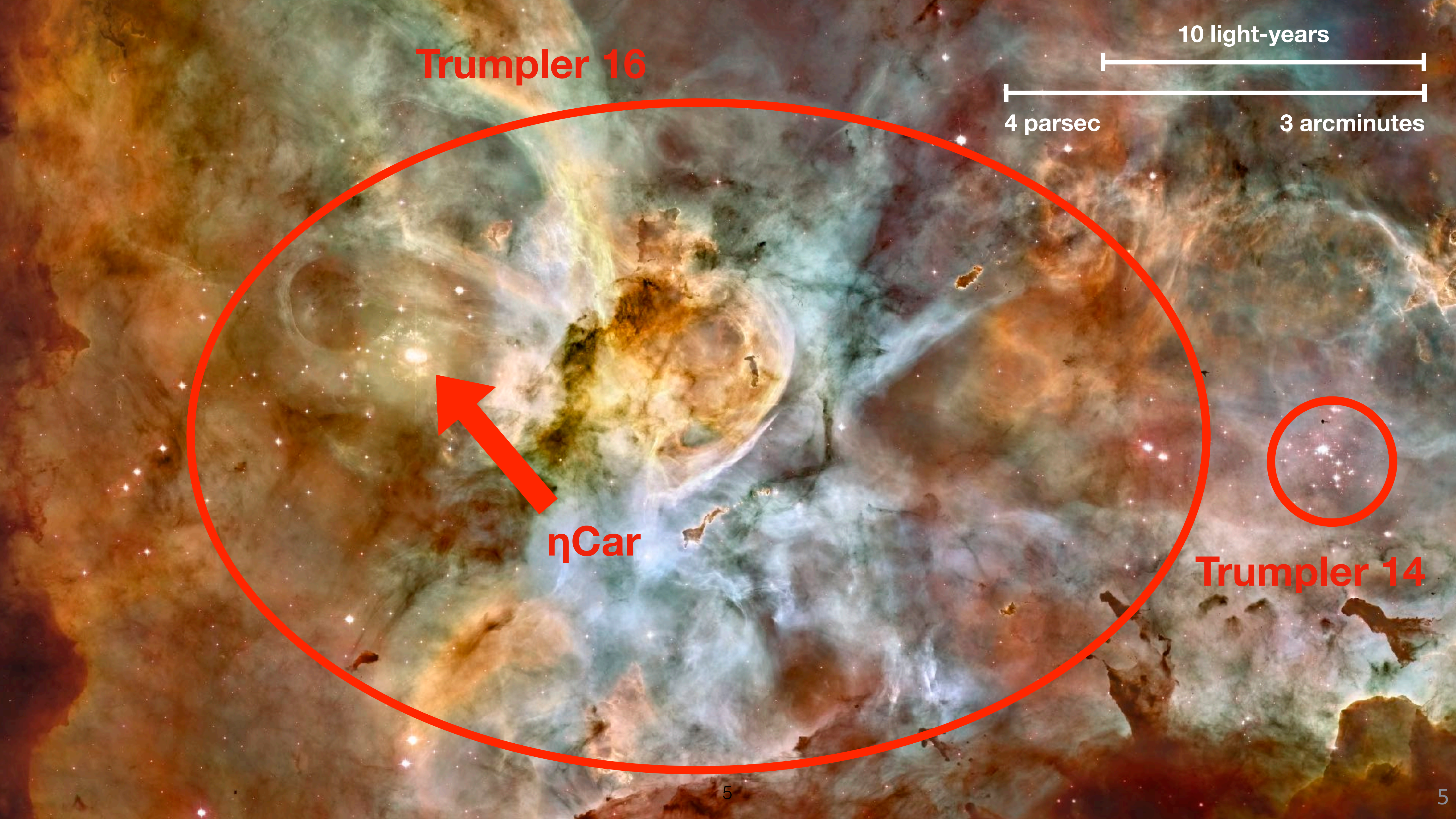
0.1°

Hertzprung
Russell



CTA
PSF@1TeV





Trumpler 16

10 light-years

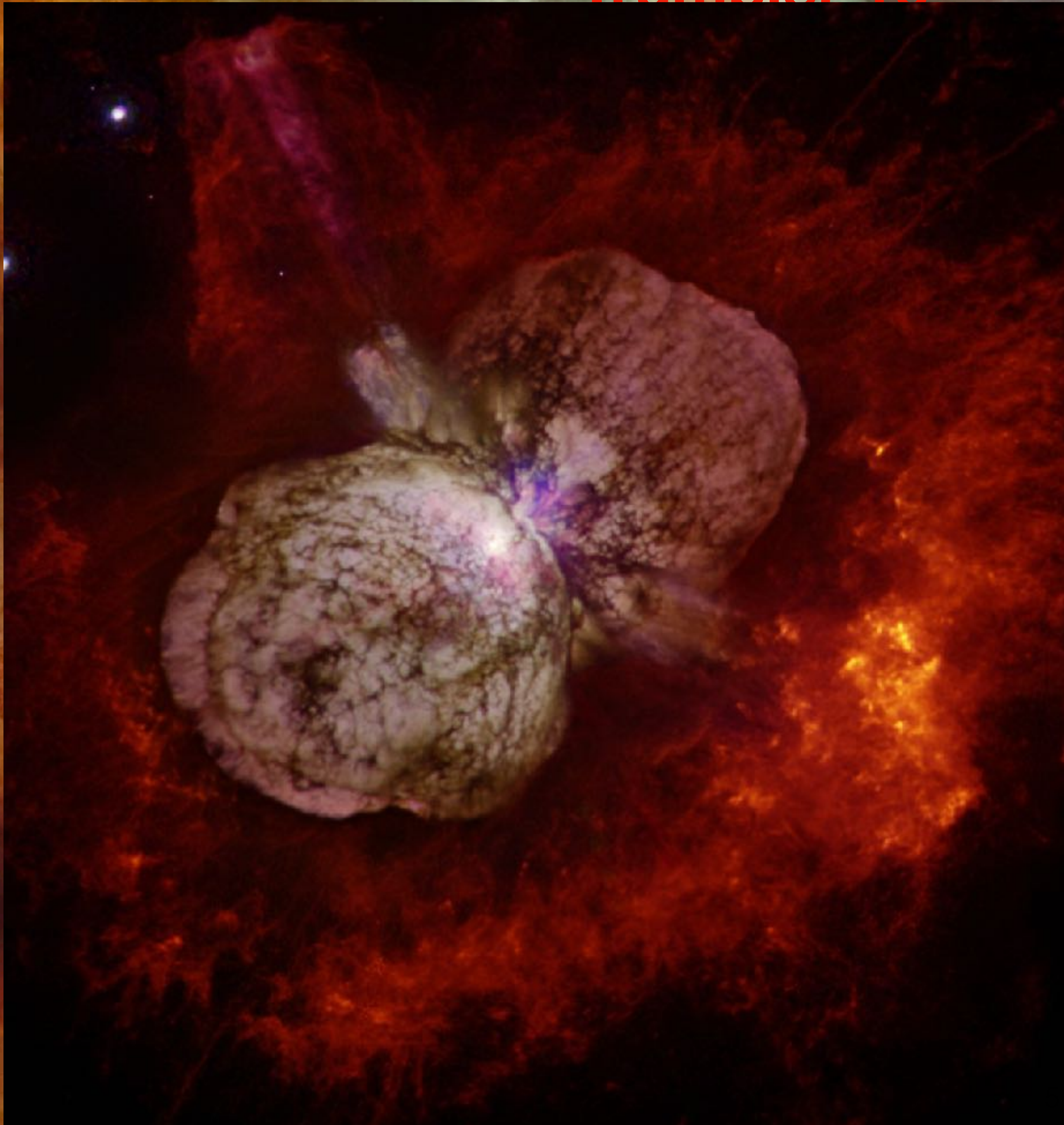
4 parsec

3 arcminutes

η Car

Trumpler 14

Trumpler 16

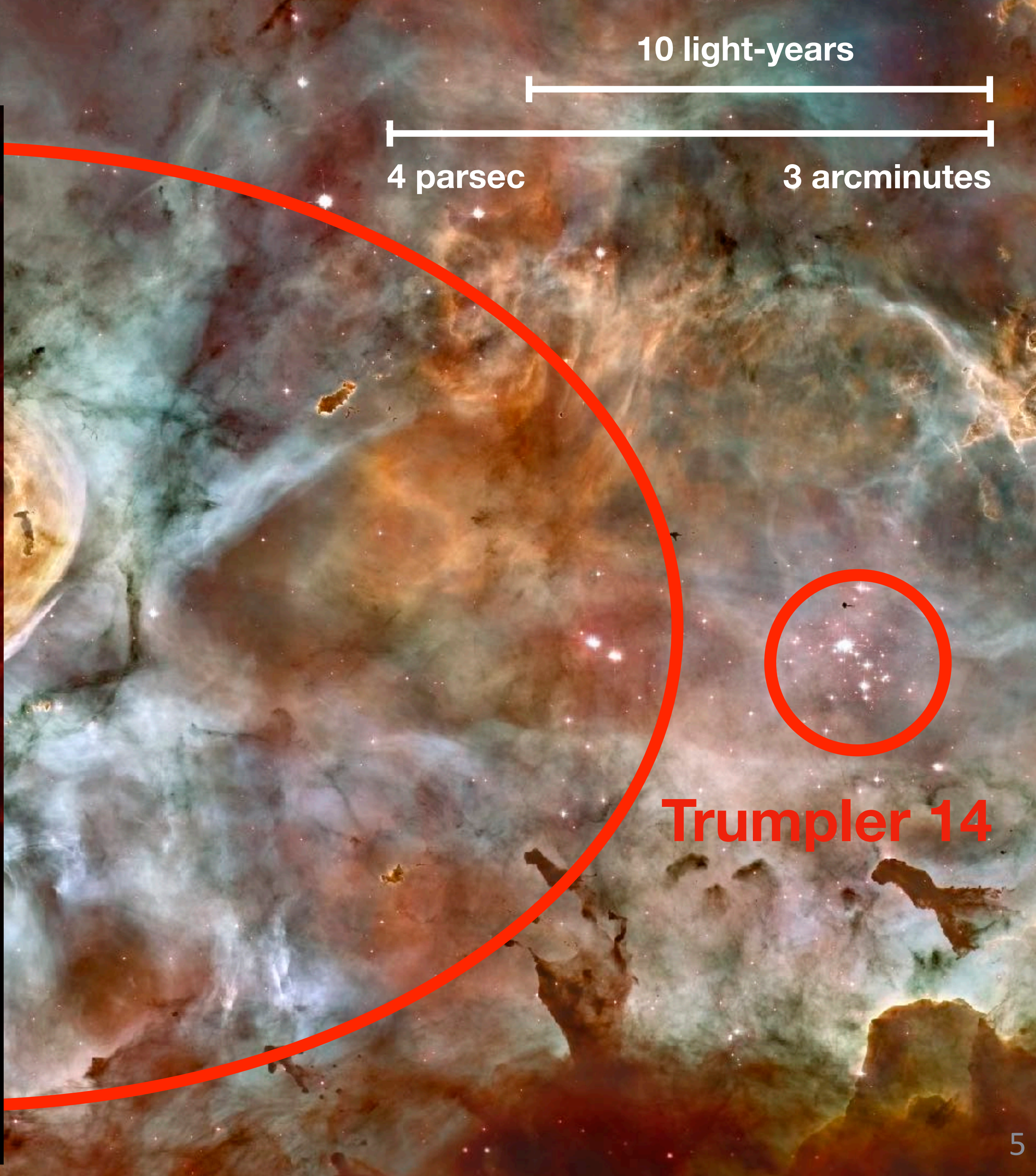


10 light-years

4 parsec

3 arcminutes

Trumpler 14



$$\dot{M} \sim 10^{-3.5} M_{\odot}/\text{yr}$$

$$L_{\text{wind}} \approx 2000 L_{\odot}$$

Colliding Wind Binaries
are predicted to be
potential sites of HE γ -
ray emission through
strong shocks due to
colliding winds

Eichler & Usov (1993) ApJ 402, 271

10^{14} cm

$10^{12} \text{ eV/cm}^3, \quad 1 \text{ G}, \quad 10^9 \text{ cm}^{-3}$

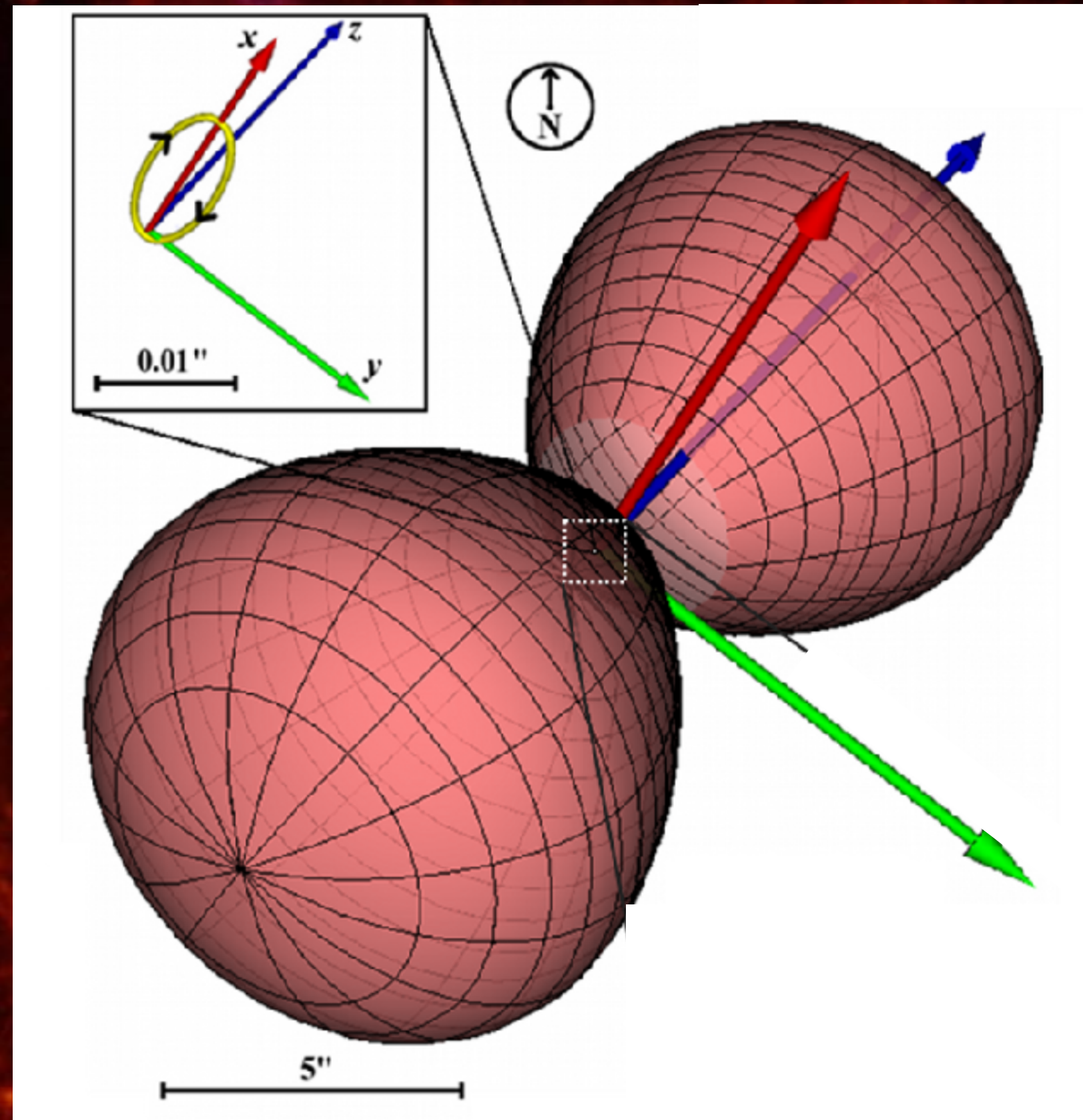
Acceleration

Electron cooling

Proton targets

$$\dot{M} \sim 10^{-3.5} M_{\odot}/\text{yr}$$

$$L_{\text{wind}} \approx 2000 L_{\odot}$$

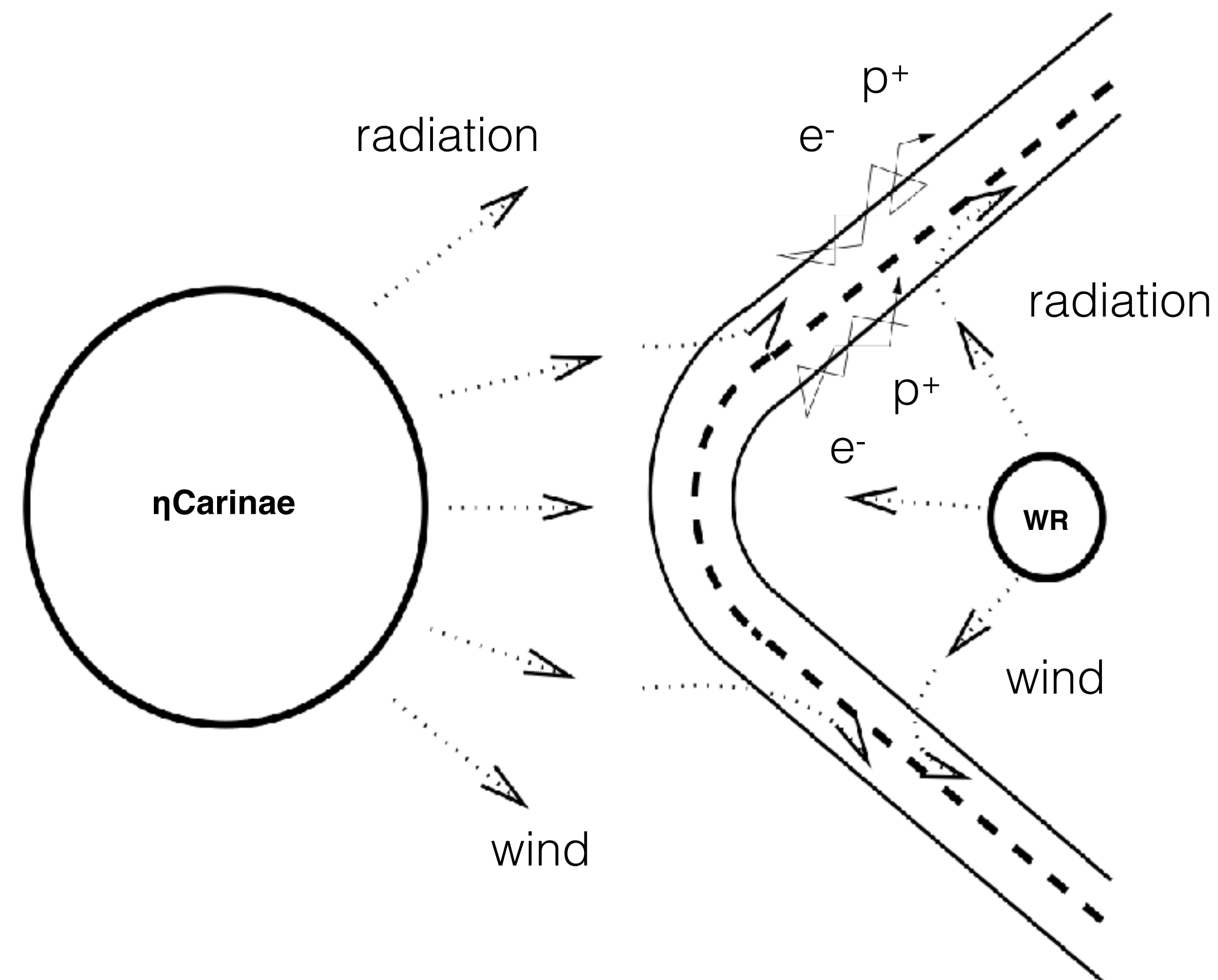
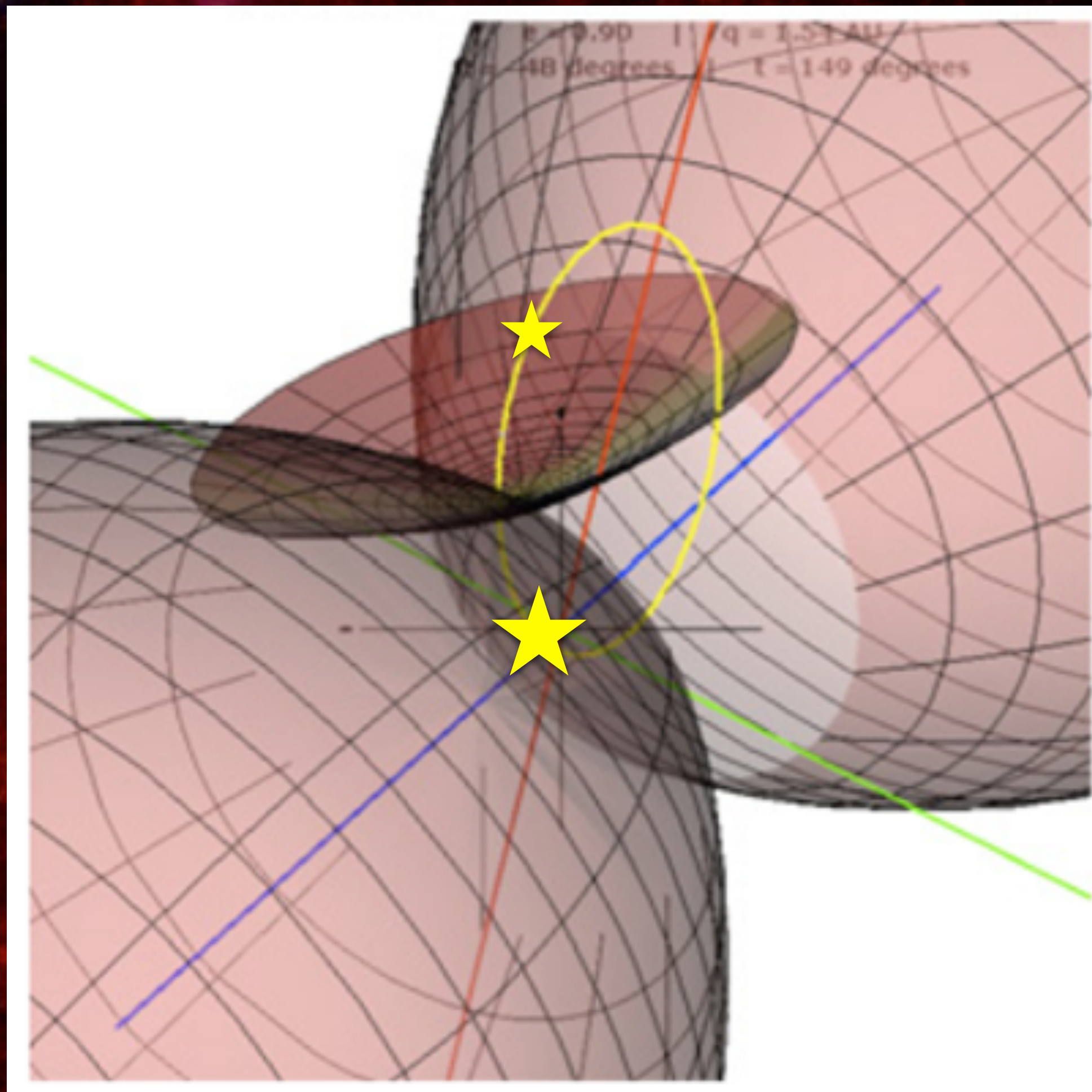


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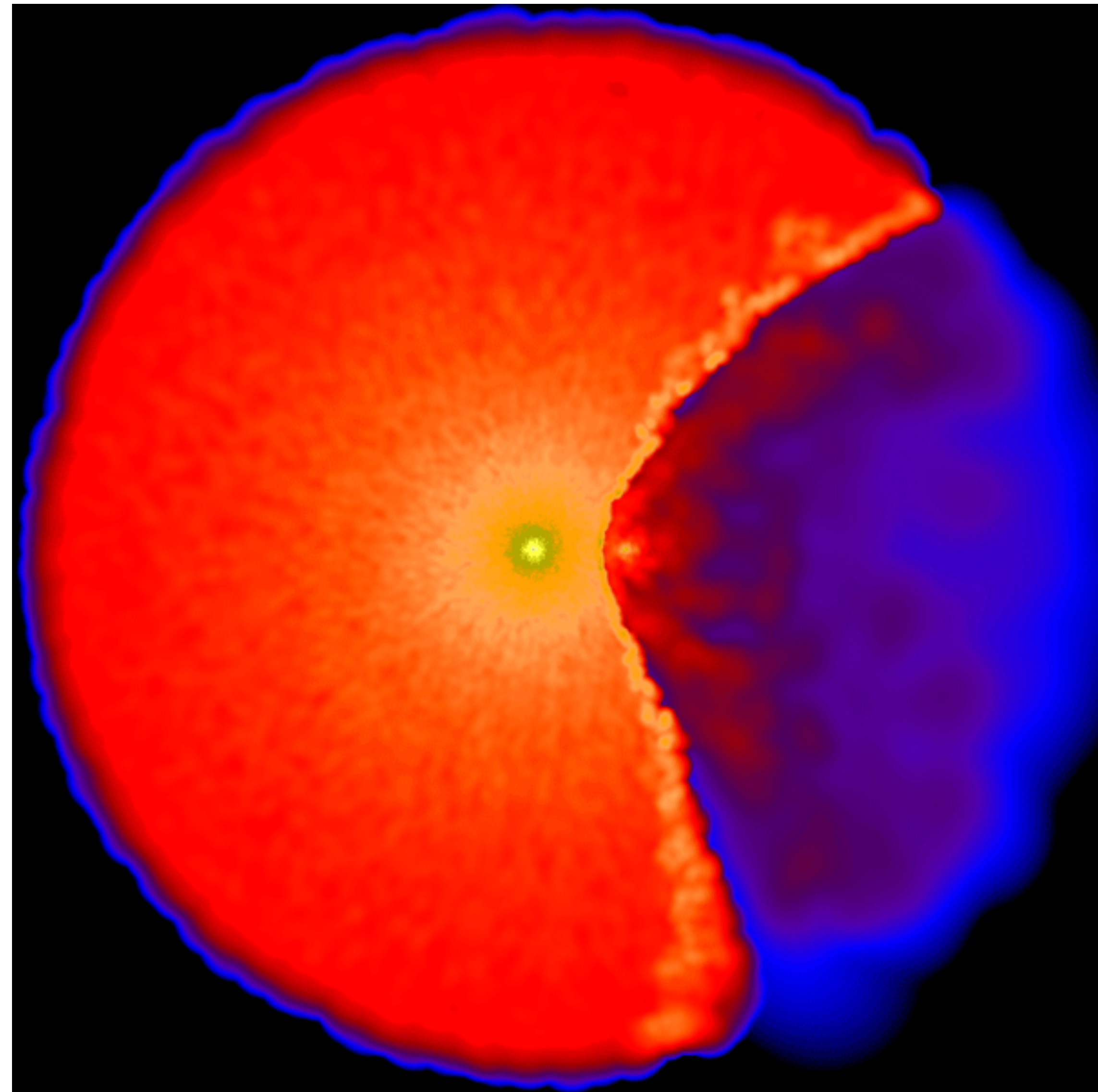
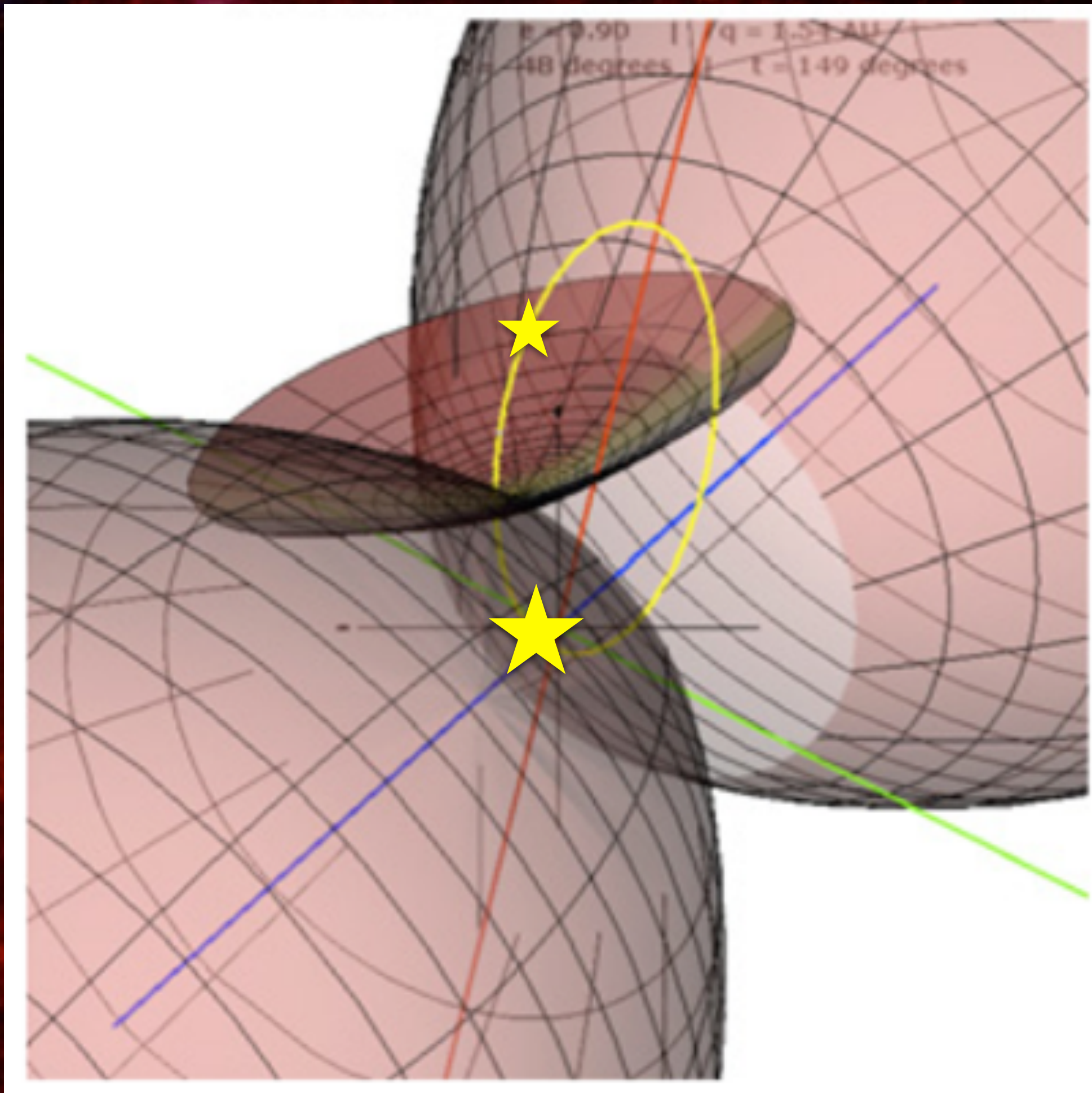
$$\eta = \frac{\dot{M}_{OB} V_{OB}^{\infty}}{\dot{M}_{WR} V_{WR}^{\infty}}$$

$$r_{WR} = \frac{1}{1 + \sqrt{\eta}} D$$

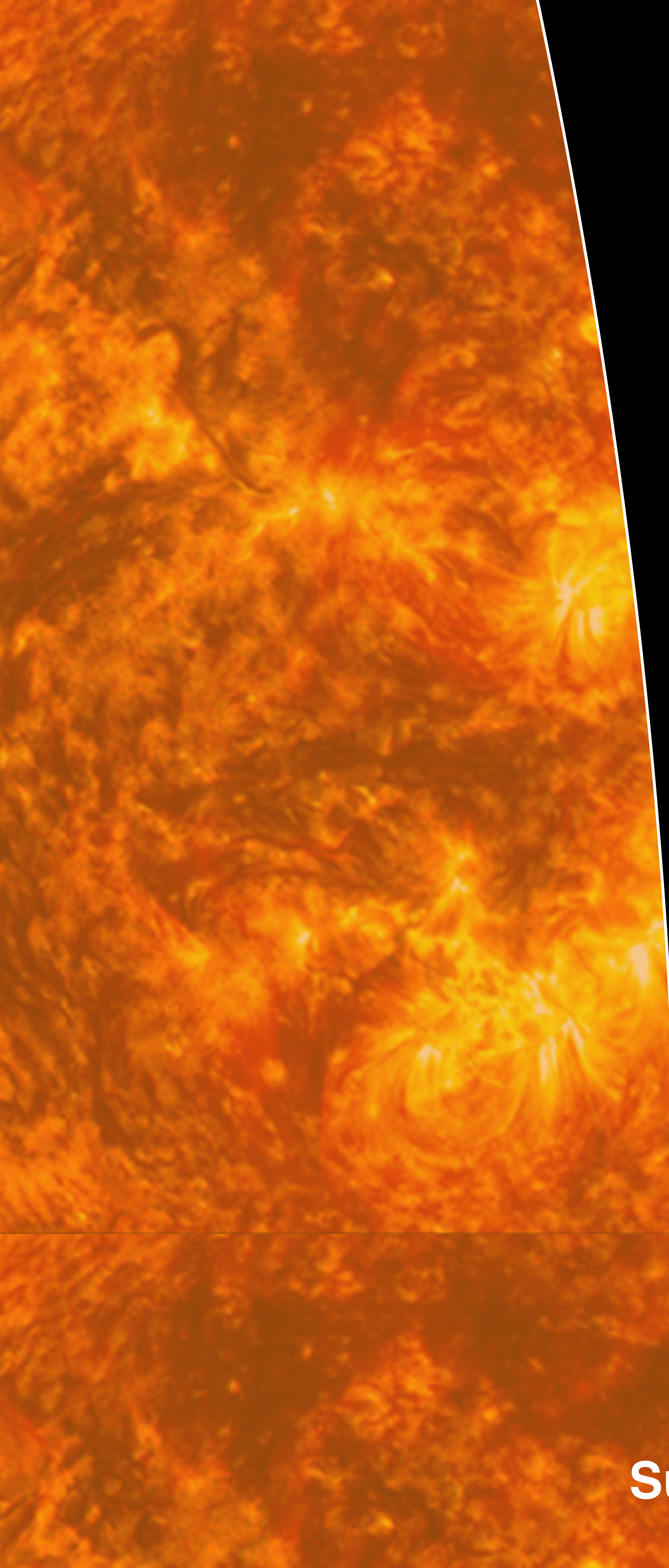
$$r_{OB} = \frac{\sqrt{\eta}}{1 + \sqrt{\eta}} D$$

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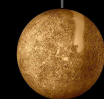


η Carinae **vs.** Solar system



Sun

Mercury



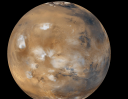
Venus



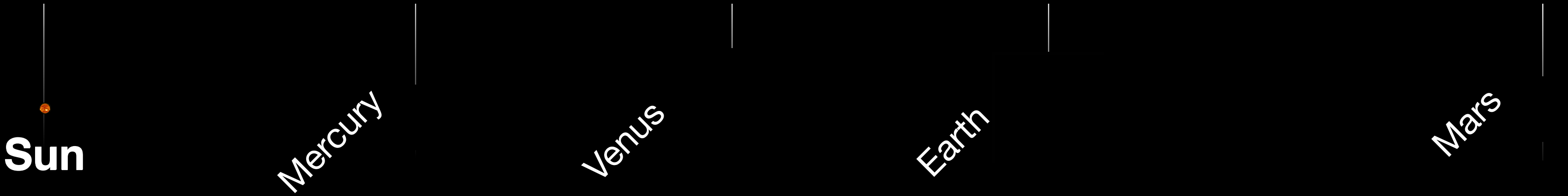
Earth



Mars

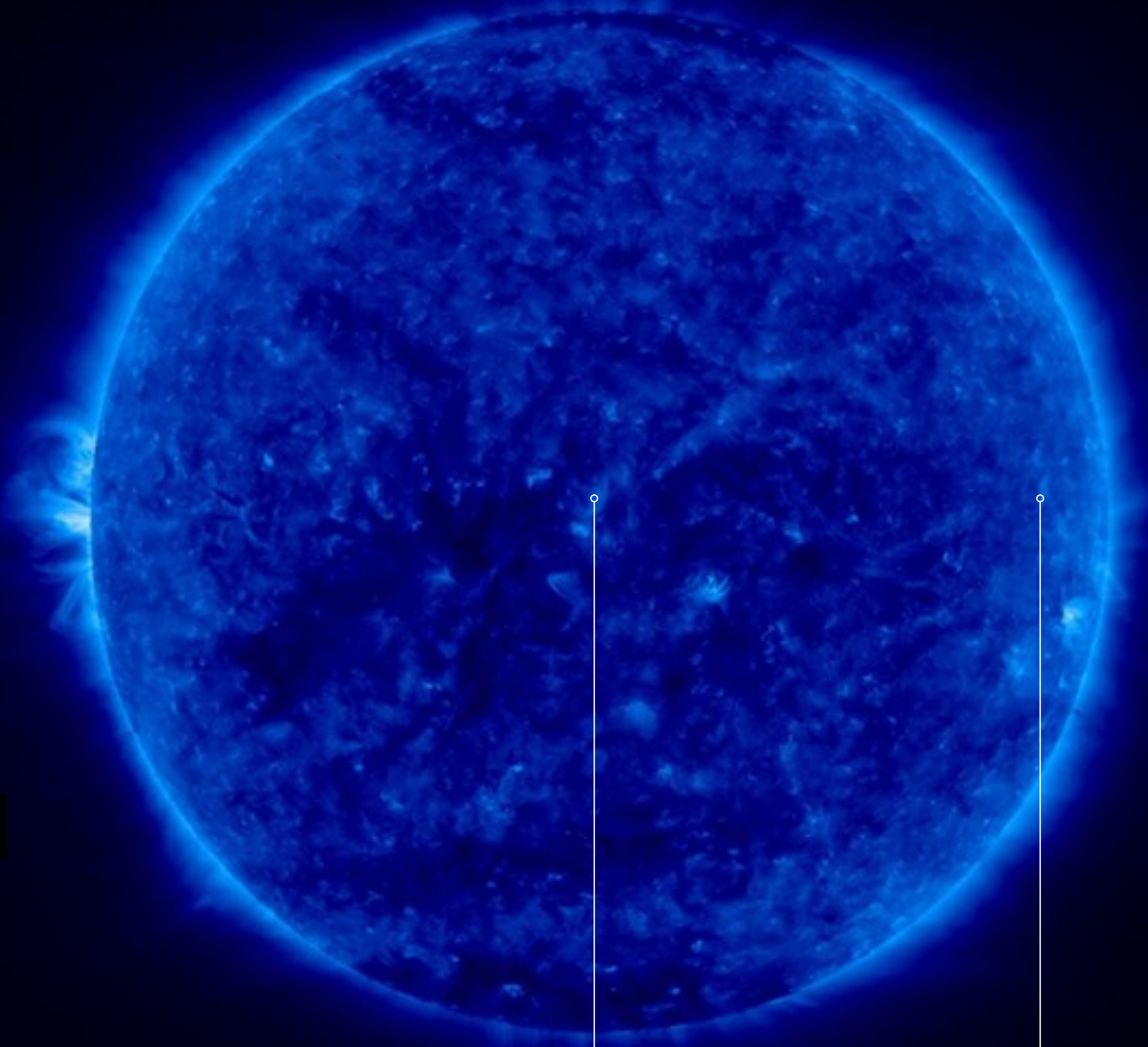


η Carinae *vs.* Solar system



η Carinae **vs.** Solar system

η Car A



Sun

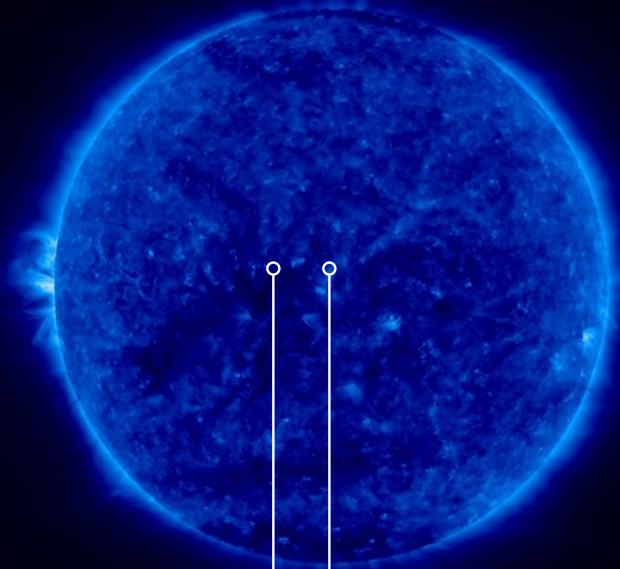
Mercury

Venus

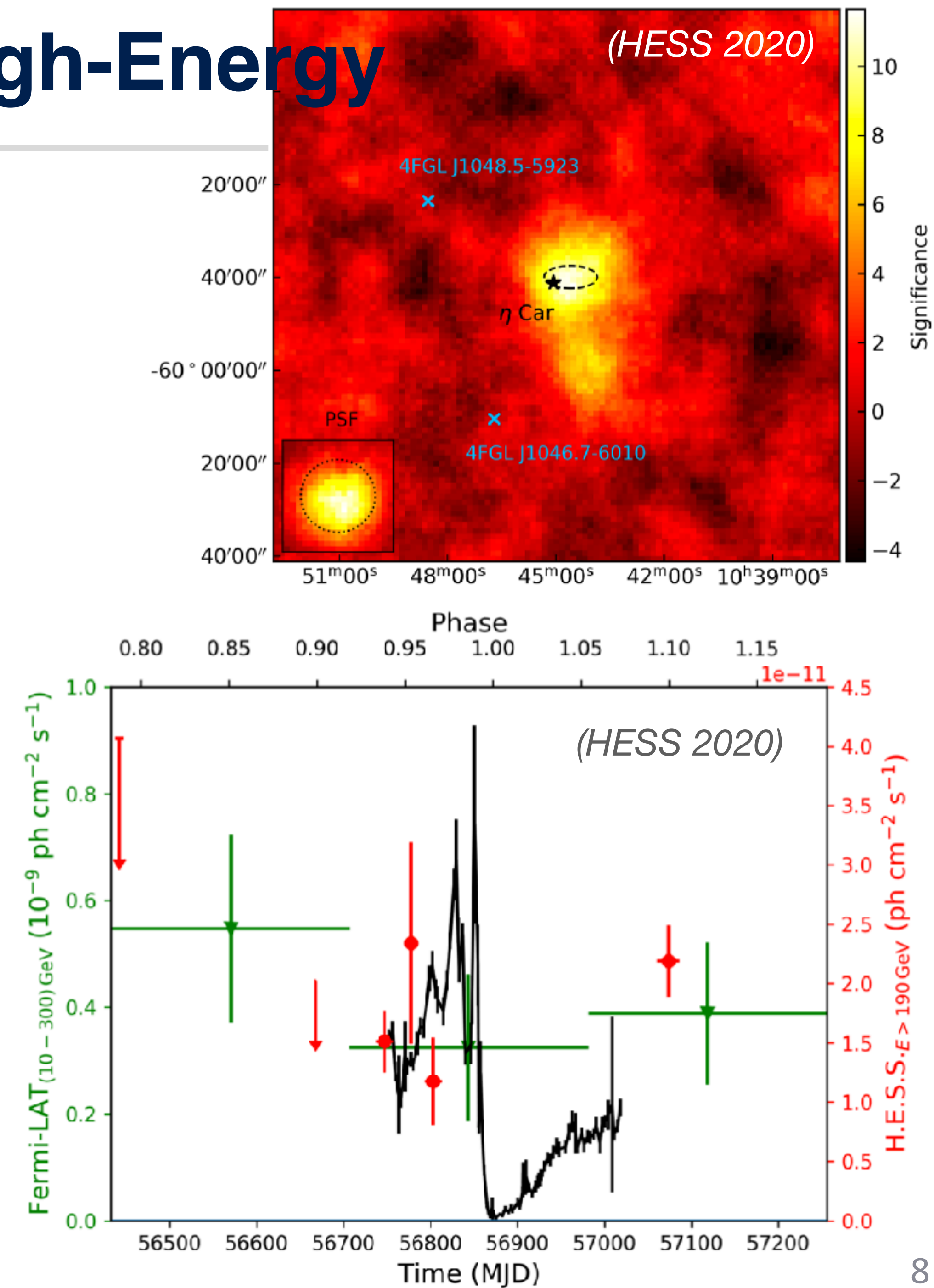
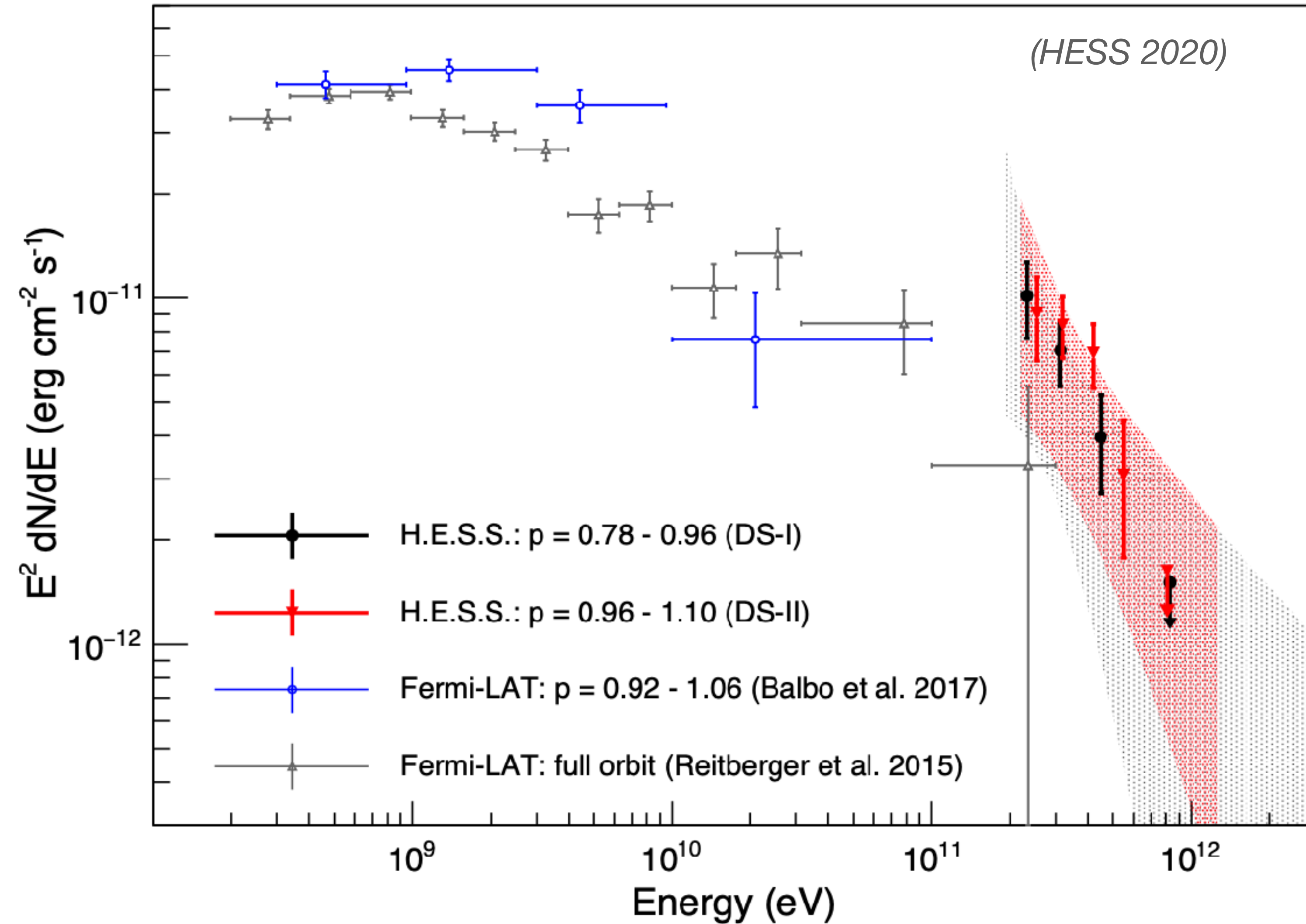
Earth

Mars

η Car B



η -Carinae @ High-Energy & Very-High-Energy

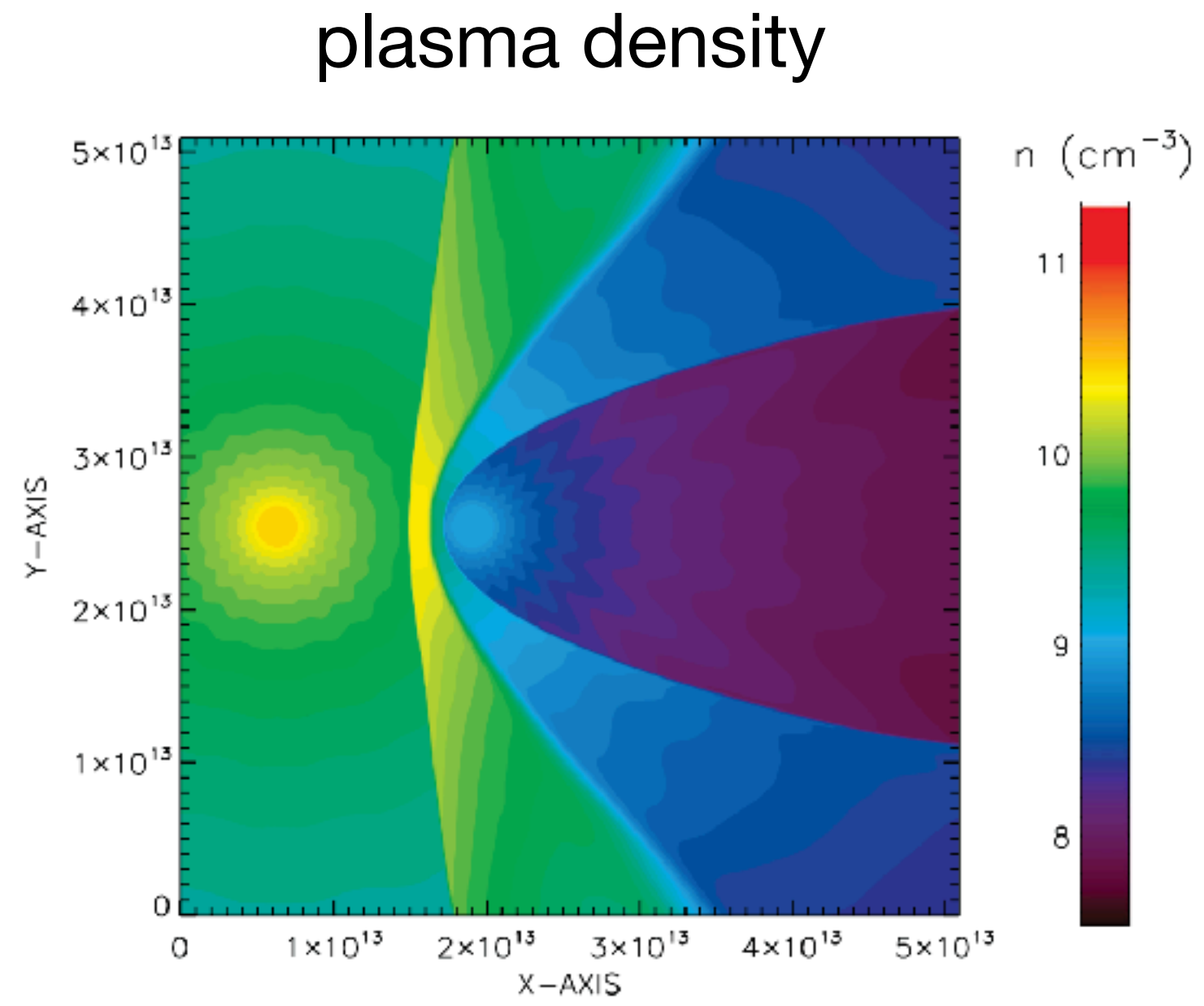


Magneto-Hydro-Dynamic simulations

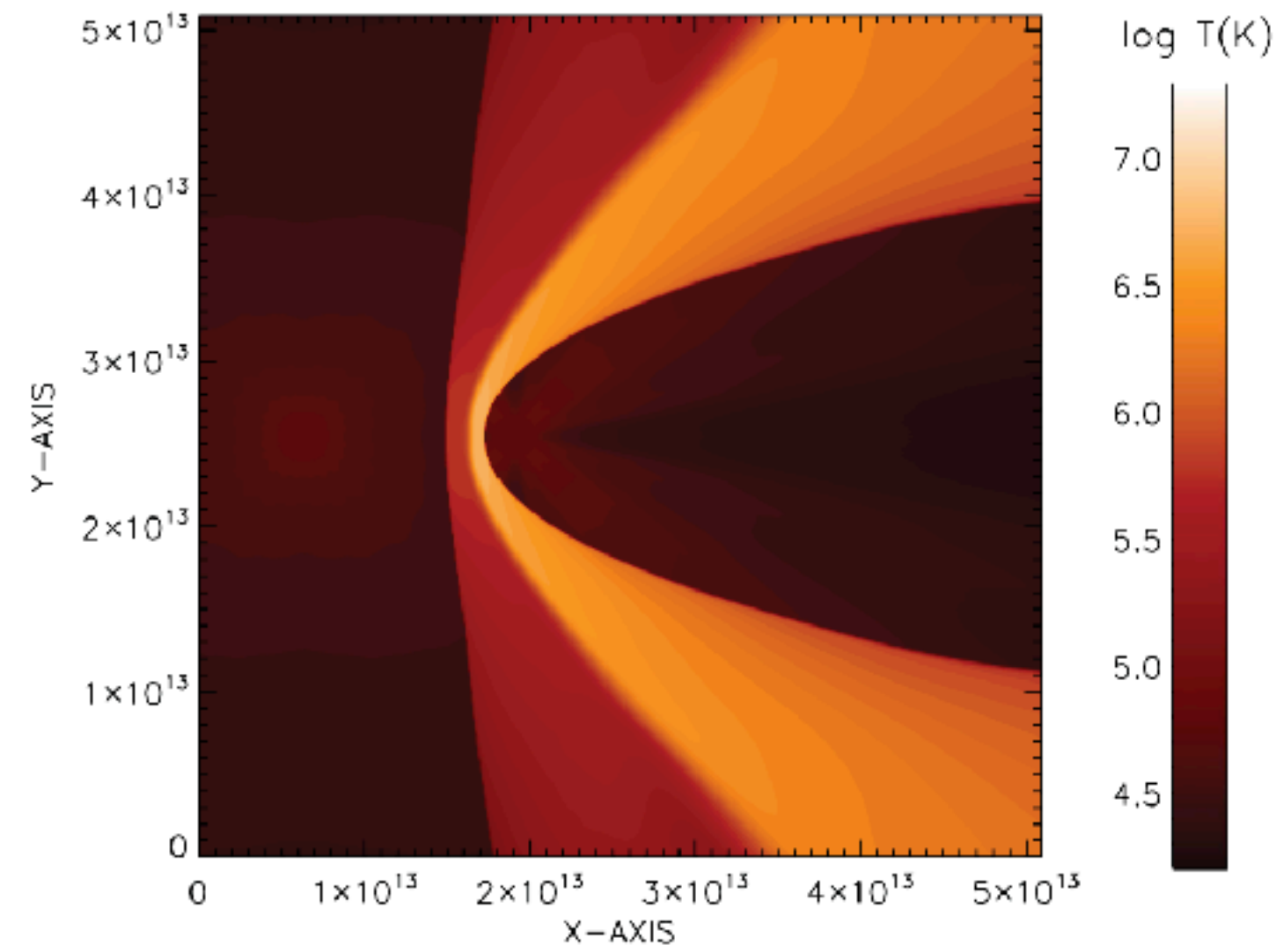
(Falceta-Gonçalves & Abraham 2012)



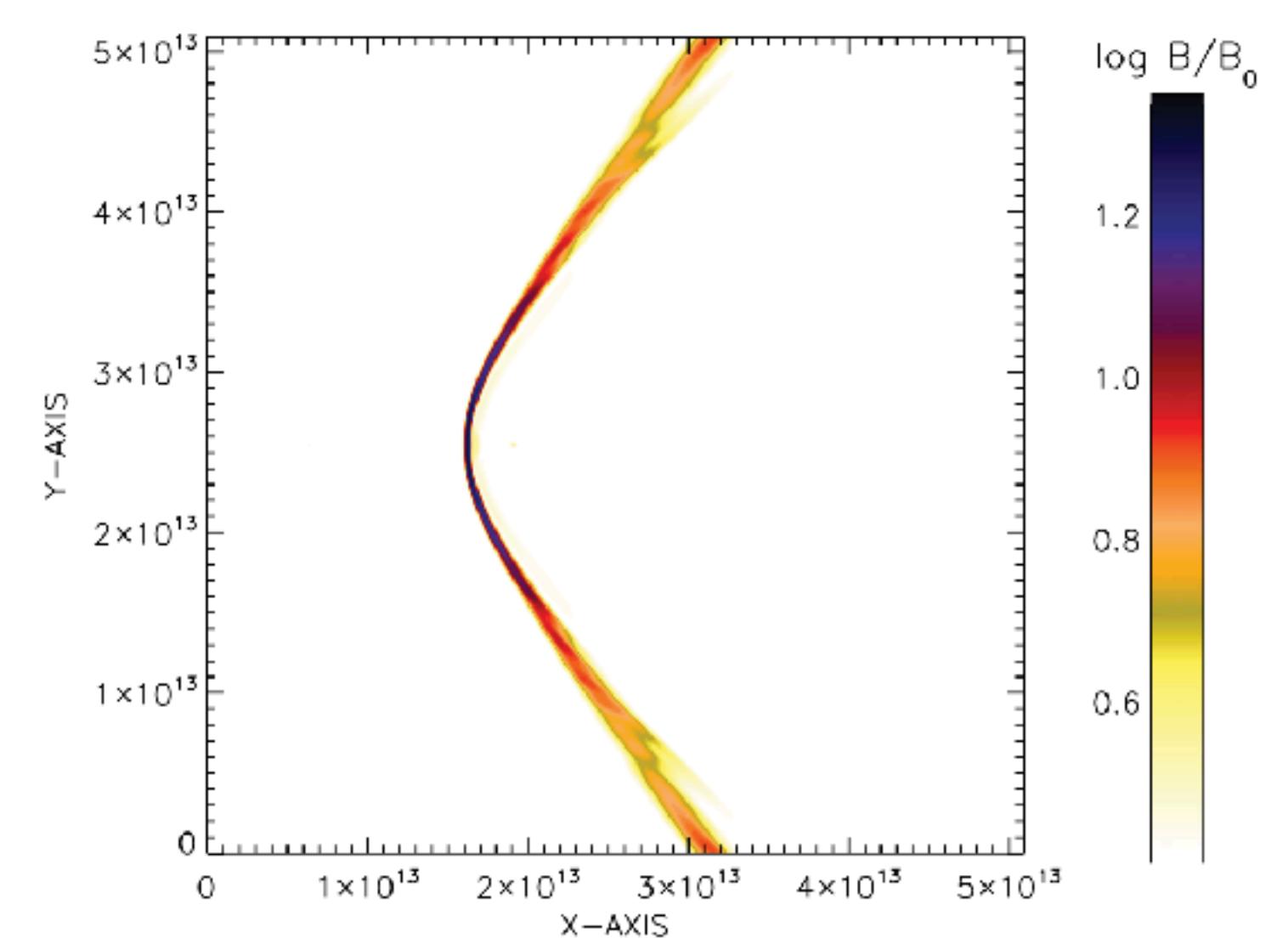
adiabatic



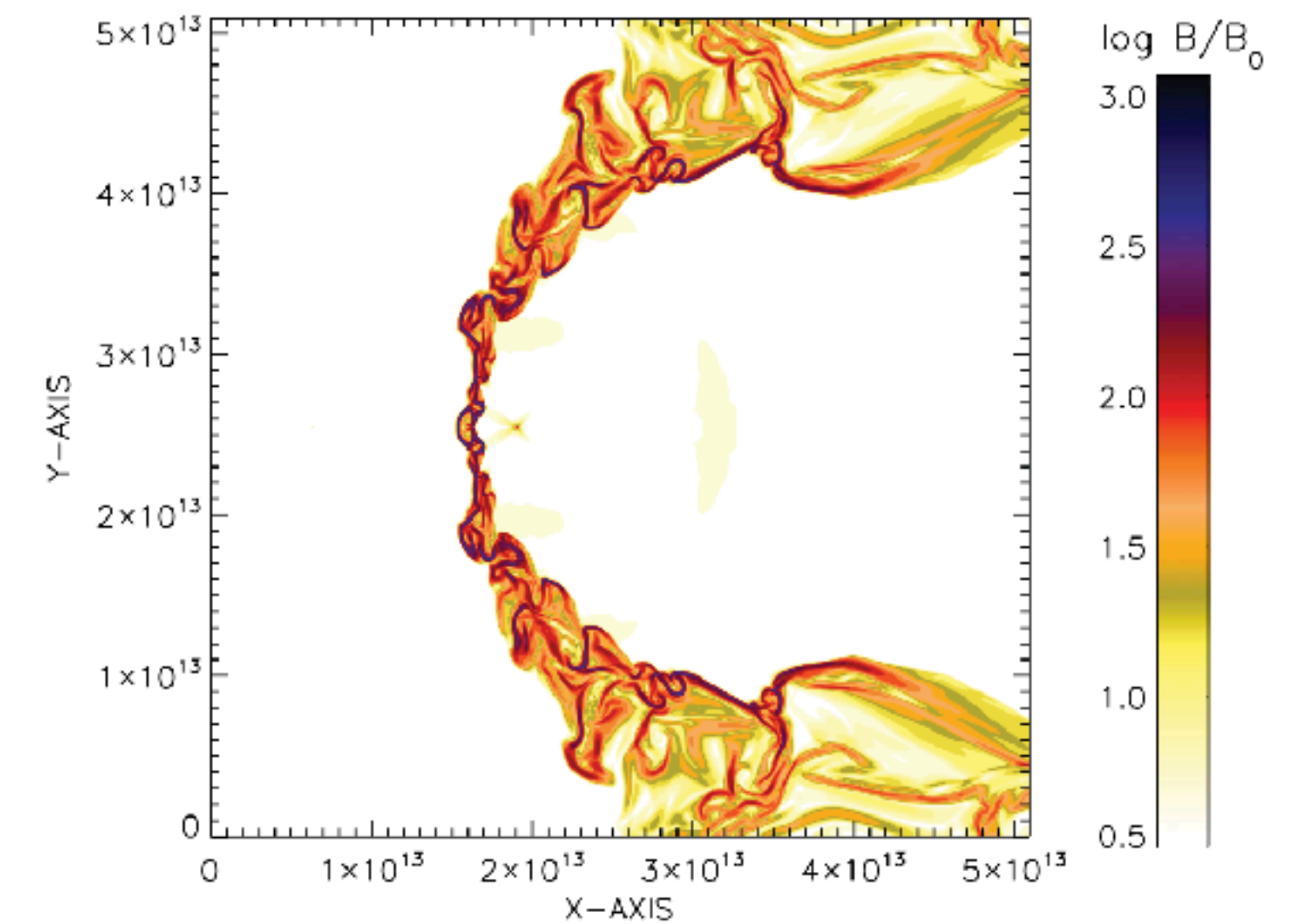
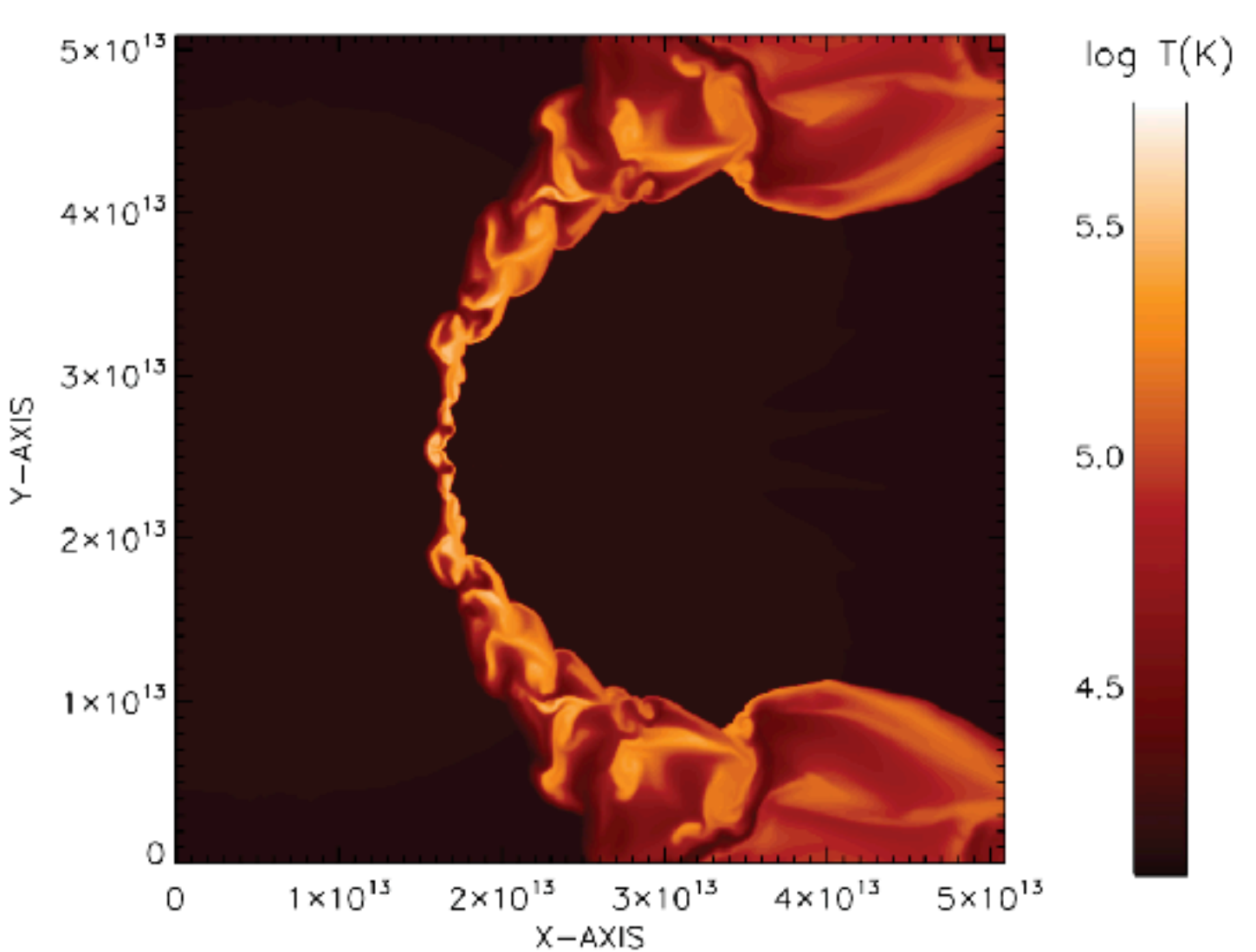
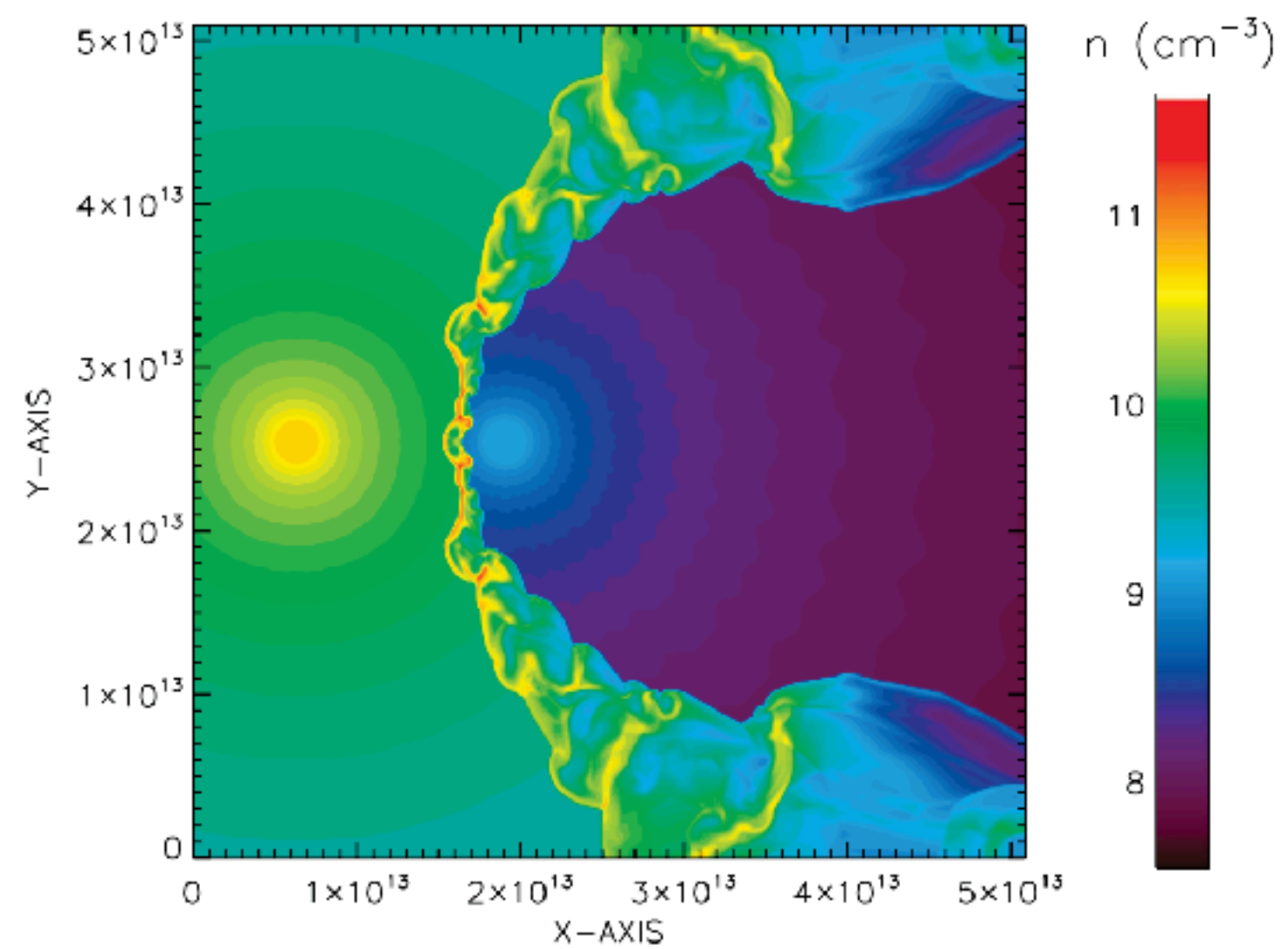
temperature



magnetic field



radiative cooling

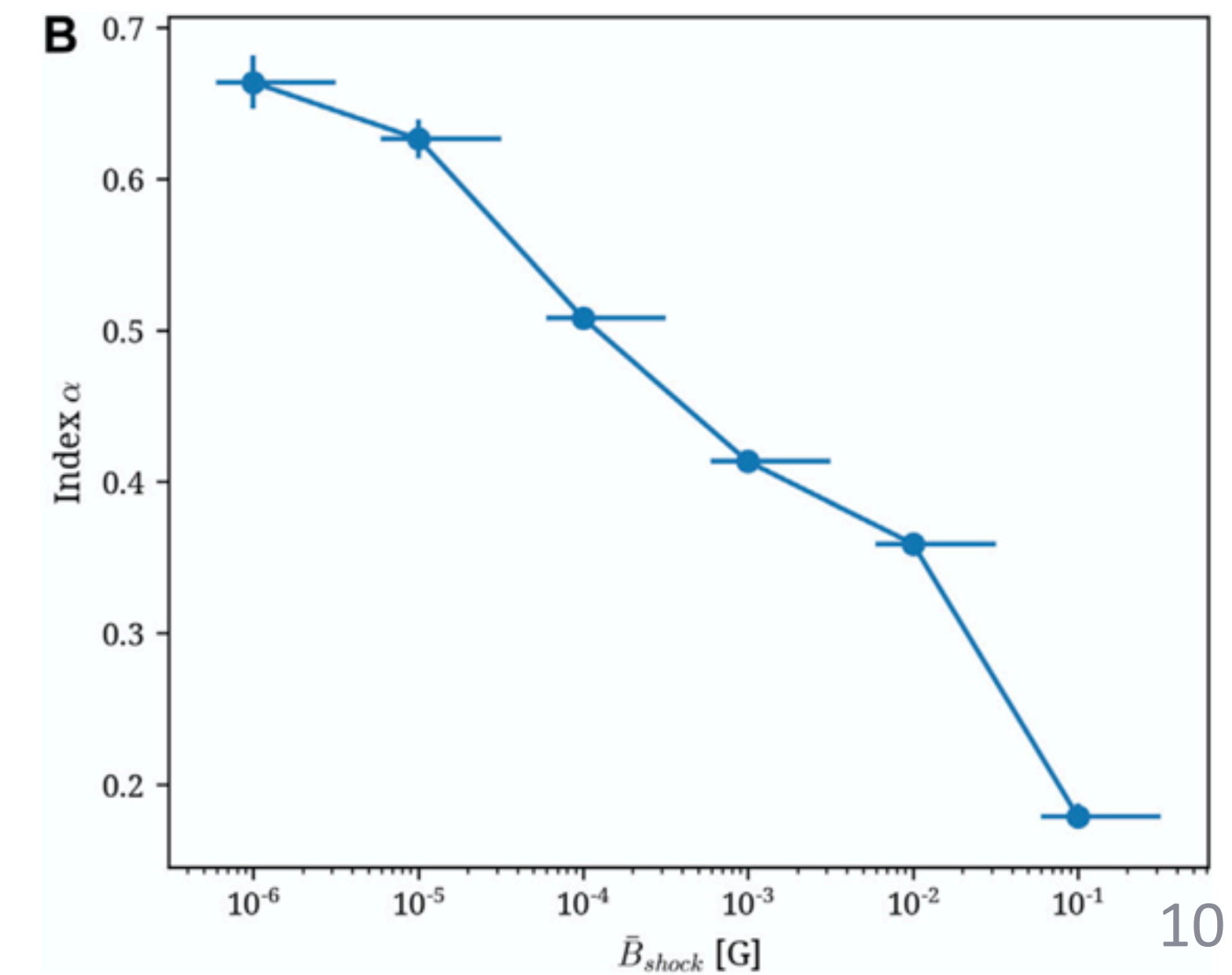
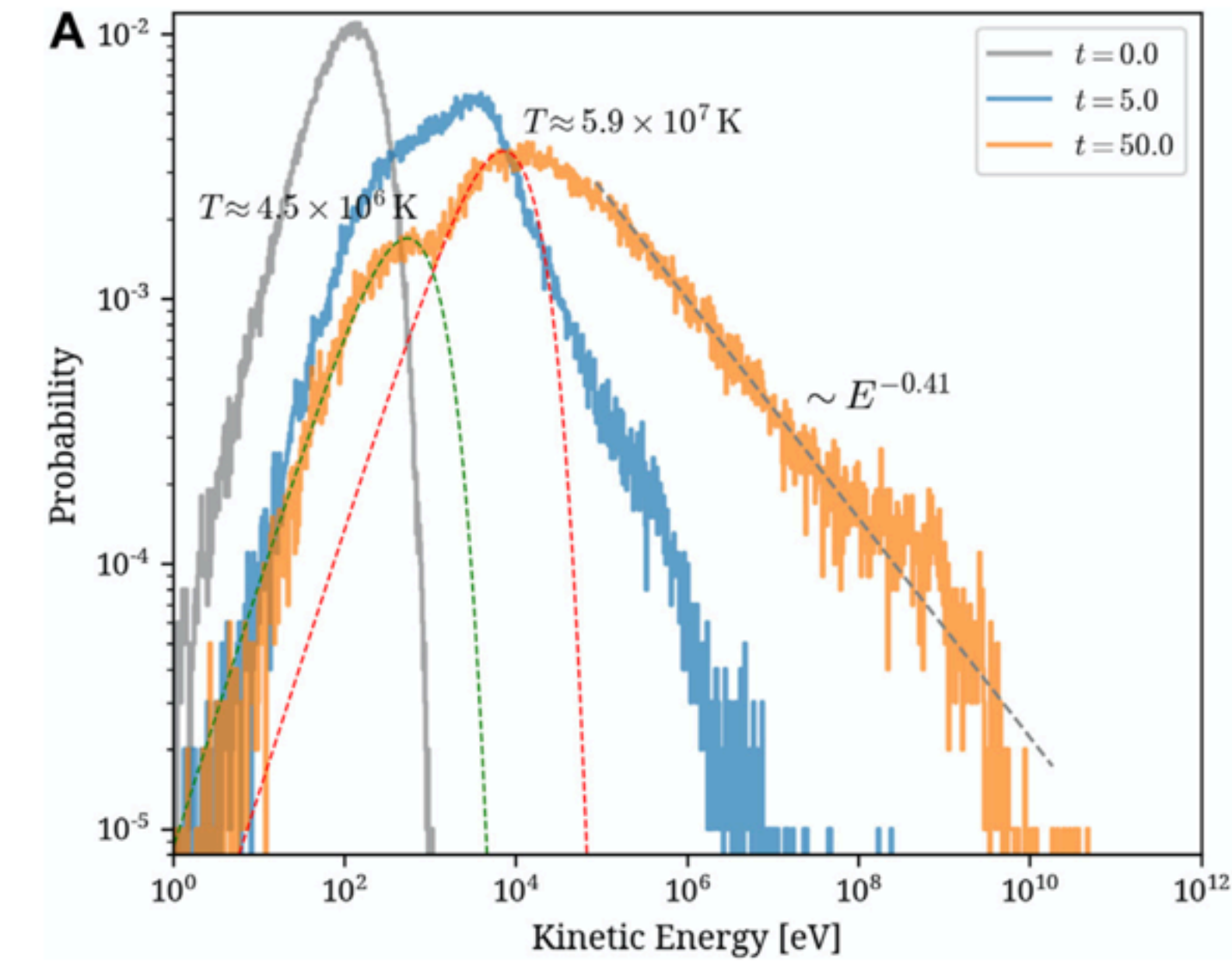
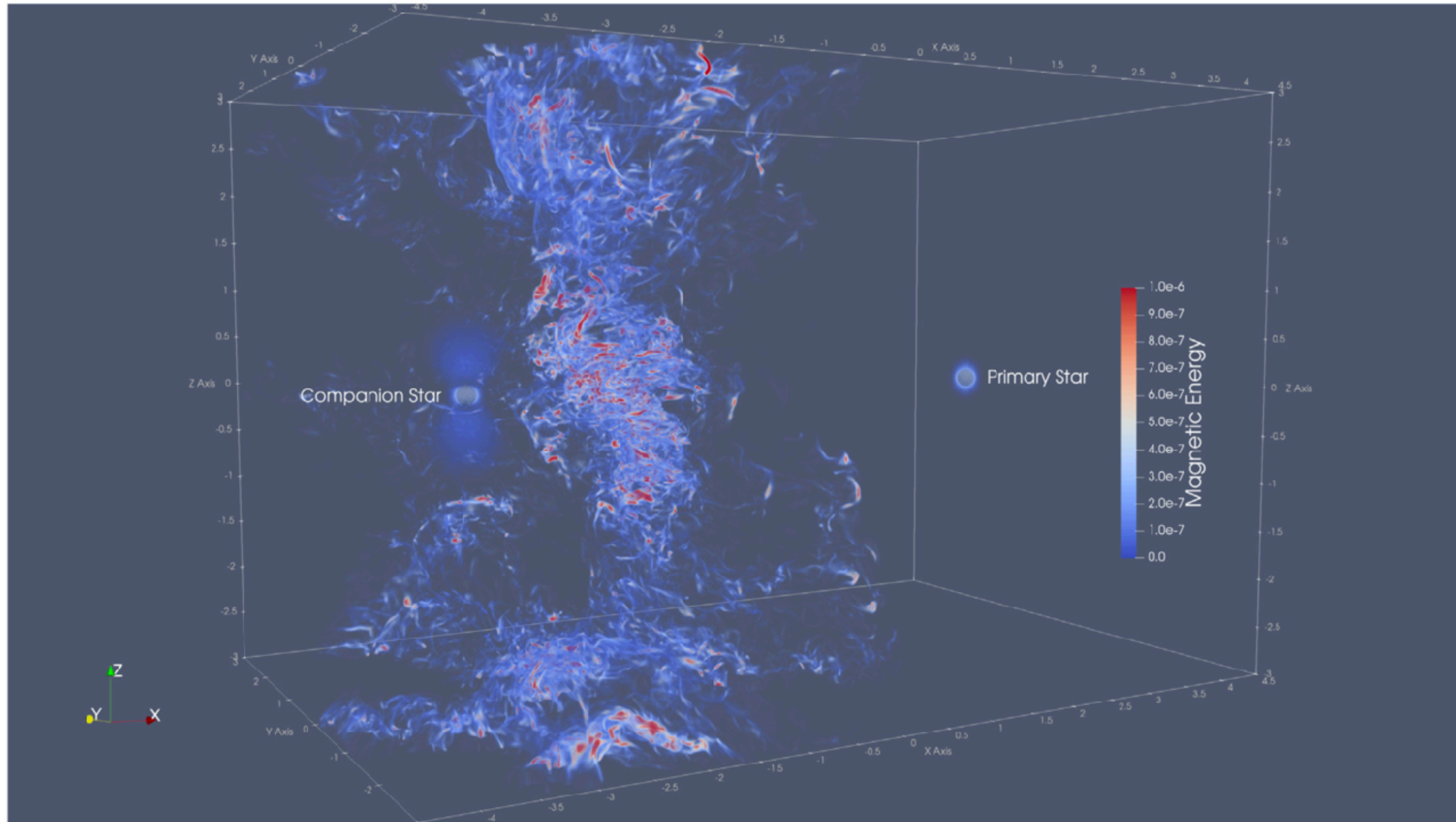


Magneto-Hydro-Dynamic simulations

(Kowal & Falceta-Gonçalves et al. 2021)



Magnetic energy distribution

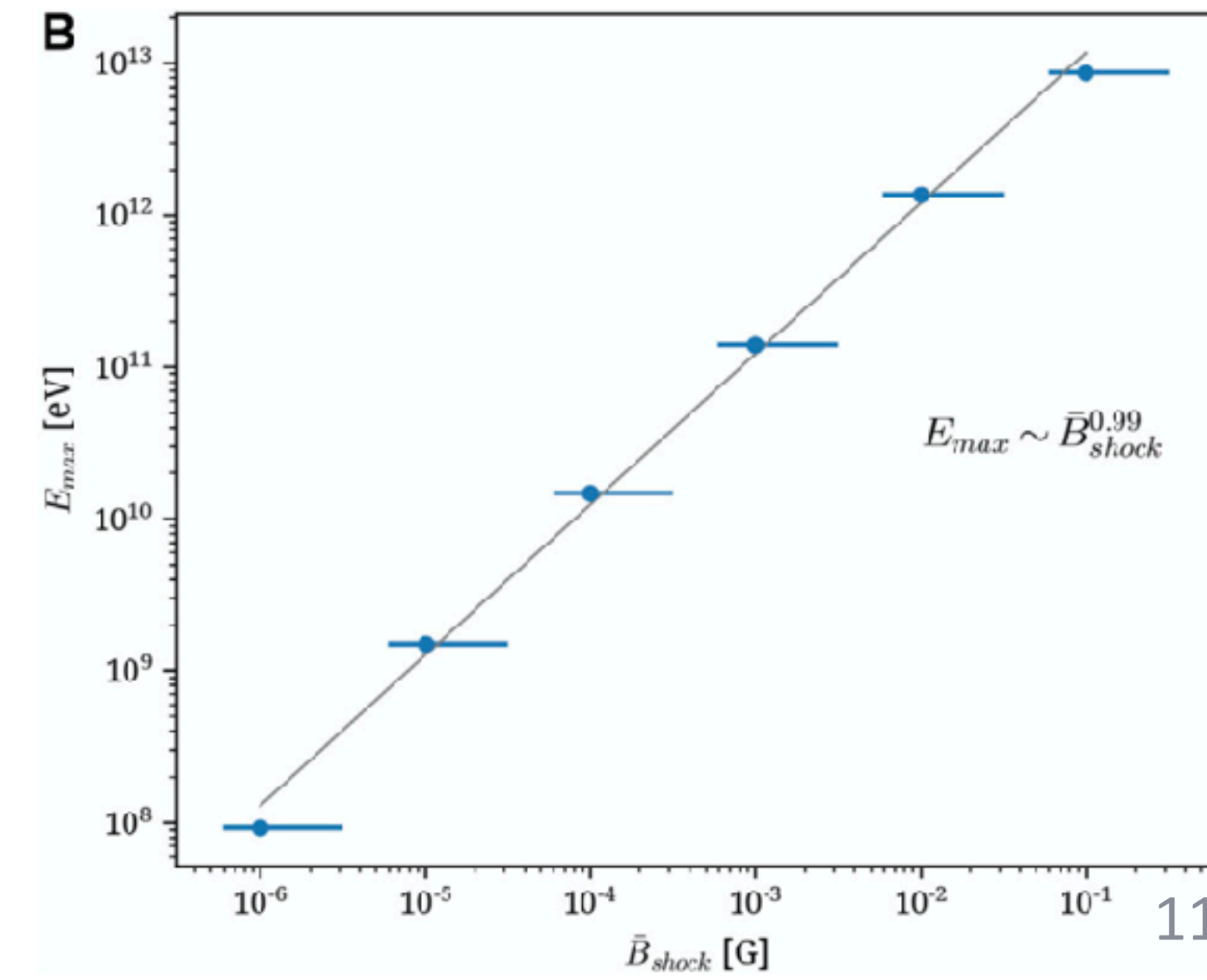
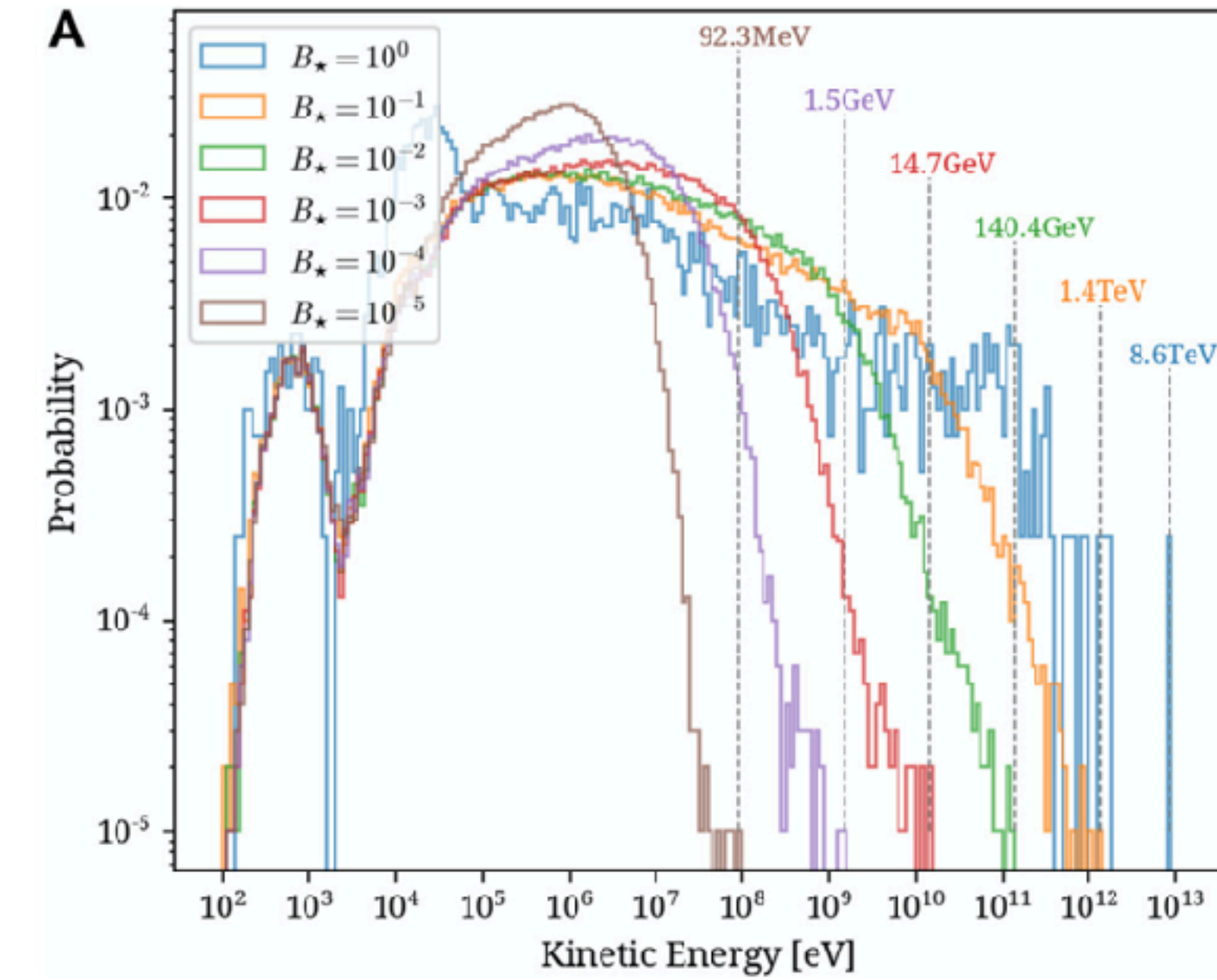
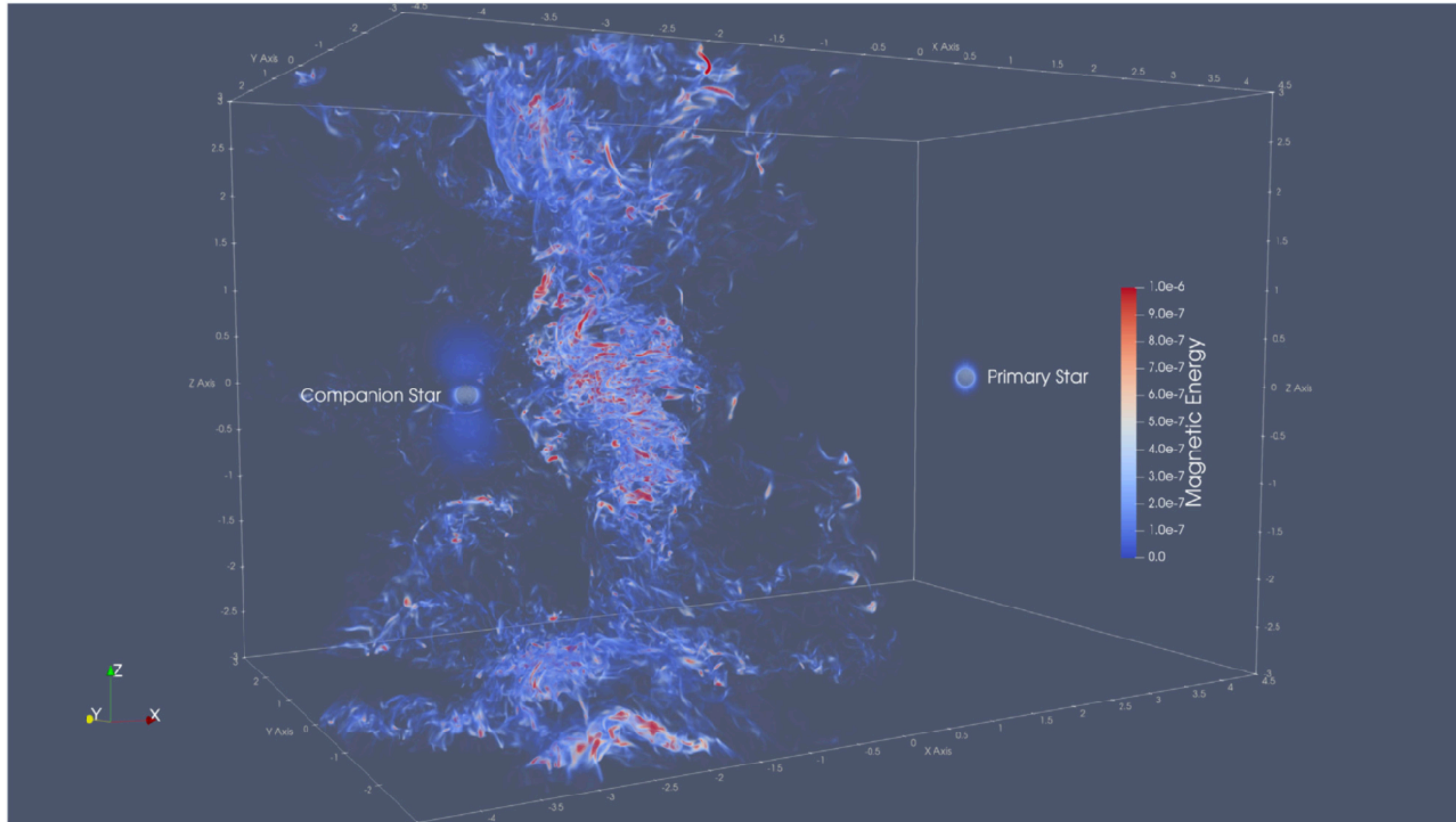


Magneto-Hydro-Dynamic simulations

(Kowal & Falceta-Gonçalves et al. 2021)

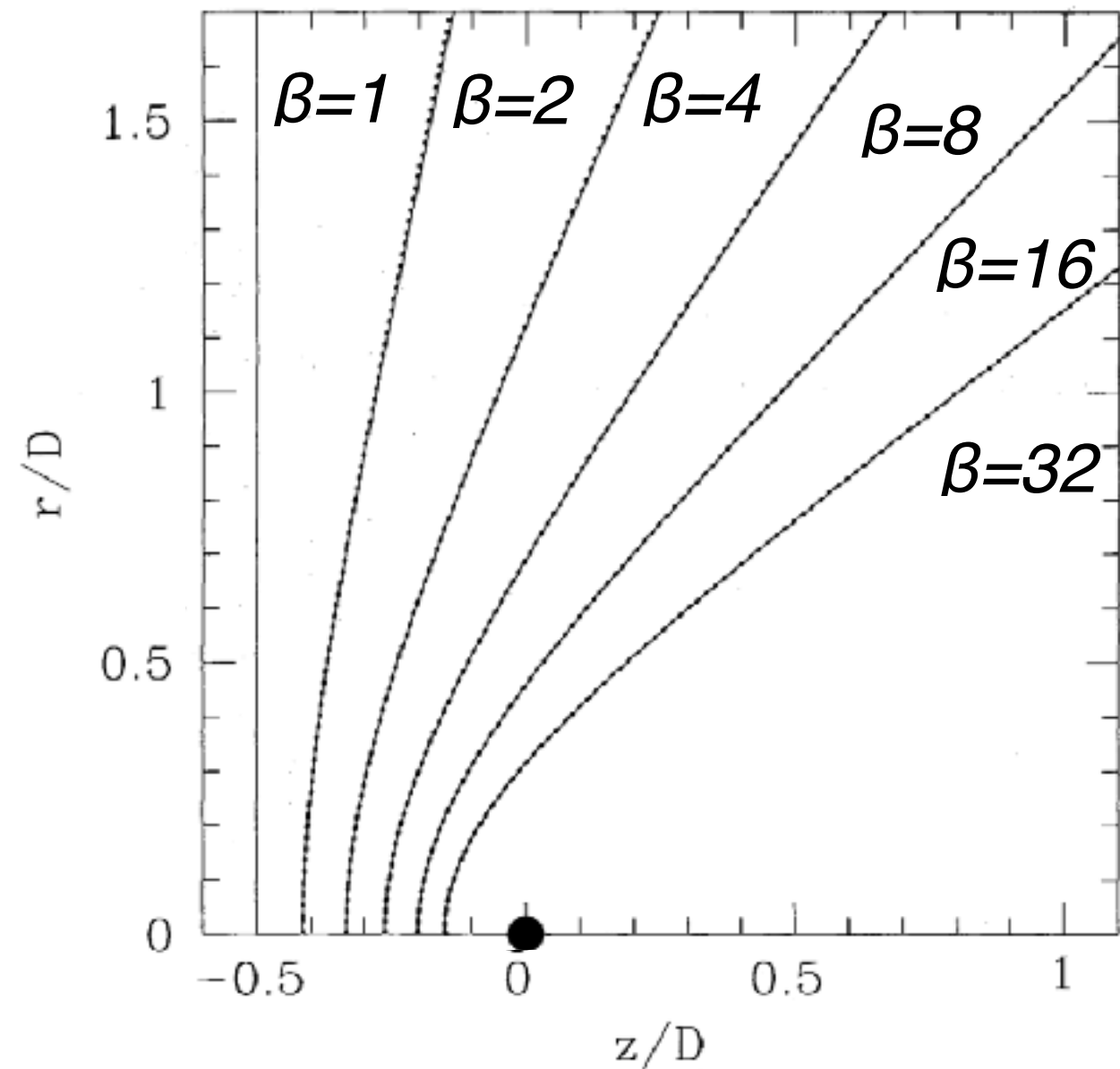


Magnetic energy distribution

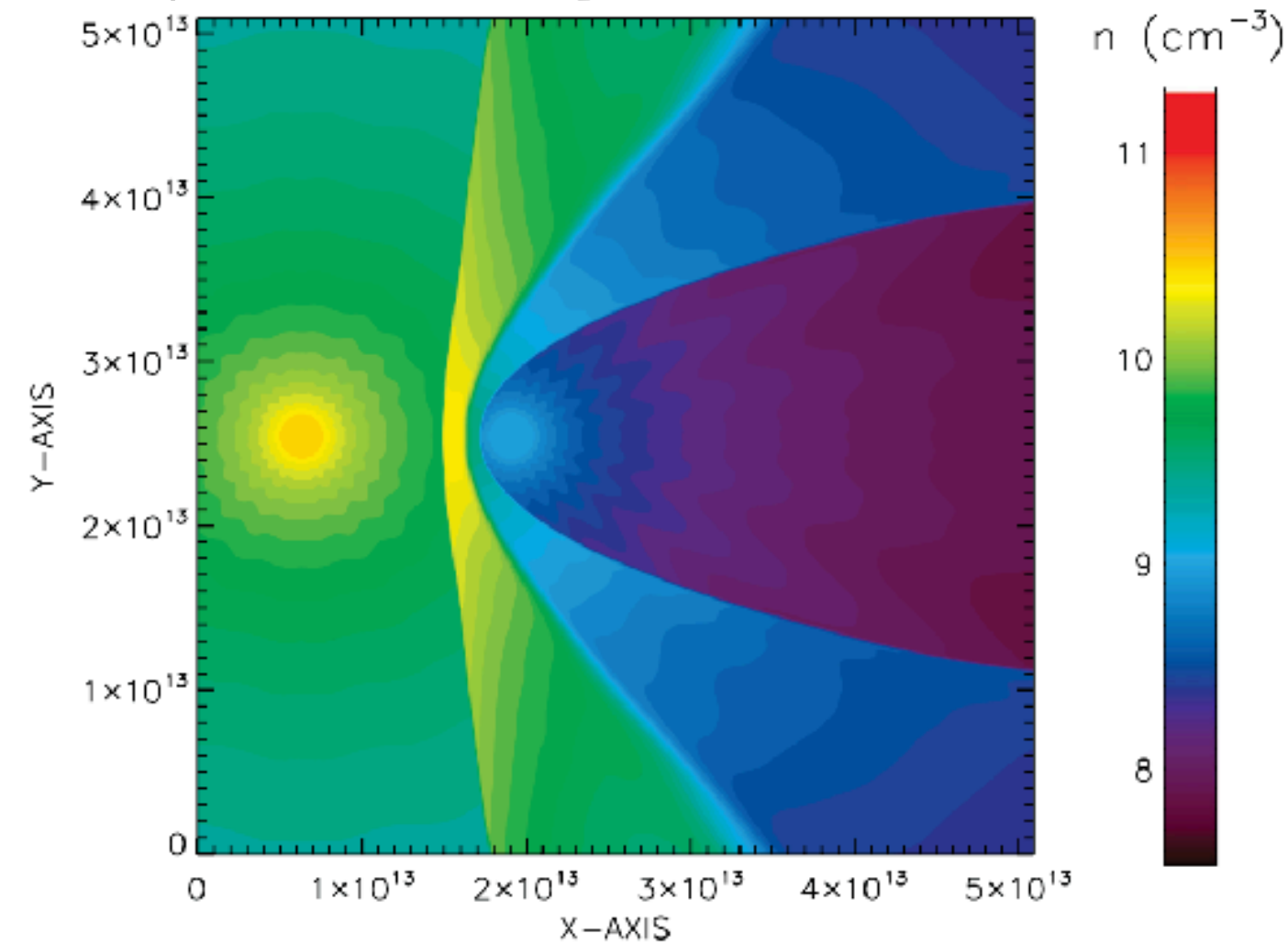


HE γ -rays: “paraboloid” approximation

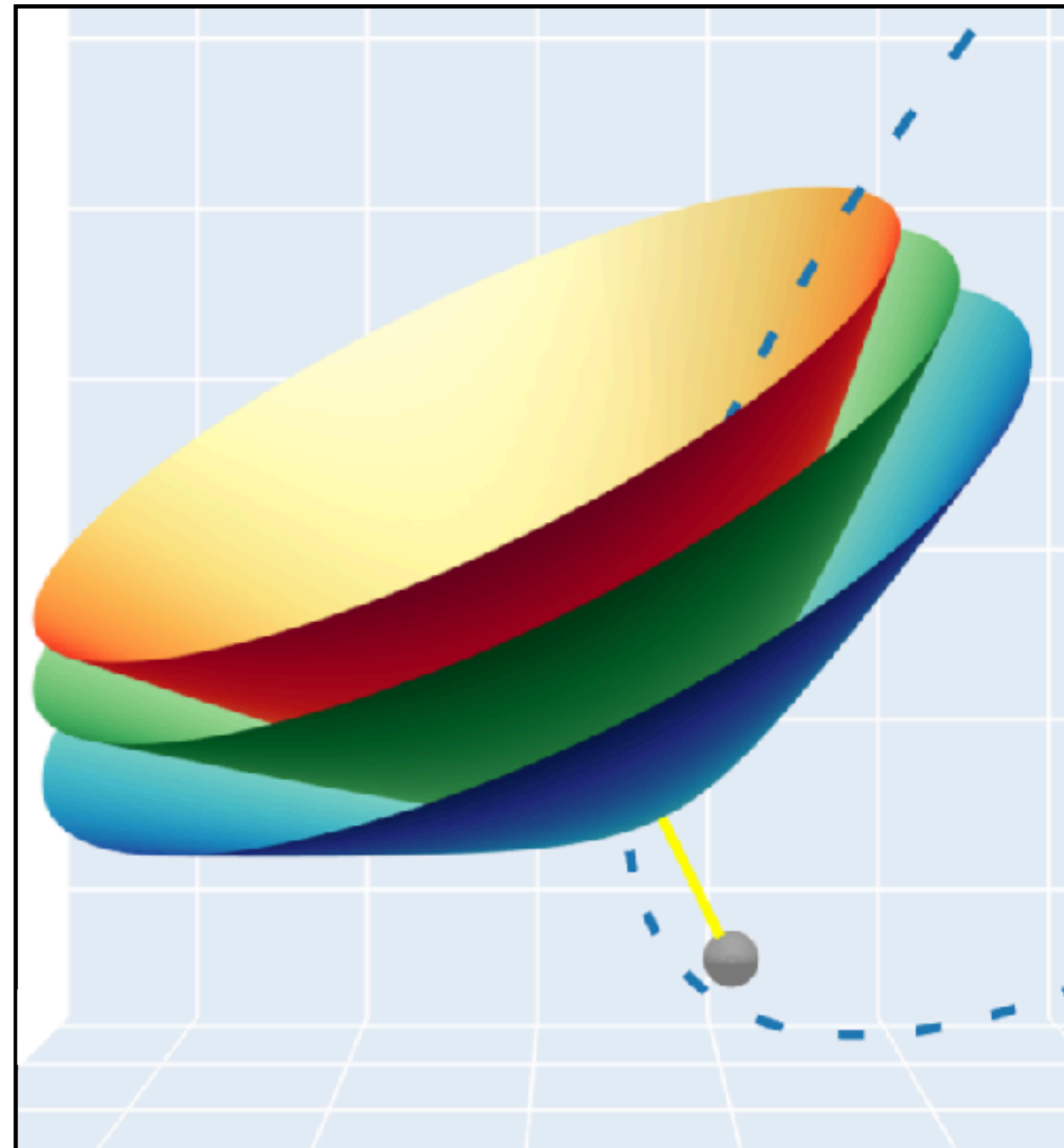
(Canto et al. 1996)



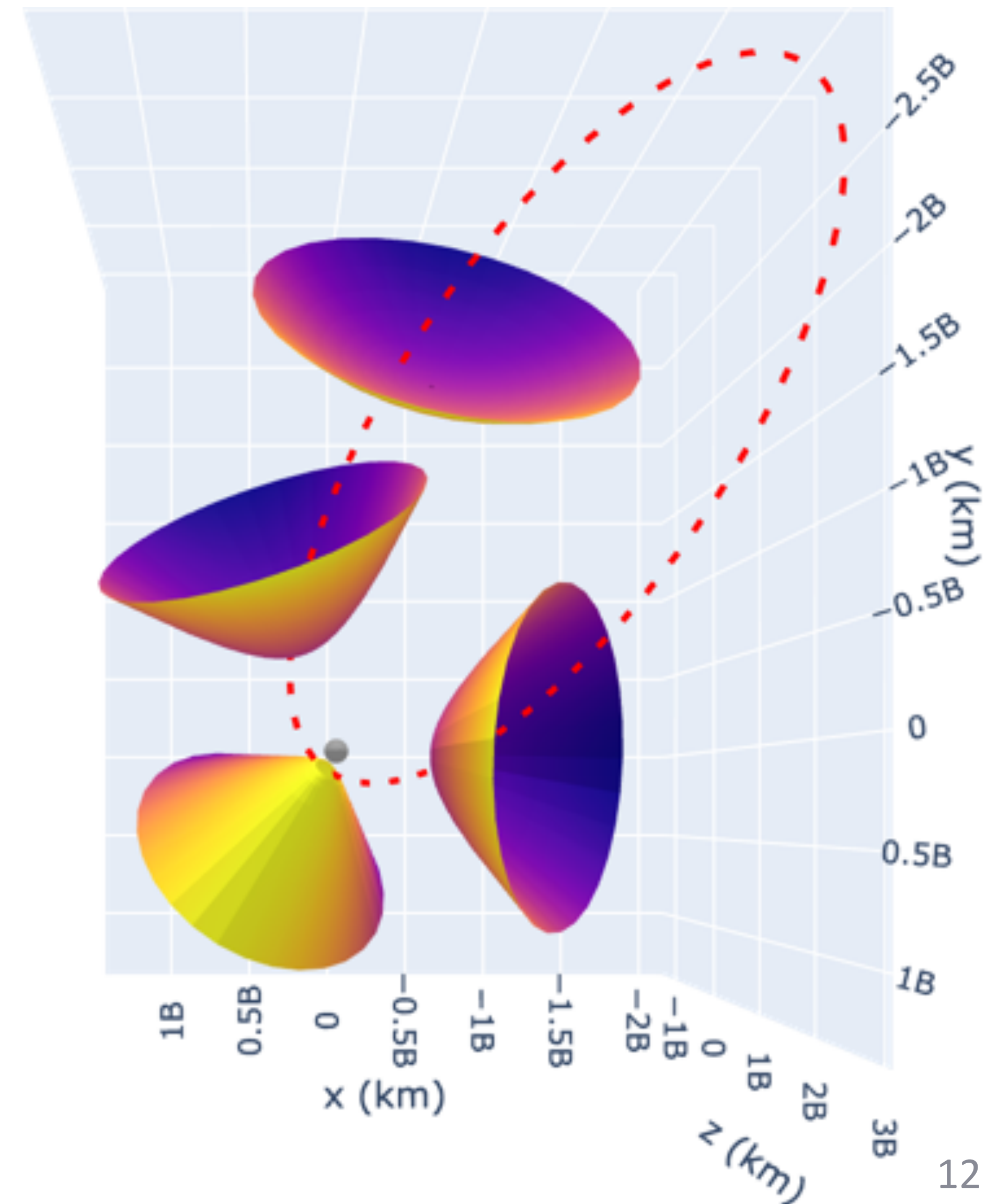
(Falceta-Gonçalves et al. 2012)



(MB & Walter, submitted)

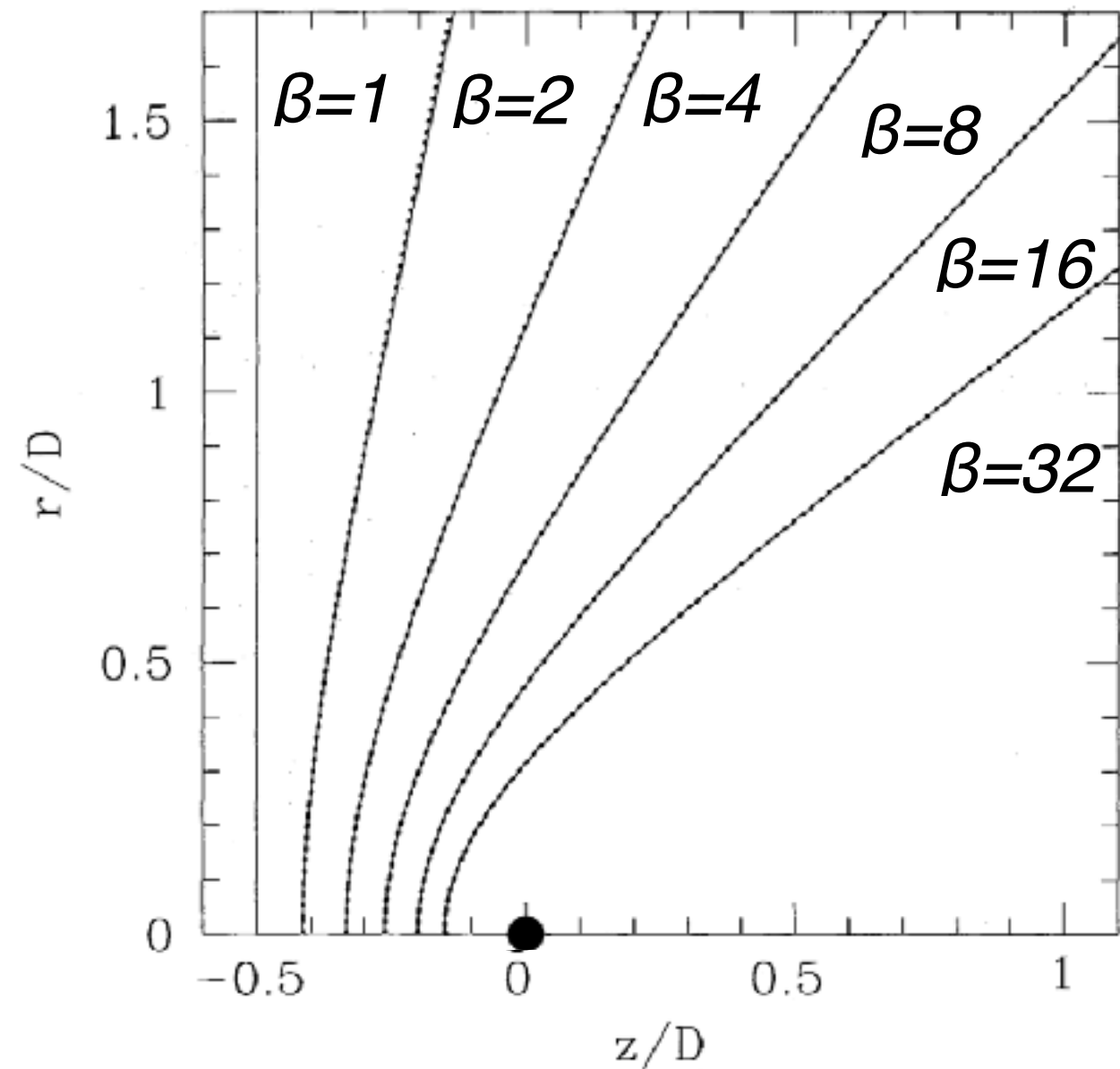


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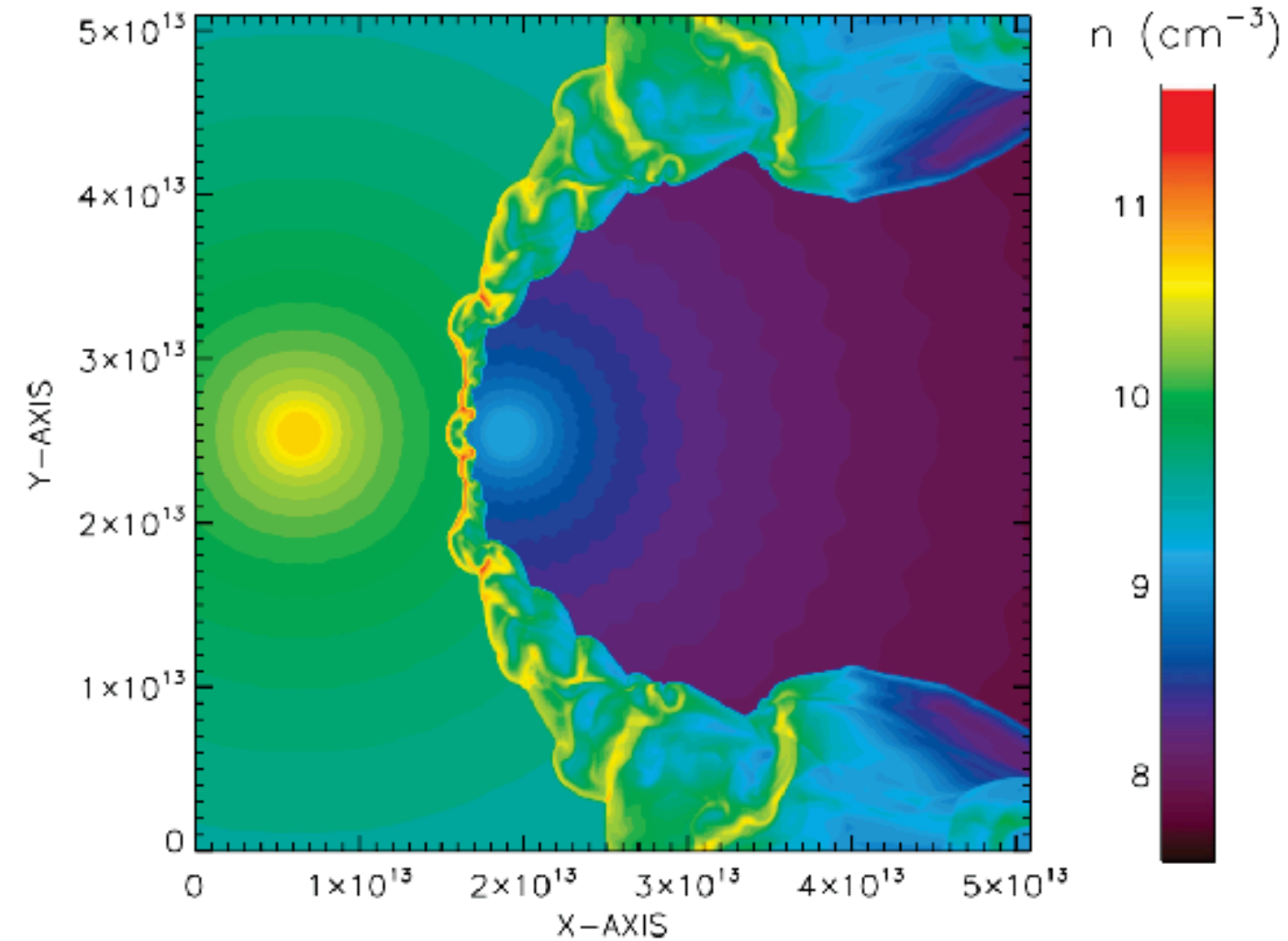


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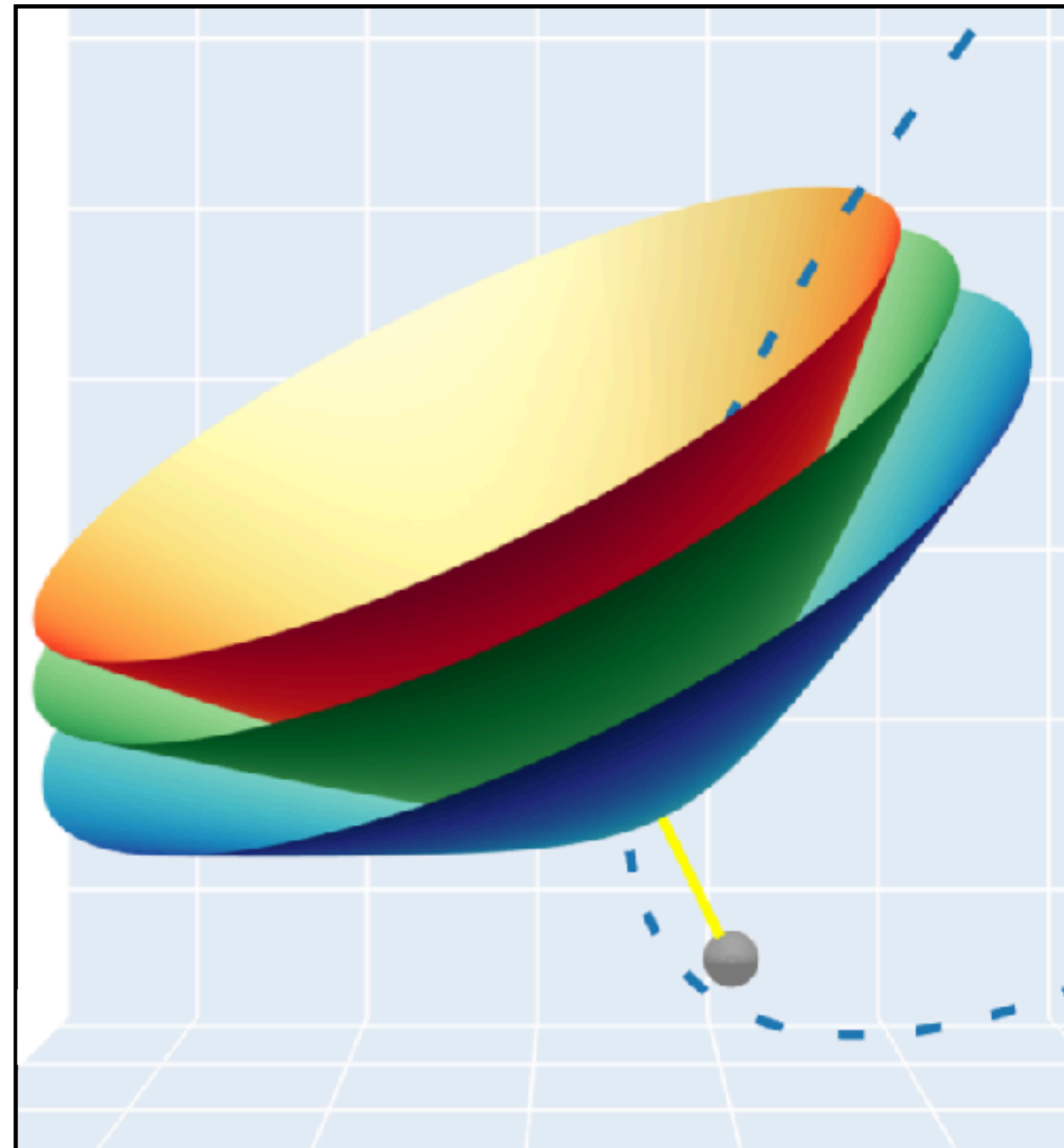
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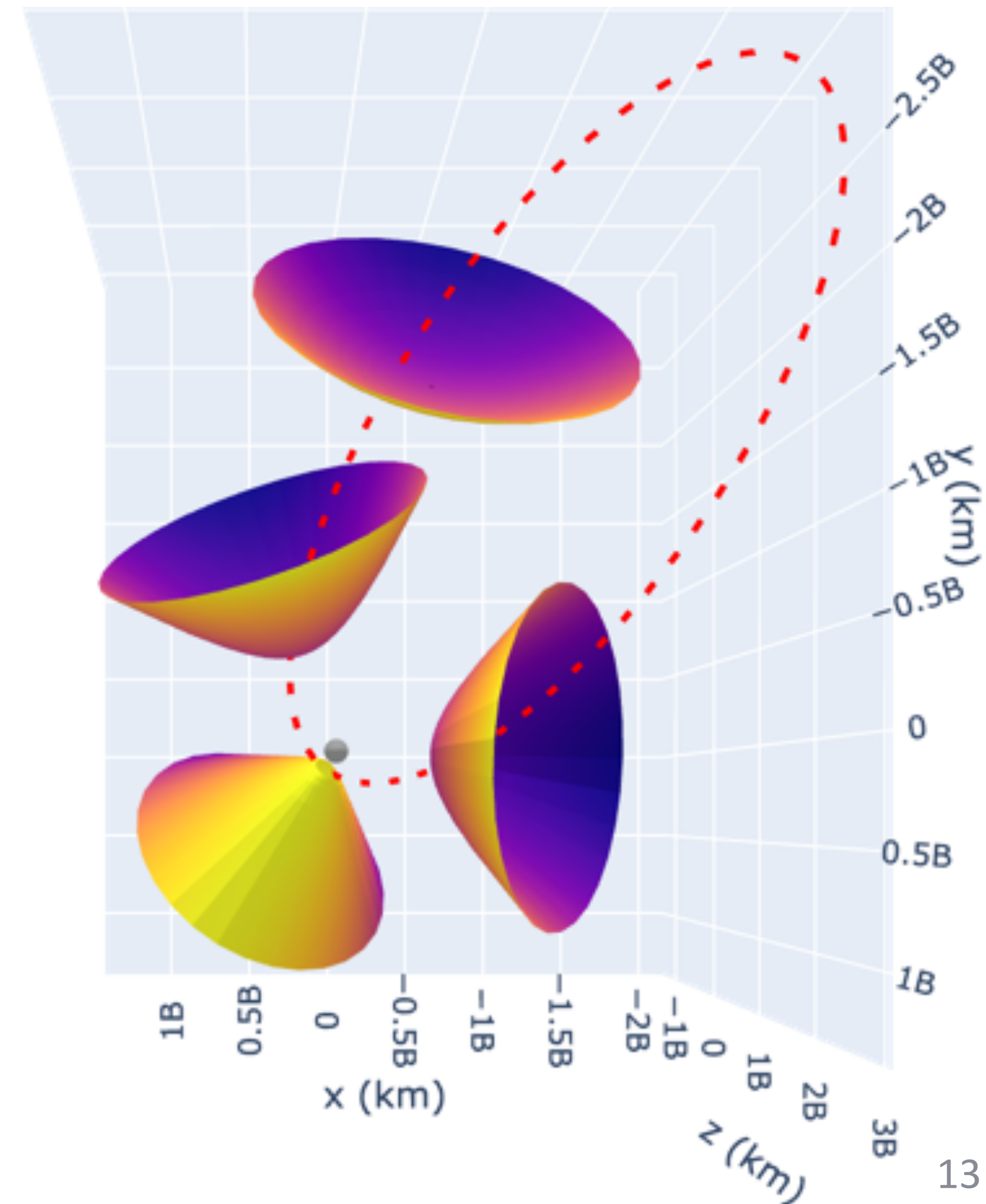
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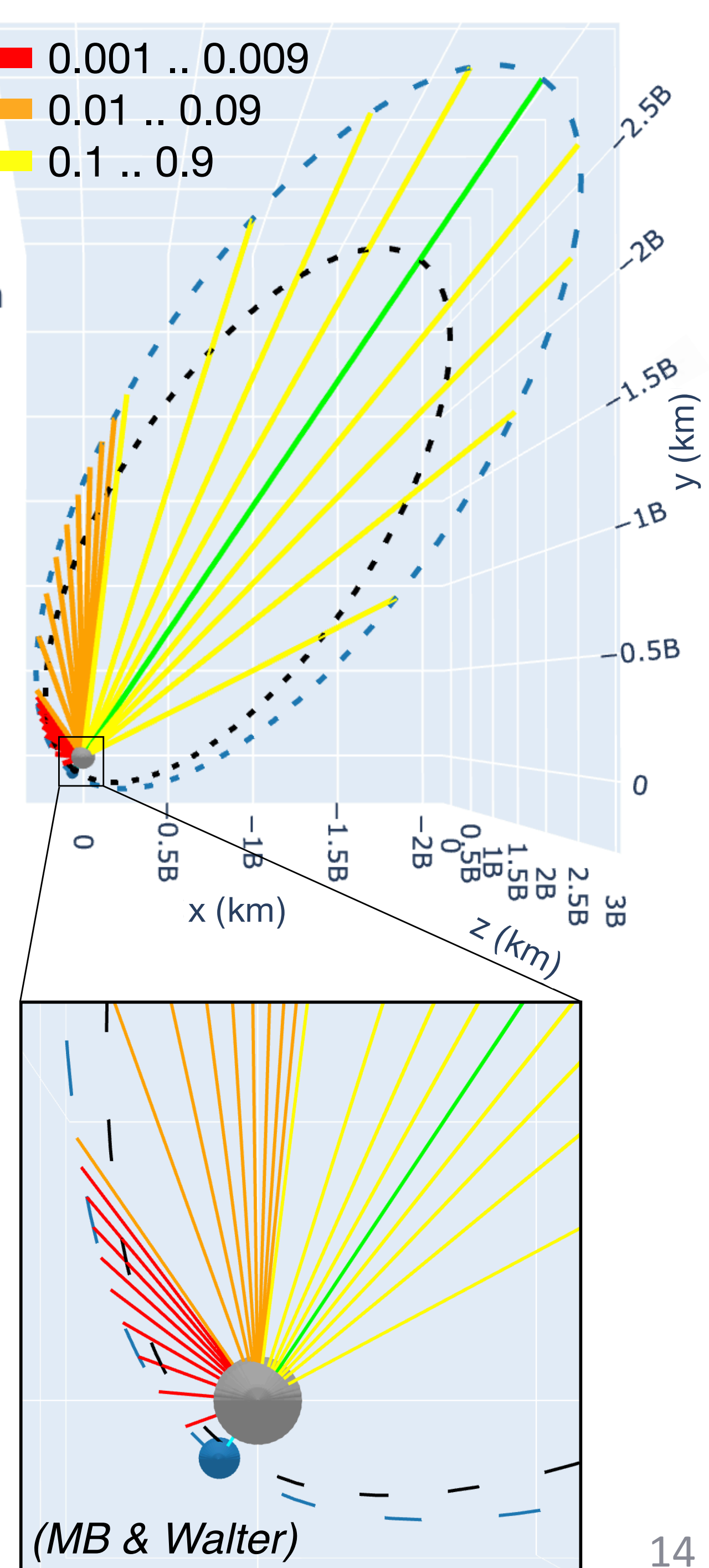
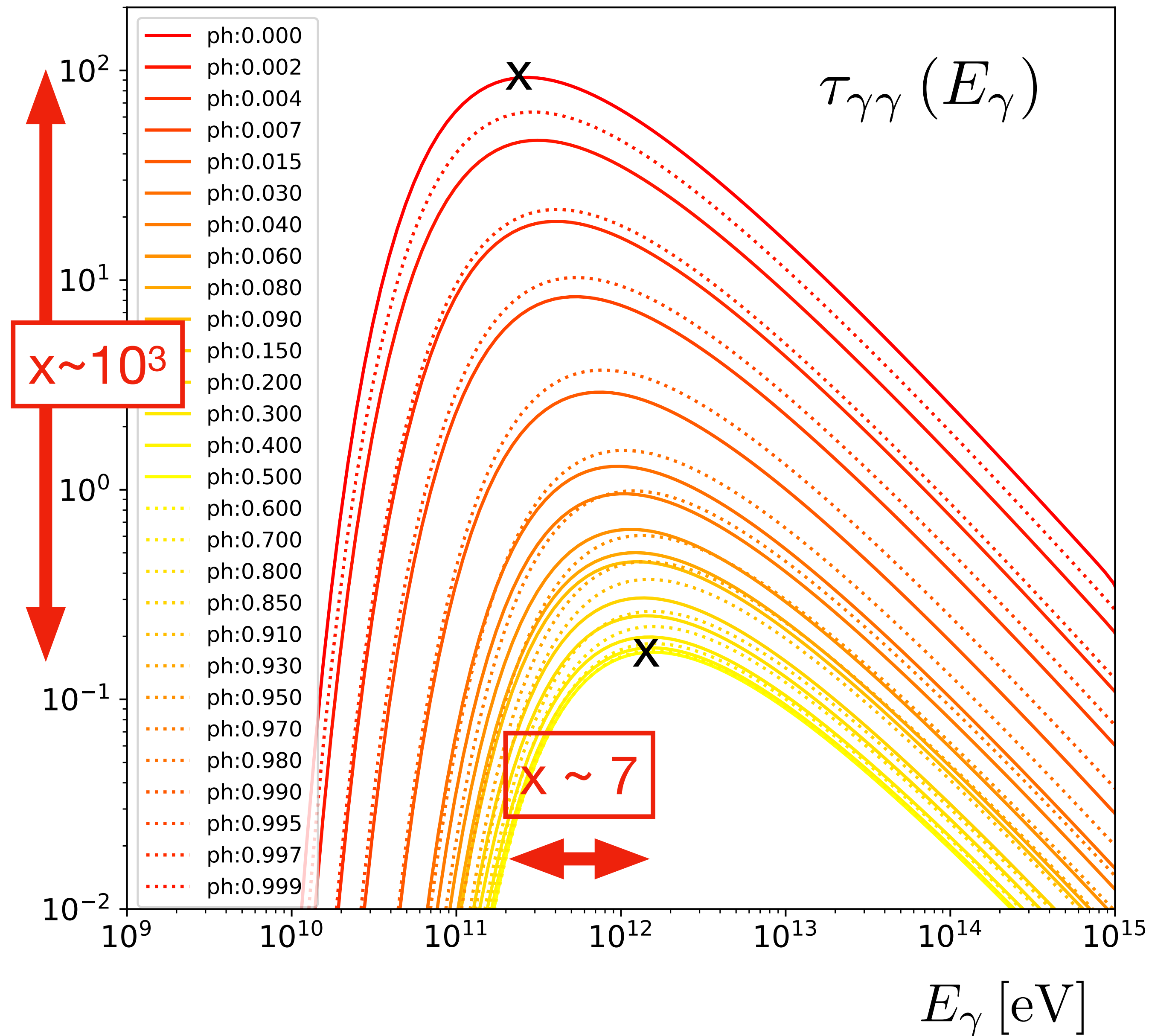


HE γ -rays: “stagnation” approximation

orbital
phases:

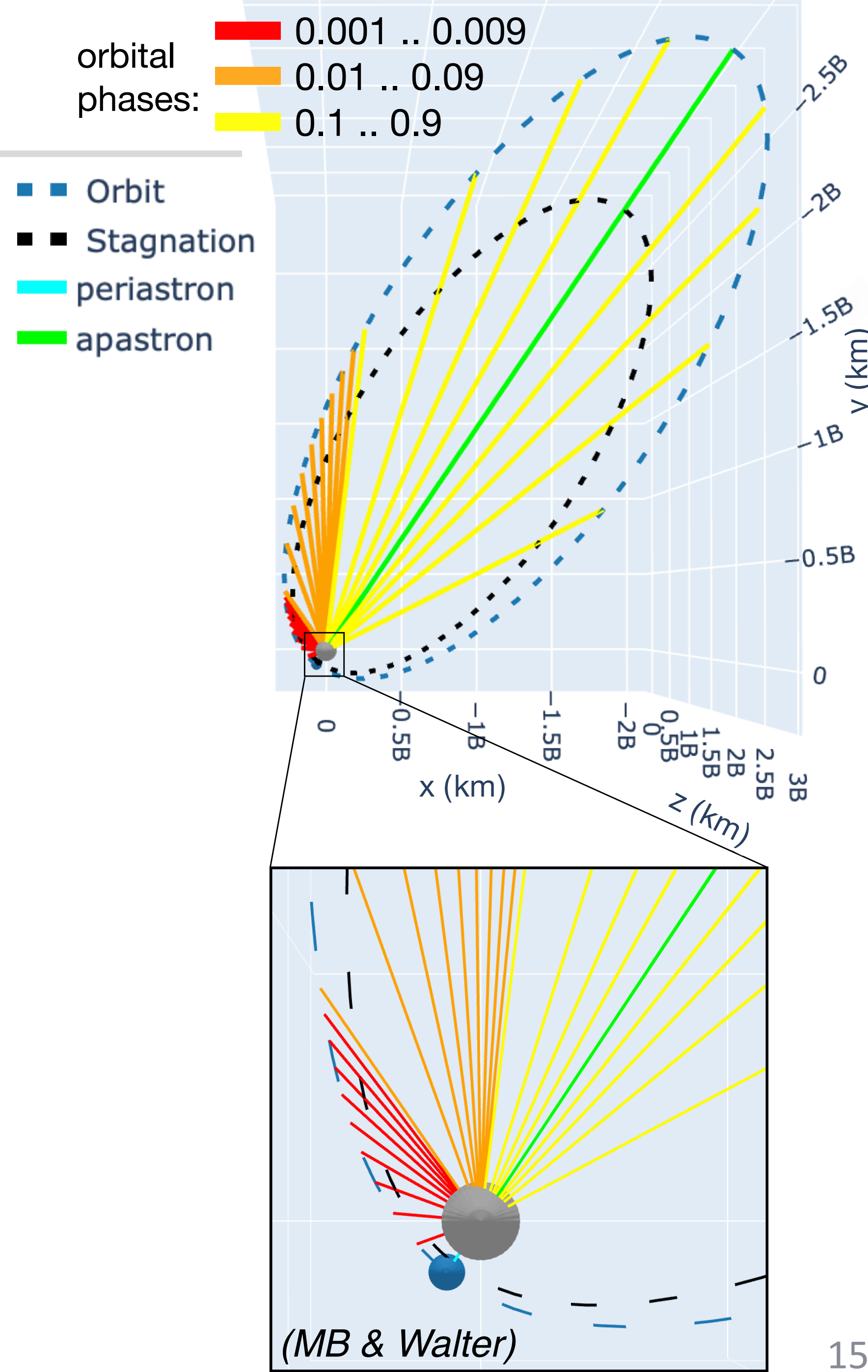
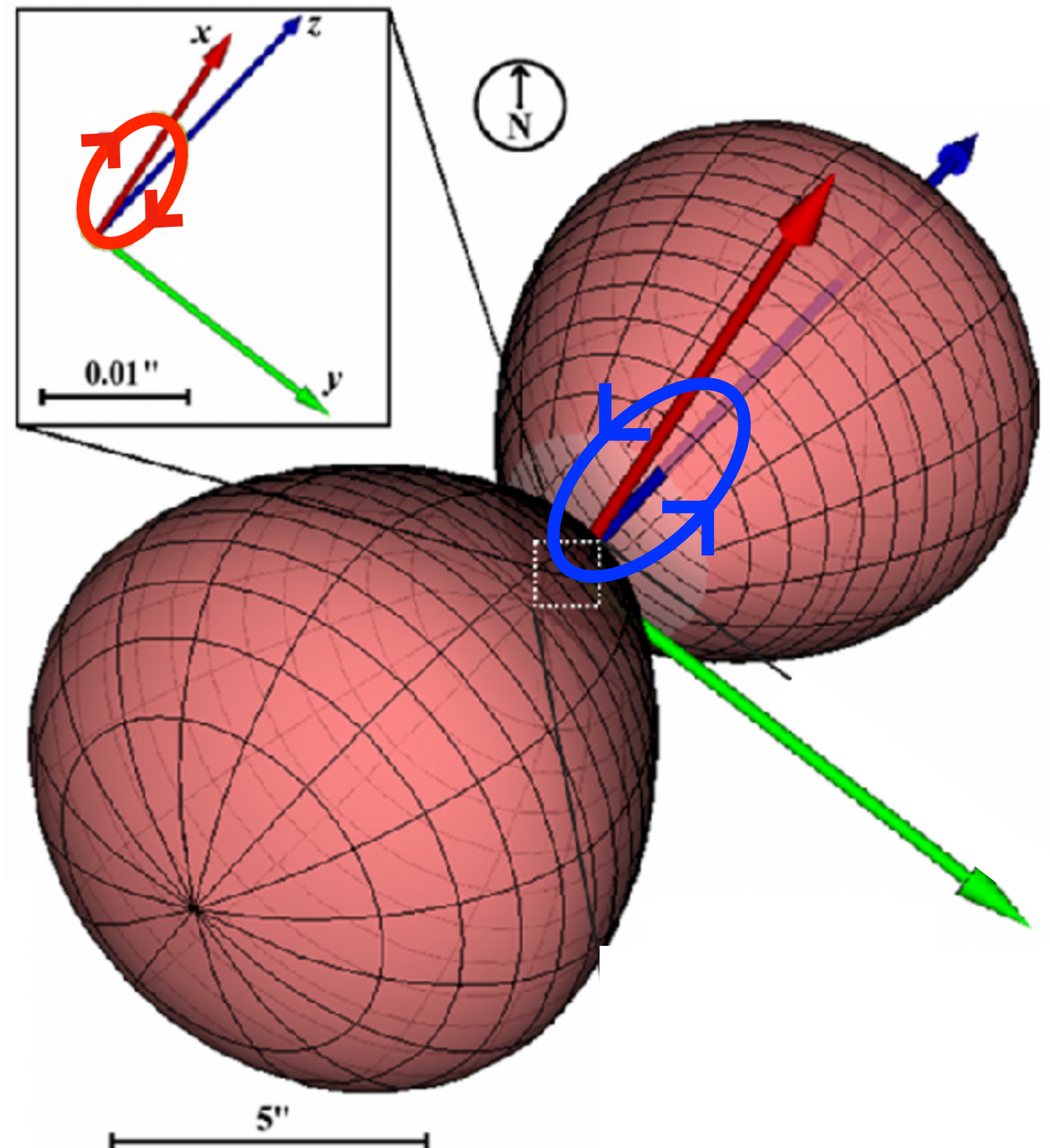
- 0.001 .. 0.009
- 0.01 .. 0.09
- 0.1 .. 0.9

Orbit
Stagnation
periastron
apastron



η Carinae possible orientations

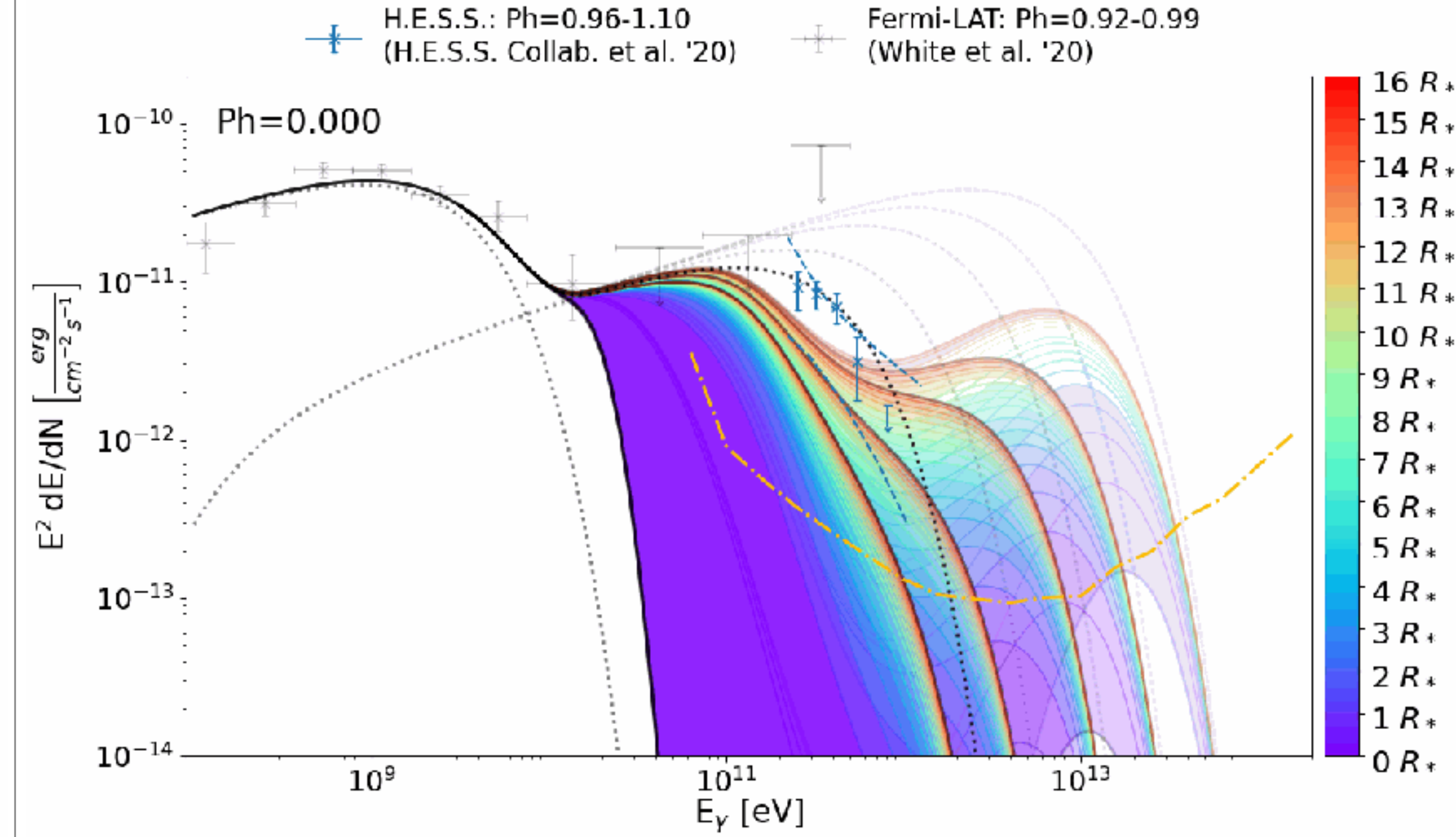
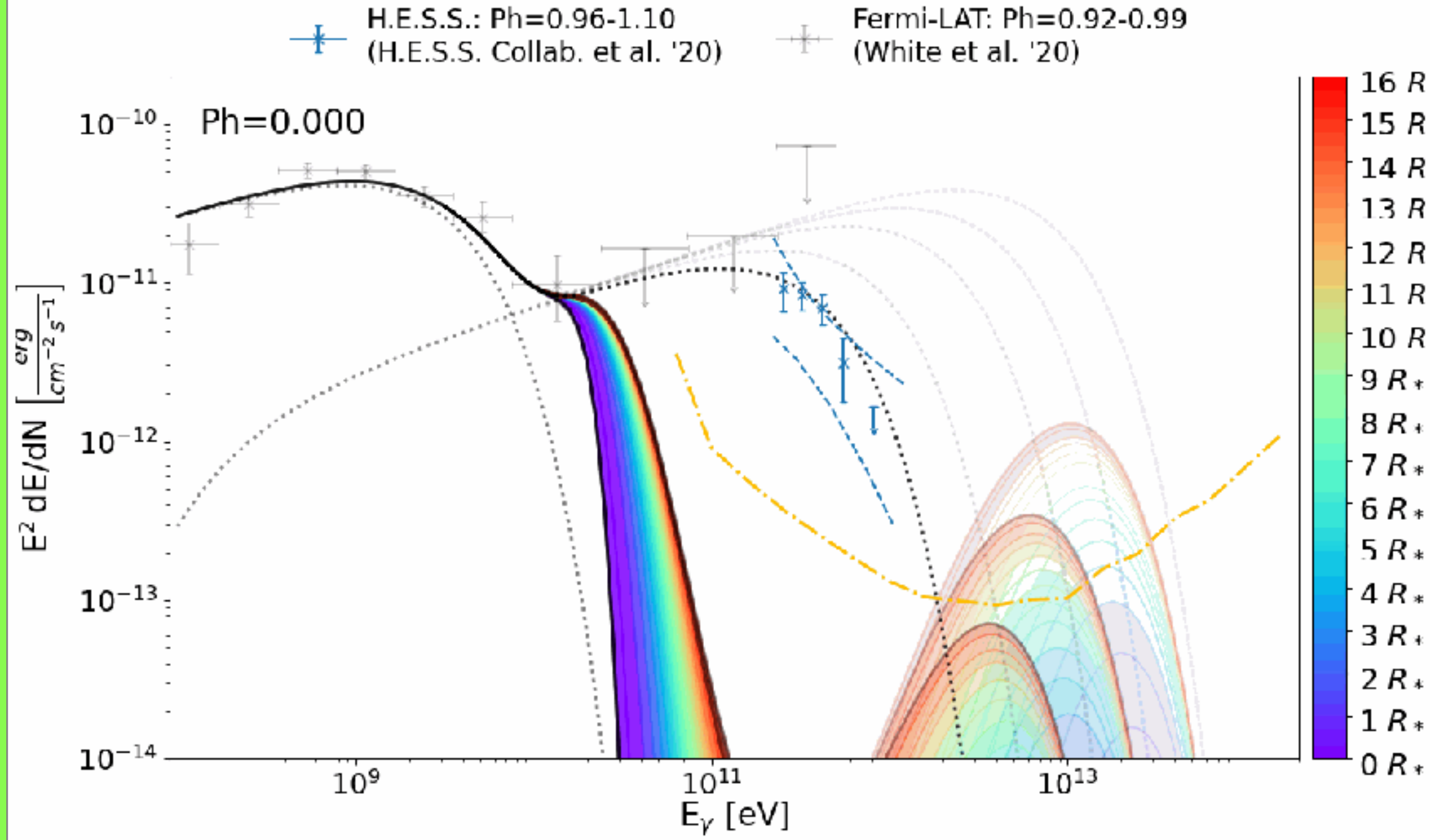
Classic
vs.
Opposite



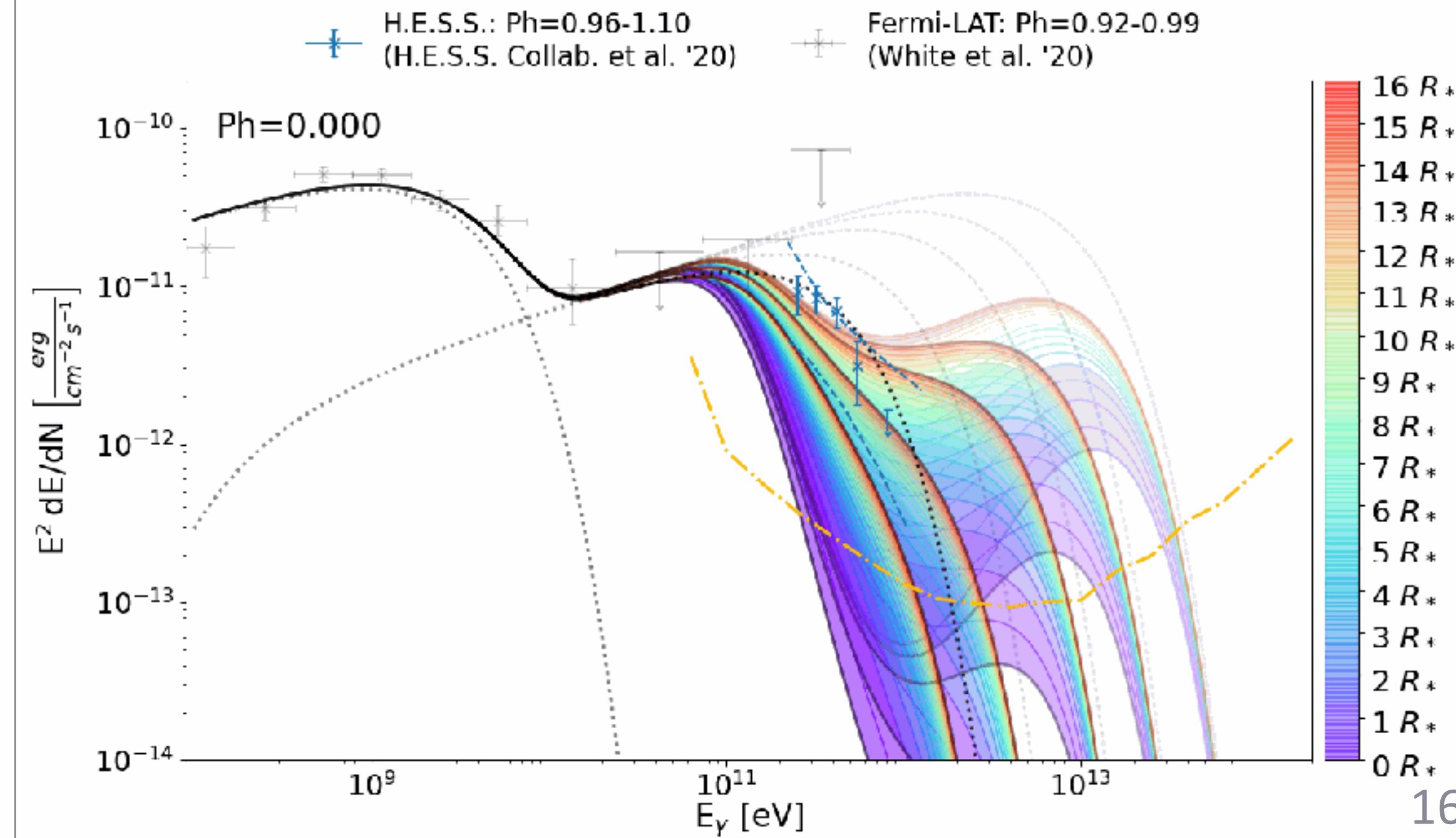
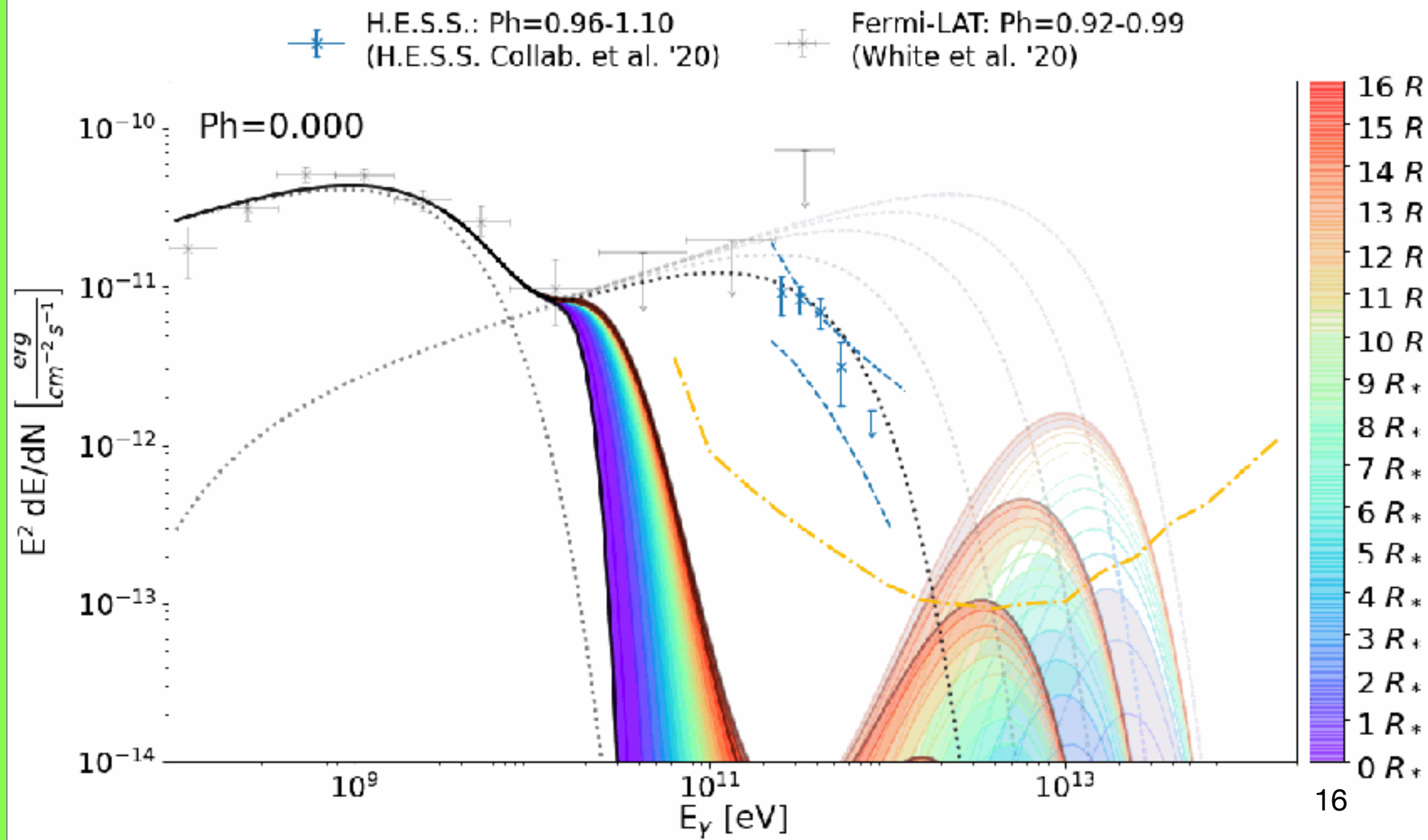
CLASSIC orientation

OPPOSITE orientation

Primary
star



Primary +
Secondary
star



Conclusions & Take home message



- γ - γ absorption with consequent e^+/e^- production in the Galaxy requires very large amount of seed photons;
- in order to pair-produce, HE γ -ray in the energy range of CTA should interact with optical/UV photons;
- periodically variable γ -ray obscuration occurs if one of the following conditions occur:
 - the density of soft photons varies;
 - the density of HE photons varies;
 - the collision angles (w.r.t. observer) vary;
- if $E_{\text{cut-off}}$ of intrinsic γ -ray spectrum $> E(\tau_{\text{max}})$, CTA observations performed during different orbital phases can provide useful indirect informations on:
 - ✓ location where HE γ -rays are produced
 - ✓ orbital orientation of the binary system
 - ✓ magnetic field
 - ✓ maximum energy at which particles can be accelerated

γ -ray binary systems

the absorption model I am developing could be an important tool to interpret CTA data