

Radiation-hydrodynamics of star-disc collisions

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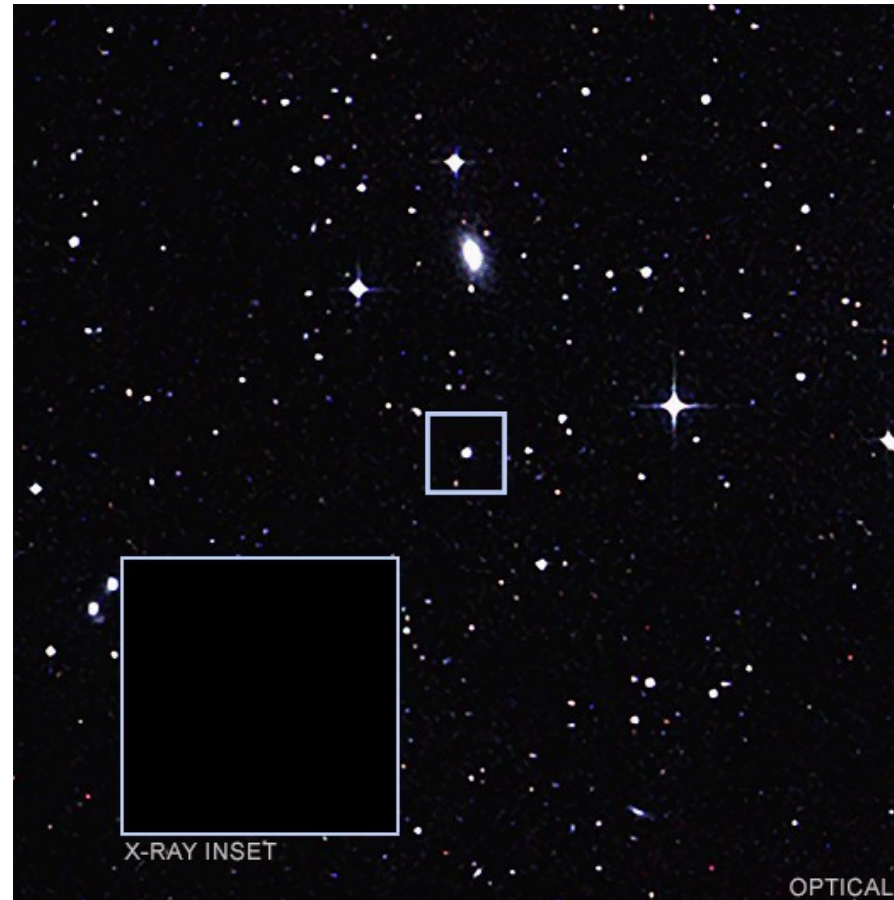
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Sergey Karpov (Institute of Physics of the Czech Academy of Sciences, CZ)

Aleksej Jurca (University of Nova Gorica, SLO)

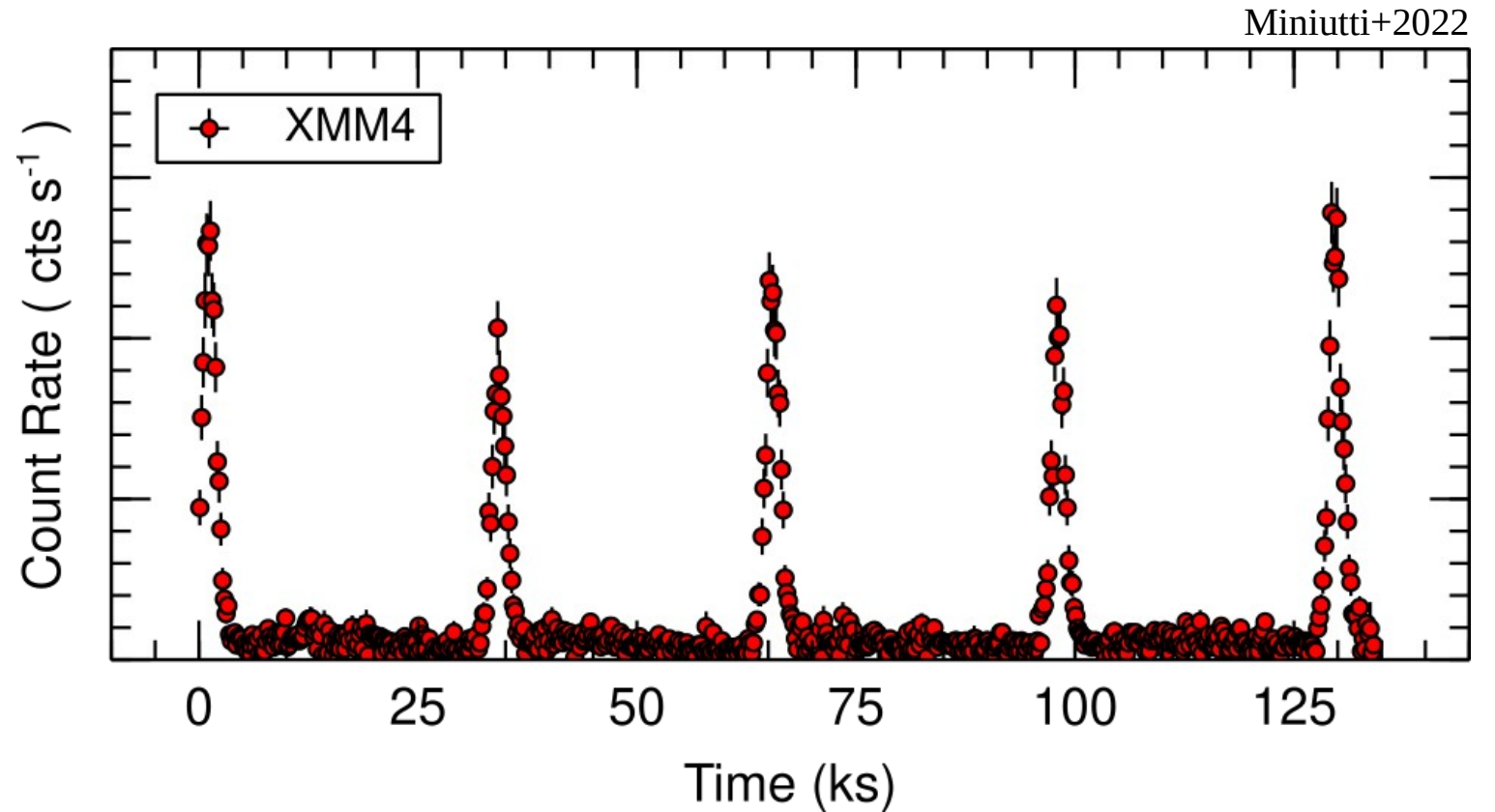
Quasi-periodic eruptions (QPEs)

X-ray: NASA/CXO/CSIC-
INTA/Miniutti+2019;
Optical: DSS

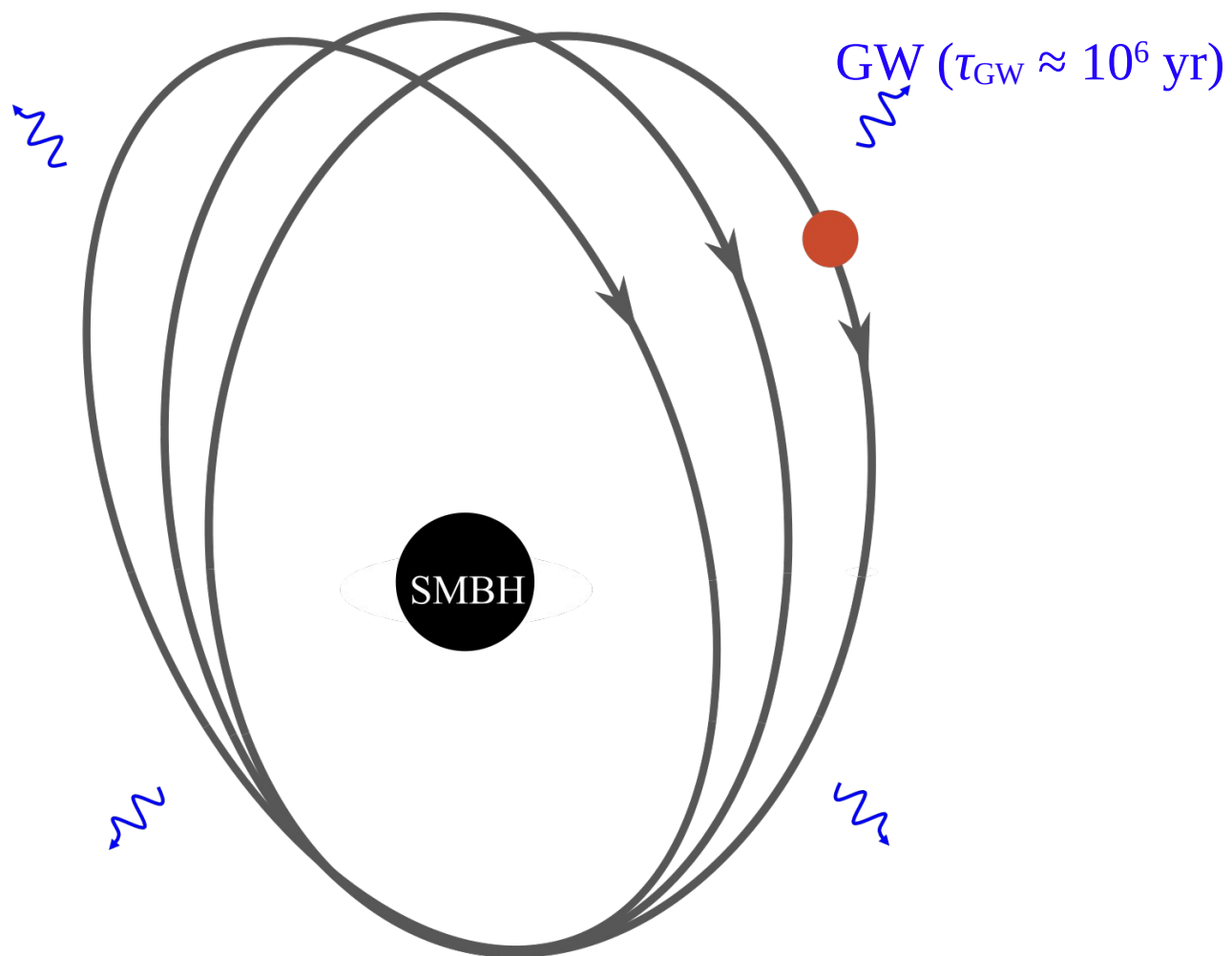


QPE lightcurves

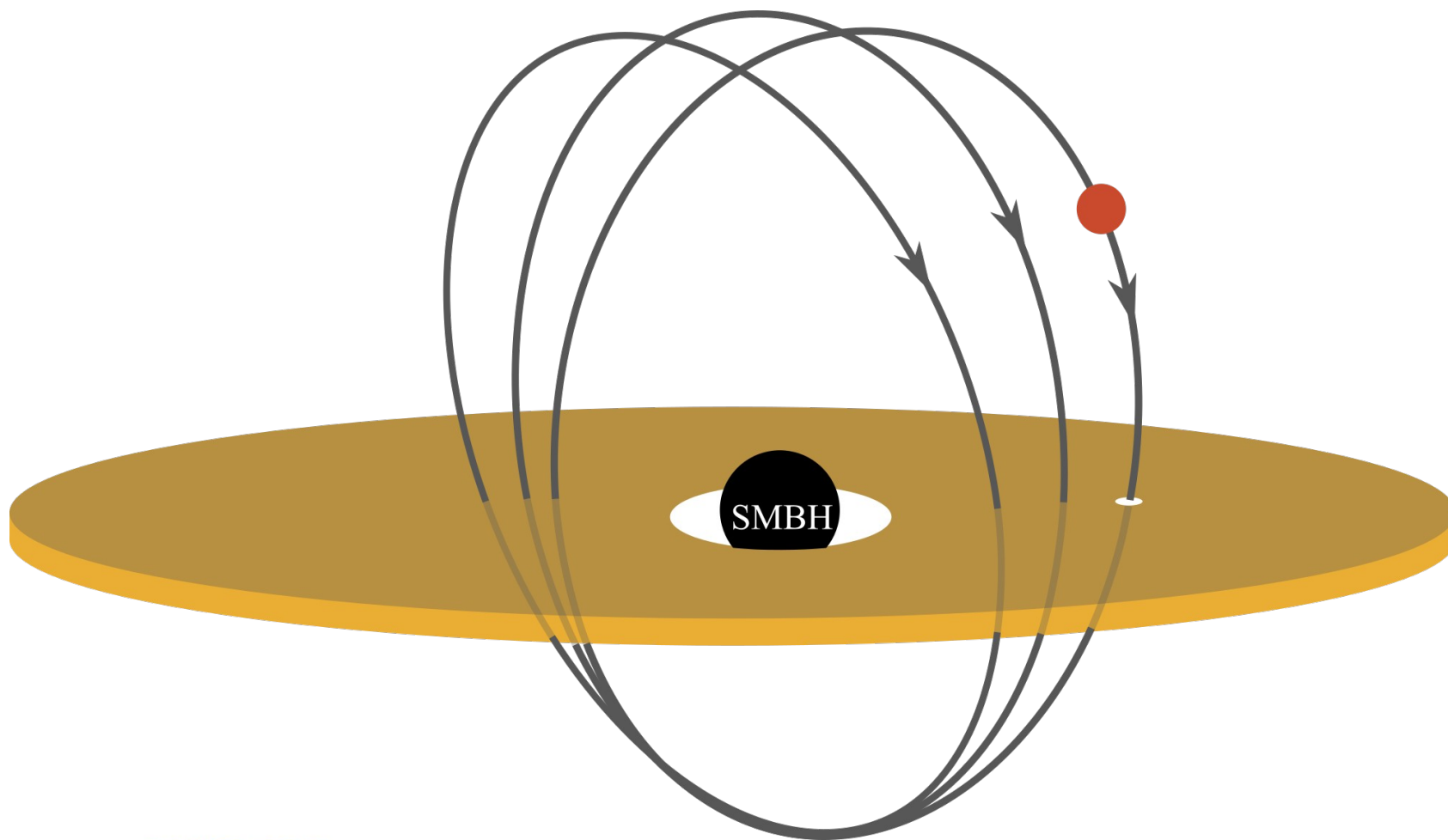
X-ray bursts every ≈ 10 hours.
“Long-short” and “strong-weak”
patterns between consecutive
flares.
 ≈ 10 candidates.



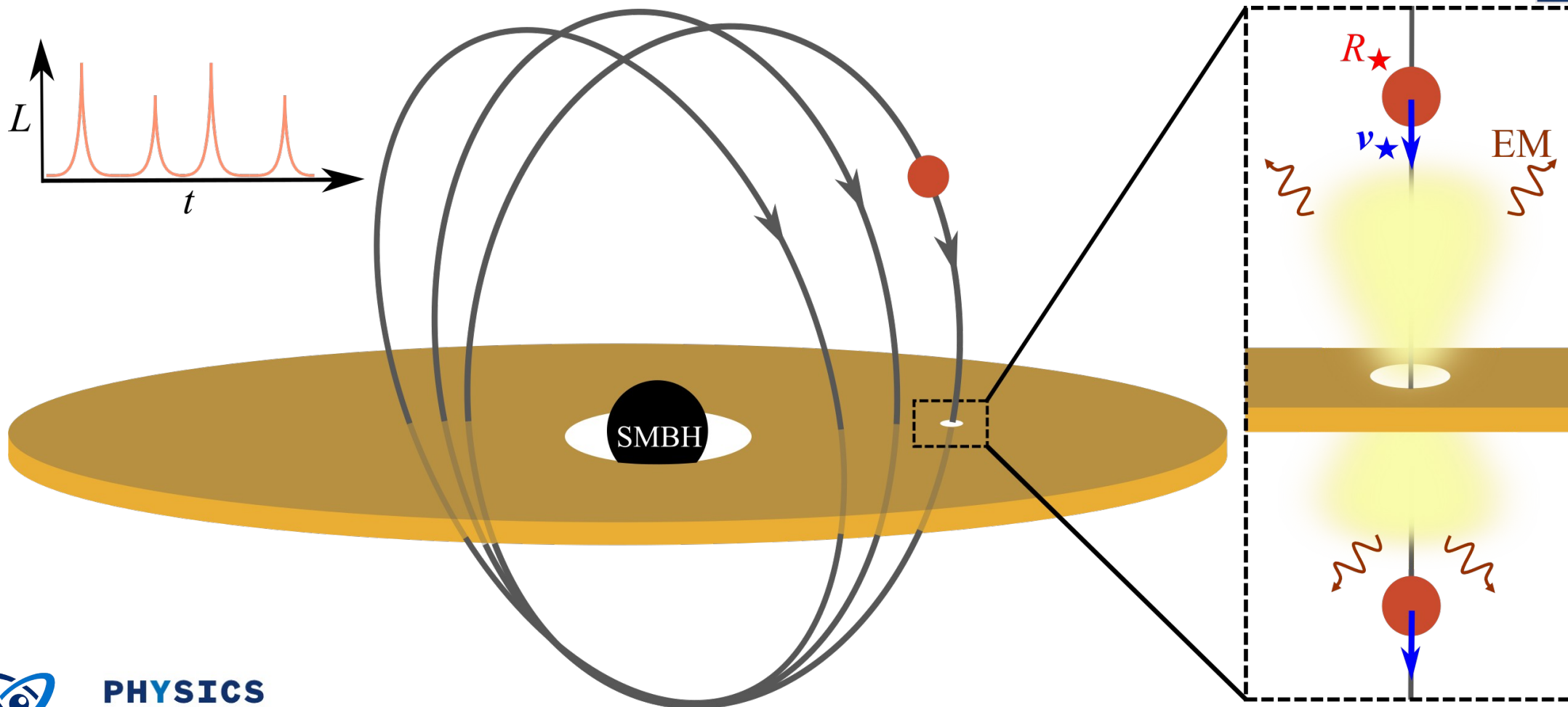
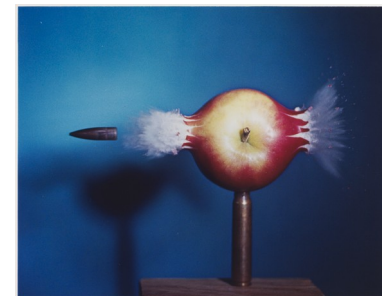
Star-disc collisions model



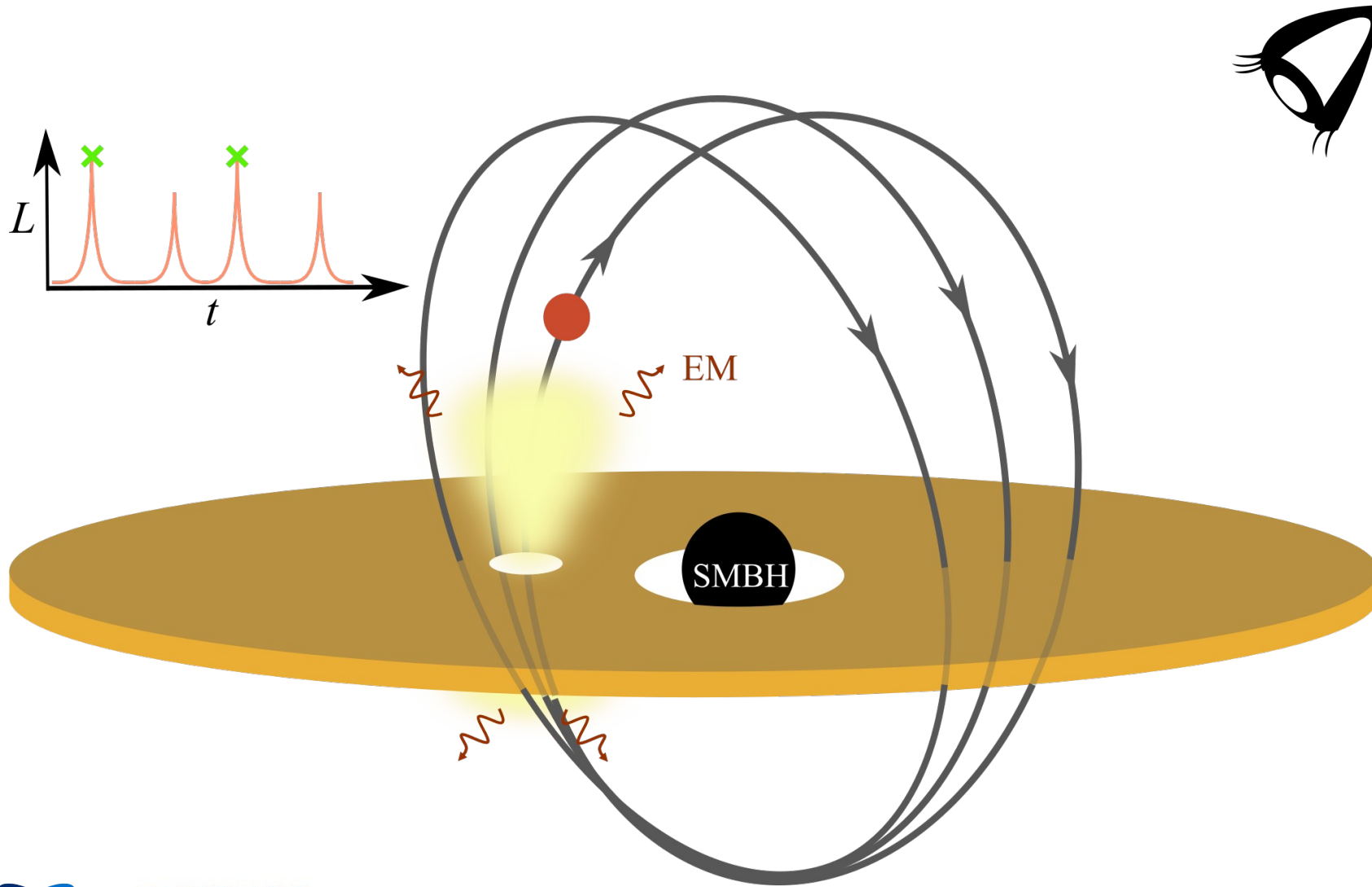
Star-disc collisions model



Star-disc collisions model



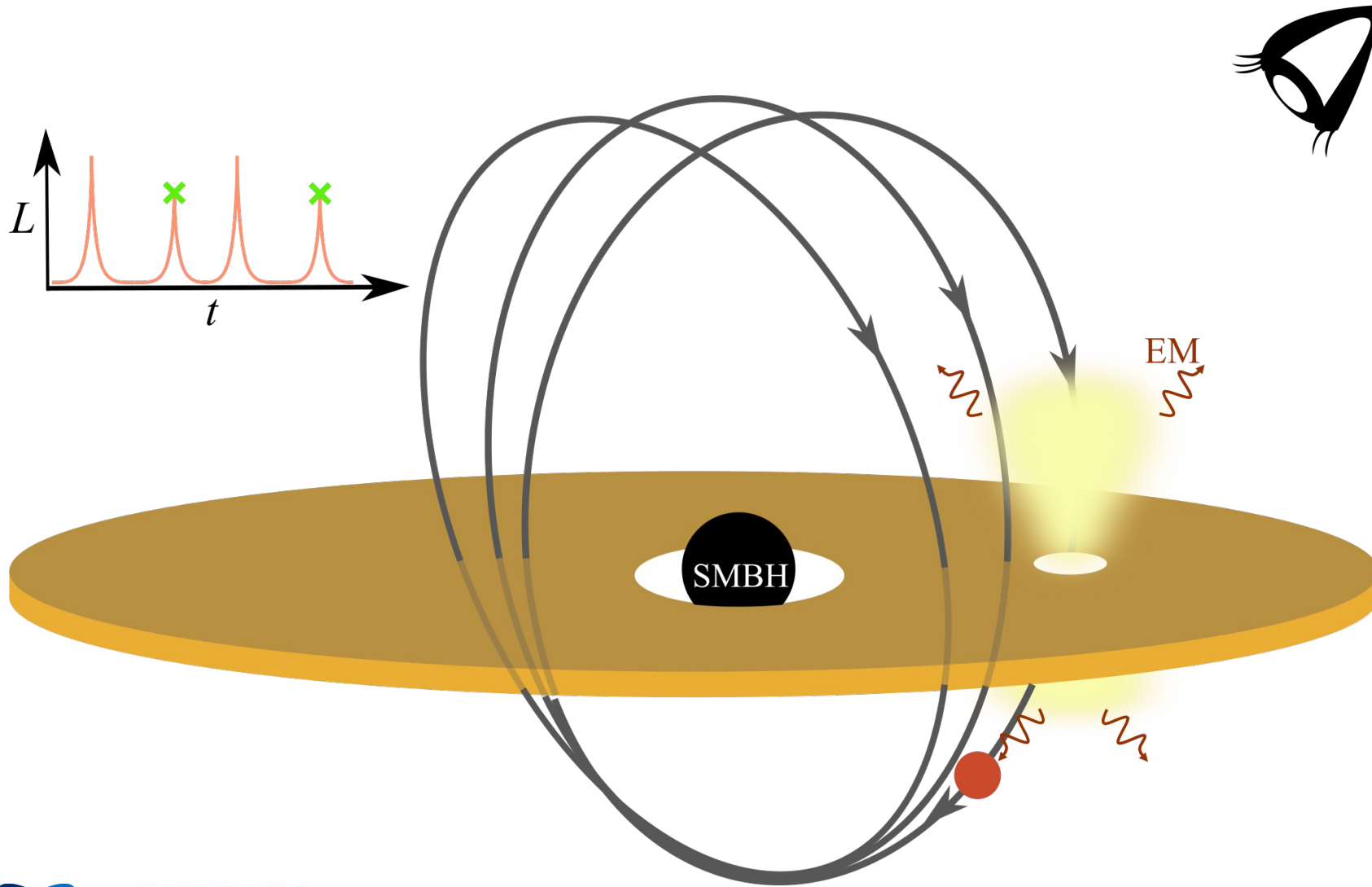
Star-disc collisions model



Natural explanation for “long-short” pattern.

Could potentially explain “strong-weak” pattern.

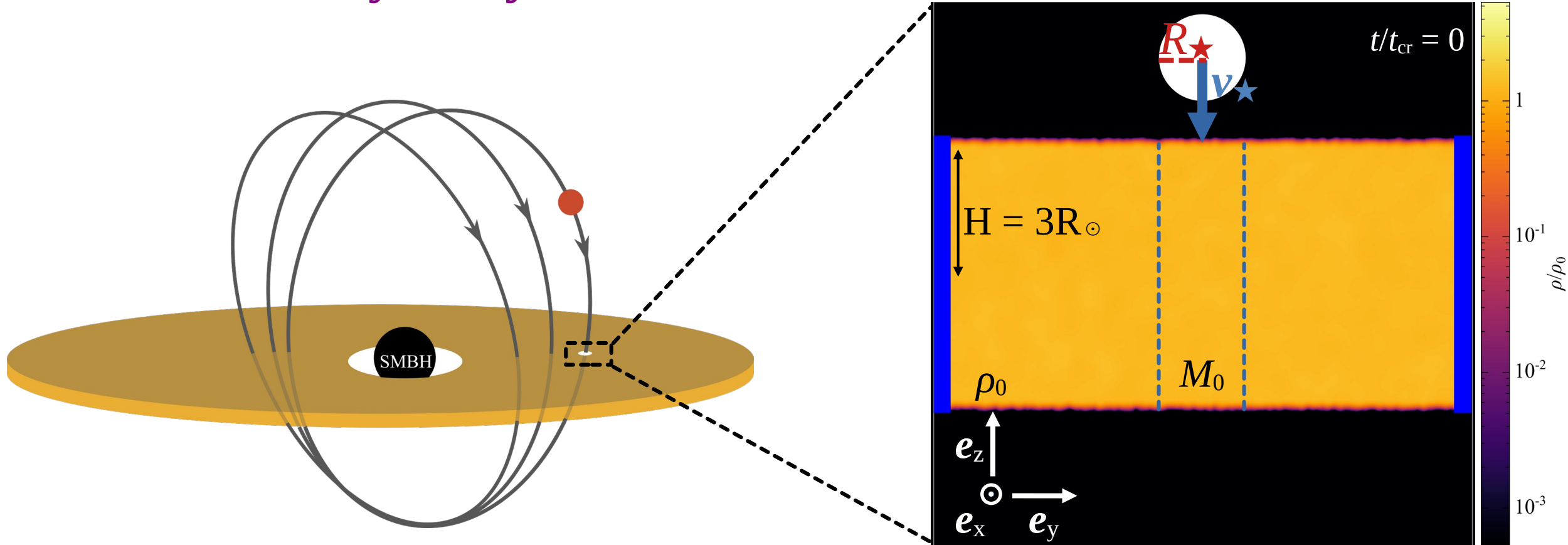
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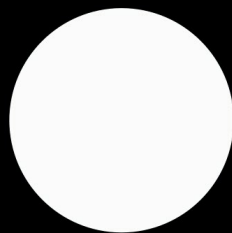
3D radiation-hydrodynamics simulation



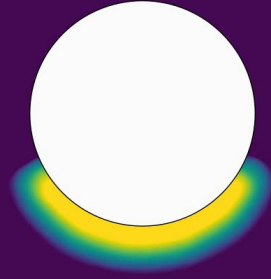
Disc: Stationary, uniform density (mass $M_0 = 10^{-7} M_{\odot}$), no gravity.

Star: Solid sphere, $R_{\star} = 1R_{\odot}$, $v_{\star} = 0.1c$, no gravity.

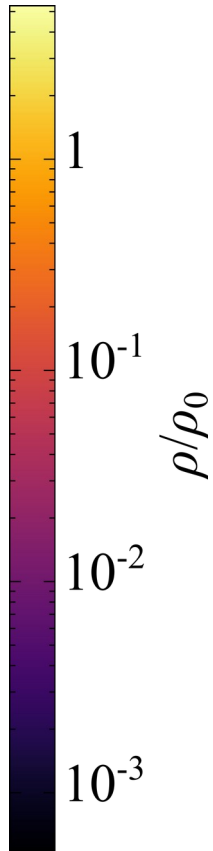
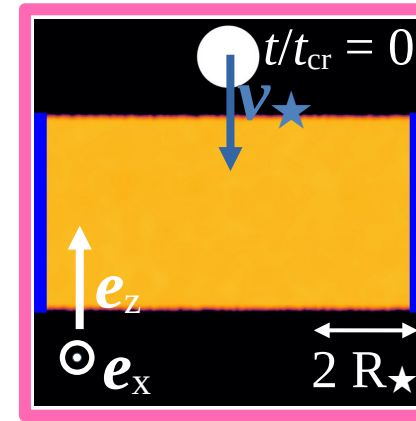
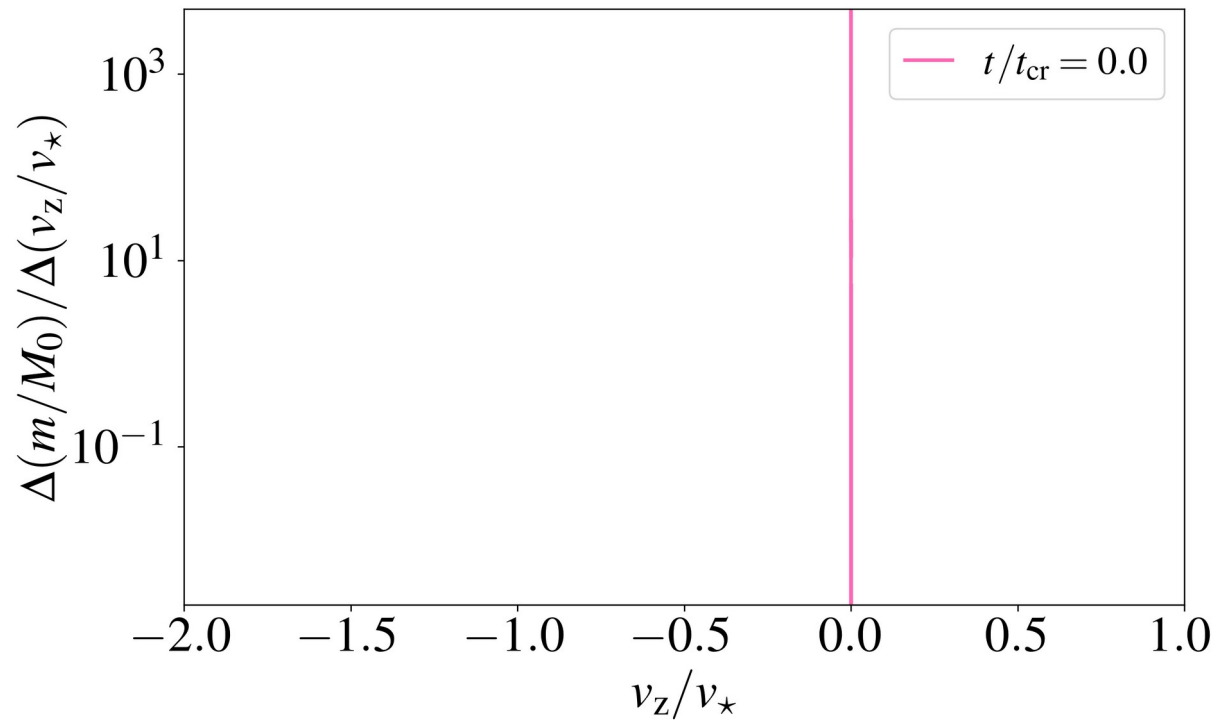
$$t/t_{\text{cr}} = 0.09$$



$$t/t_{\text{cr}} = 0.18$$

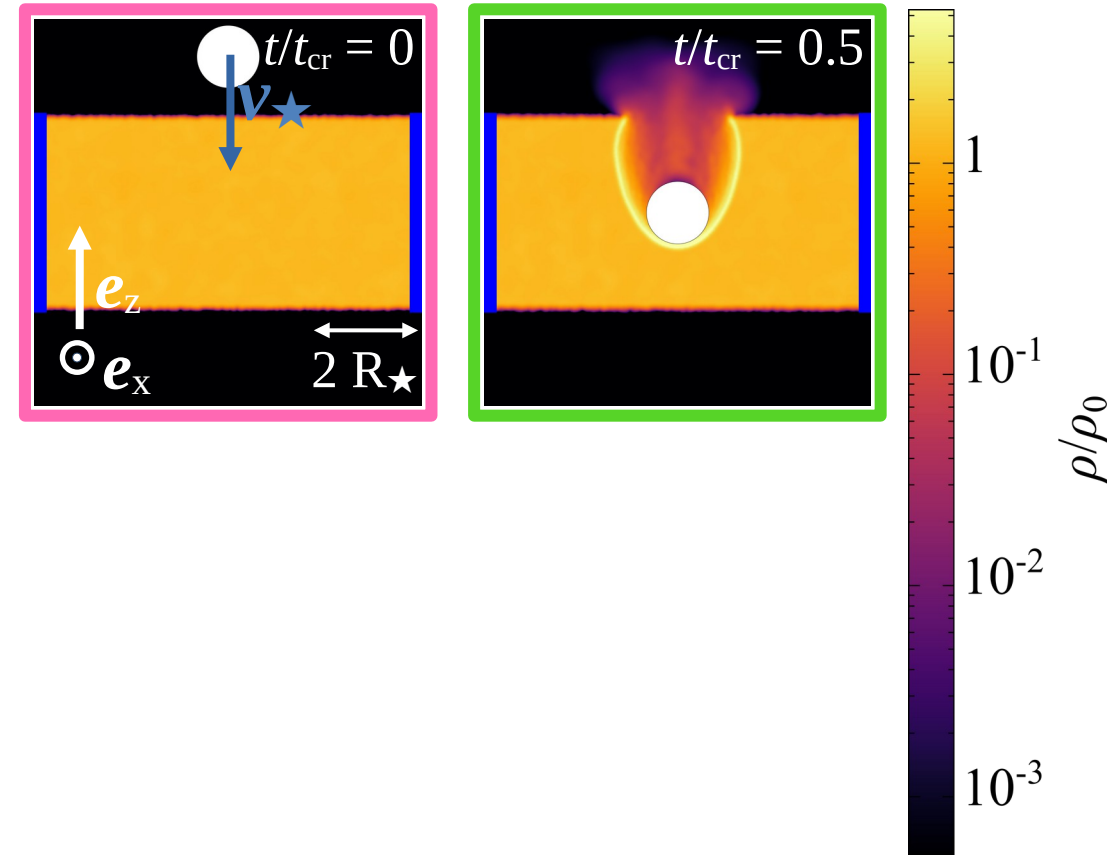
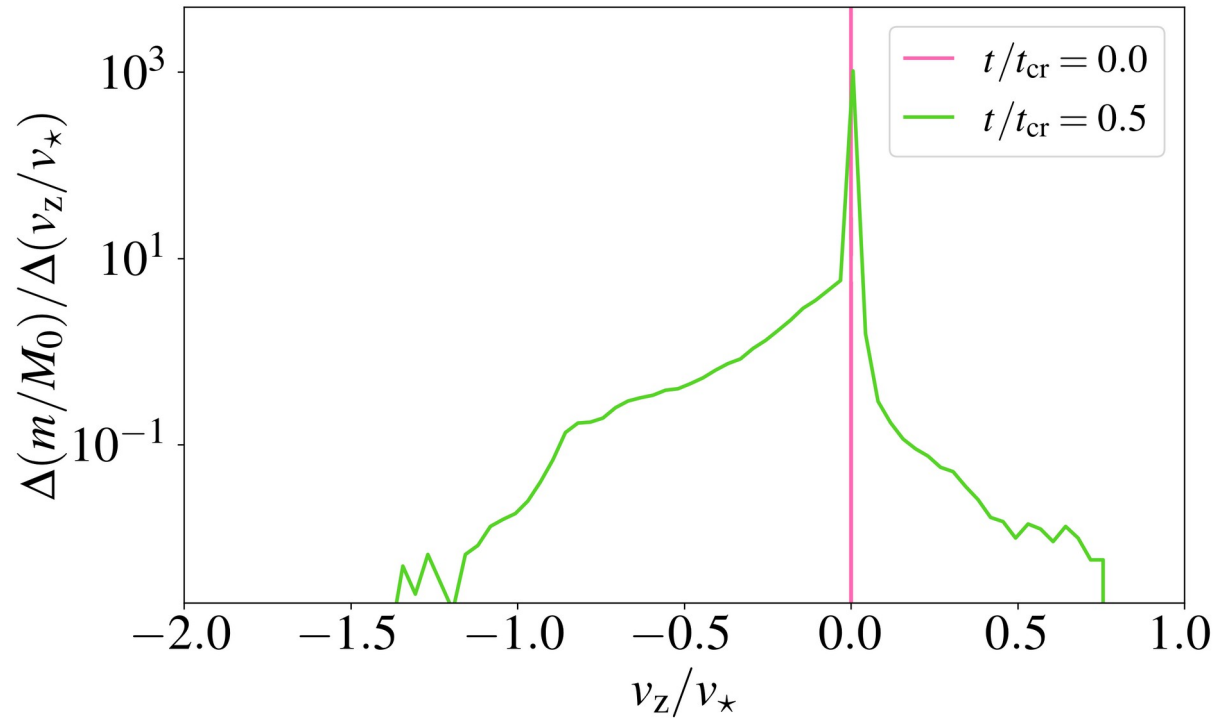


Momentum distribution



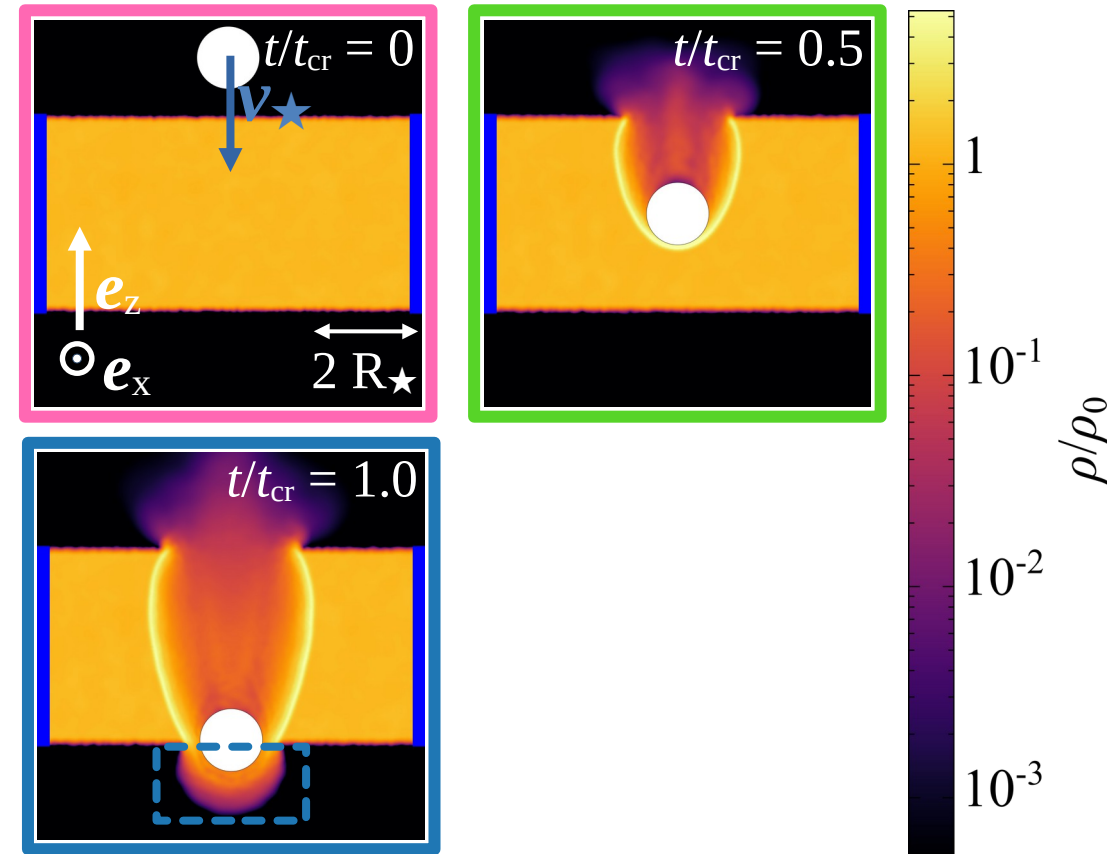
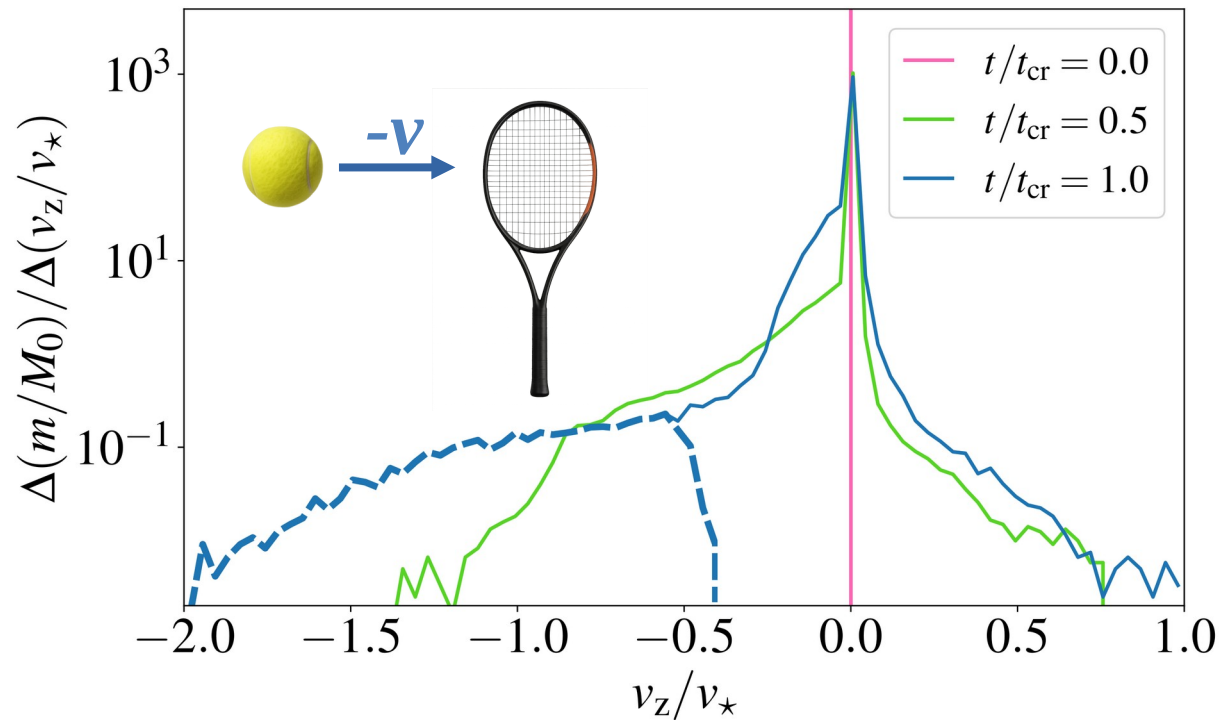
Gas initially at rest.

Momentum distribution



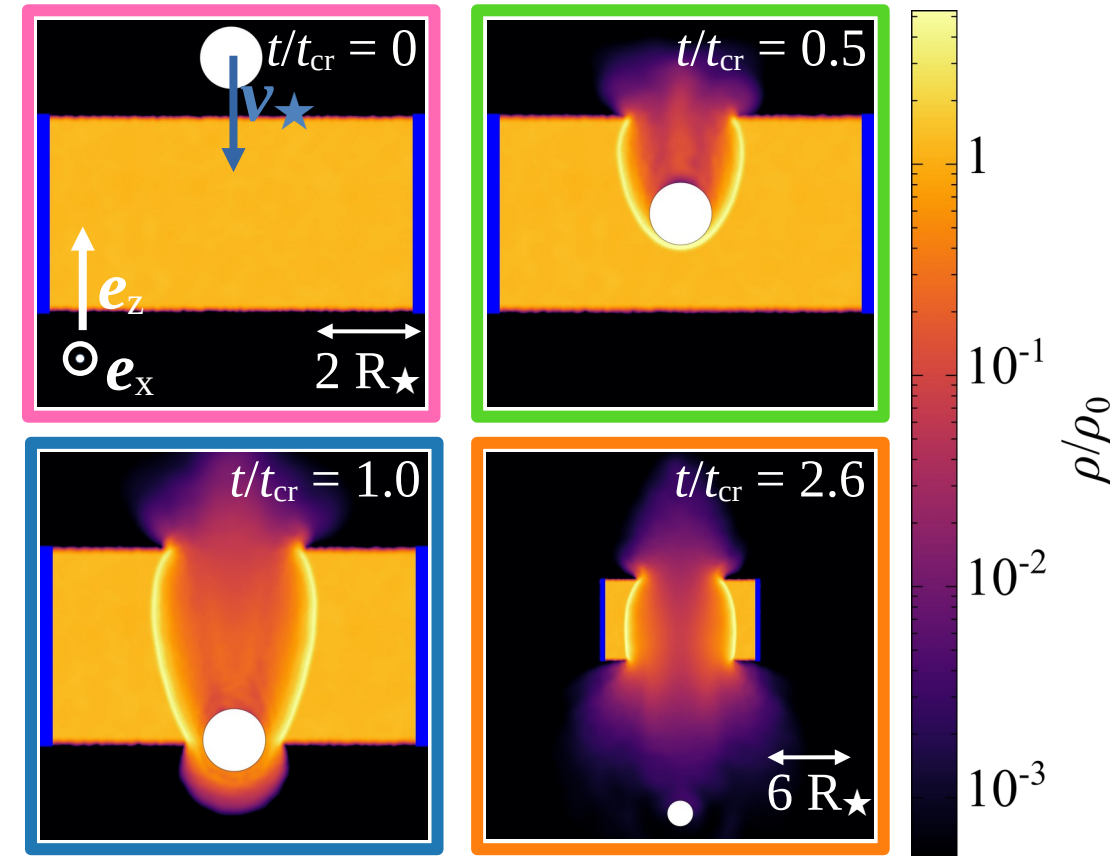
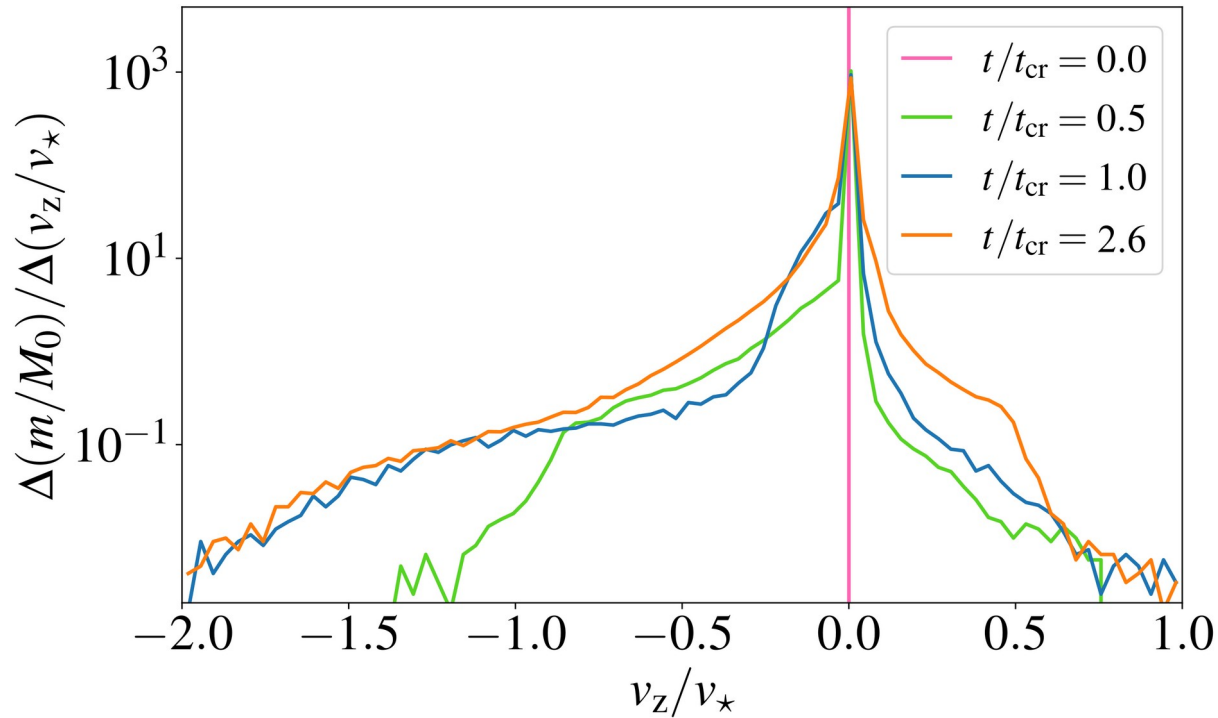
Star injects momentum, which is redistributed asymmetrically.

Momentum distribution



Gas ejected during forward shock breakout is faster.

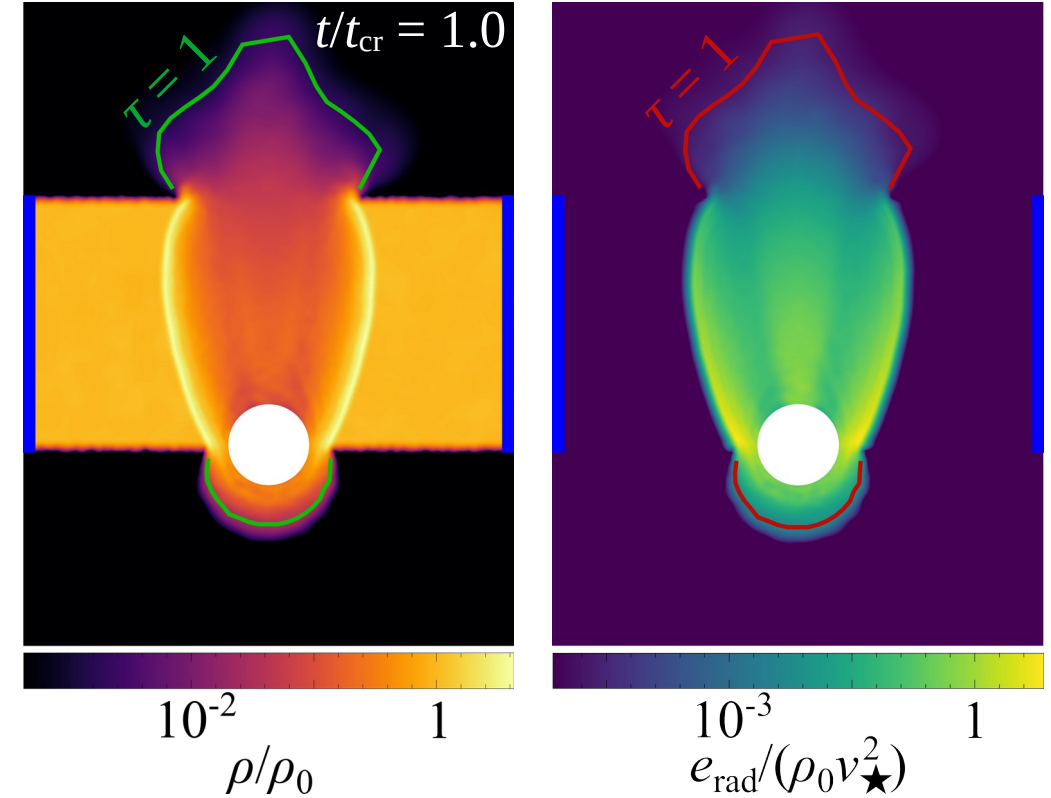
Momentum distribution



Forward direction → Elastic collision.
Backward direction → Radiation pressure.

Lightcurve

Radiation transported via advection and diffusion.
Luminosity: Integrate total radiation flux across the photosphere (optical depth $\tau = 1$).



Lightcurve

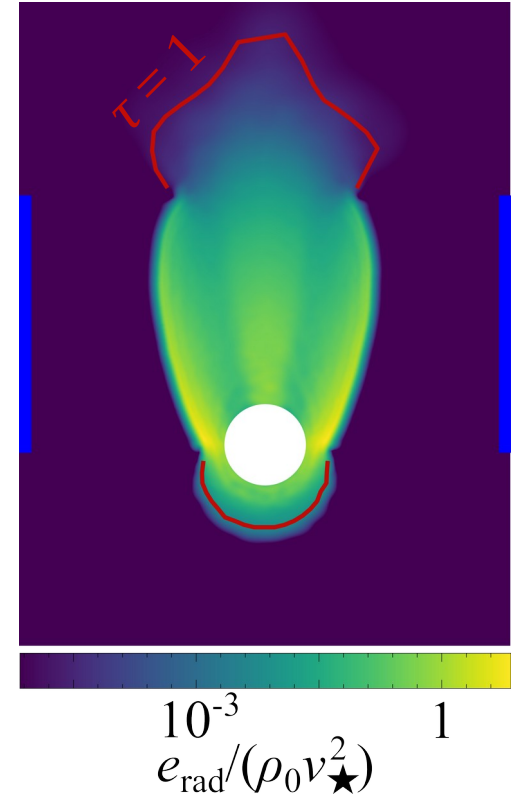
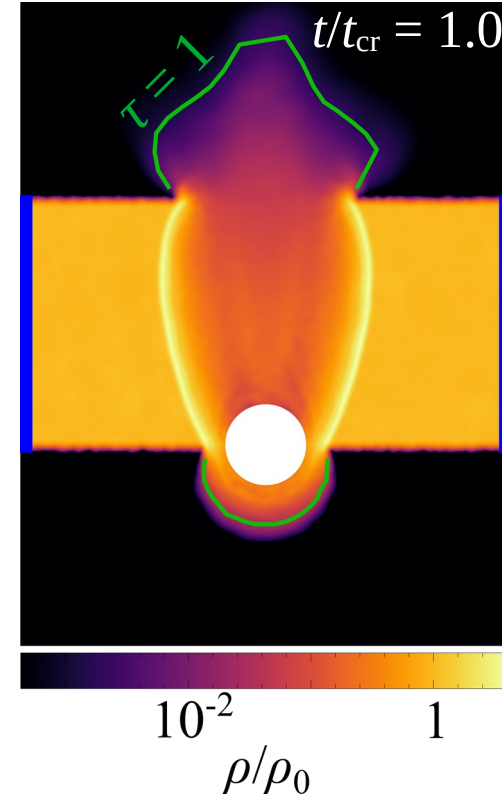
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Luminosity: Integrate total radiation flux across the photosphere (optical depth $\tau = 1$).

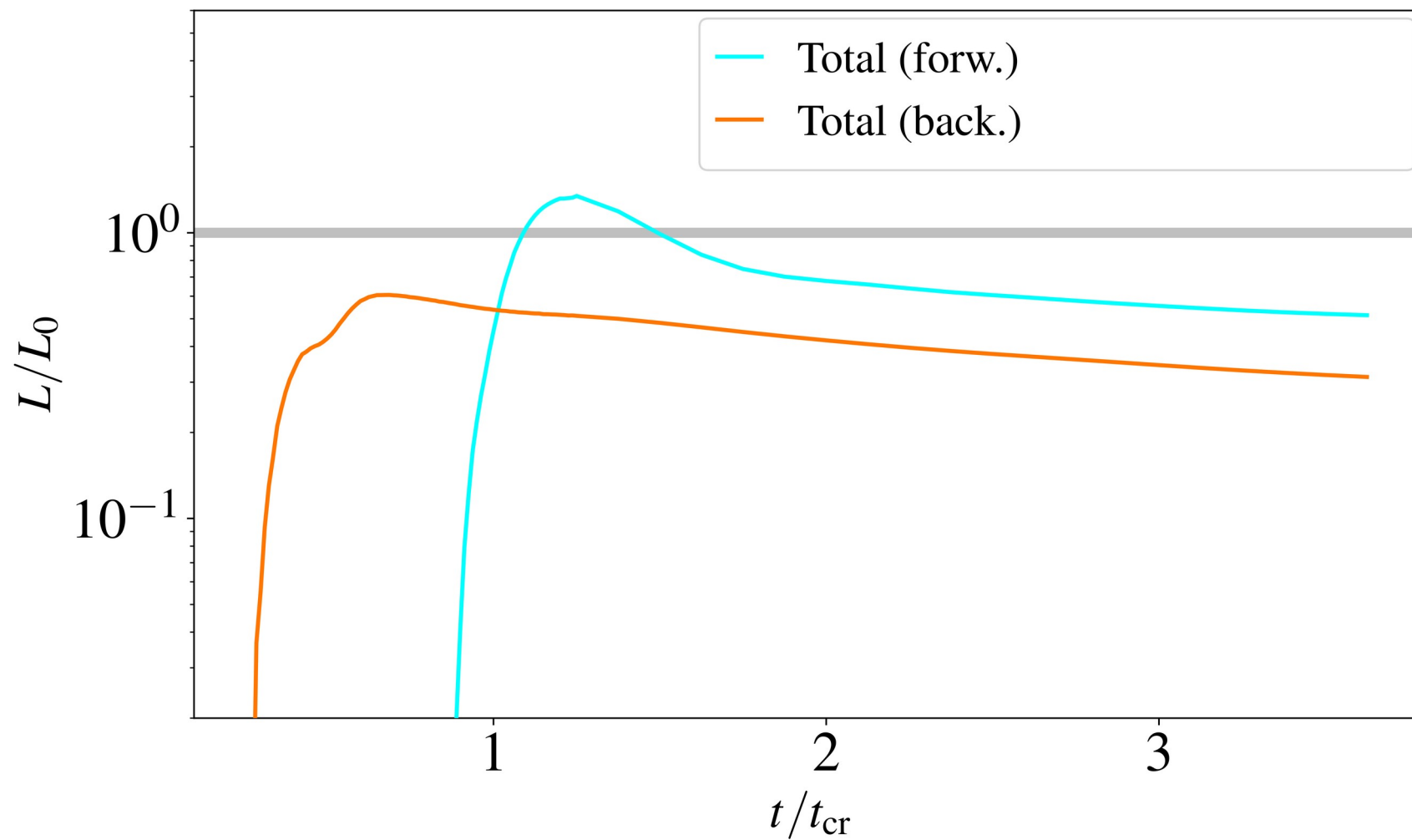
adiabatic losses emission timescale

energy redistribution injected energy

Characteristic L : $L_0 = \frac{1}{2} \eta E_{\text{in}} / t_{\text{QPE}} = 10^{41} \text{ erg/s}$



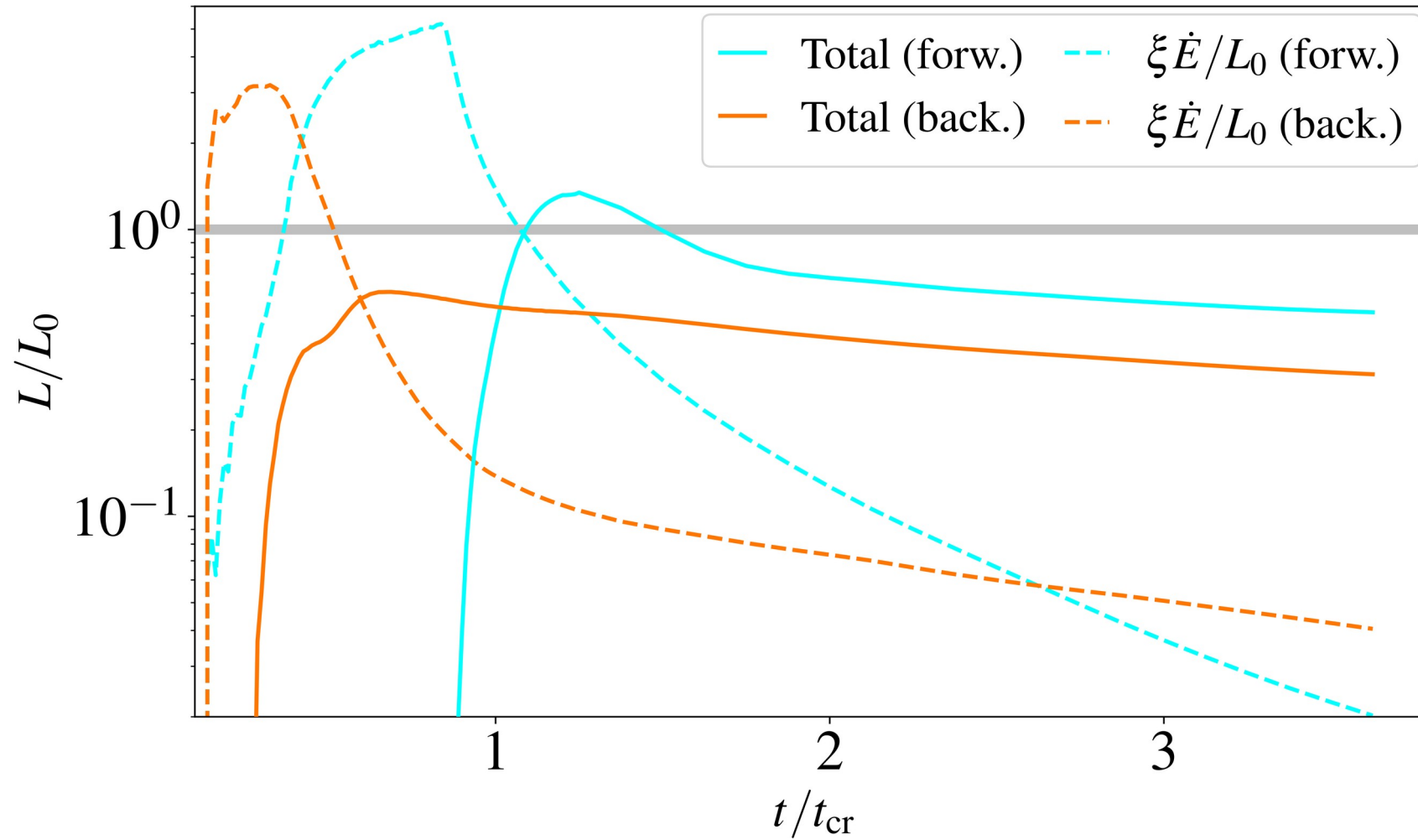
Lightcurve



At peak $L/L_0 \sim 1$.

Forward outflow
 $\sim 2\times$ higher L .

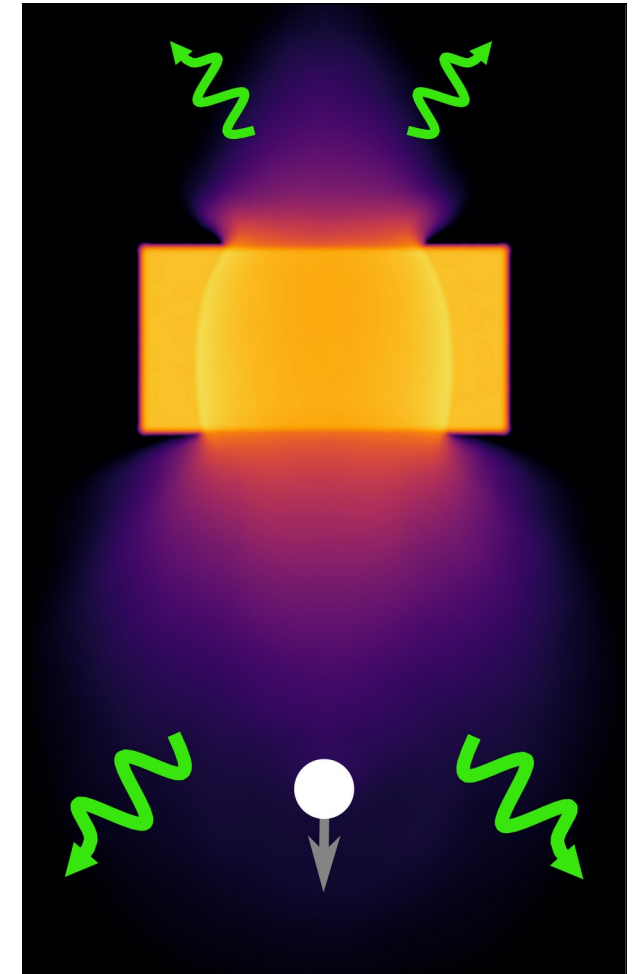
Lightcurve

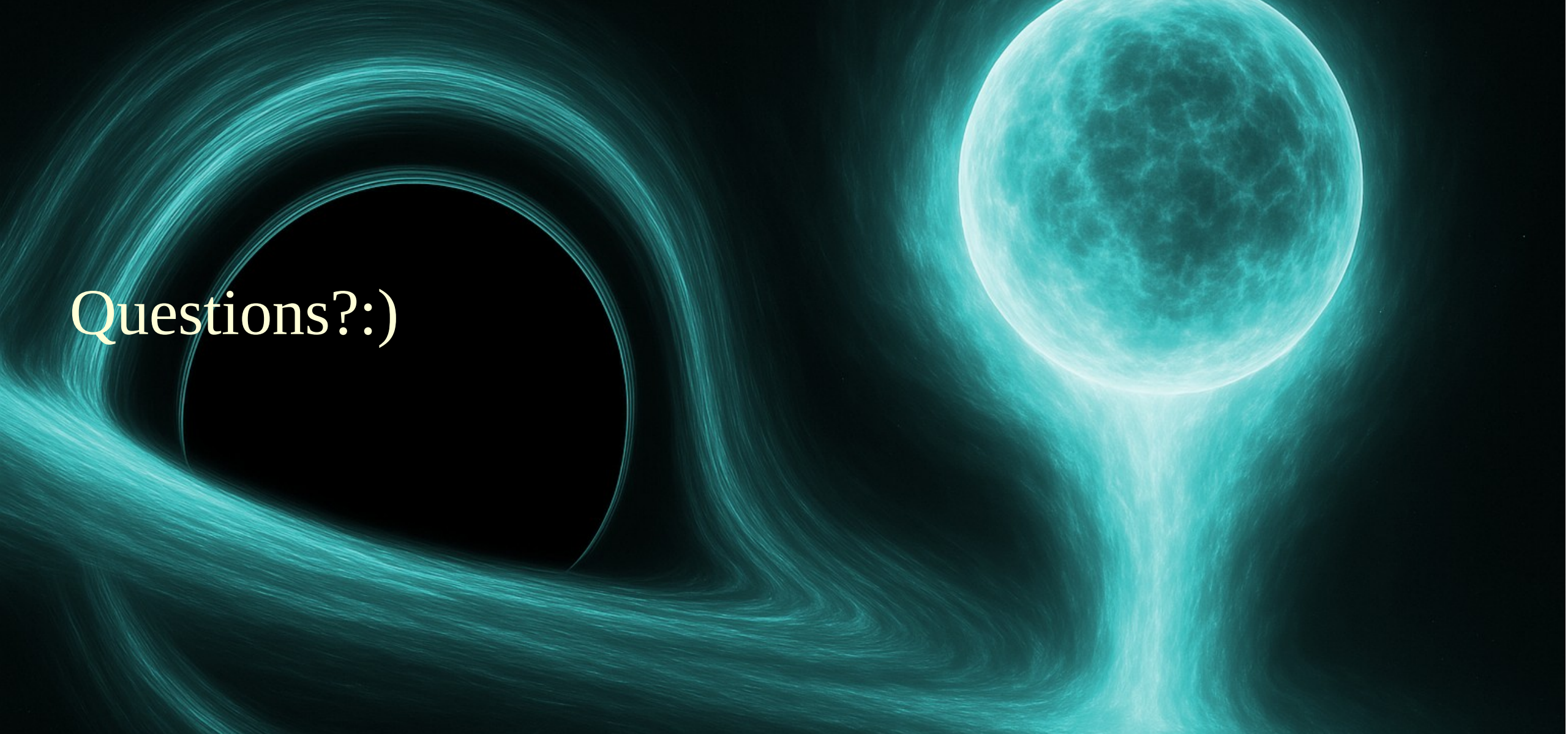


Forward ejected gas
 $\sim 2\times$ higher shock
heating rate $\dot{E}$.

Summary

- The collision drives asymmetric outflows of gas.
- Forward outflow expands faster and is more massive.
- Forward outflow is brighter.
- Star-disc collisions could reproduce the “strong-weak” brightness pattern.





Questions?:)



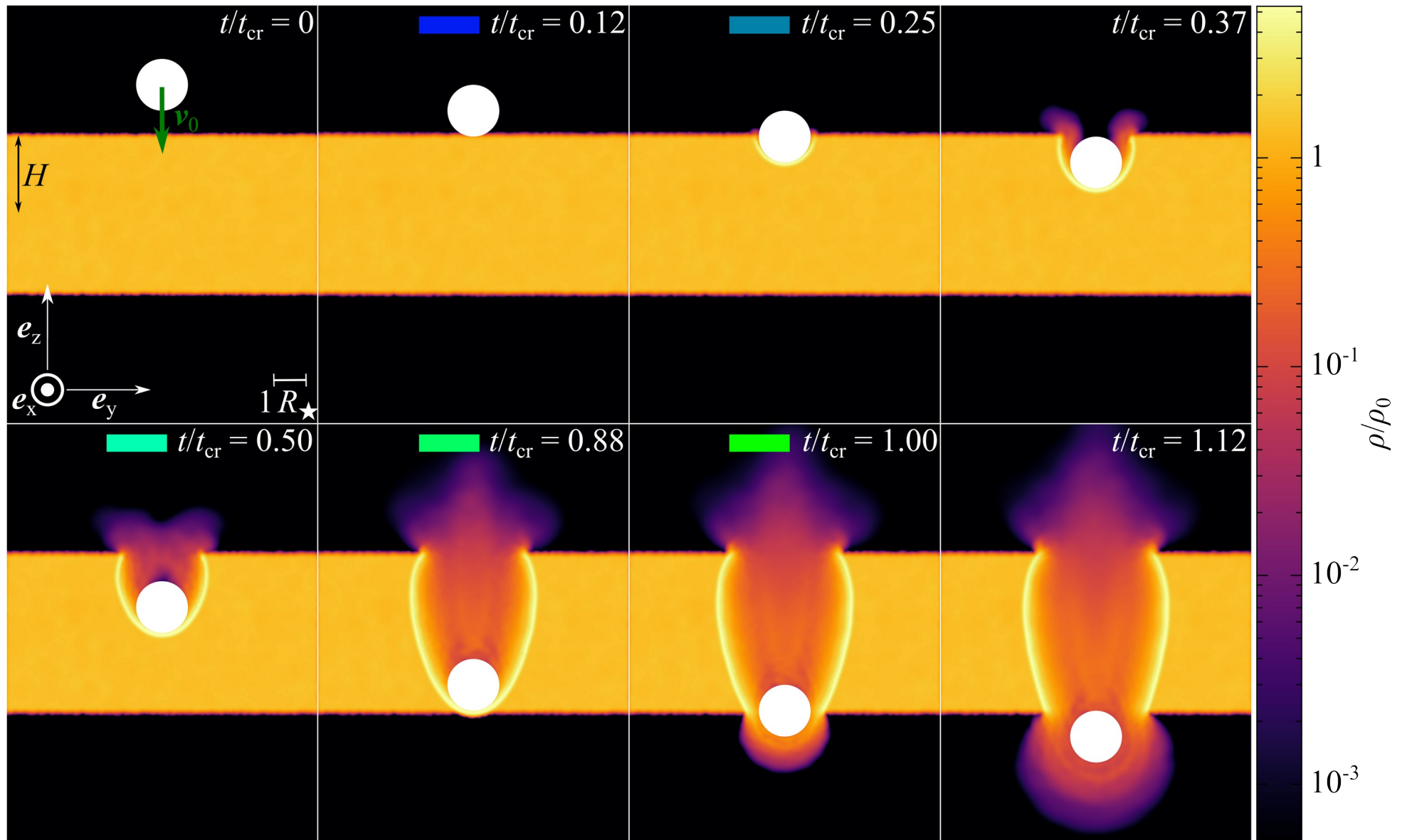
**PHYSICS
FOR
FUTURE**

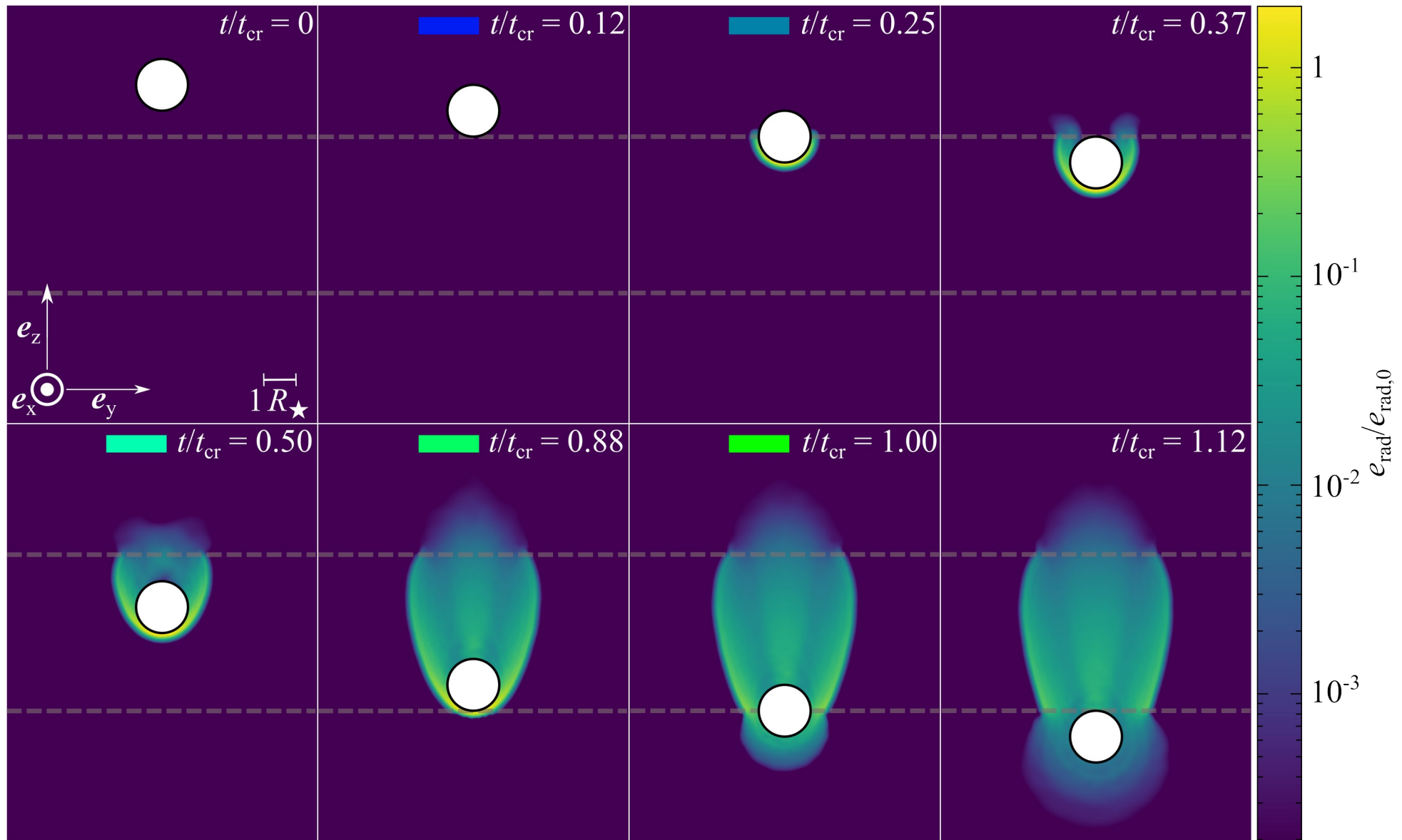


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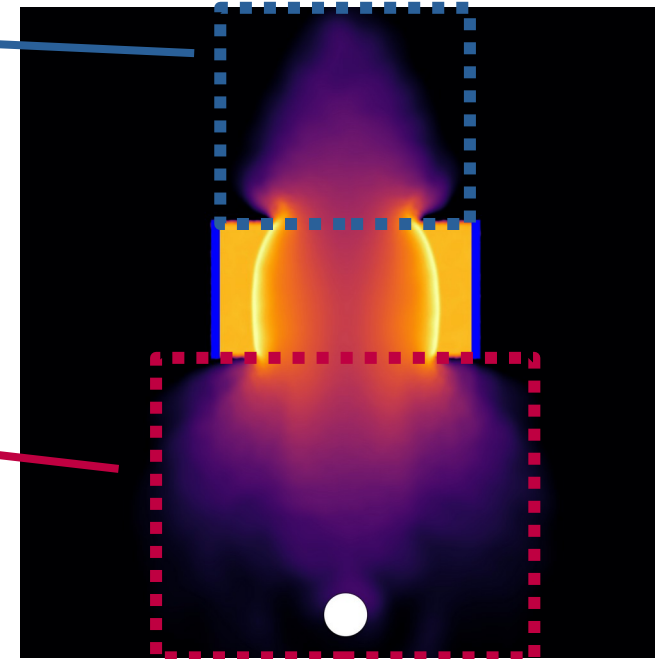
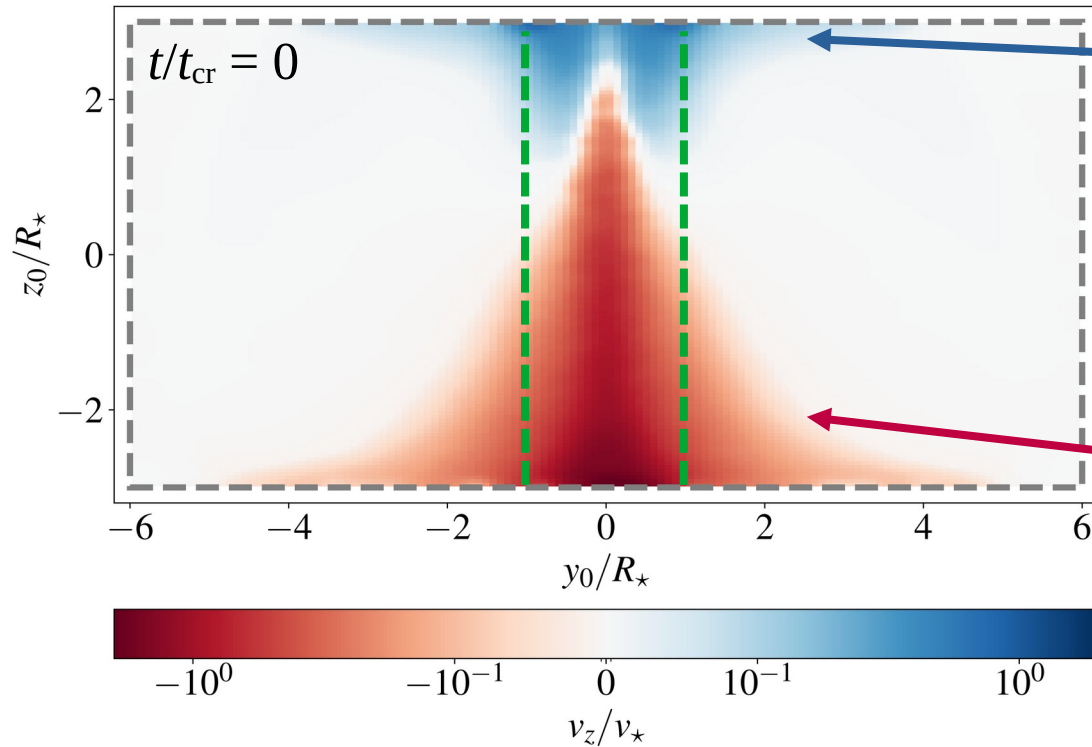


Asymmetric shock heating rate

$$\dot{E} = \dot{M}_{\text{in}} \Delta u$$

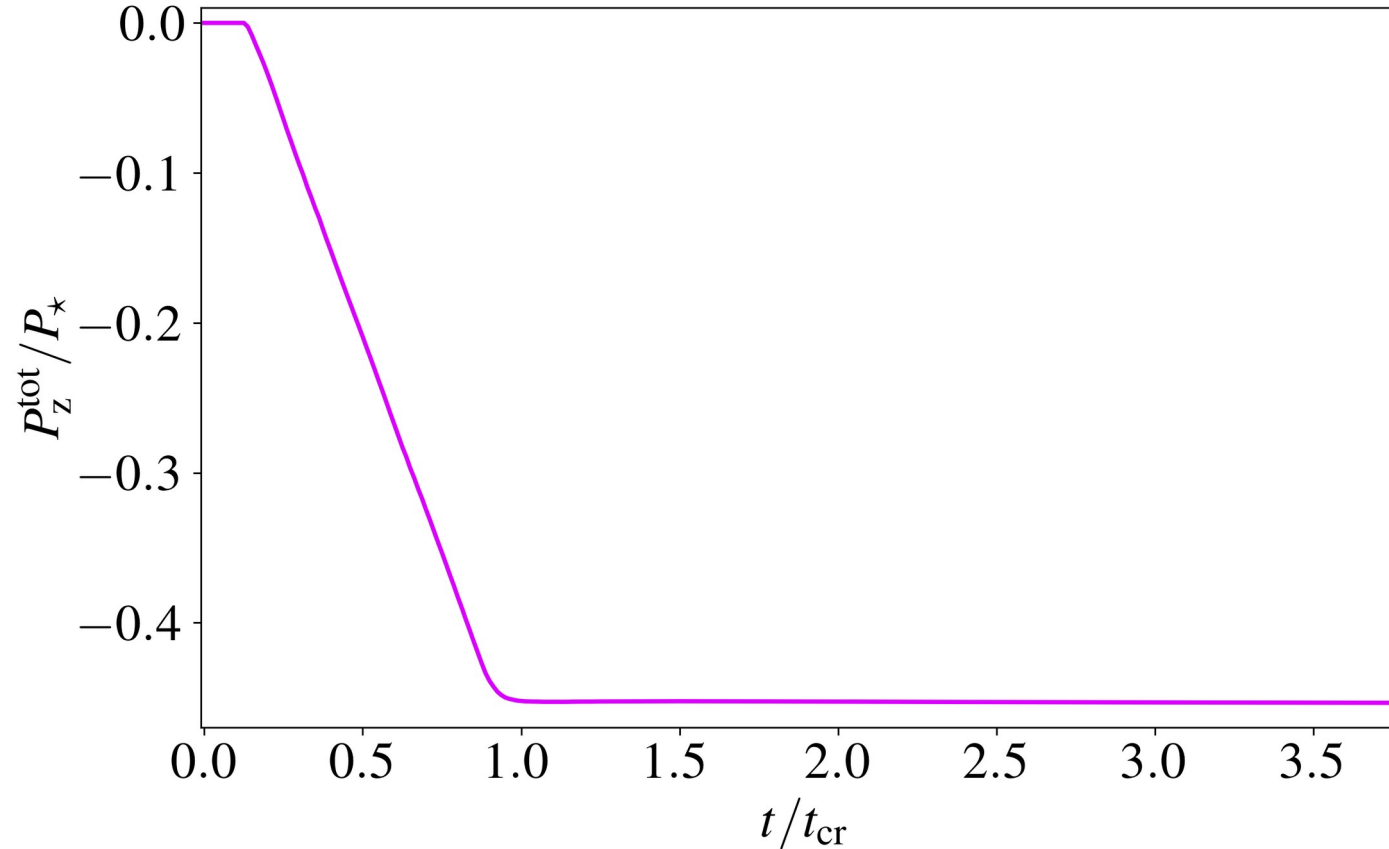
mass inflow rate

increase in specific thermal energy



Backward-moving gas: Lower $\dot{M}_{\text{in}}$ and $\Delta u \rightarrow$ Lower $\dot{E}$.

Momentum evolution



- Star injects momentum ($P_{\star} = M_0 v_{\star}$)
- Momentum asymptotes