Aspherical SNe & Oblique Shock Breakout

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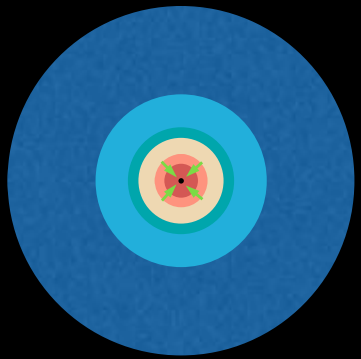
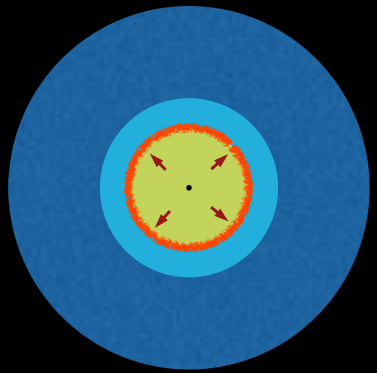
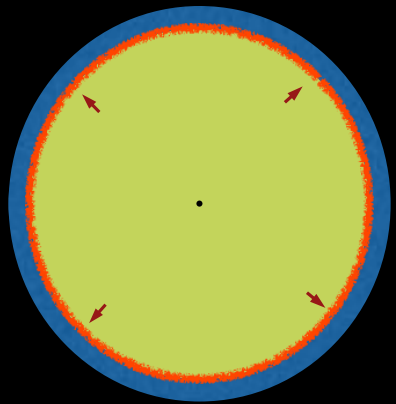
What is Shock Breakout?



Inert, unstable Fe core
Core collapse
Rebounds



Strong, non-relativistic explosion!



Shock about to breakout!

Chevalier 1992
Matzner & McKee 1999
Nakar & Sari 2010
Rabinak & Waxman 2011

Examples of Aspherical Dynamics

SNe + LGRB

Jets -> bow shock -> hot cocoon drives shock waves into the star, possibly unbinding it -> SN associated with GRB

(MacFadyen1999).

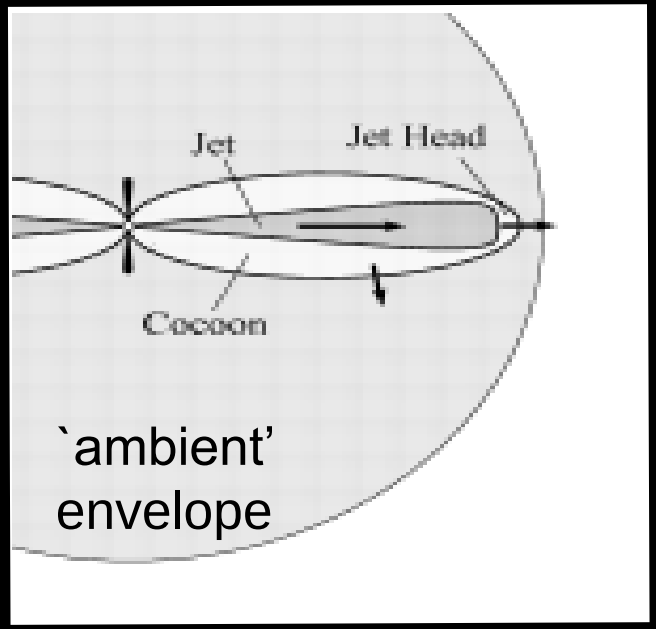


Figure from Matzner 2003

Examples of Aspherical Dynamics

NASA News Release

ESA2002/medialab

Oblate rapidly rotating progenitor

Tidally deformed progenitor:
Roche-lobe overflow binary system

Examples of Aspherical Dynamics

Aspherical CCSN mechanism

Jet driven explosions
Aspherical core collapse due to instabilities

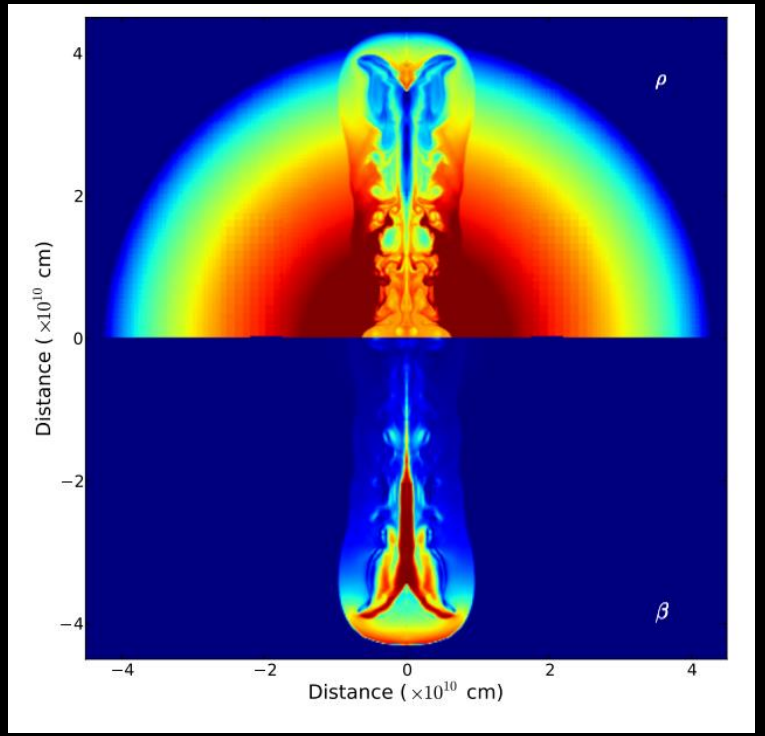
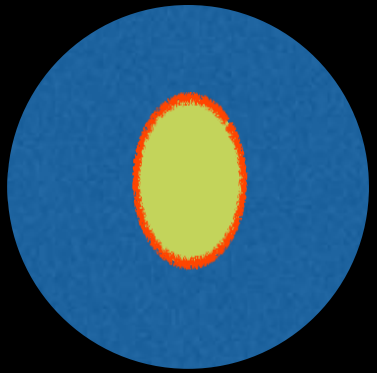
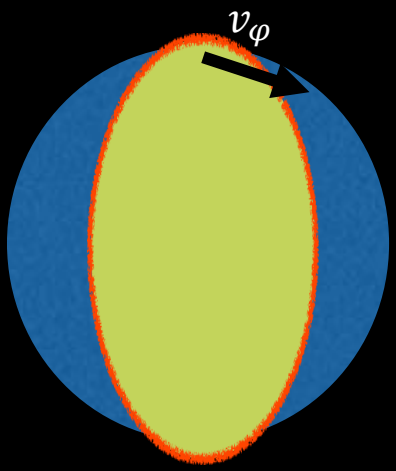


Figure from Lazzati+ 2011

Oblique Shock Breakout

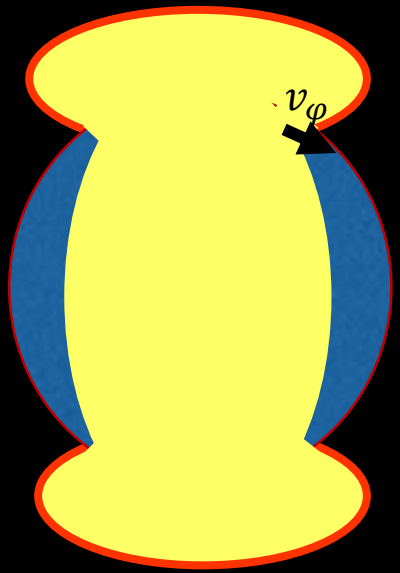


Axisymmetric explosion



Normal Shock

$v_\varphi \gg v_{sh}$



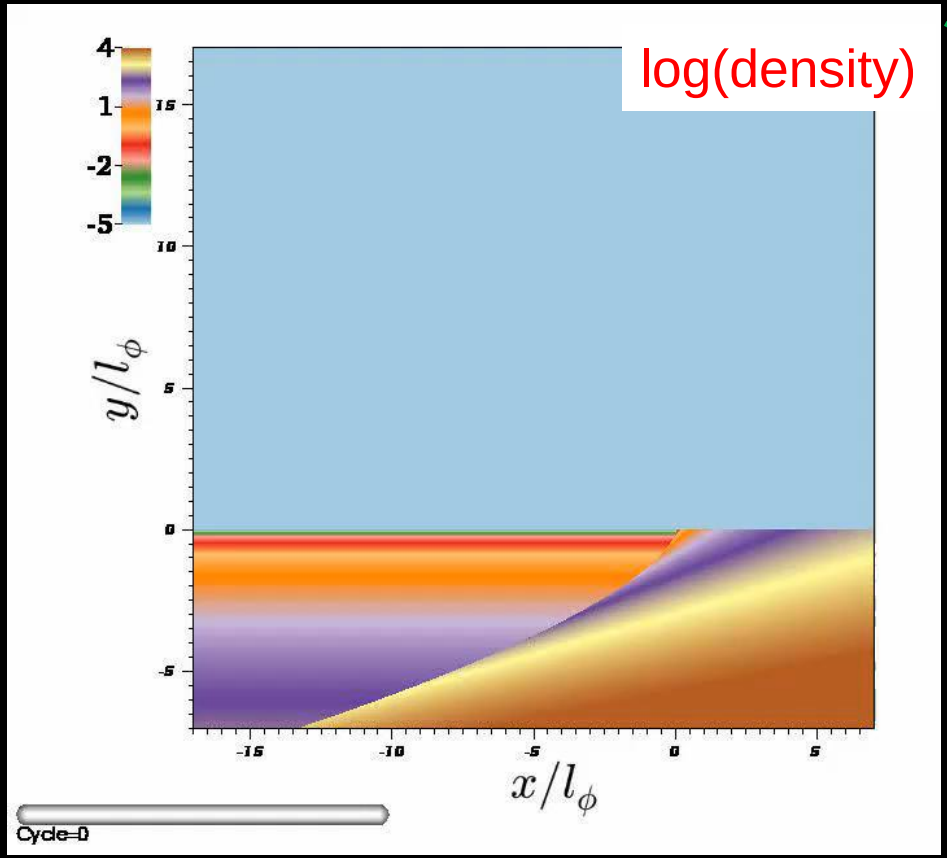
Oblique Shock

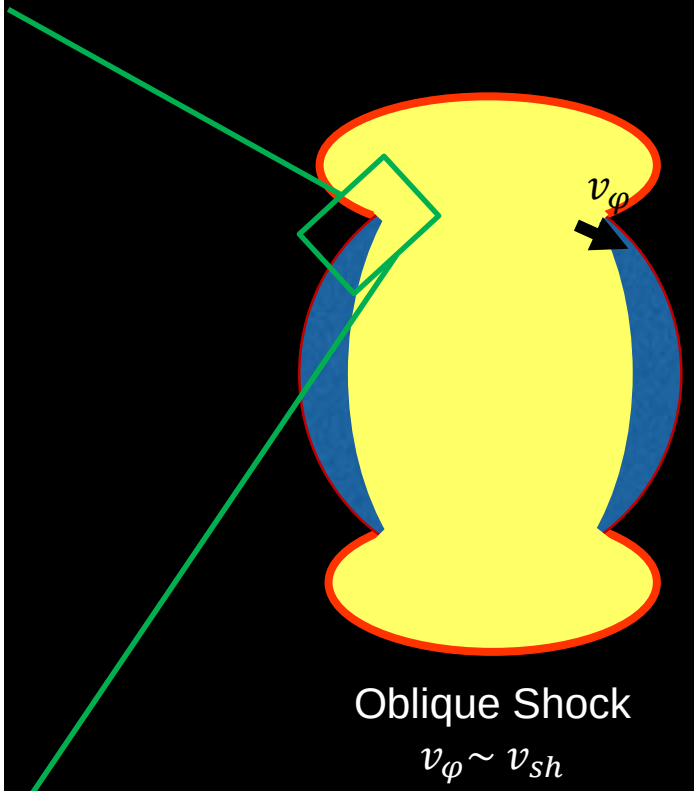
$v_\varphi \sim v_{sh}$

Why is it important to consider aspherical dynamics?

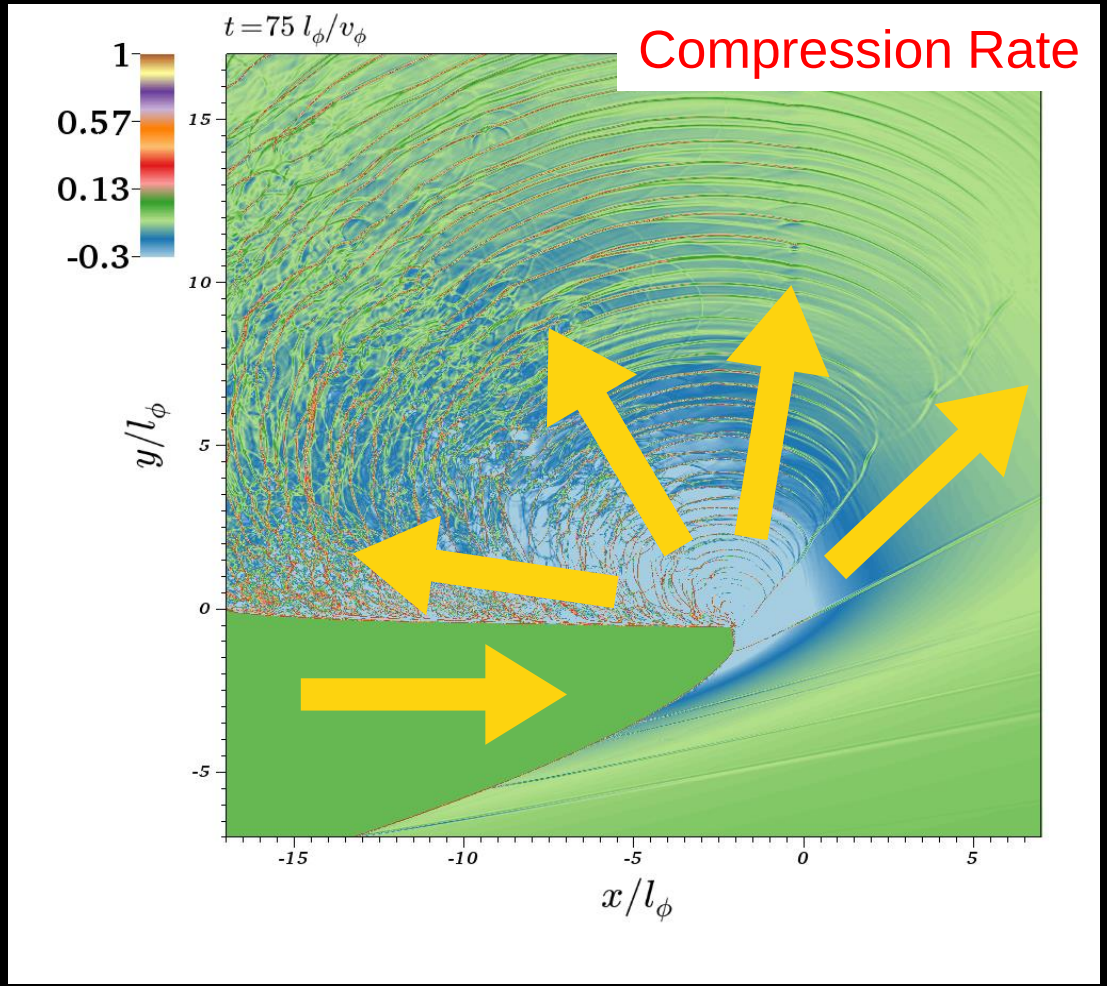
- Different interpretation for constraining the progenitor (e.g., *SN 2011dh, 2008D)*
- Obliquity alters the distribution of matter and heat across velocity (and angle) in the highest-velocity ejecta
- Difficulty in explaining the polarization information by spherical theory

Previous Work (Matzner+ 2013, Salbi+ 2014)



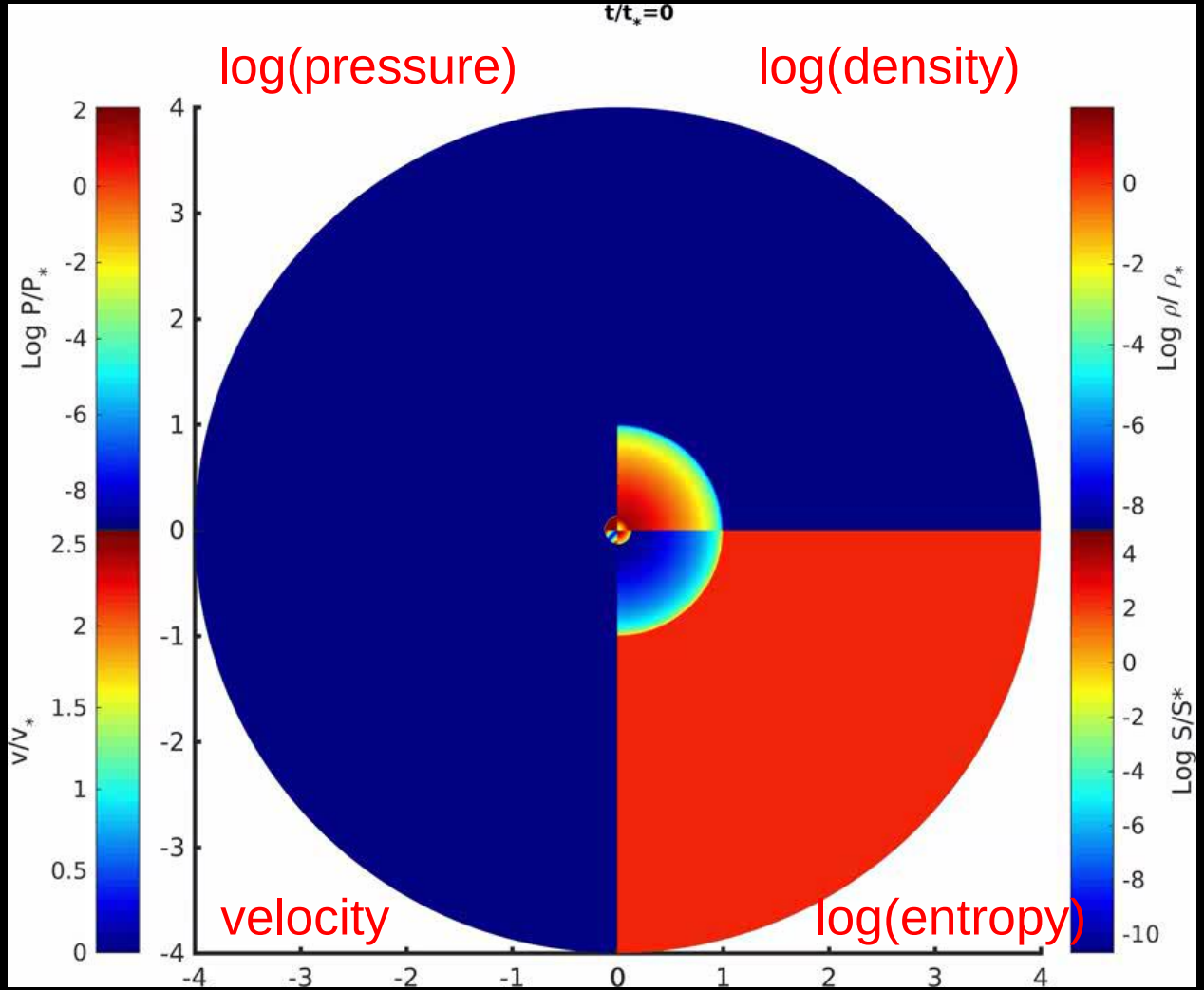


Salbi+ 2014



Athena simulation

FLASH Simulation (Afsariardchi & Matzner in prep)



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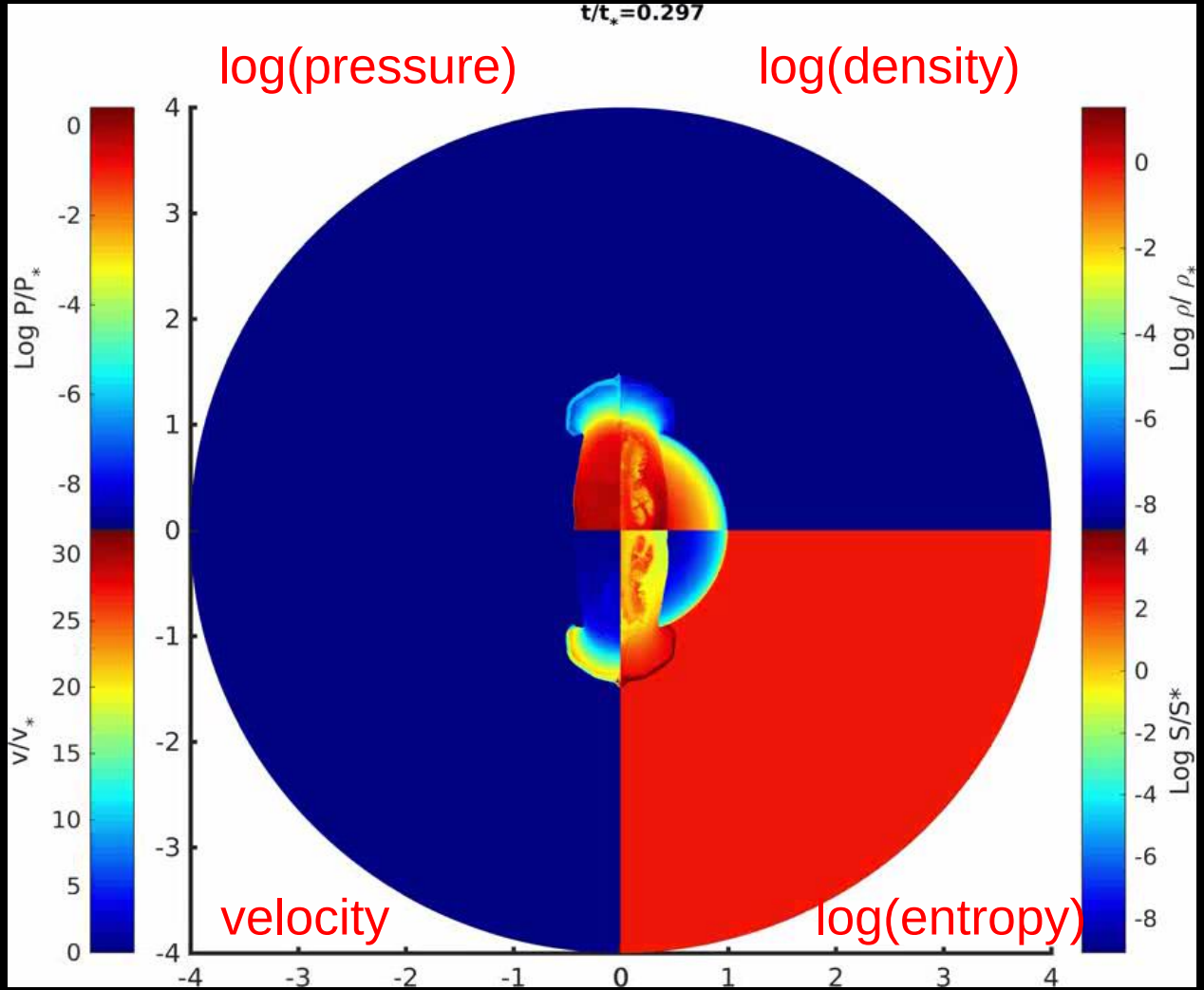
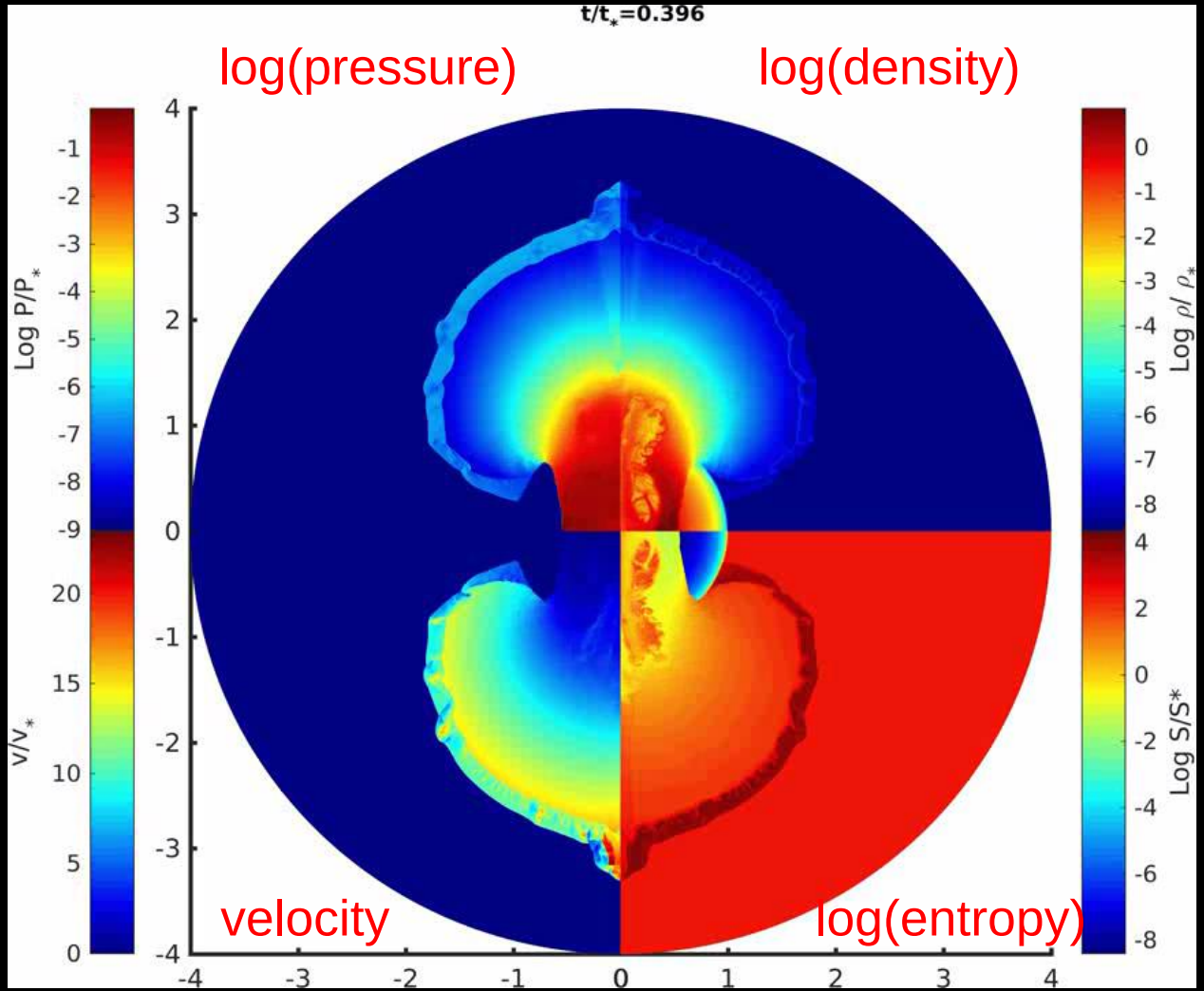
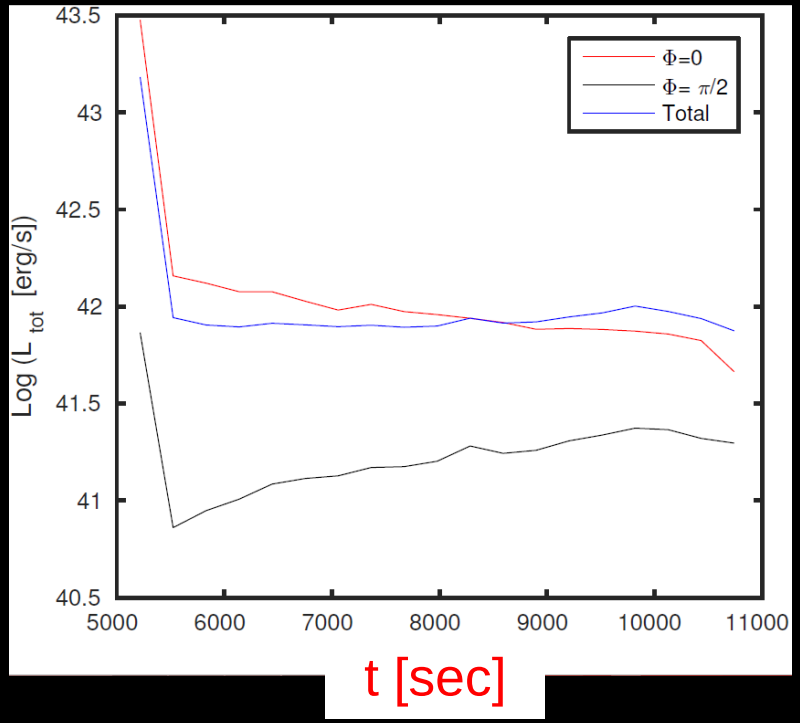


FLASH Simulation (Afsariardchi & Matzner in prep)

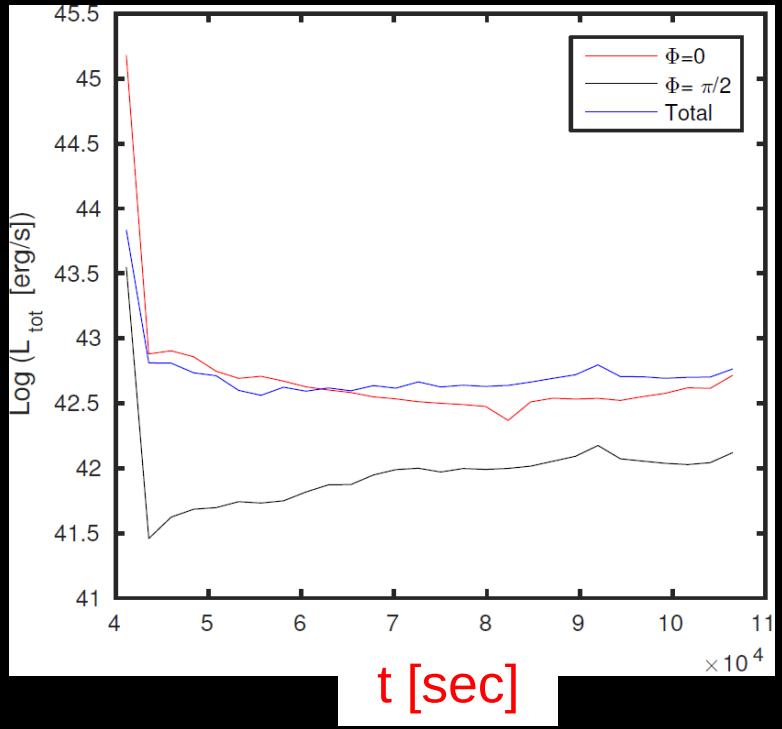


Early Bolometric Light Curve

Afsariardchi & Matzner, in prep



BSG model



RSG model

Conclusion

- Oblique shock breakout changes the progenitor analysis
- Oblique shock breakout is more dramatic on axis, but non-radial flow quenches the flash (off-axis)
- … and removes highest-velocity ejecta (off-axis),
- Therefore, it alters early SN light curve
- Oblique shock breakout enhances the production of thermal photons
- New sorts of transients by ejecta collisions

Thank you!

Oblique Shock Emergence

1. Breakout light is mostly or completely hidden from the observer

2. Energy conservation enforces a new speed limit
   (twice the pattern speed, if non relativistic)

3. Ejecta sprays in a variety of directions,
   including along the stellar surface

4. Therefore, ejecta collide outside the star.
   This collision is a new source of emission

5. Early light curve evolution is changed.