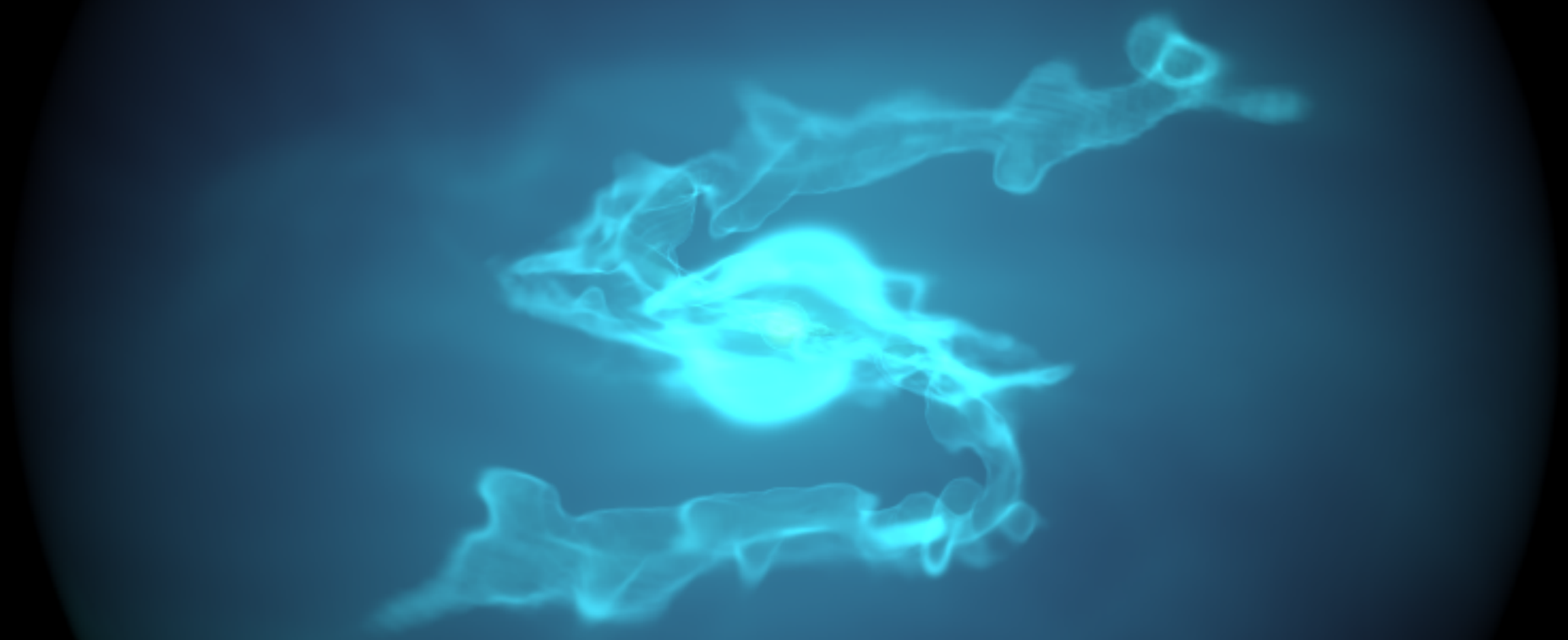
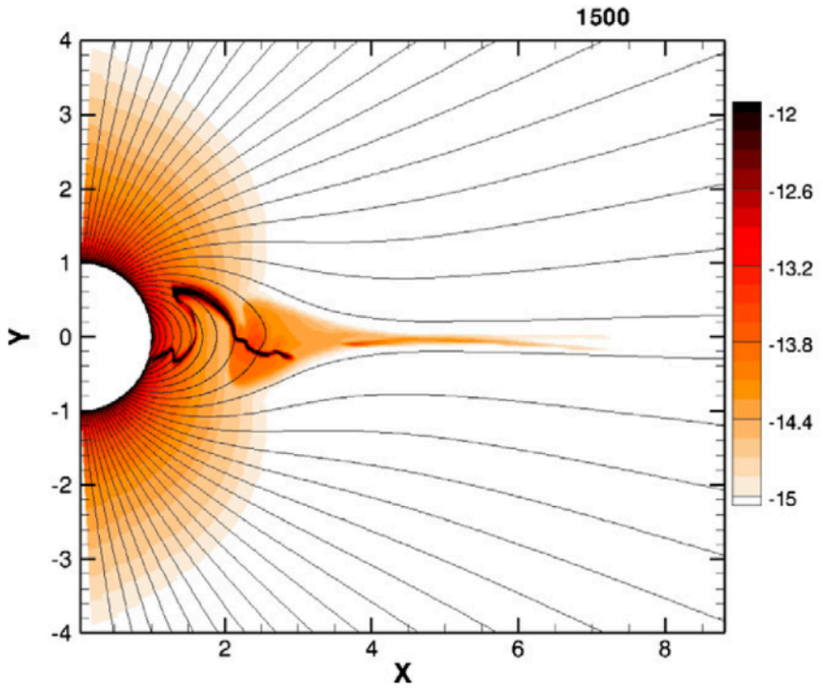
Fields and Flows:
Magnetic Massive Stars

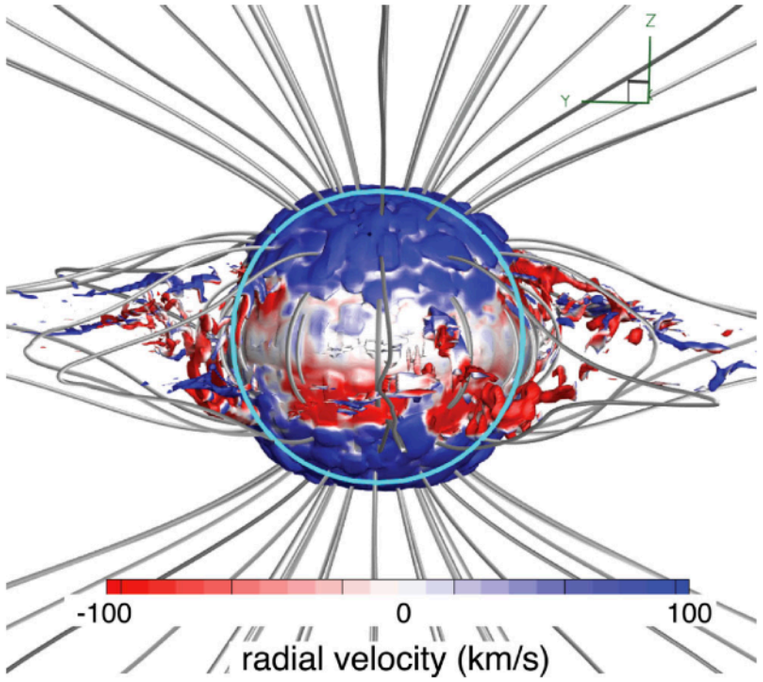


Simon Daley-Yates
Supervisor: Dr Ian Stevens
University of Birmingham

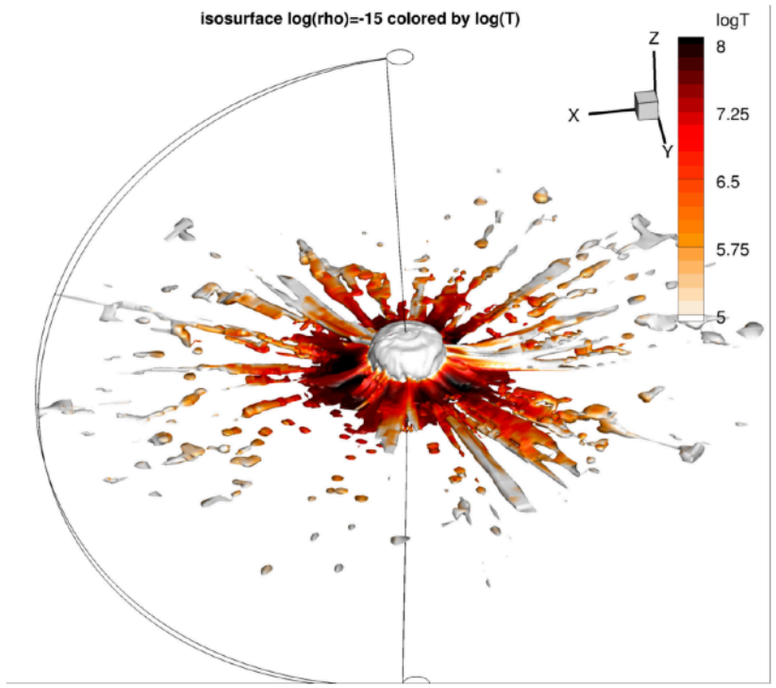
Magnetically Confined O-star Winds



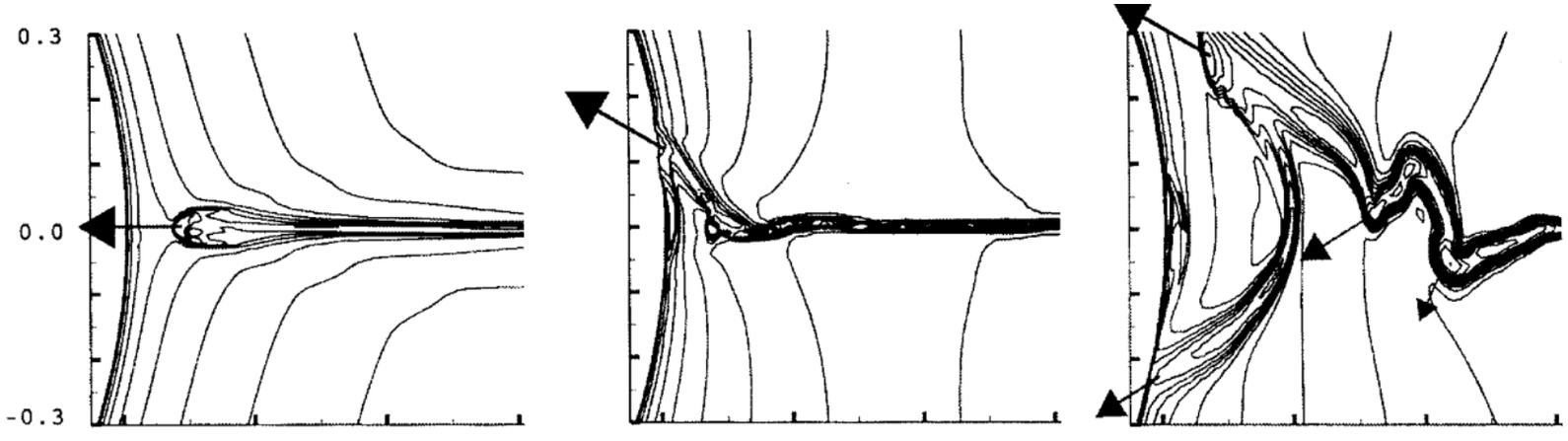
ud-Doula & Nazé 2002



ud-Doula et al. 2013



Nazé et al. 2016



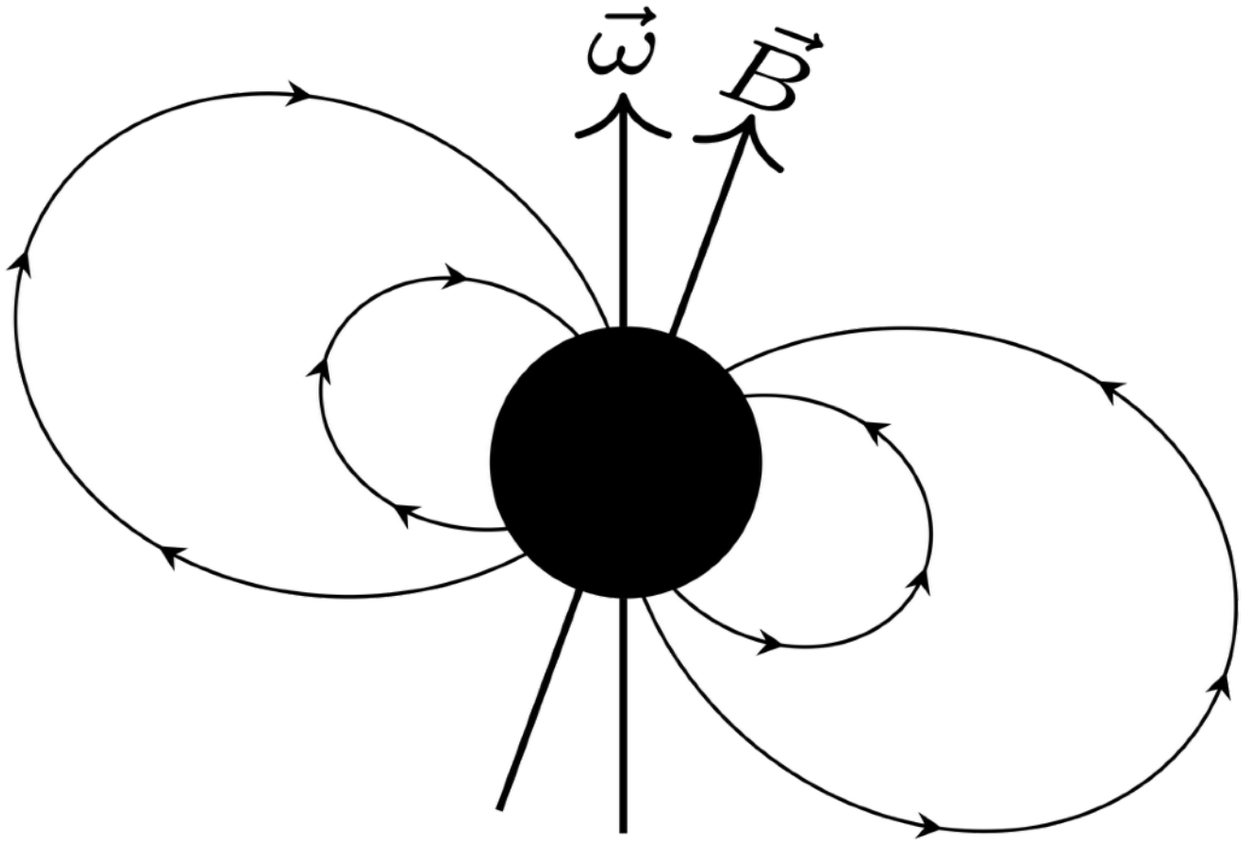
ud-Doula & Owocki 2002

Inclined Magnetic Rotating O-star

- Breaks the symmetry of the wind.

- Results in a rotationally modulated wind structure.

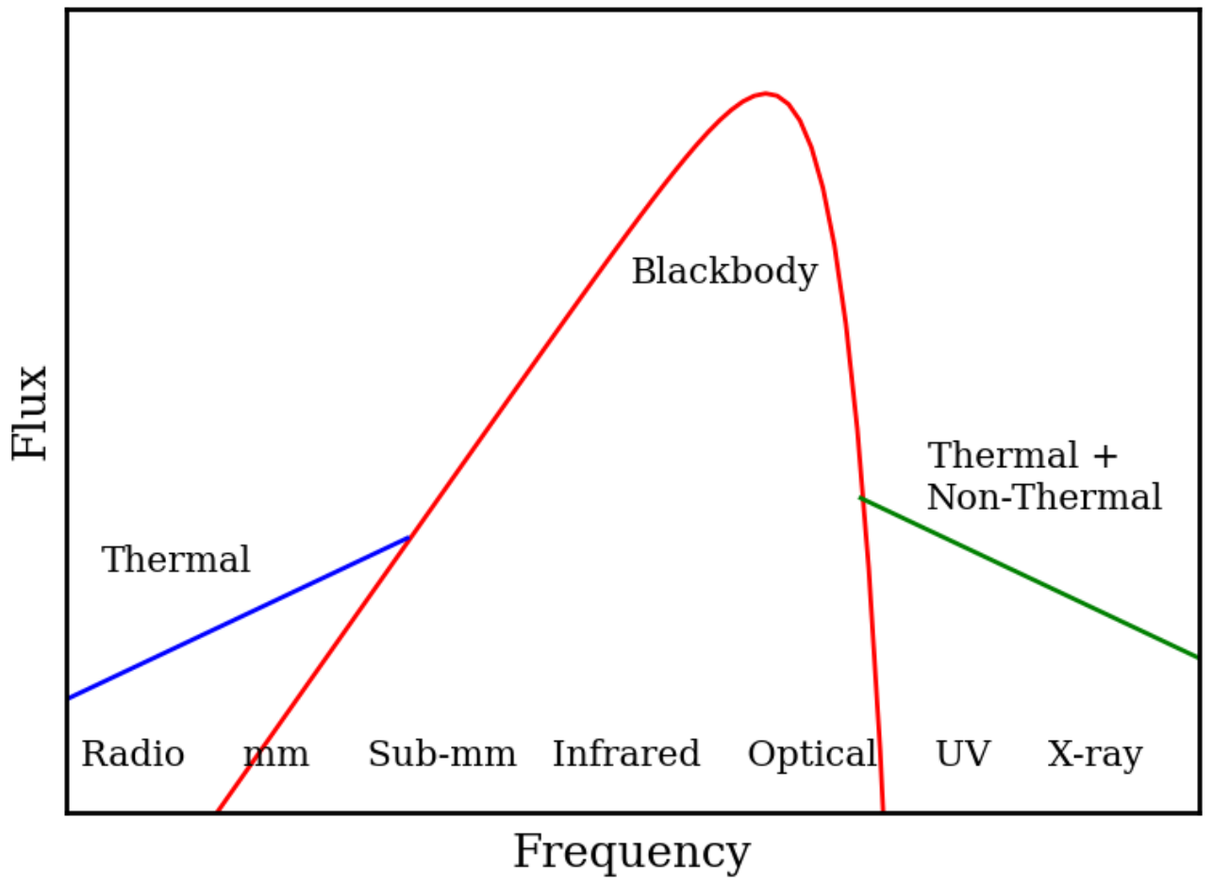
- Time dependent emission



Thermal Radio Emission

Gives us an observational window onto the stellar wind dynamics.

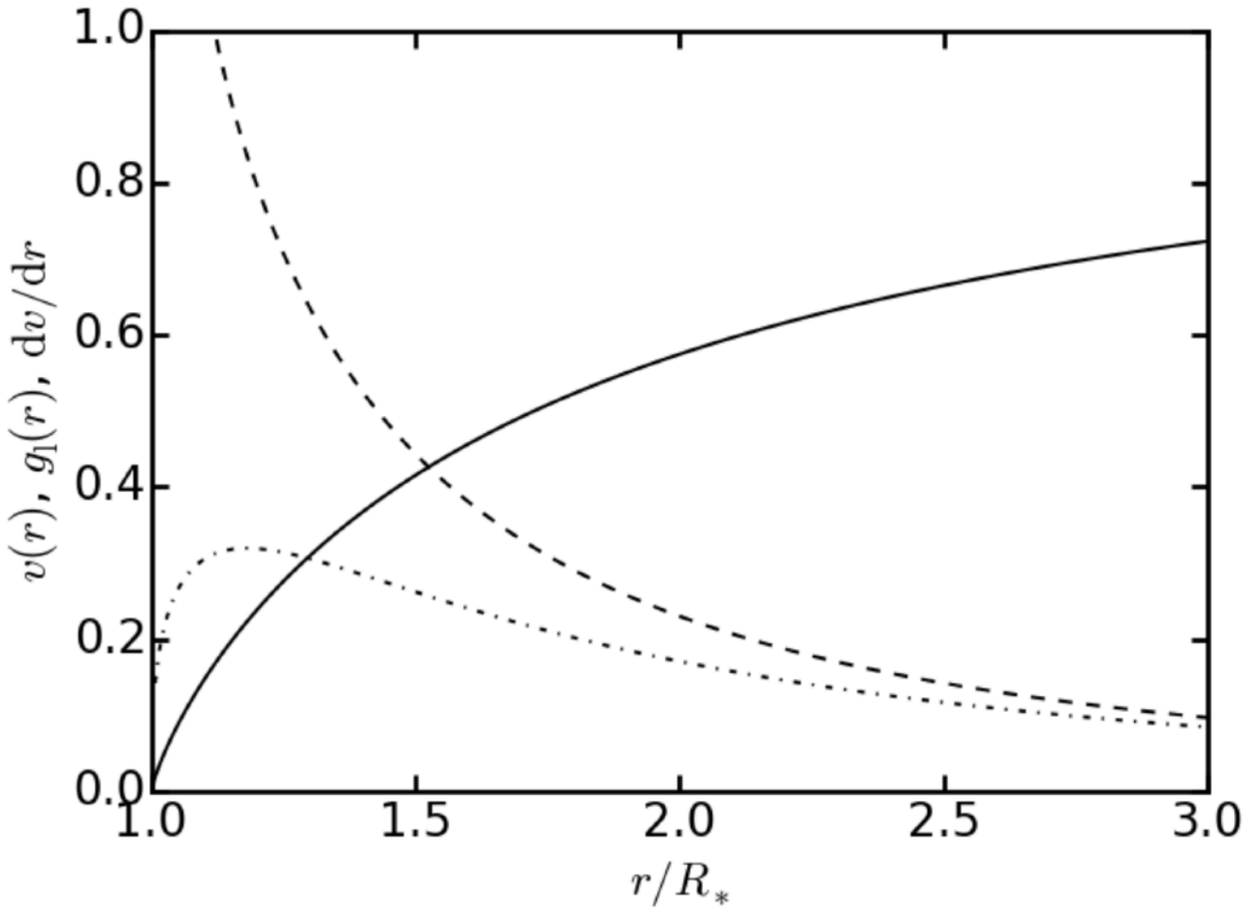
- Allows us to calculate mass-loss rates.
- Gives constraints on the stellar age and evolution.
- Important for population synthesis, end of life processes such as supernova and black hole formation etc…



Radiatively Driven Winds

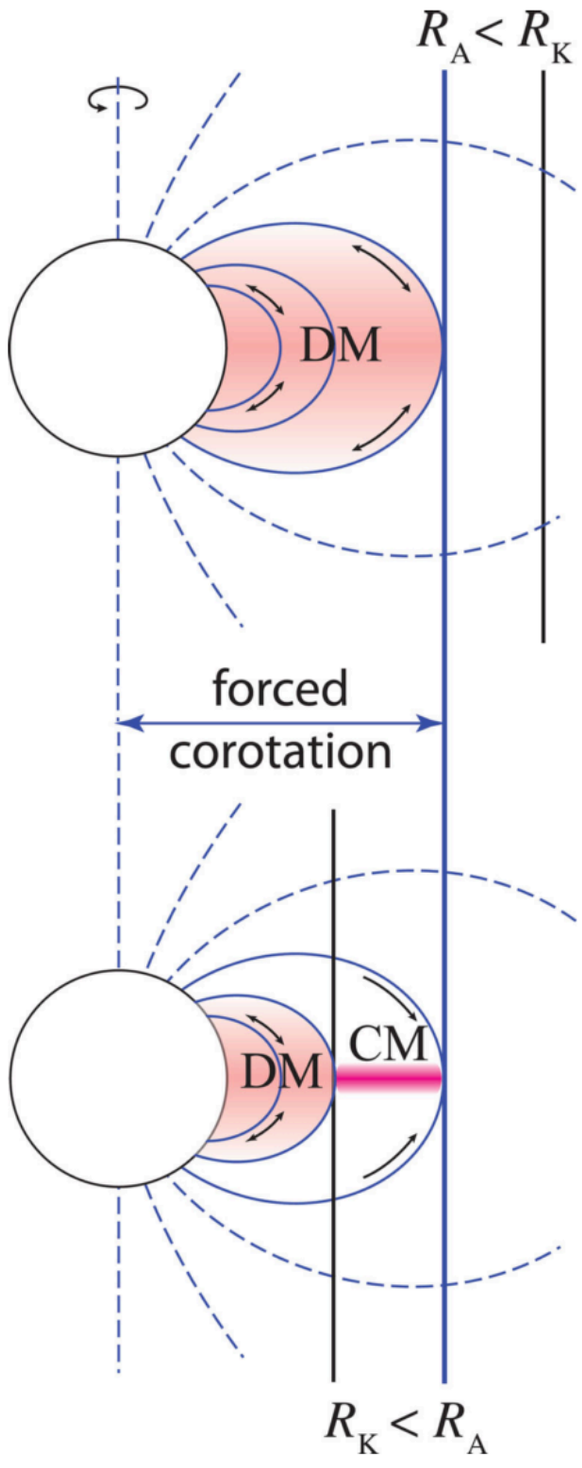
C. A. K. Theory (Castor, Abbott and Kline)

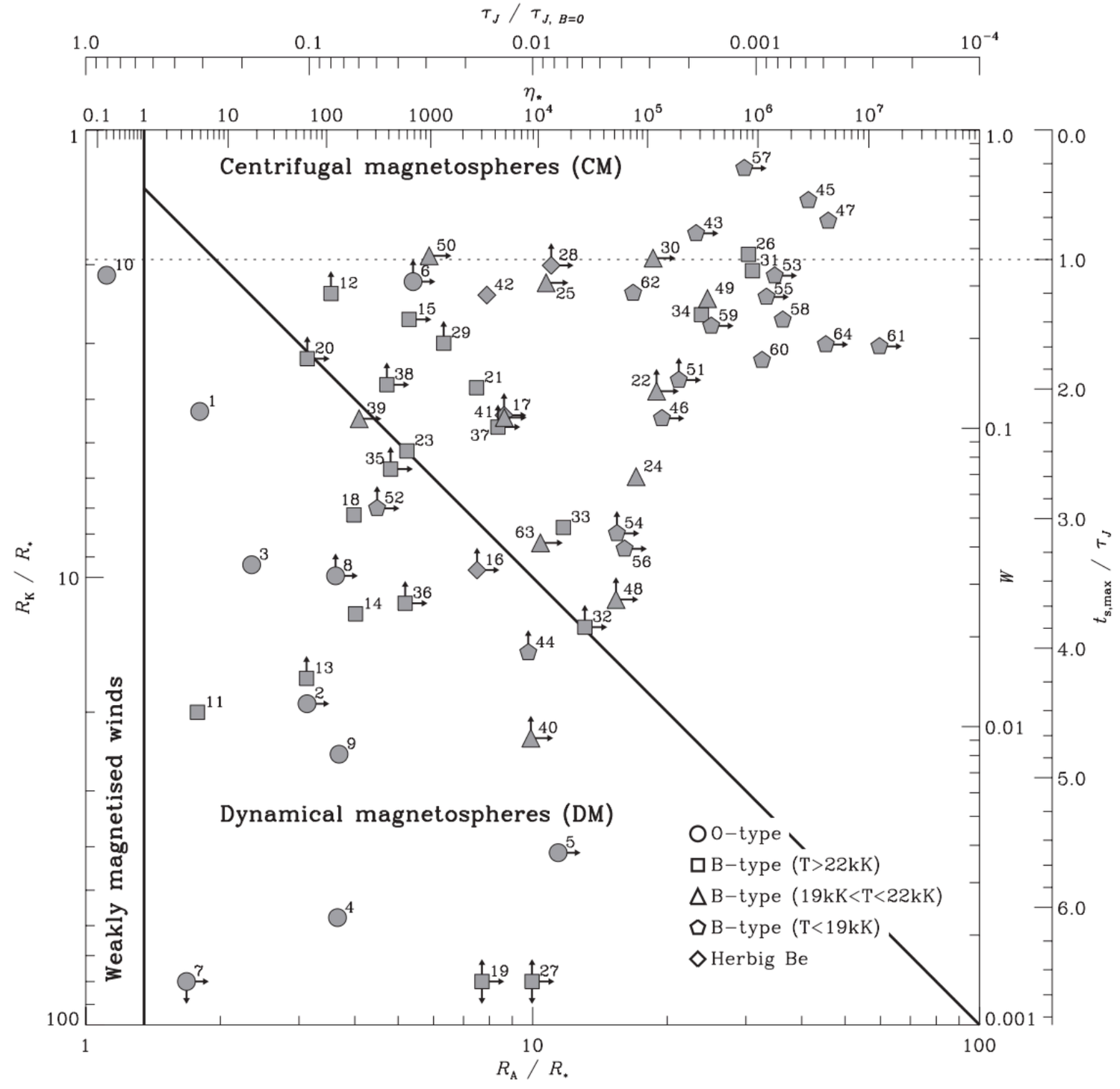
- The wind is driven by scattering of stellar radiation in emission wind absorption lines.
- Inherently unstable, with extensive observational evidence for variability and on large and small scales.



$$g_l = \frac{f_\mathrm{D}}{(1-\alpha)} \frac{\kappa_e L_* \overline{Q}}{4\pi r^2 c} \left(\frac{\mathrm{d}\boldsymbol{v}/\mathrm{d}r}{\rho c \overline{Q} \kappa_\mathrm{e}} \right)^\alpha$$

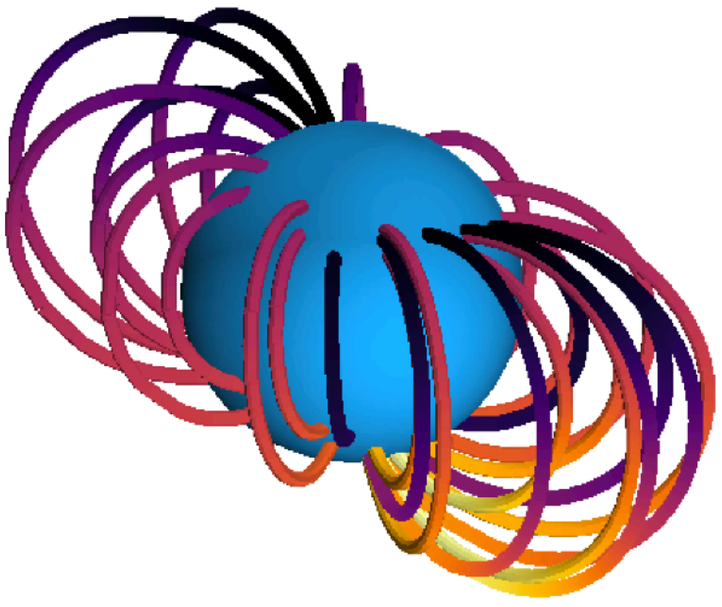
Magnetism In MassivE Stars (MIMES)



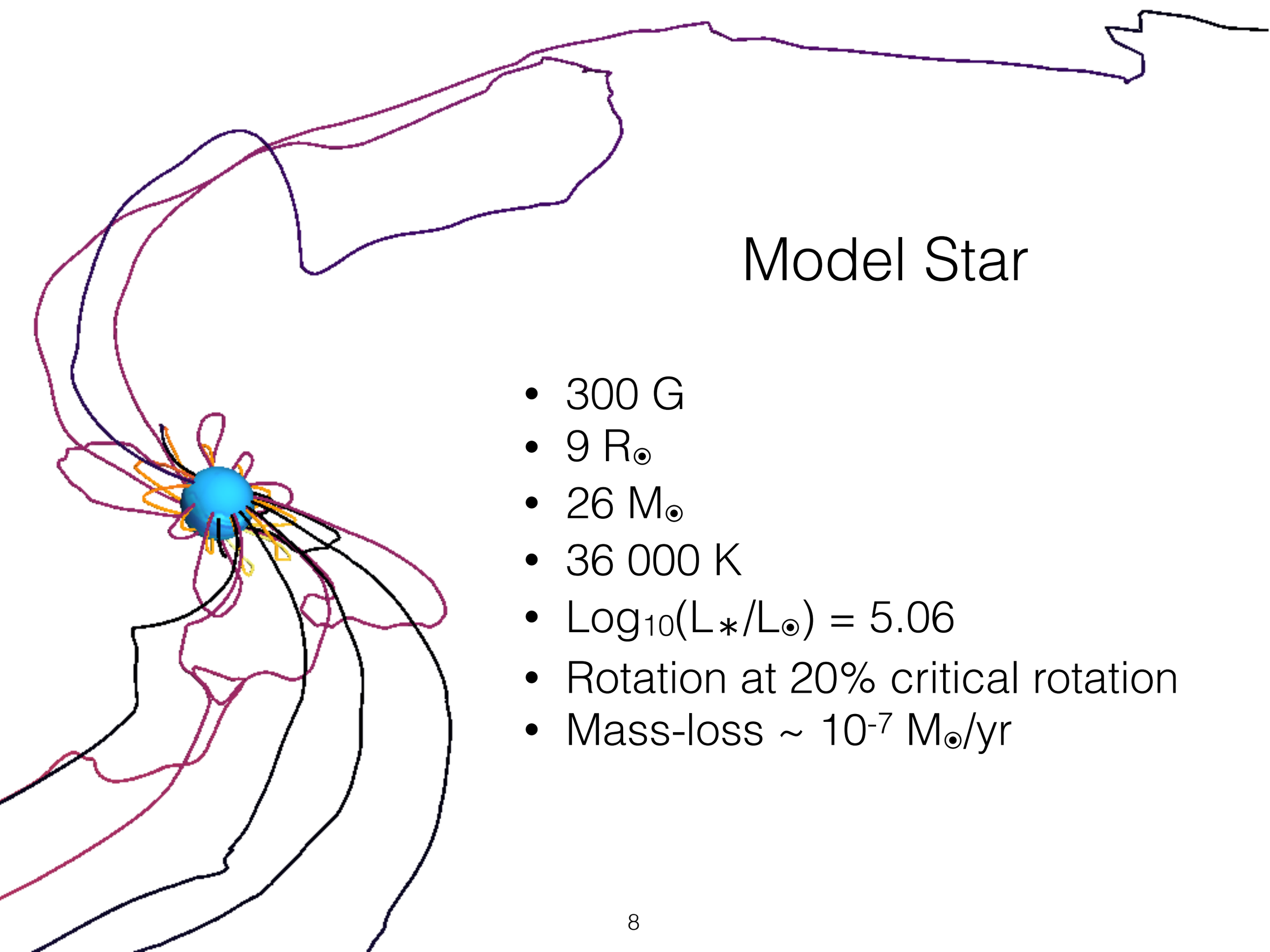


Petit et al., 2013, MNRAS, 398, 429

Magnetic Field Topology

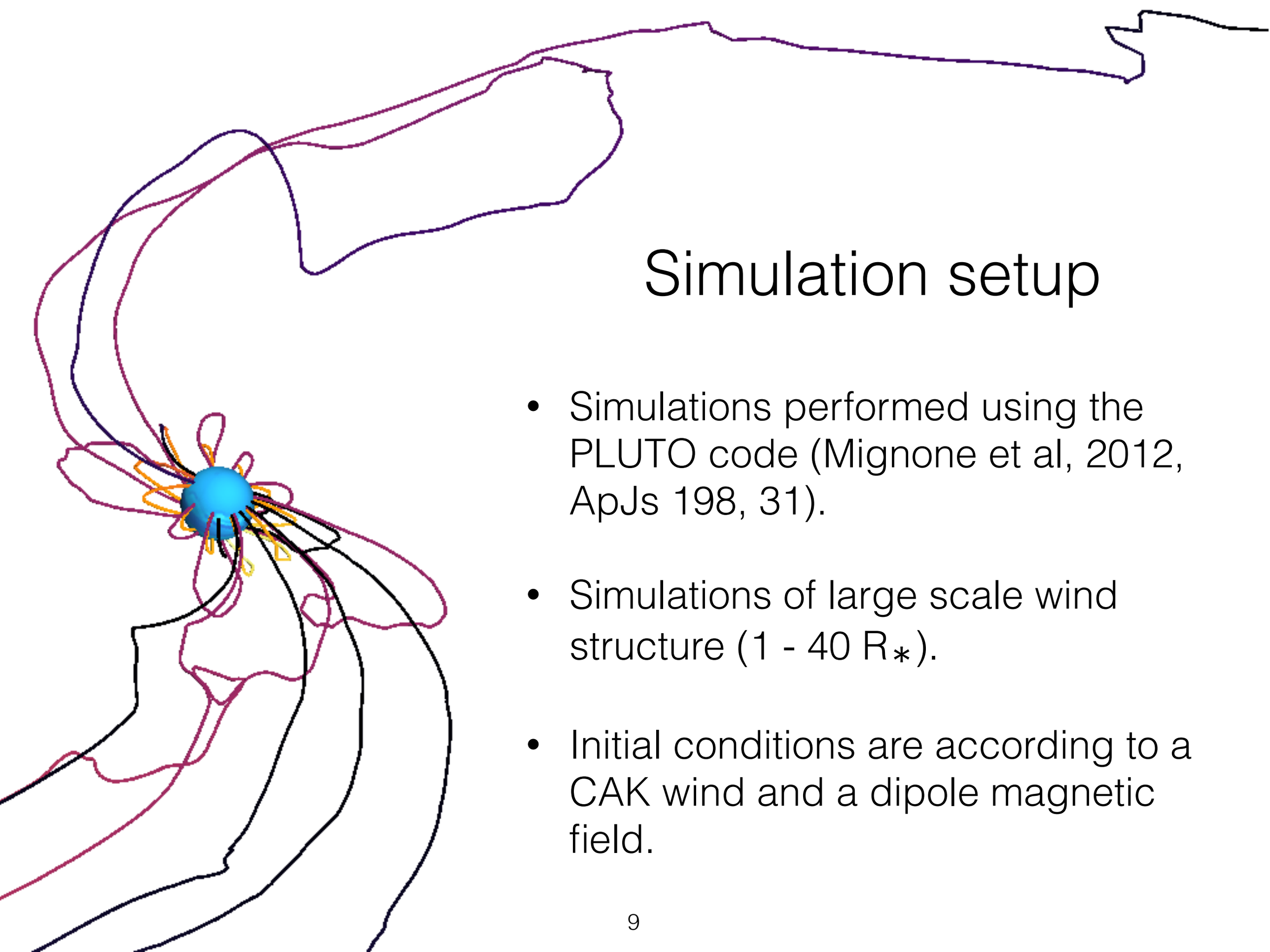


- Dipole magnetic field topology.
- Inclined with respect to rotation axis
- Common configuration among massive stars.
- For this study, an inclination of 30^{O} was chosen.



Model Star

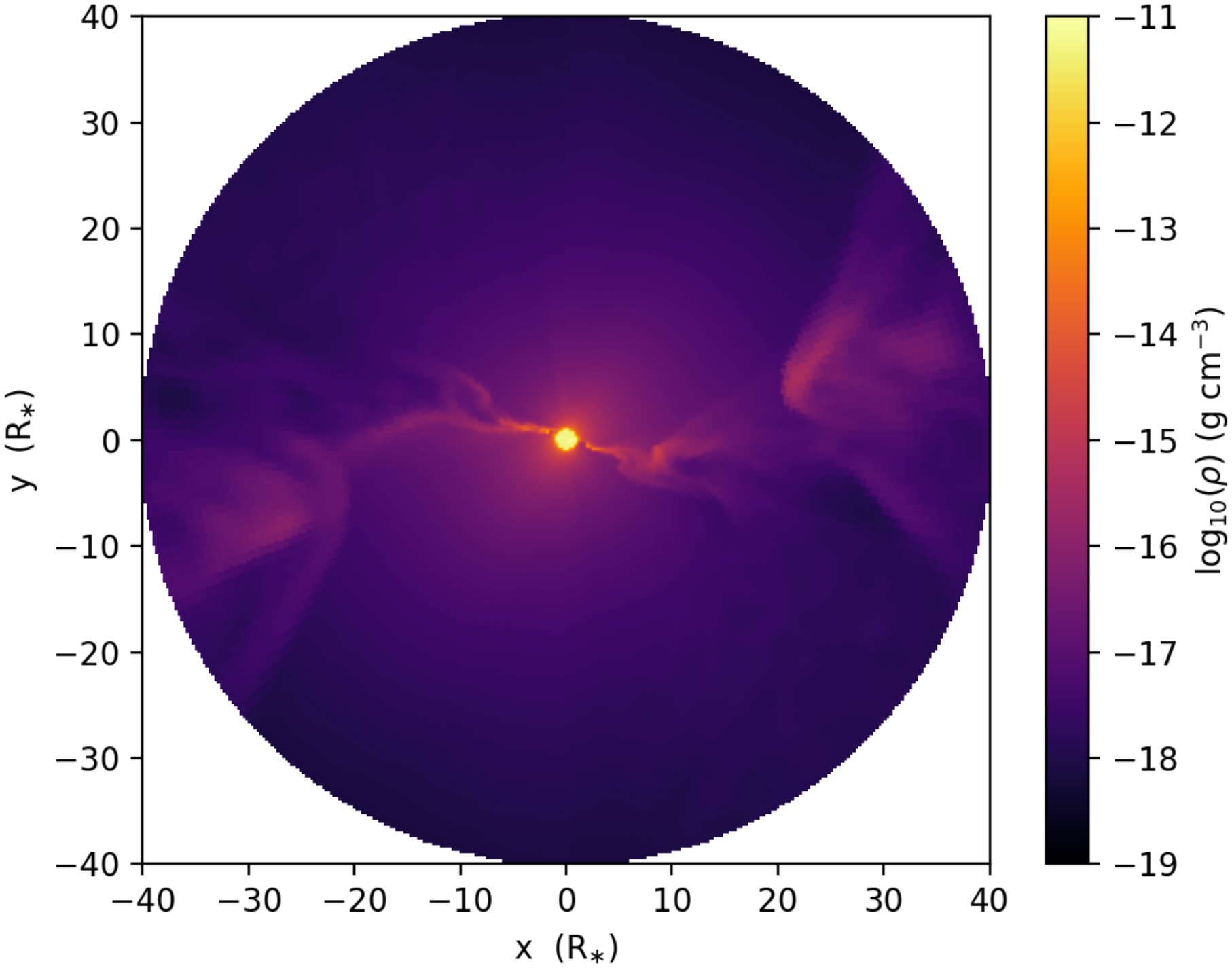
- 300 G
- 9 $R_\odot$
- 26 $M_\odot$
- 36 000 K
- $Log_{10}(L_*/L_\odot) = 5.06$
- Rotation at 20% critical rotation
- Mass-loss ~ 10^{-7} $M_\odot$/yr



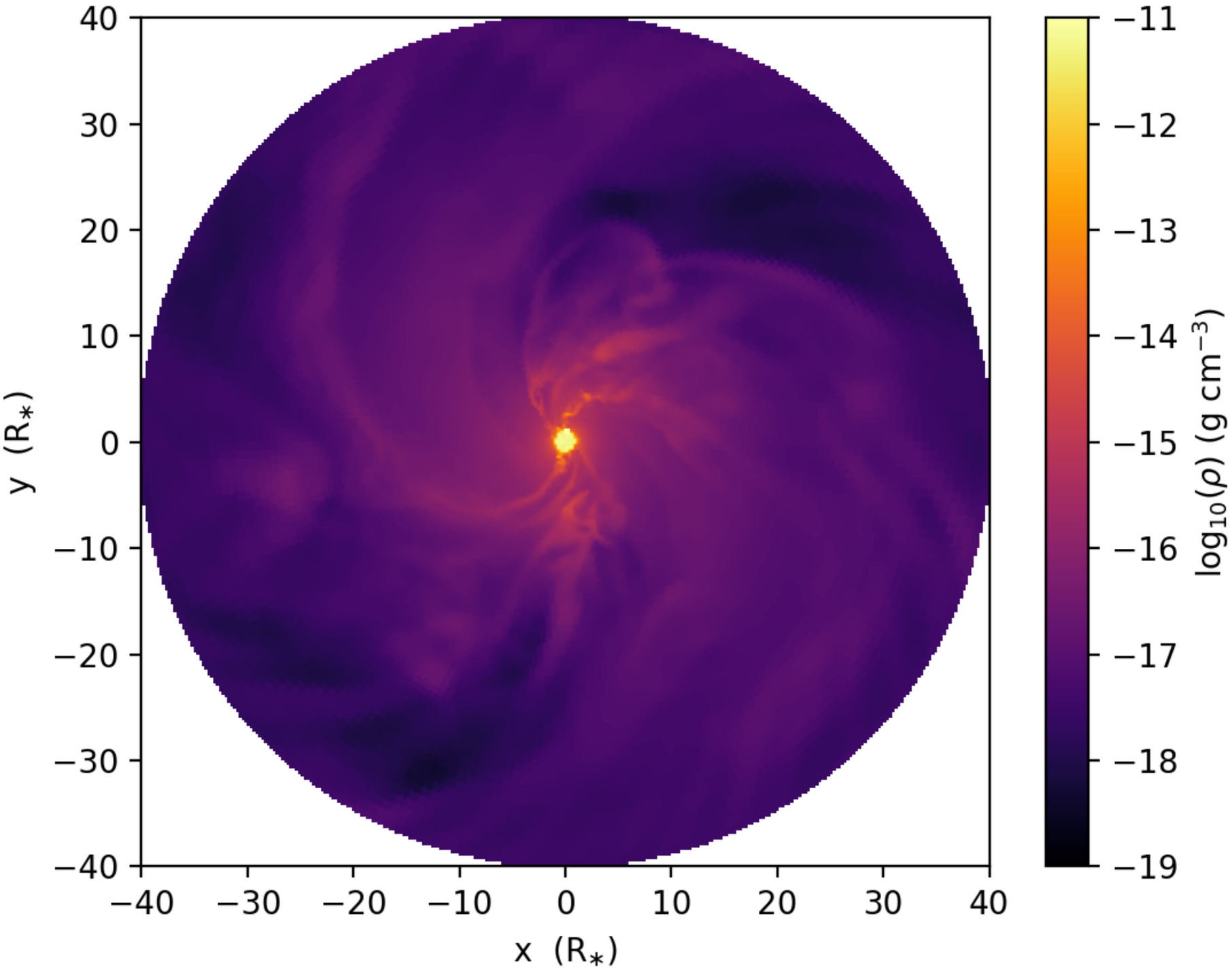
Simulation setup

- Simulations performed using the PLUTO code (Mignone et al, 2012, ApJs 198, 31).
- Simulations of large scale wind structure (1 - 40 R_*).
- Initial conditions are according to a CAK wind and a dipole magnetic field.

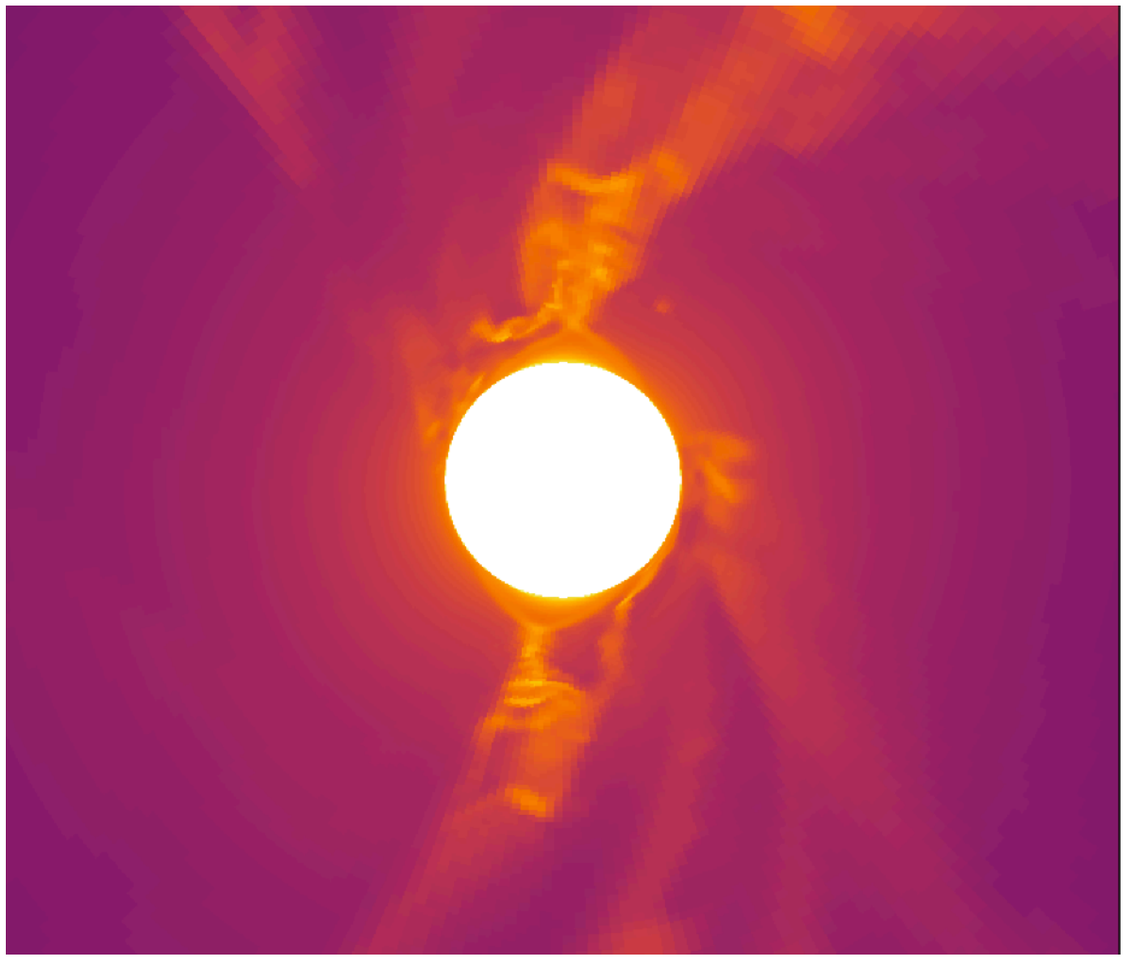
Density Structure

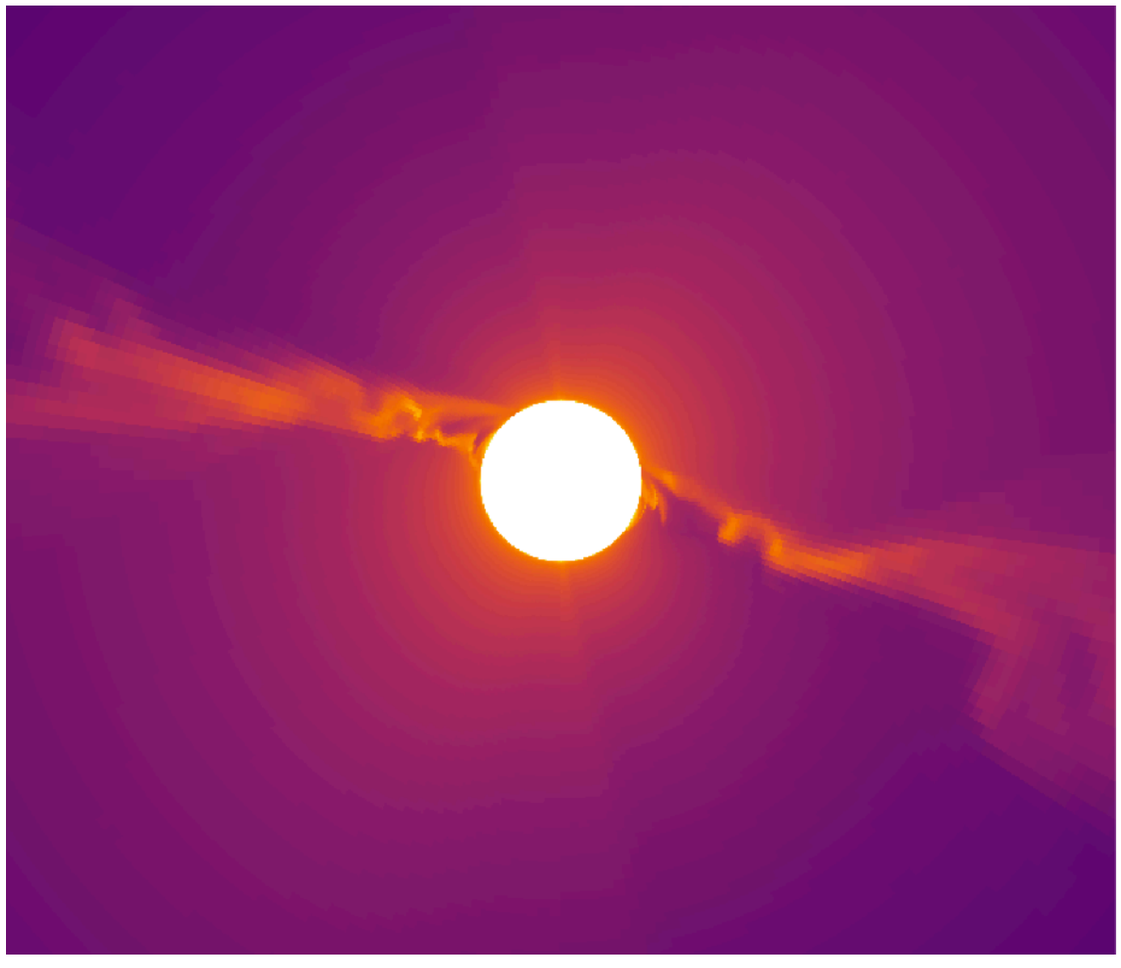


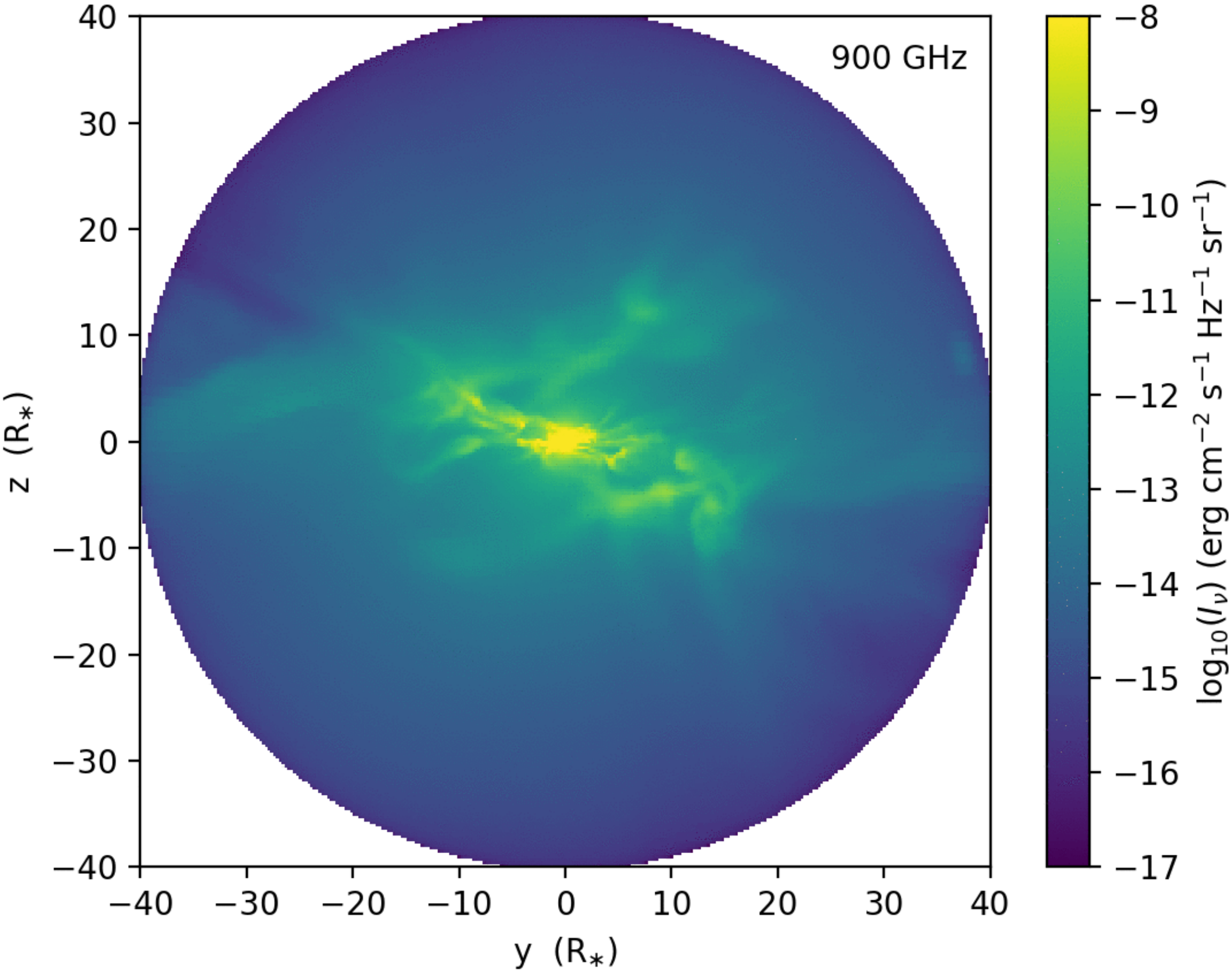
Density Structure



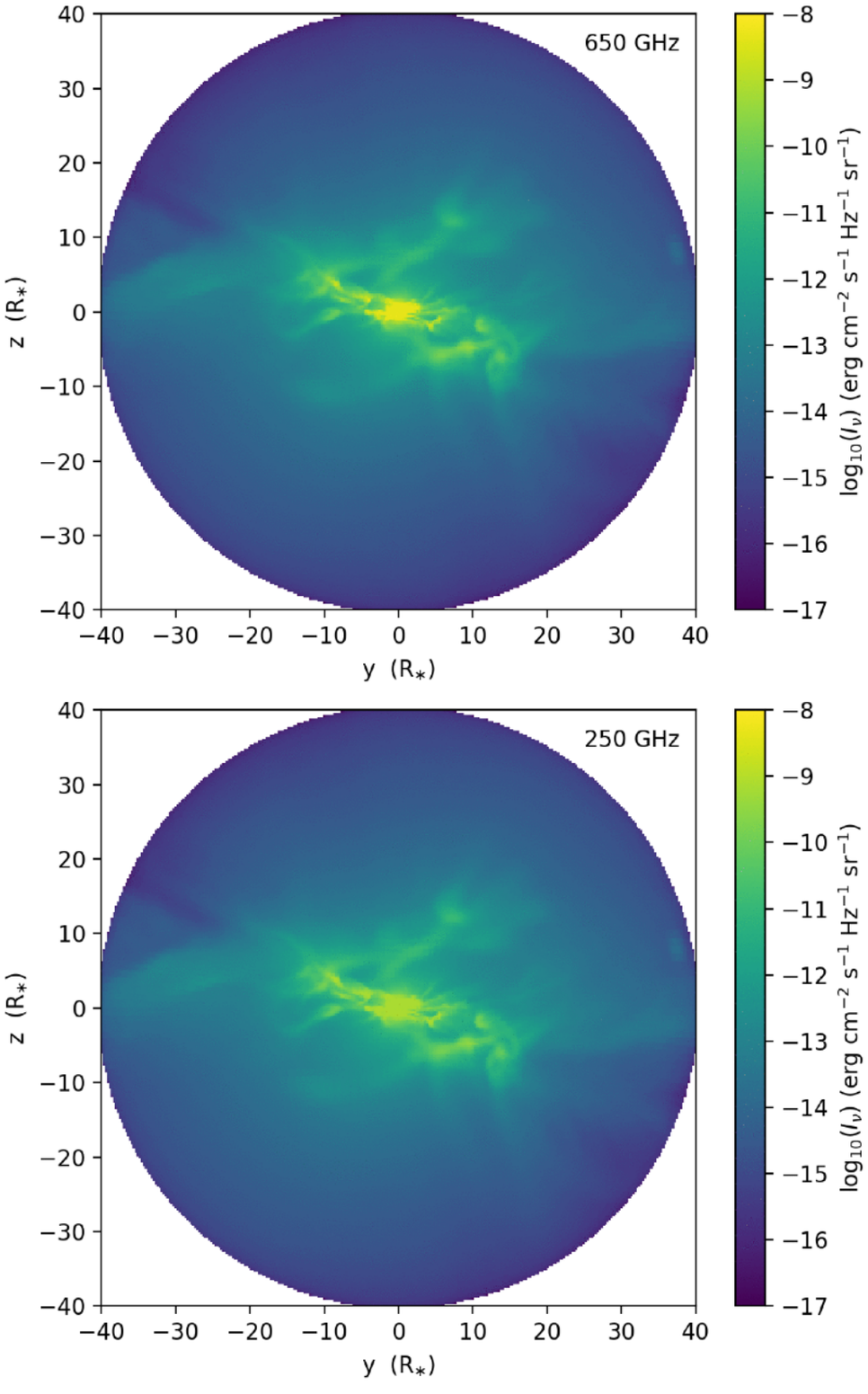
Density Structure

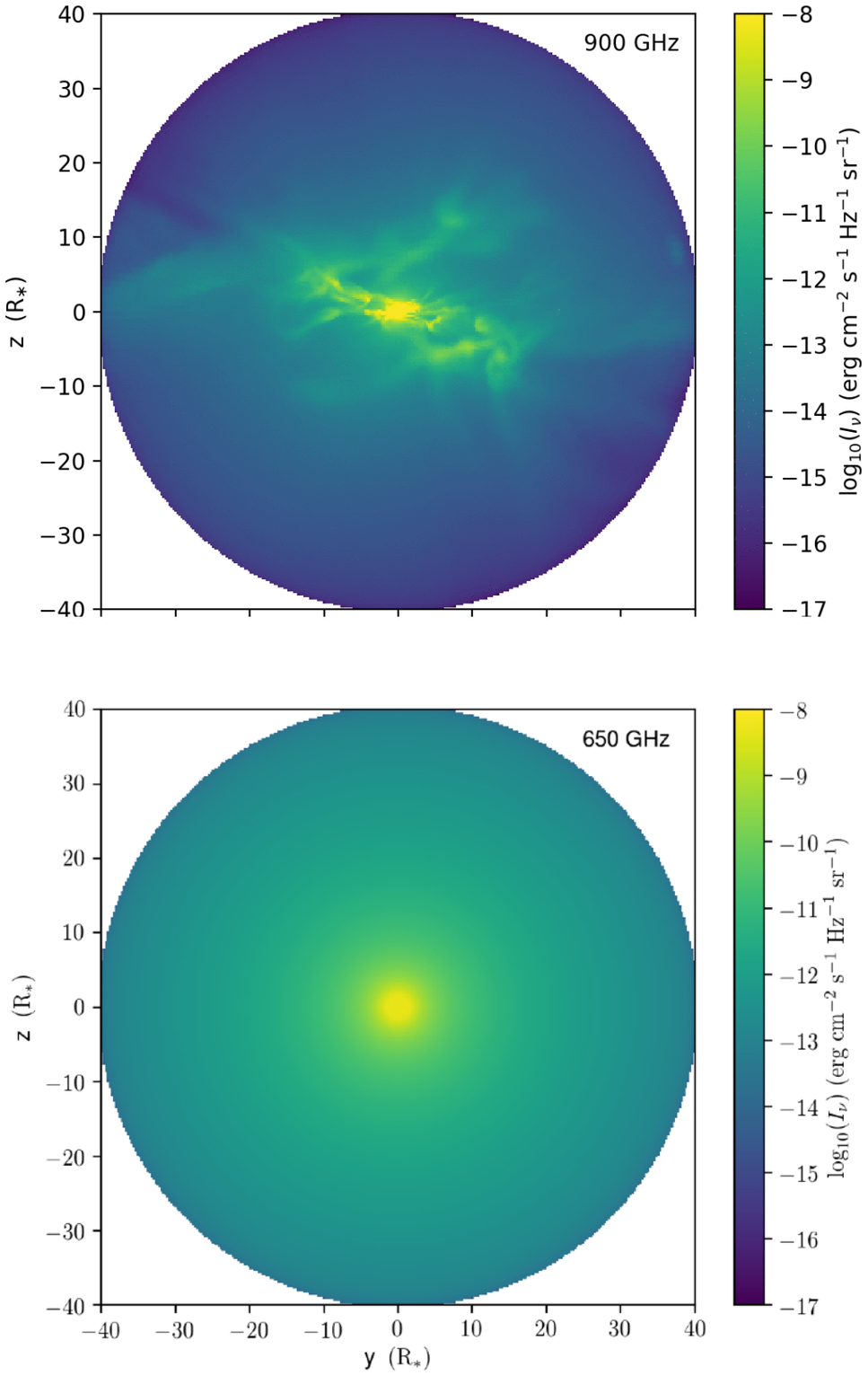





900 GHz
z (R∗)
y (R∗)
log10(Iν) (erg cm−2 s−1 Hz−1 sr−1)
40
30
20
10
0
−10
−20
−30
−40
−8
−9
−10
−11
−12
−13
−14
−15
−16
−17

Thermal Radio Emission





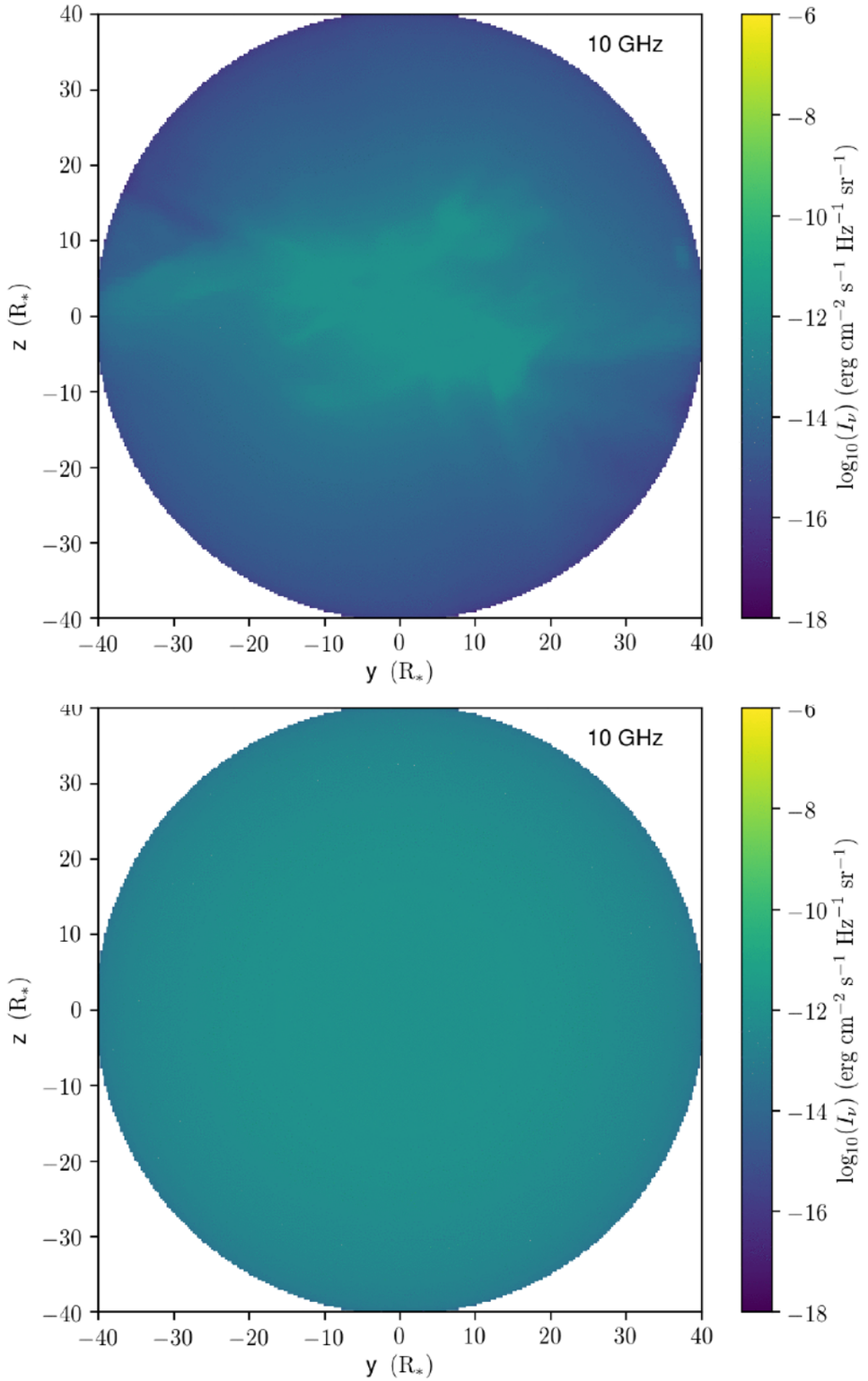
Wind Structure

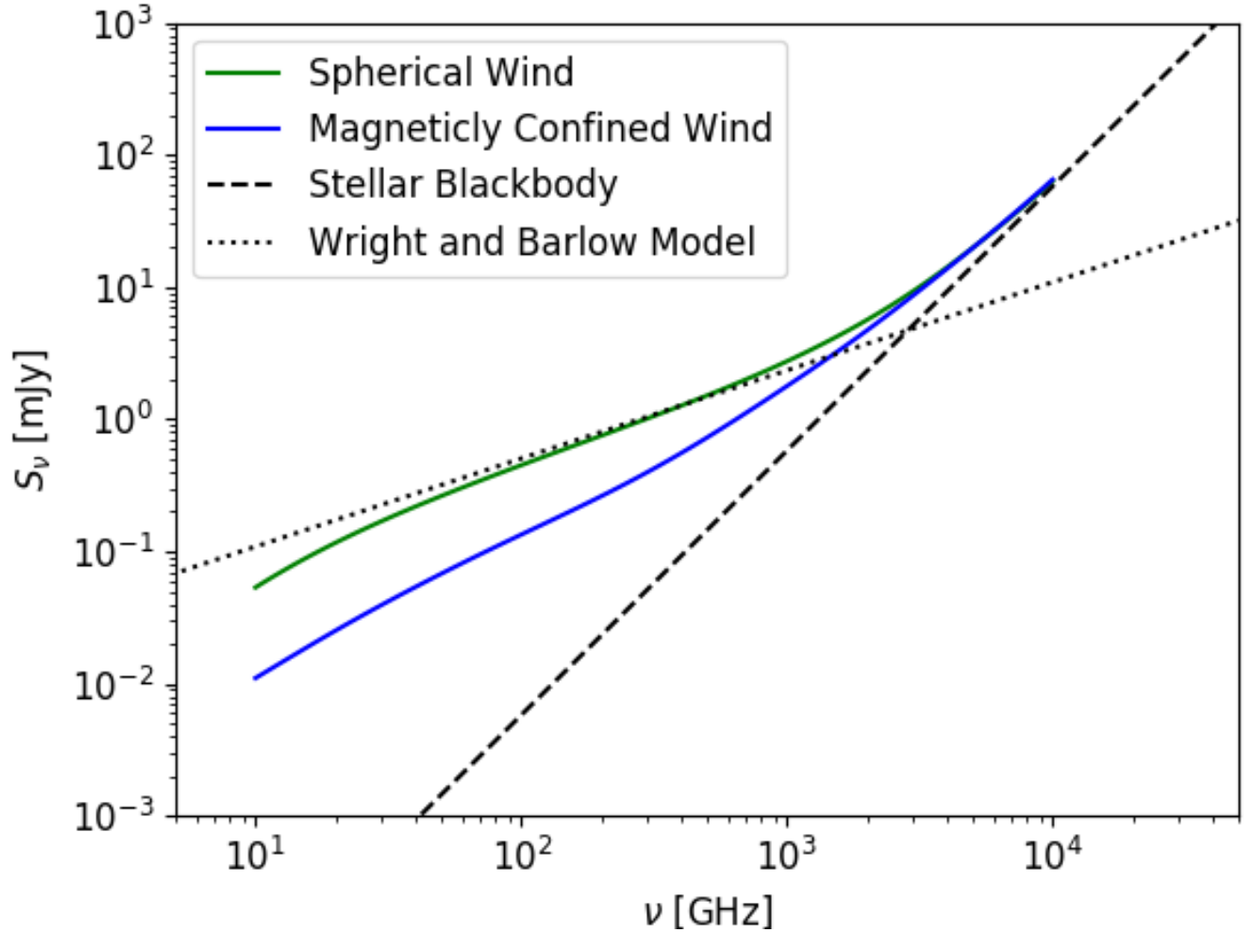
The magnetic field leads to confinement of the wind material into a disk, close to the star.

Stellar rotation with magnetic field tension, acts to break the disk up at larger radii.

→ Macro-clumping at larger radii

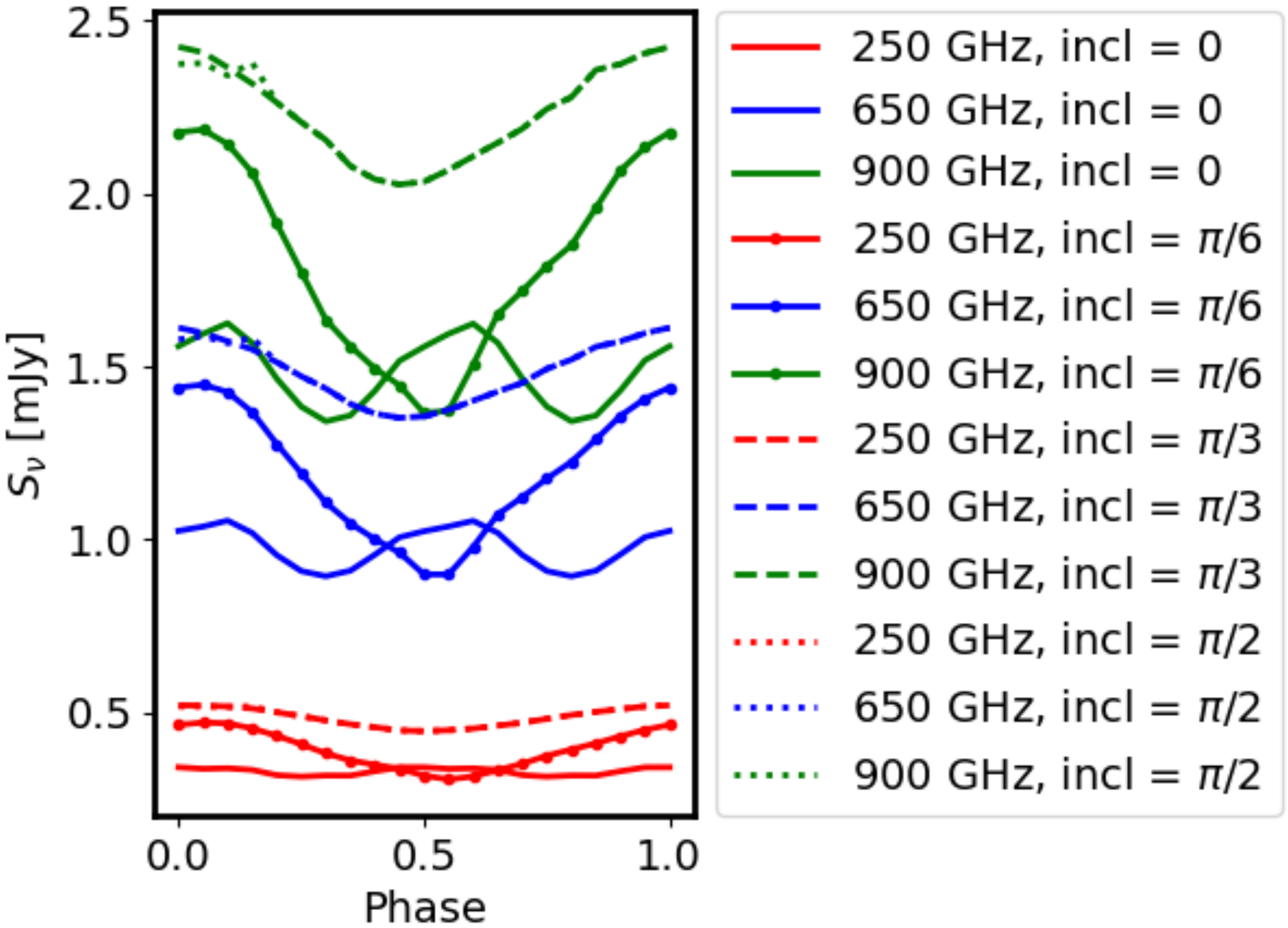
Thermal Radio Spectrum





$$\dot{M} \propto S_{\nu}^{3/4}$$

Time Varying Thermal Radio Emission



Time Varying Thermal Radio Emission

Radio emission has a strong dependance on the inclination with respect to the observer and rotational phase.

Emission can vary by a factor of 1.5 over a stellar rotation.

Summary

- Magnetic field plays a strong role in the shaping the non-symmetric evolution of the wind.

- This non-symmetry should be apparent in thermal radio observations.

- Mass-loss modulation by the magnetic field can be see in the radio spectrum.

- Radio light curves together with inclination are critical to understanding the impact of the field on the wind.