

An ultracool bridge to exoplanet magnetic fields

Robert Kavanagh

ASTRON/University of Amsterdam, the Netherlands

ASTRON

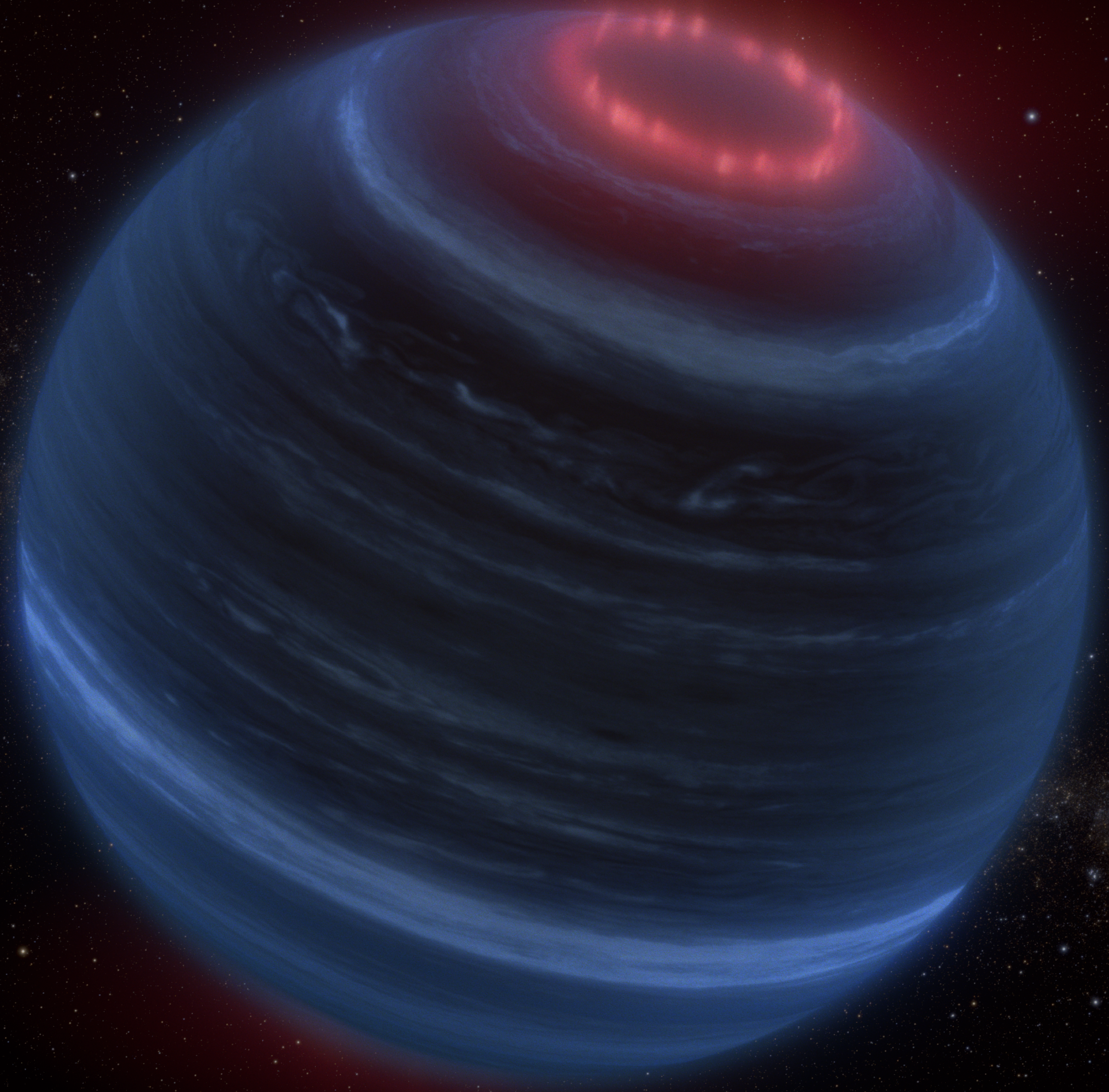
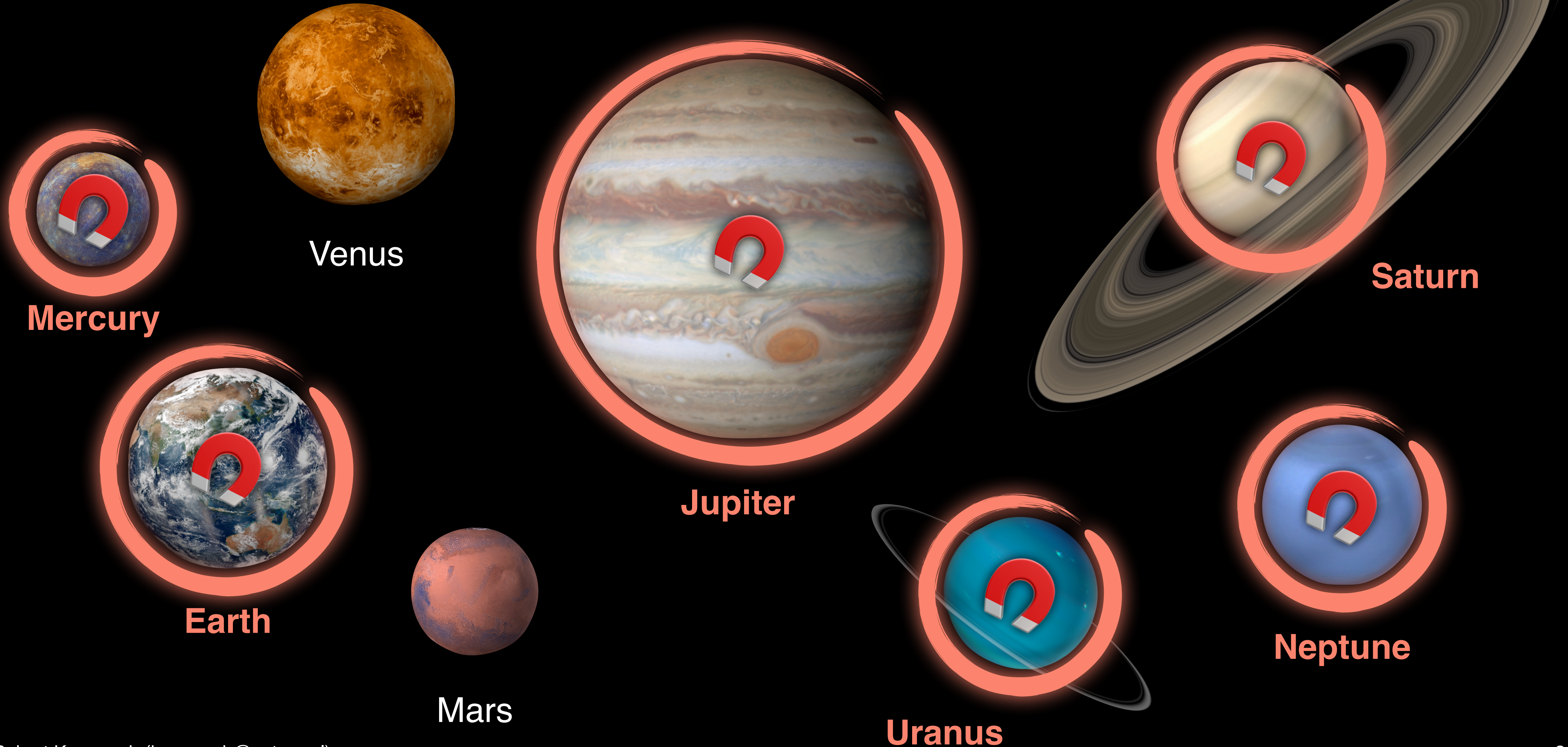


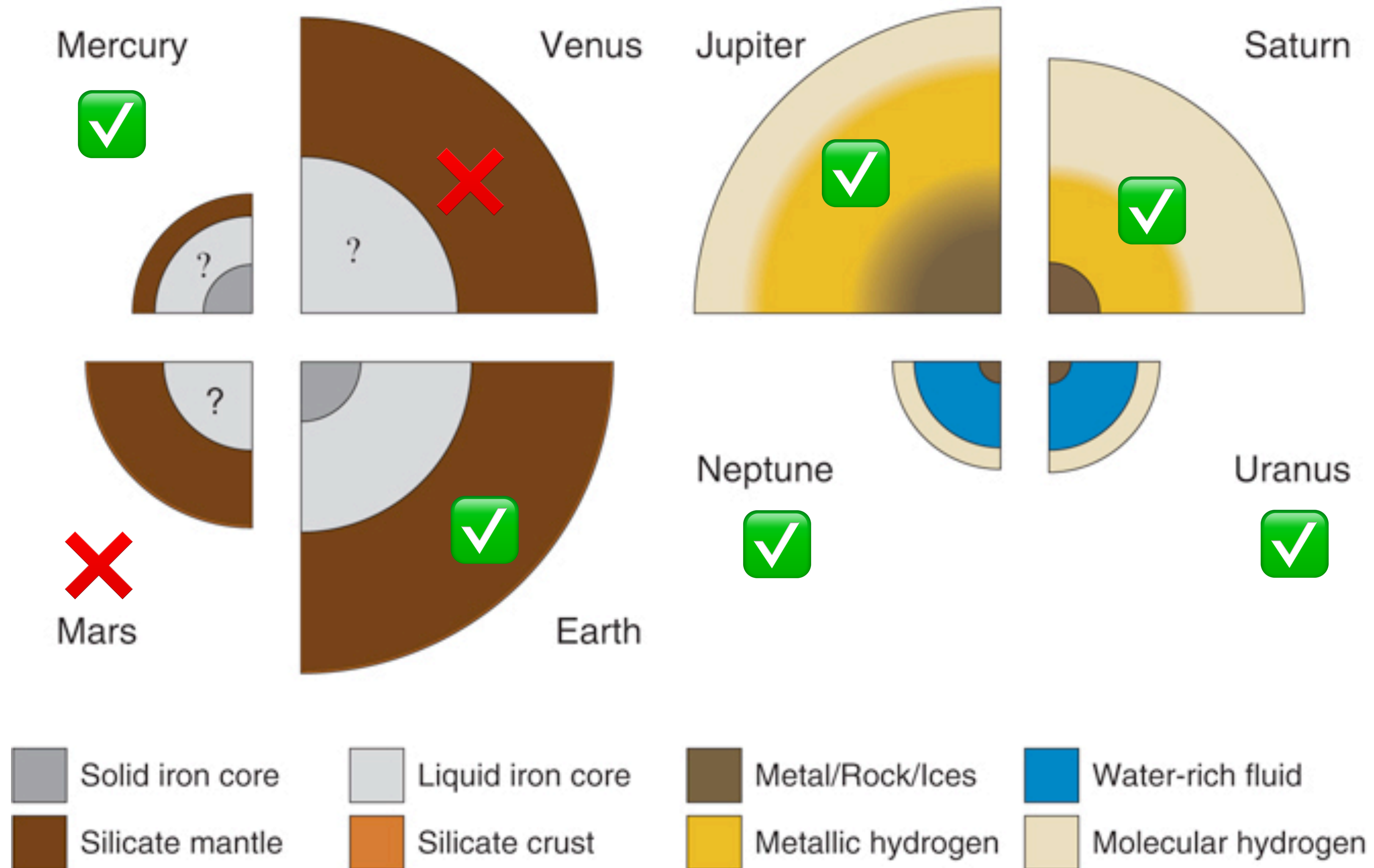
Image: Leah Hustak

Planet diversity in our solar system



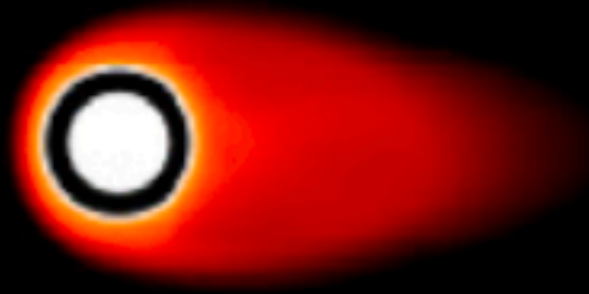
Interior design

Salyk & Lewis (2020)

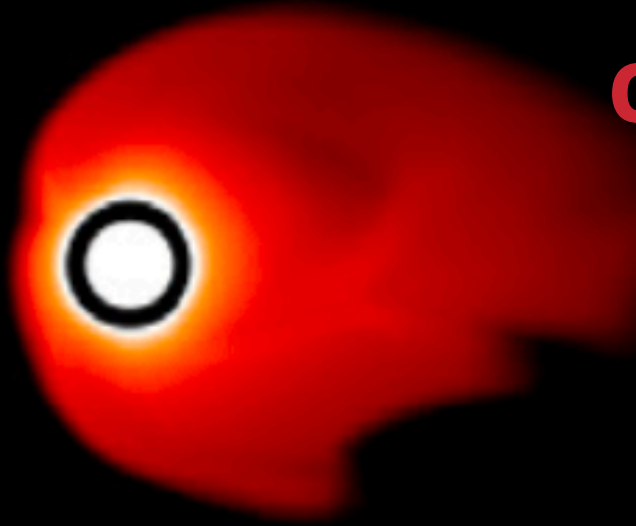


Magnetic fields shape atmospheric escape

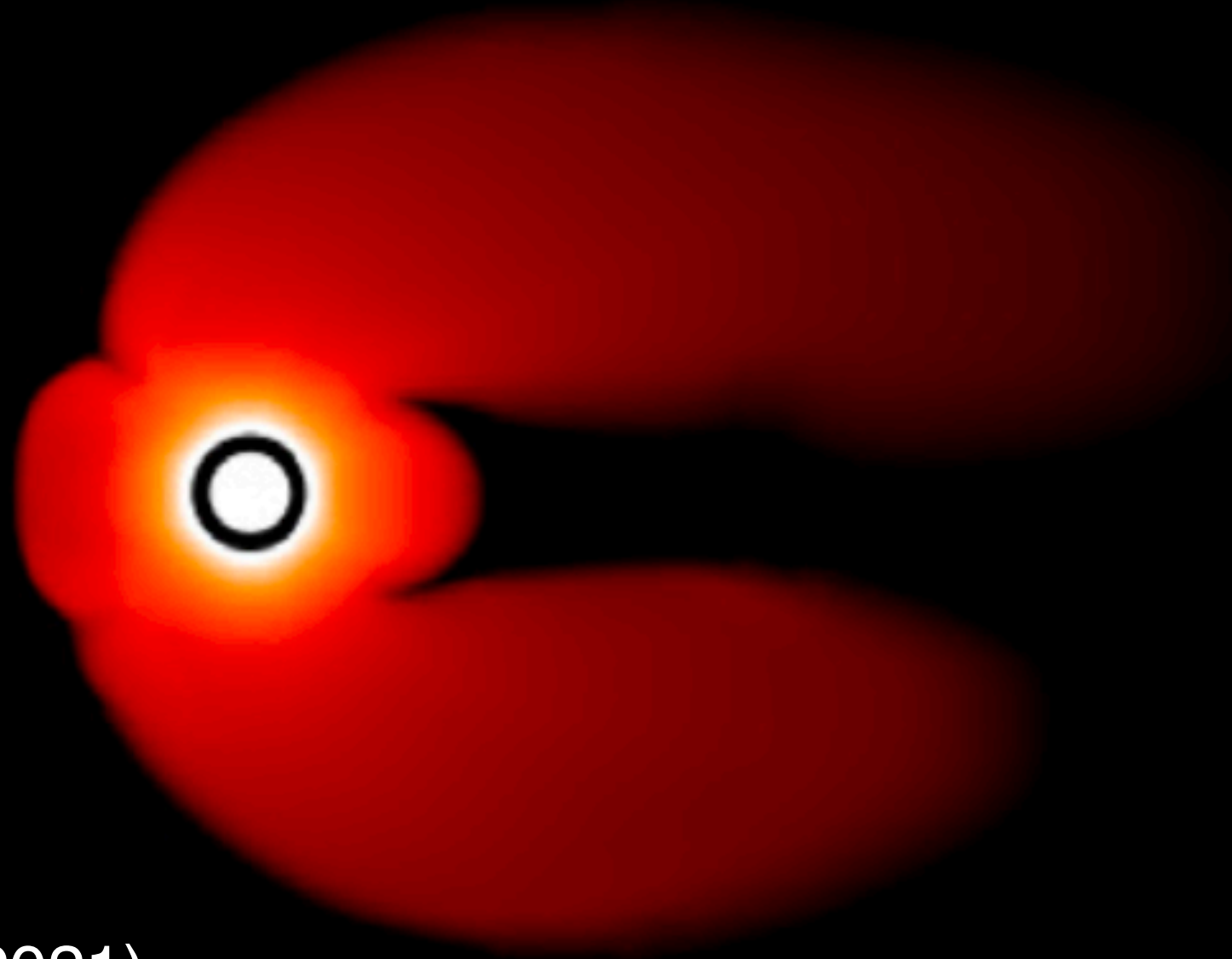
No magnetic field



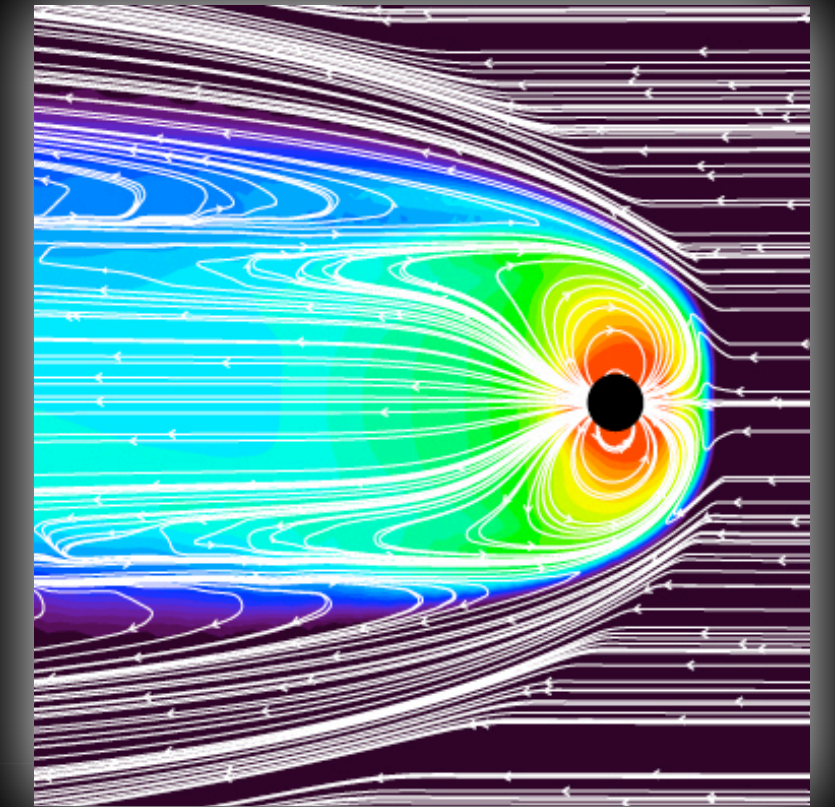
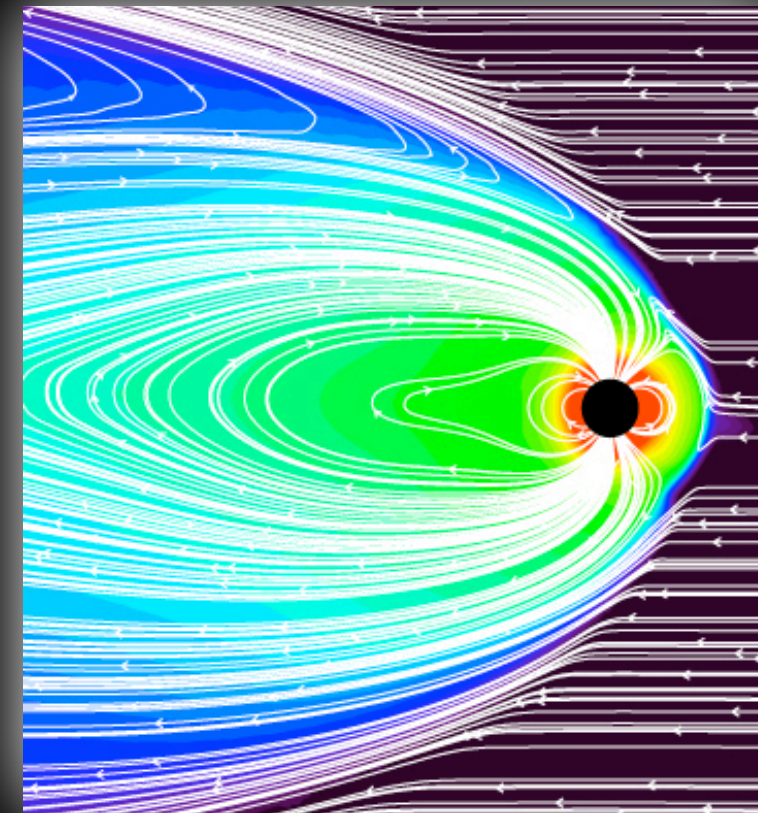
1 G



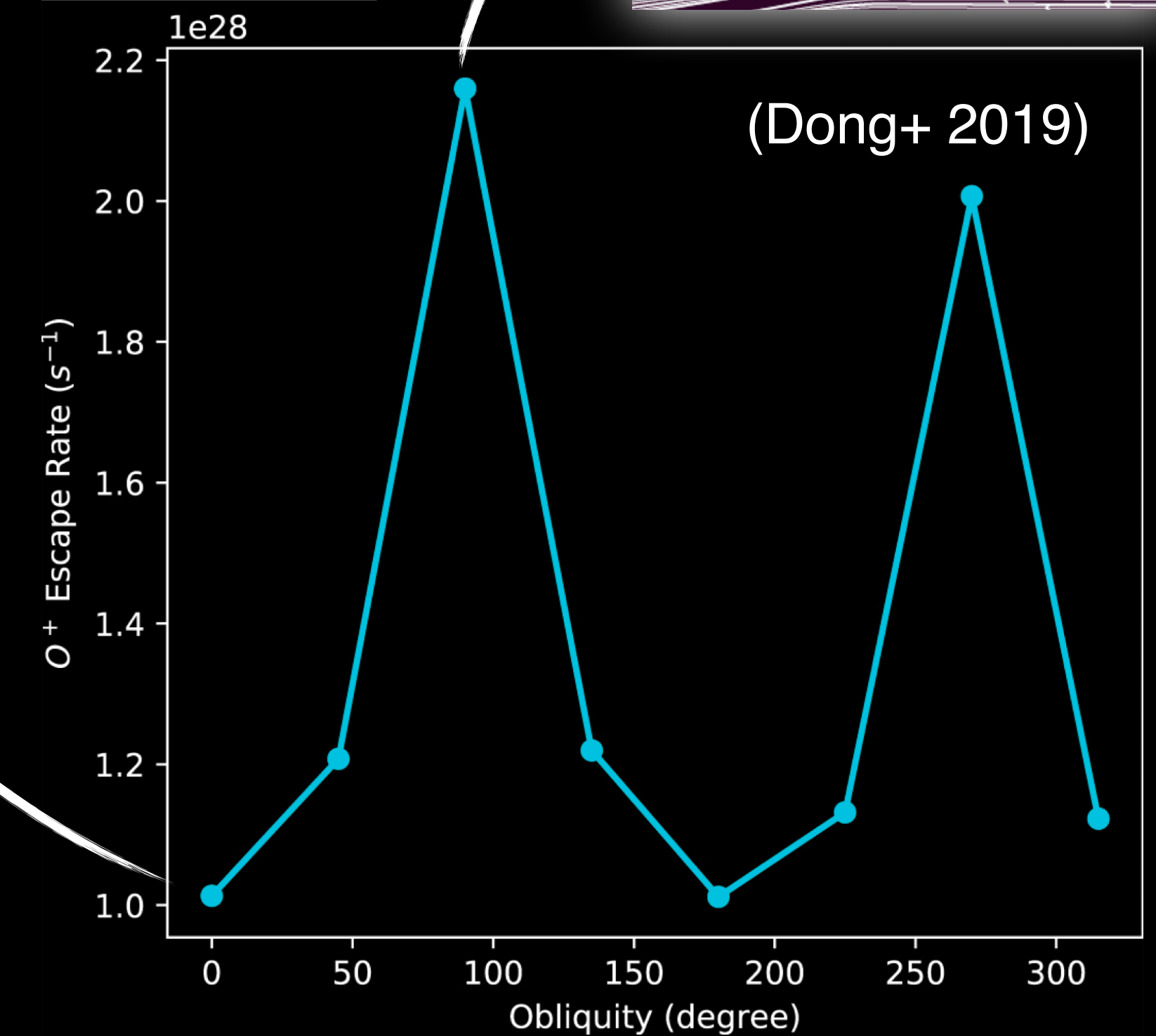
10 G



Field strength controls escape of neutral hydrogen

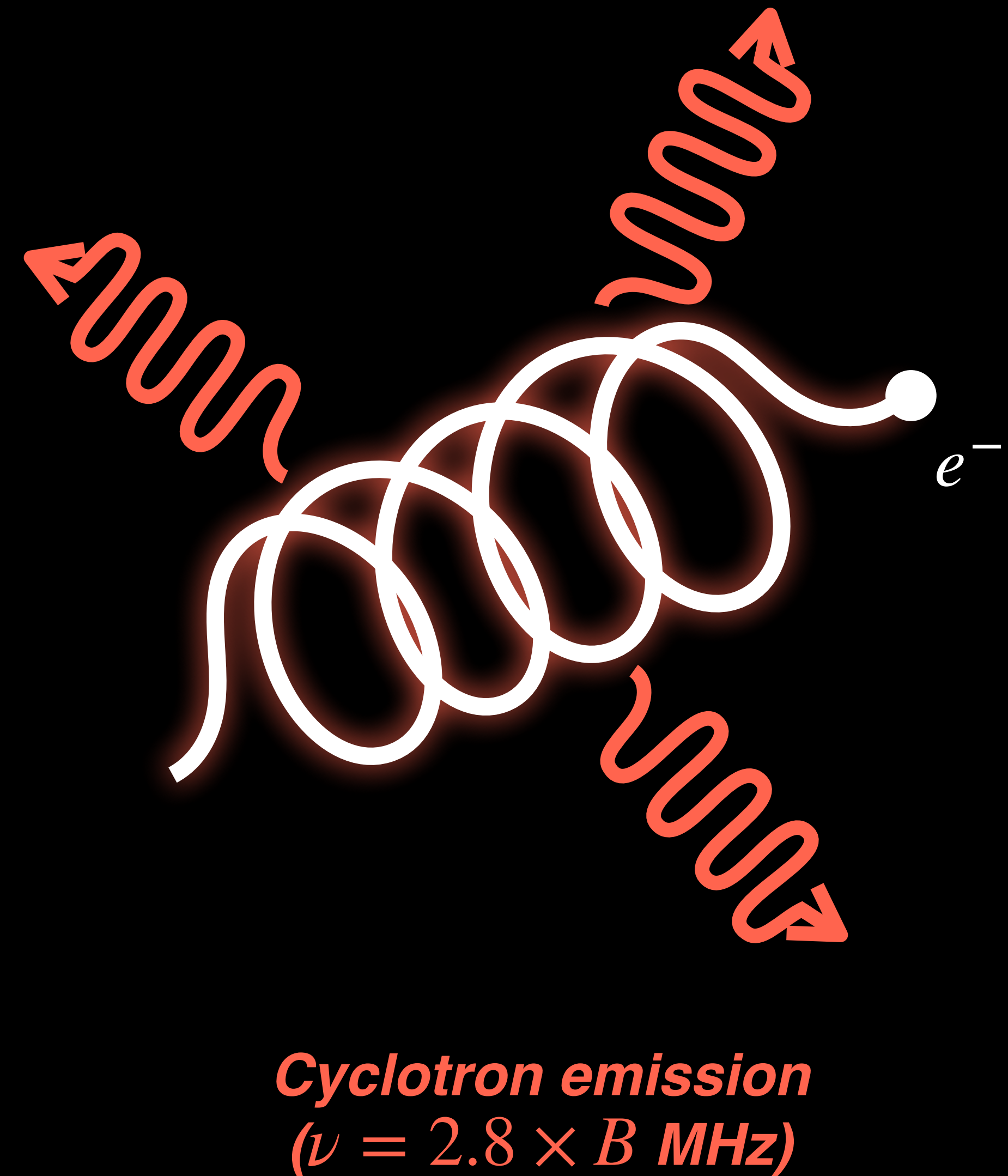
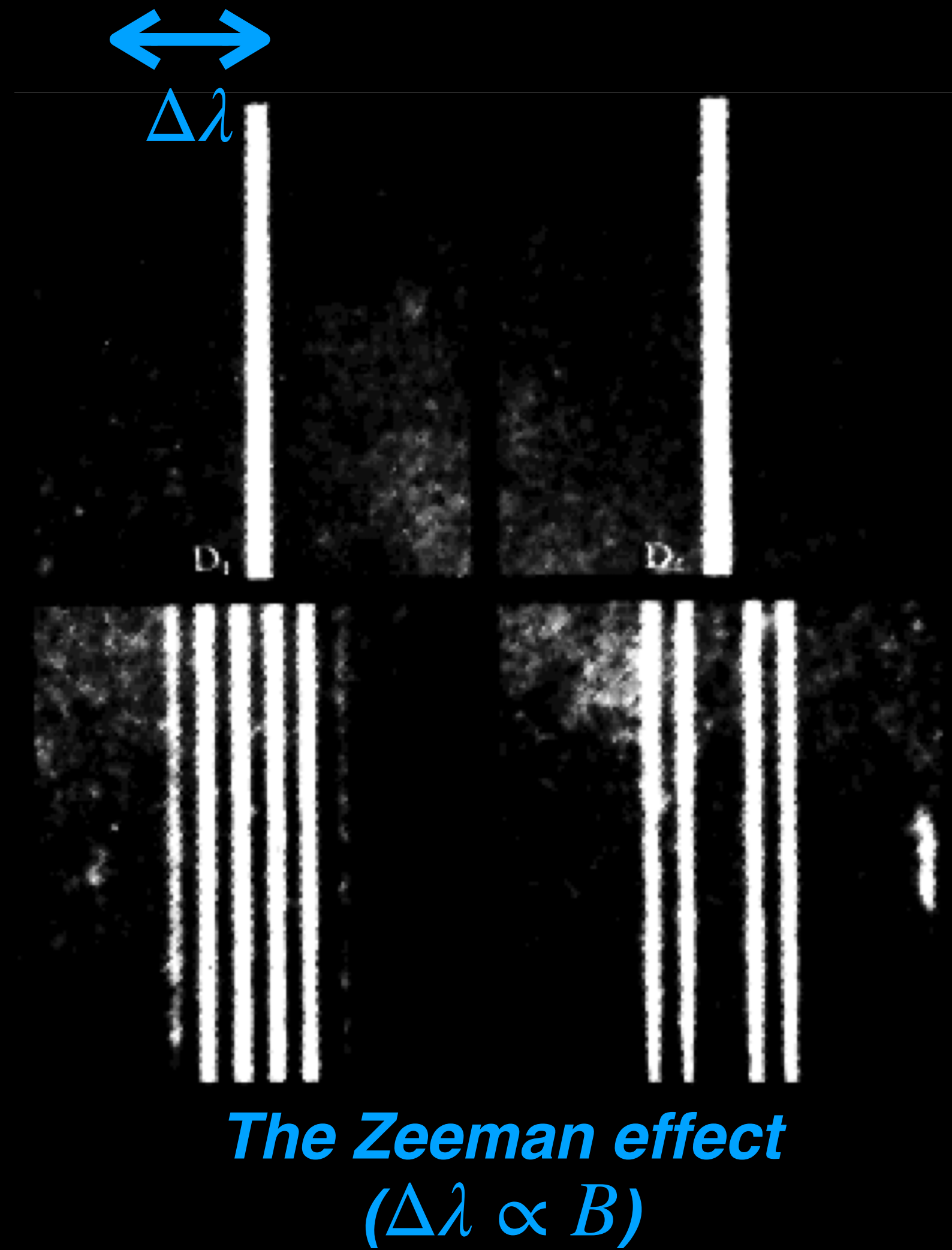


+ geometry

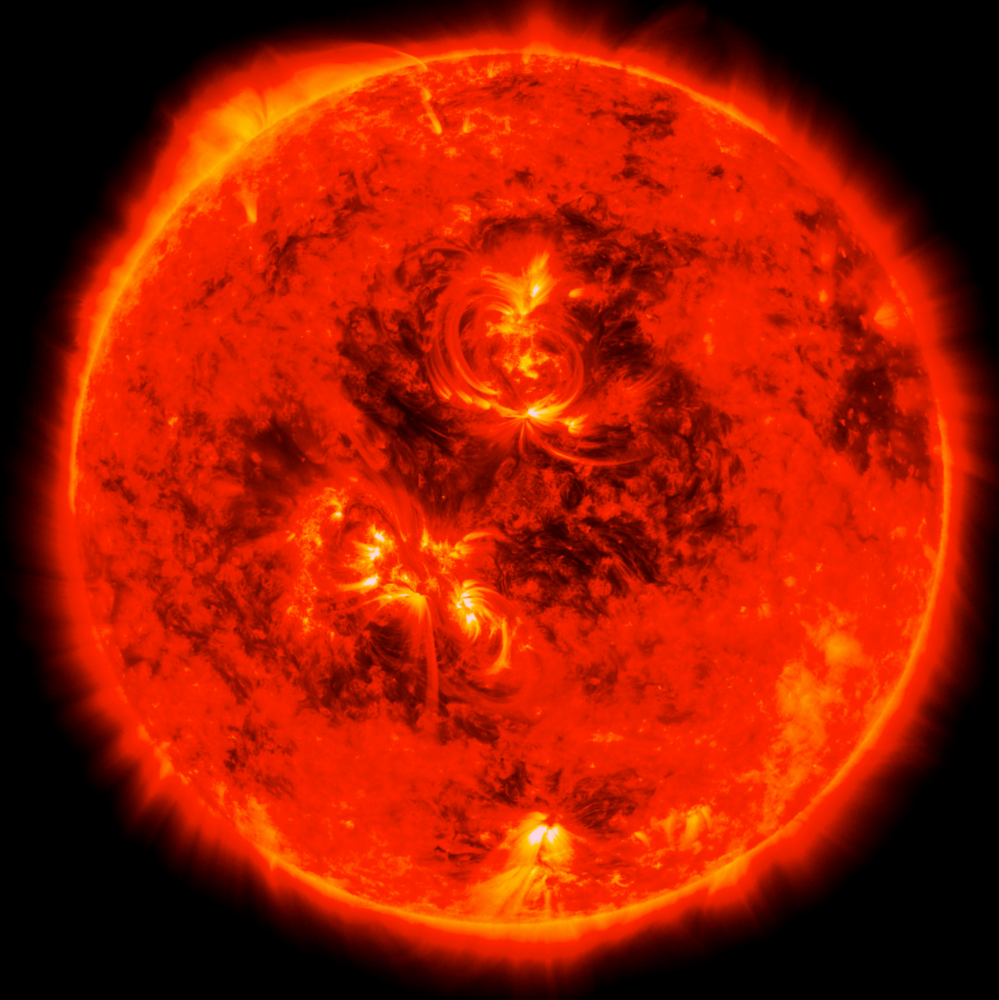


(Carolan+ 2021)

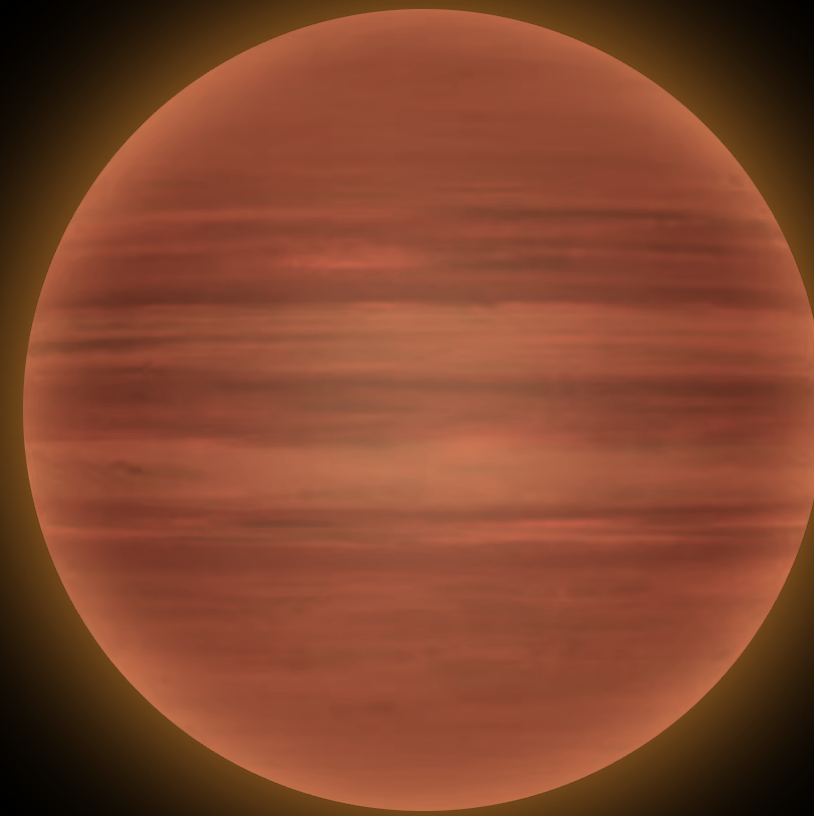
Direct measurements of magnetic fields



Bridging a knowledge gap



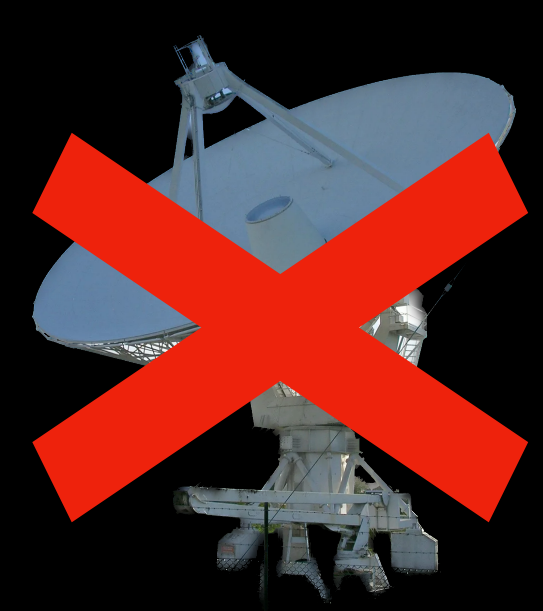
late M dwarf ($\lesssim M7$)



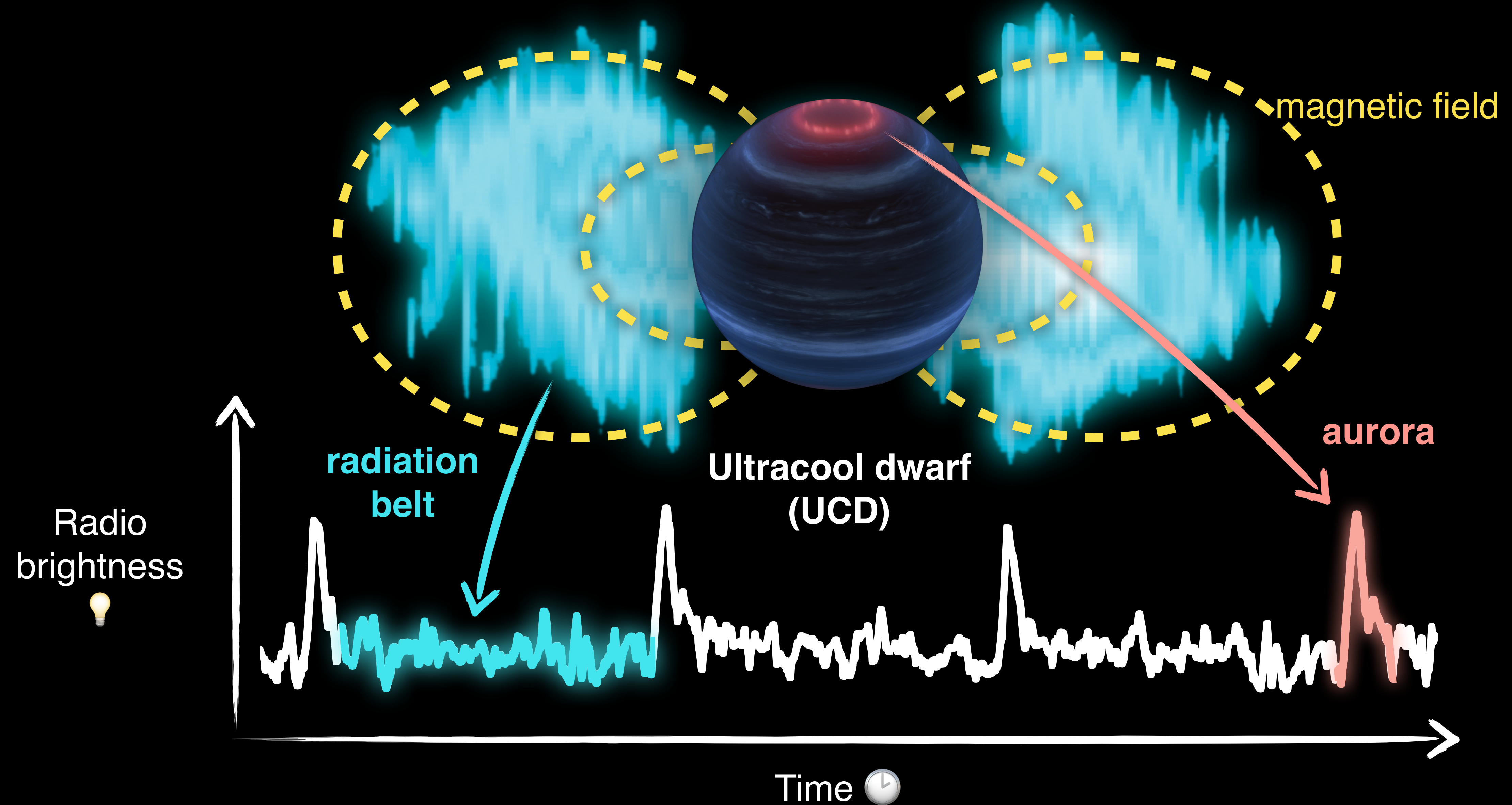
ultracool dwarf
(UCD)



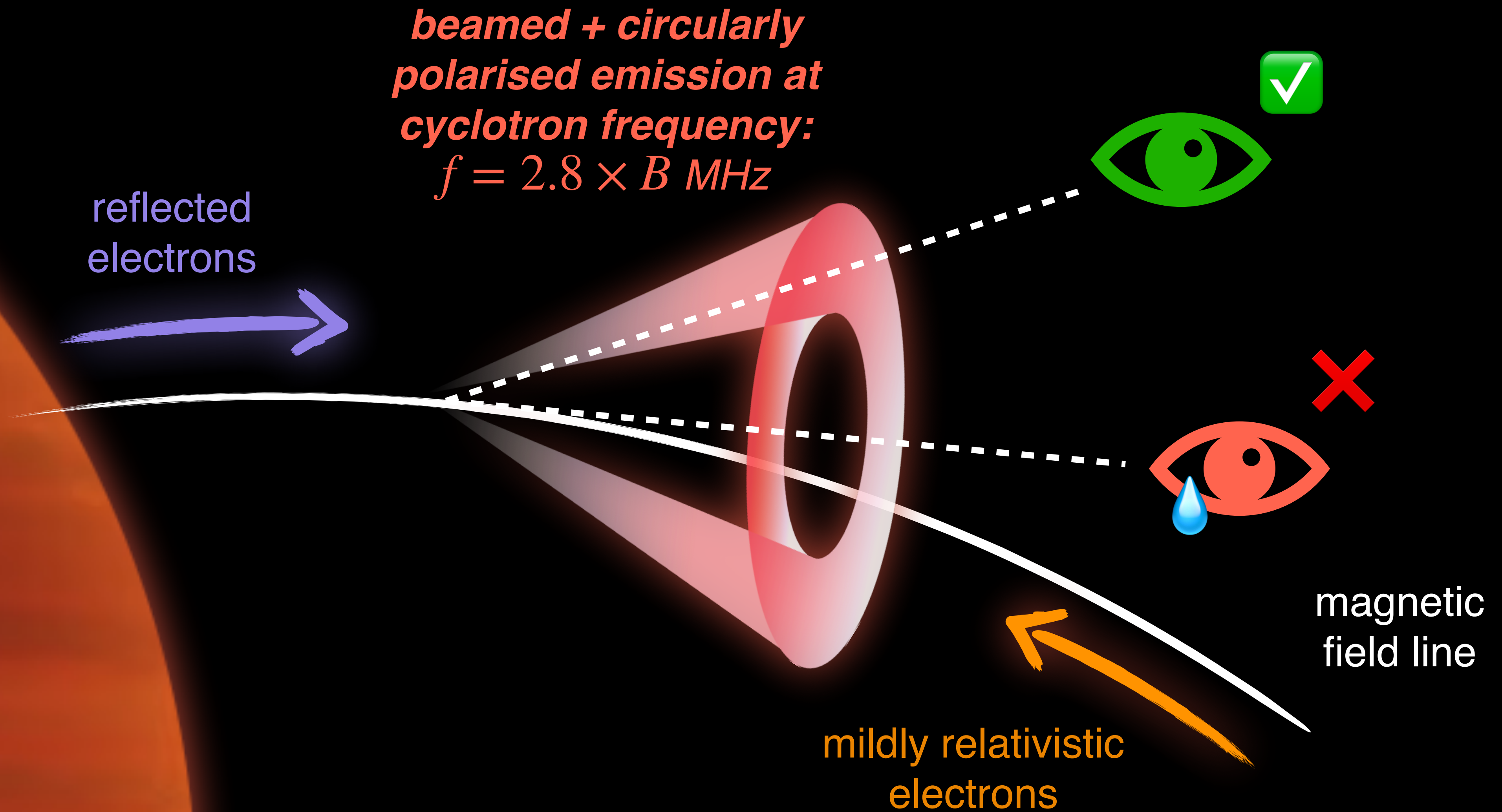
exoplanet



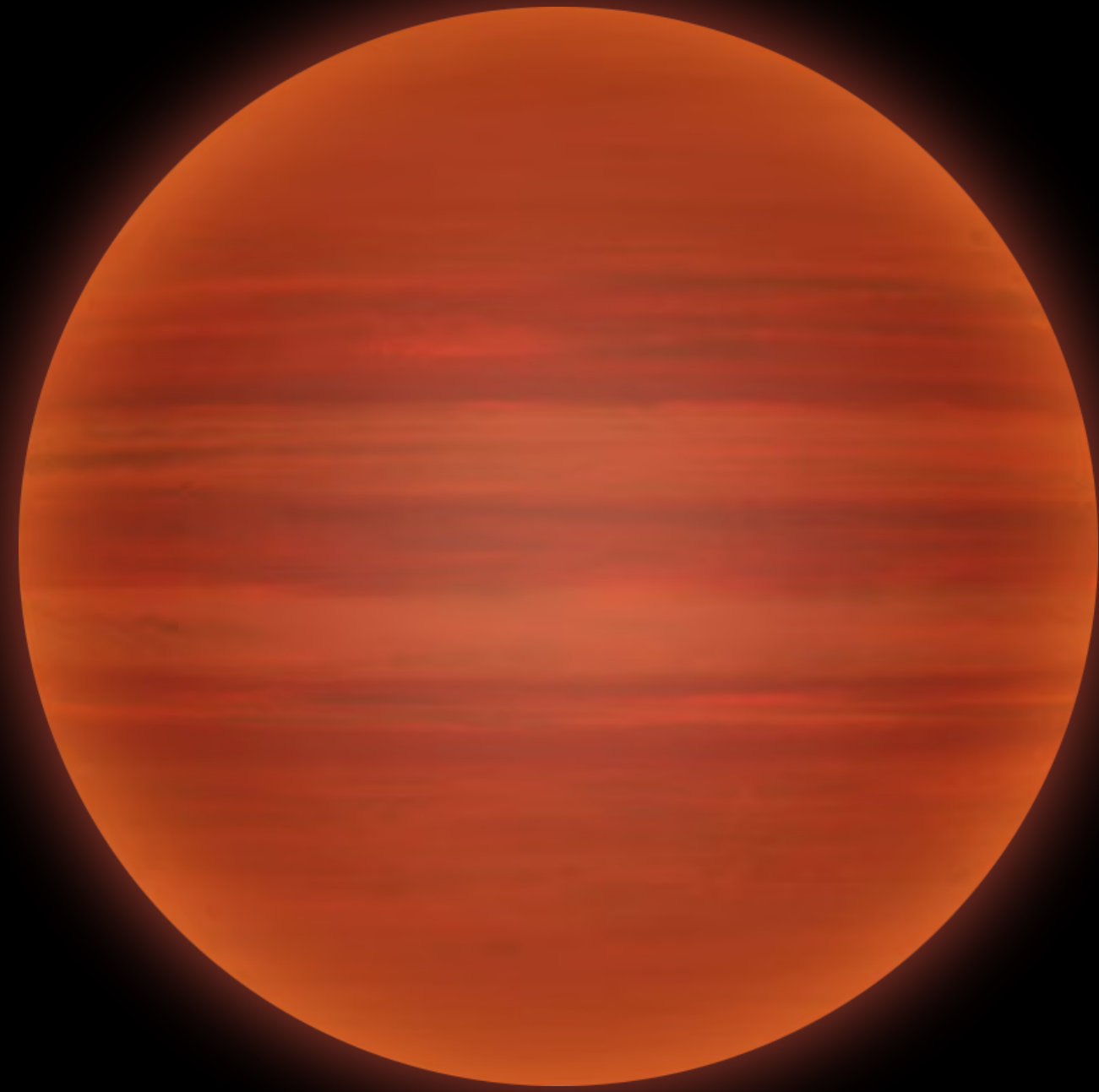
Radio processes on ultracool dwarfs 📻



Auroral emission is encoded with the field characteristics

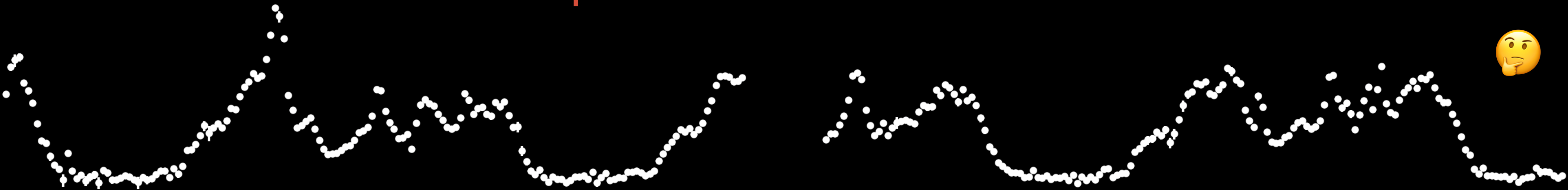


Puzzling periodic pulses

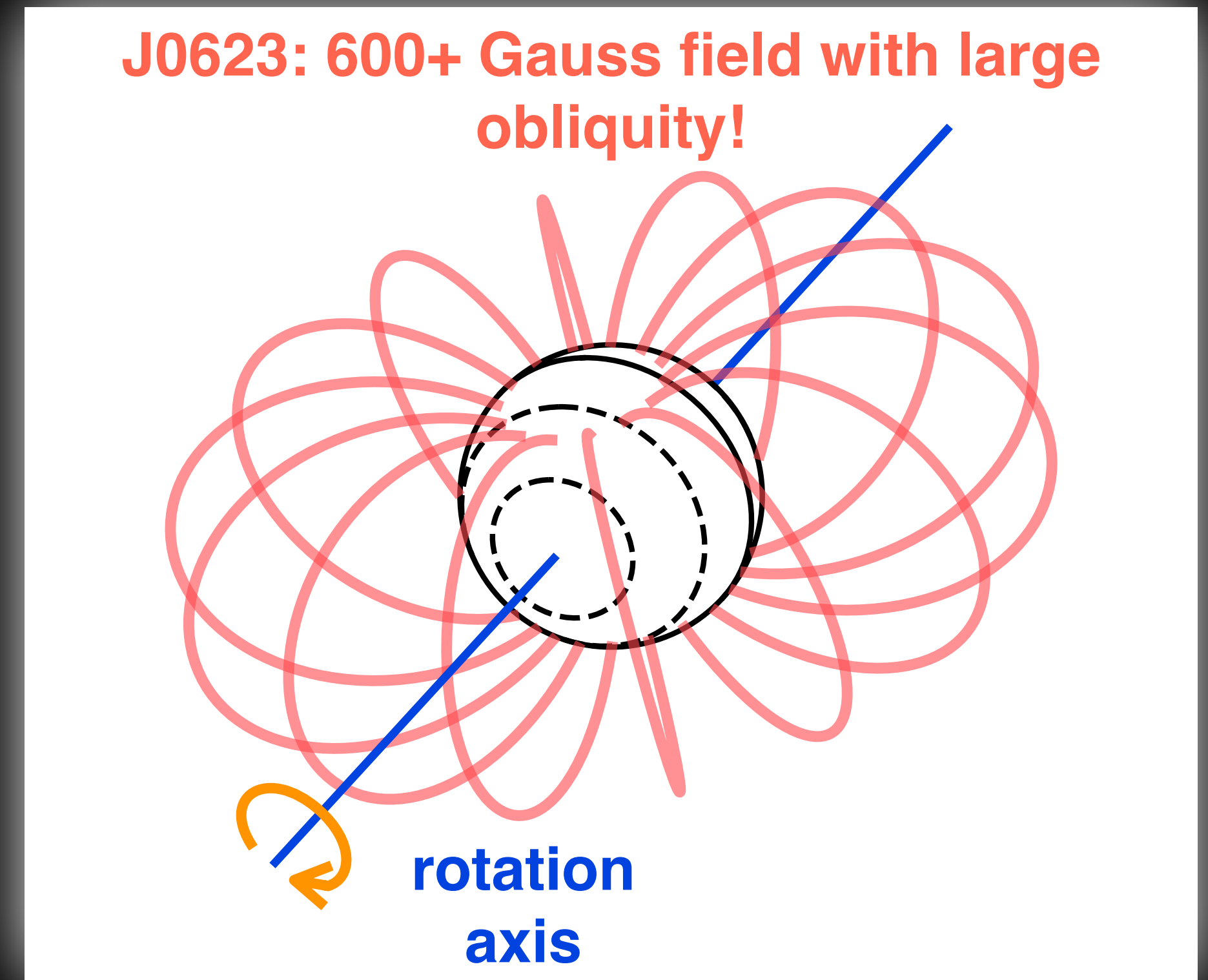
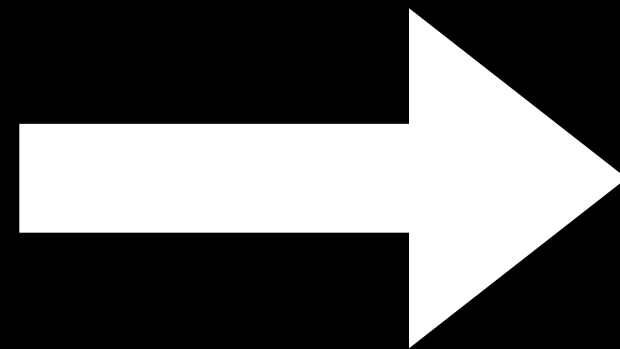
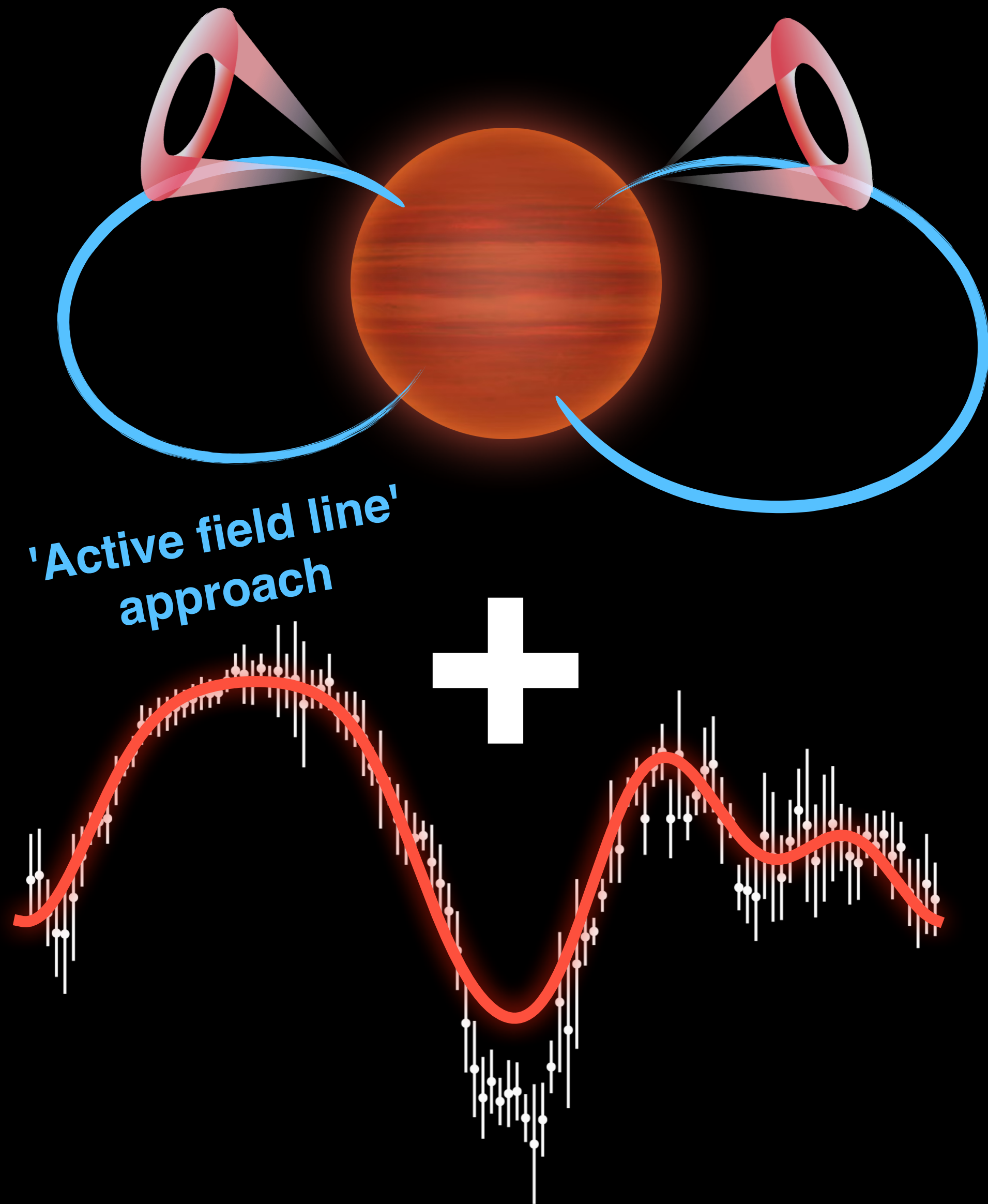


$$T_{\text{eff}} \sim 700 \text{ K}$$

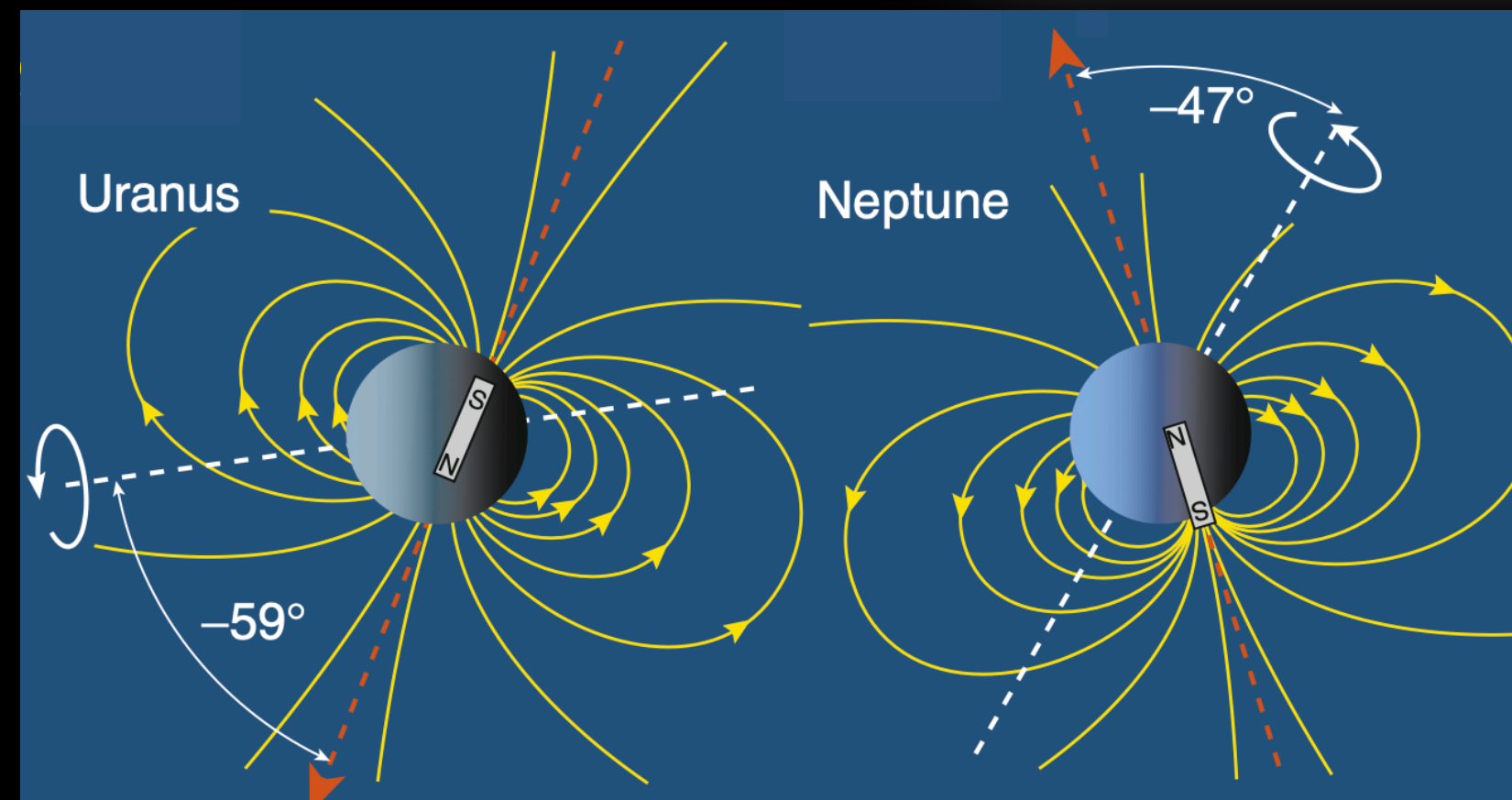
20 Jupiter-mass ultracool dwarf J0623



Magnetic geometry retrieval

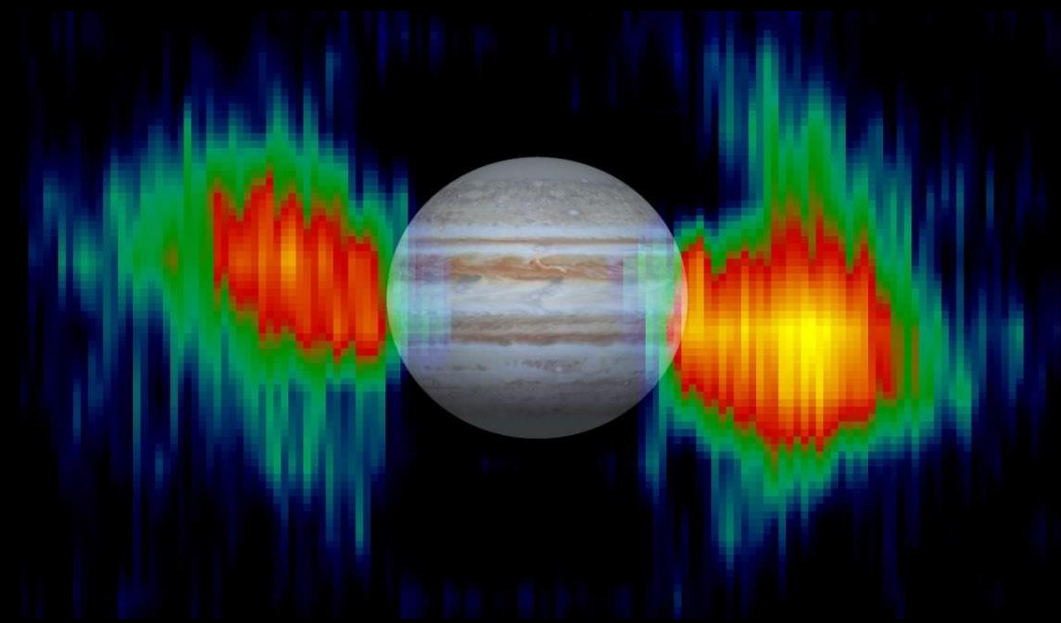


Kavanagh+ (2024)

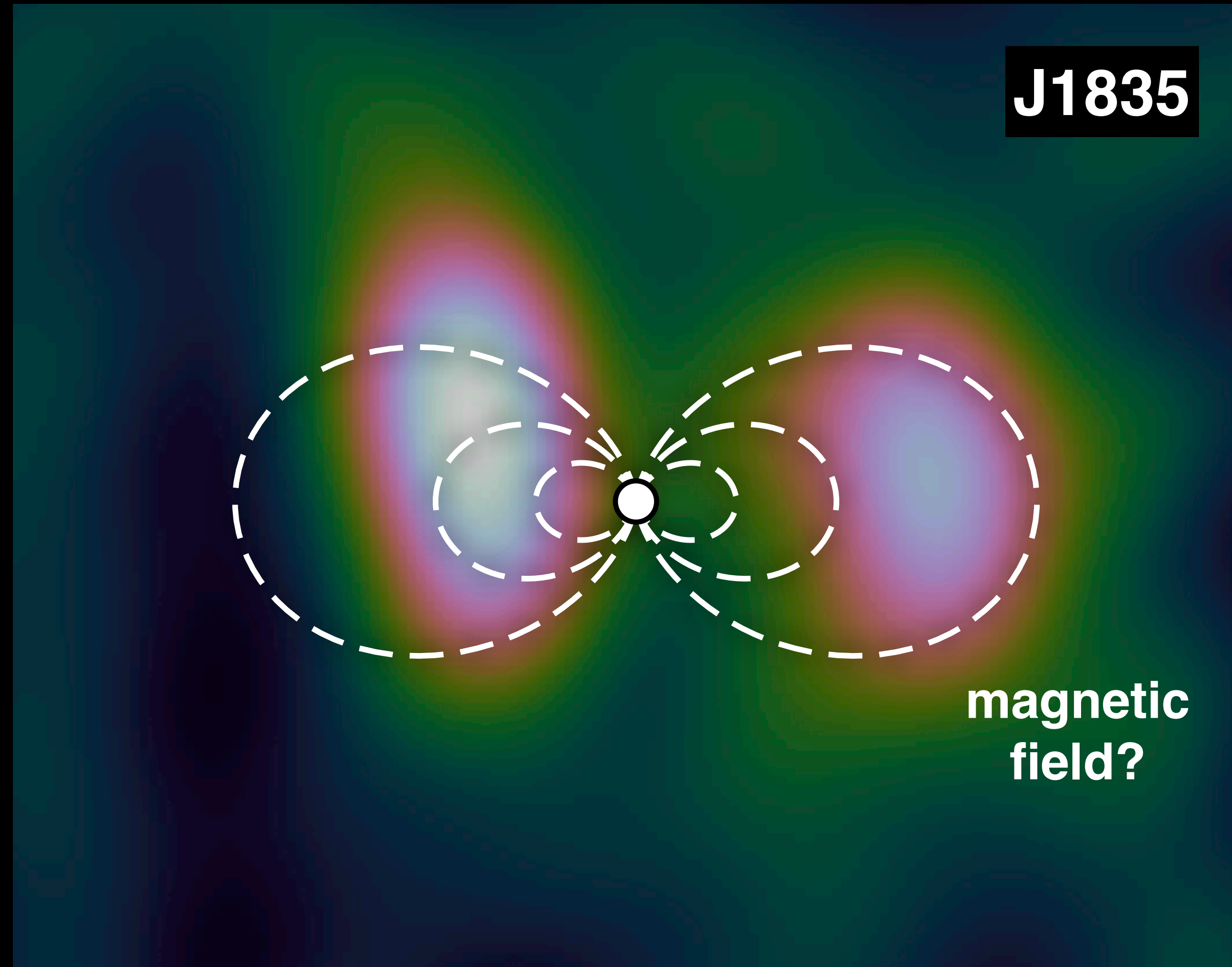


Bagenal (2013)

The first spatially-resolved extrasolar radiation belt

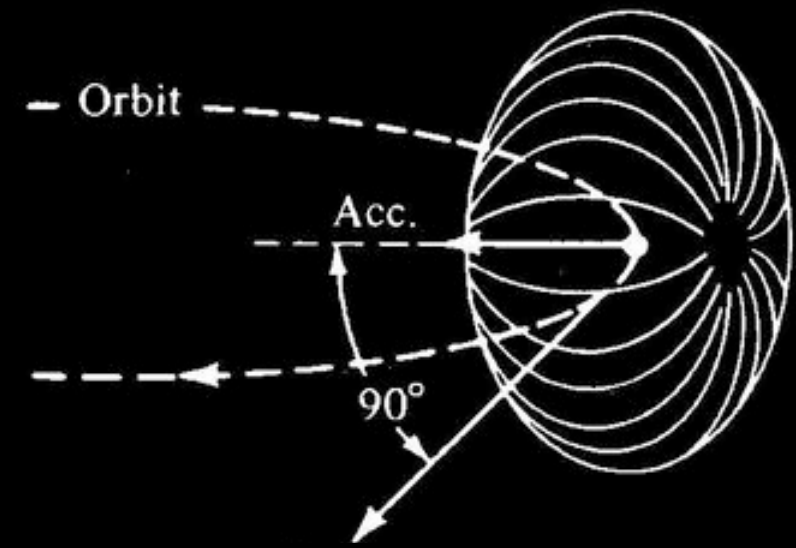


Jupiter

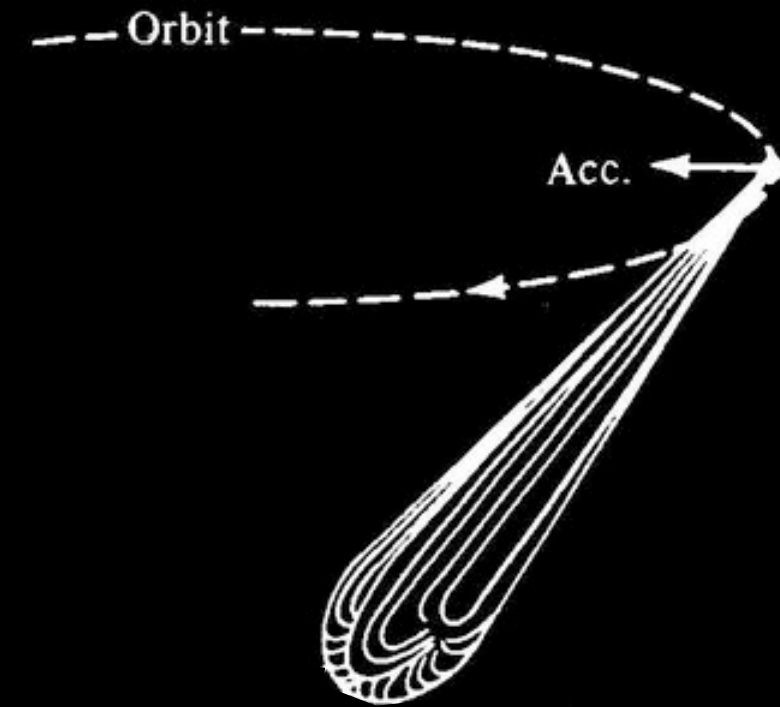


From Climent+ (2023) – see also Kao+ (2023)

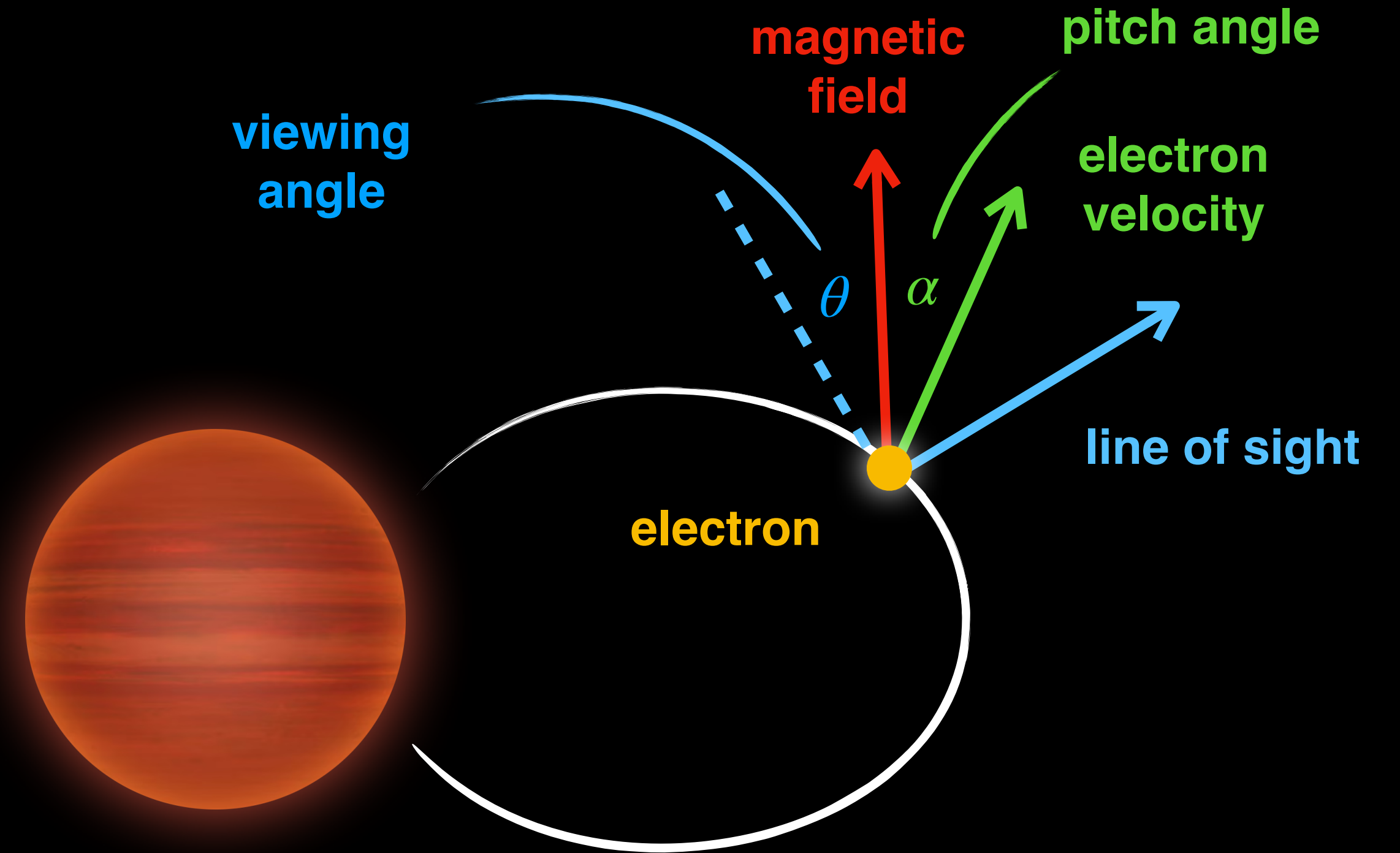
Synchrotron emission from radiation belts



Velocity $\ll$ speed of light



Velocity $\lesssim$ speed of light

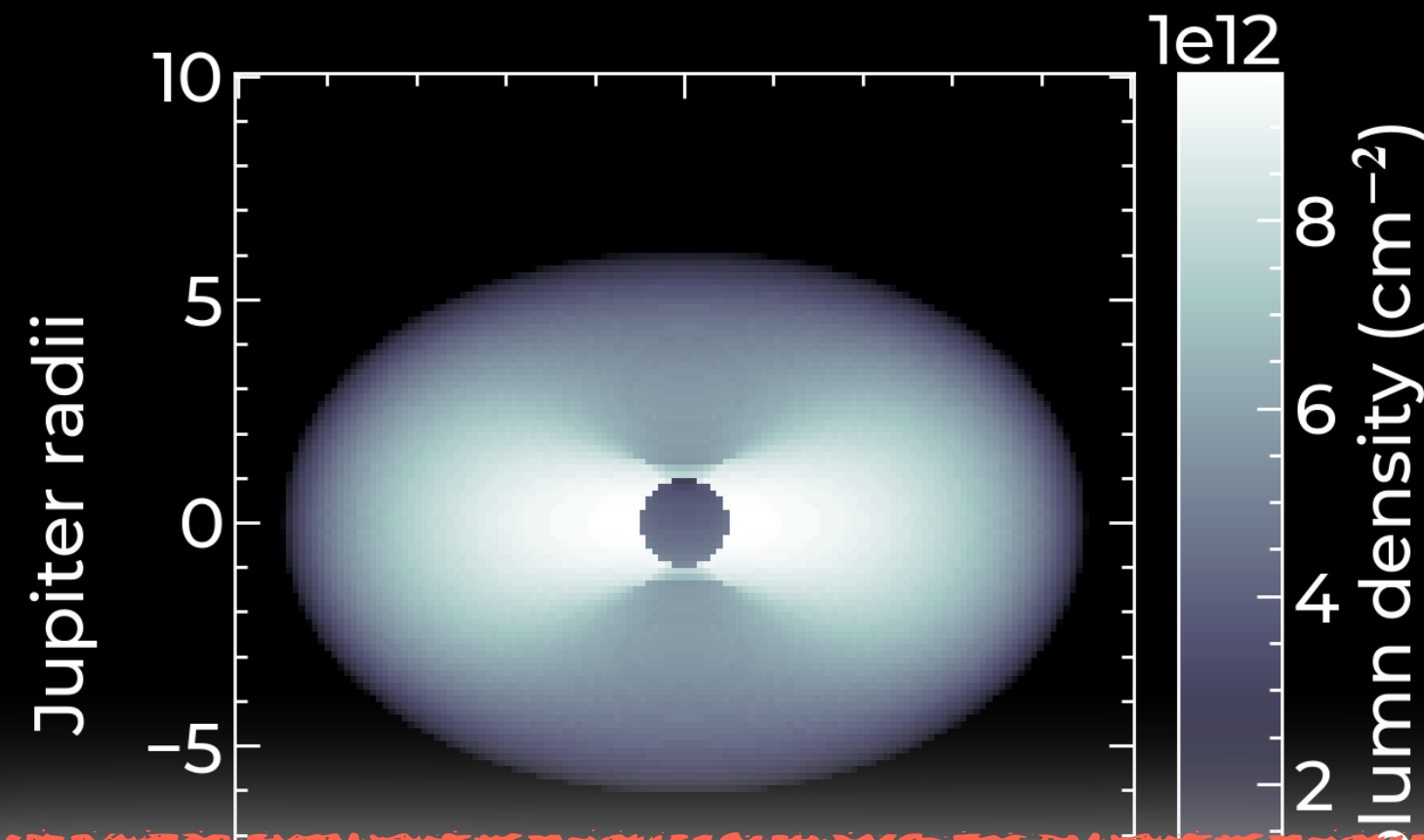


$$\text{Emissivity} = \frac{em}{6c^2\pi^3} \frac{1}{B\gamma} \left(\frac{u\omega\theta_\gamma}{\sin\alpha} \right)^2 \left(\theta^2 K_{1/3}^2(\eta) + \frac{\theta_\gamma^2}{\gamma^2} K_{2/3}^2(\eta) \right)$$

Polarised image synthesis for UCD radiation belts

Parameters:

- 60 deg inclination
- 1 kG field
- Observing at 1 GHz
- 20 MeV electrons
- 80 deg pitch angle
- 100 cm^{-3} electrons
- 9 Jupiter radii magnetosphere

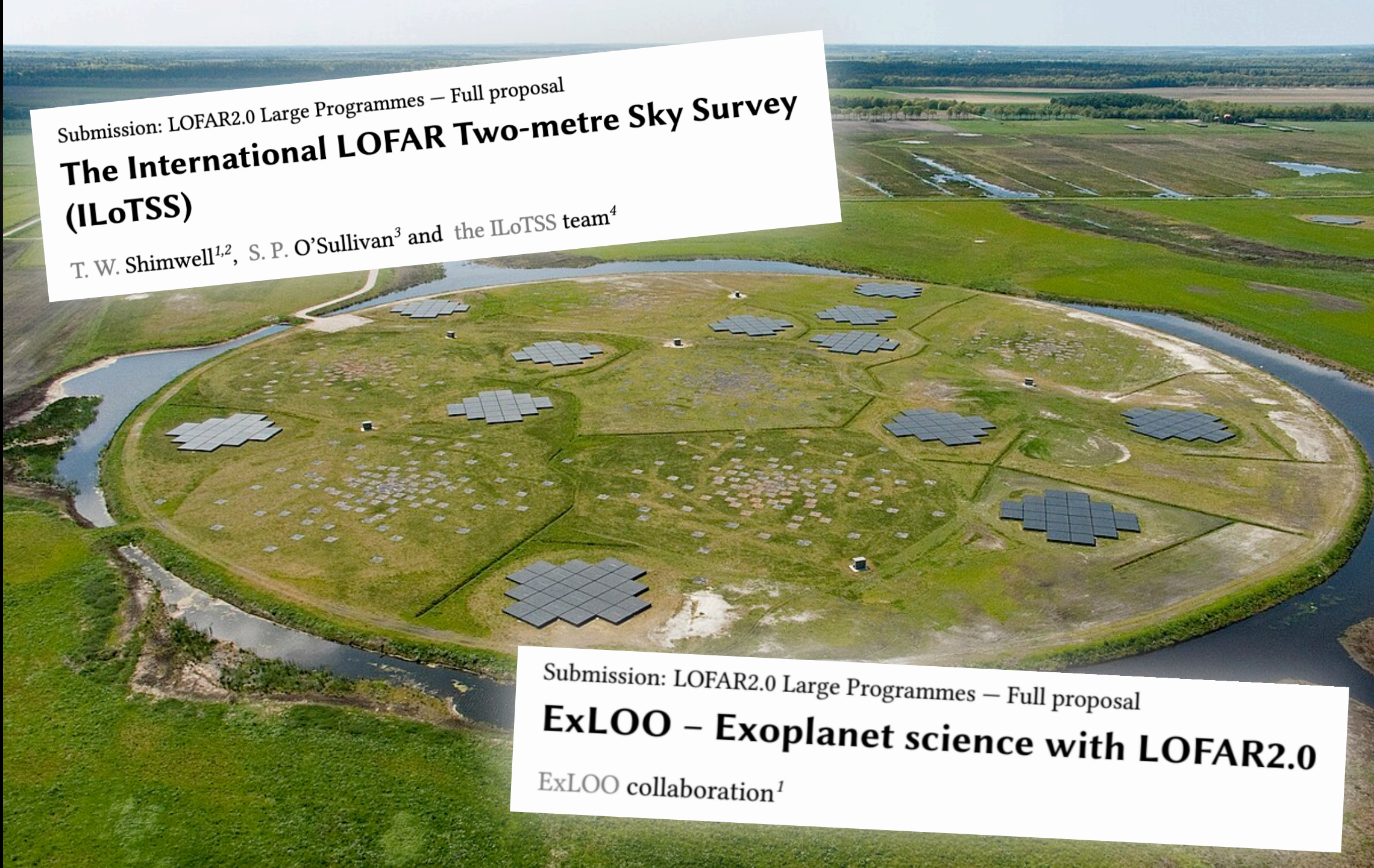


To do:

- Magnetic field characteristics + electron properties for J1835
- Predict resolvable radiation belts on other UCDs?

Kavanagh+ (in prep.)

Future prospects



Upcoming large surveys with LOFAR 2.0

See poster for SKA science meeting next week!



The SKA will be a game-changer!