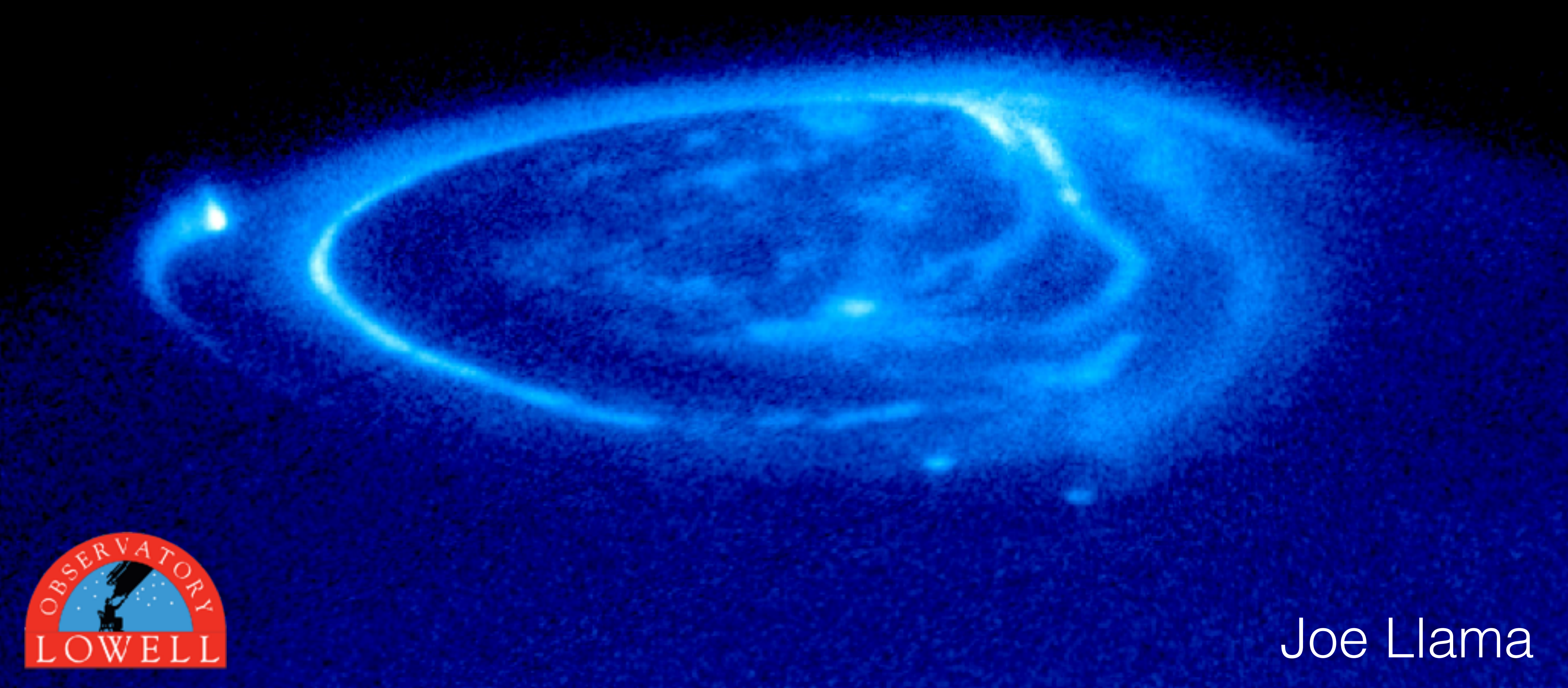
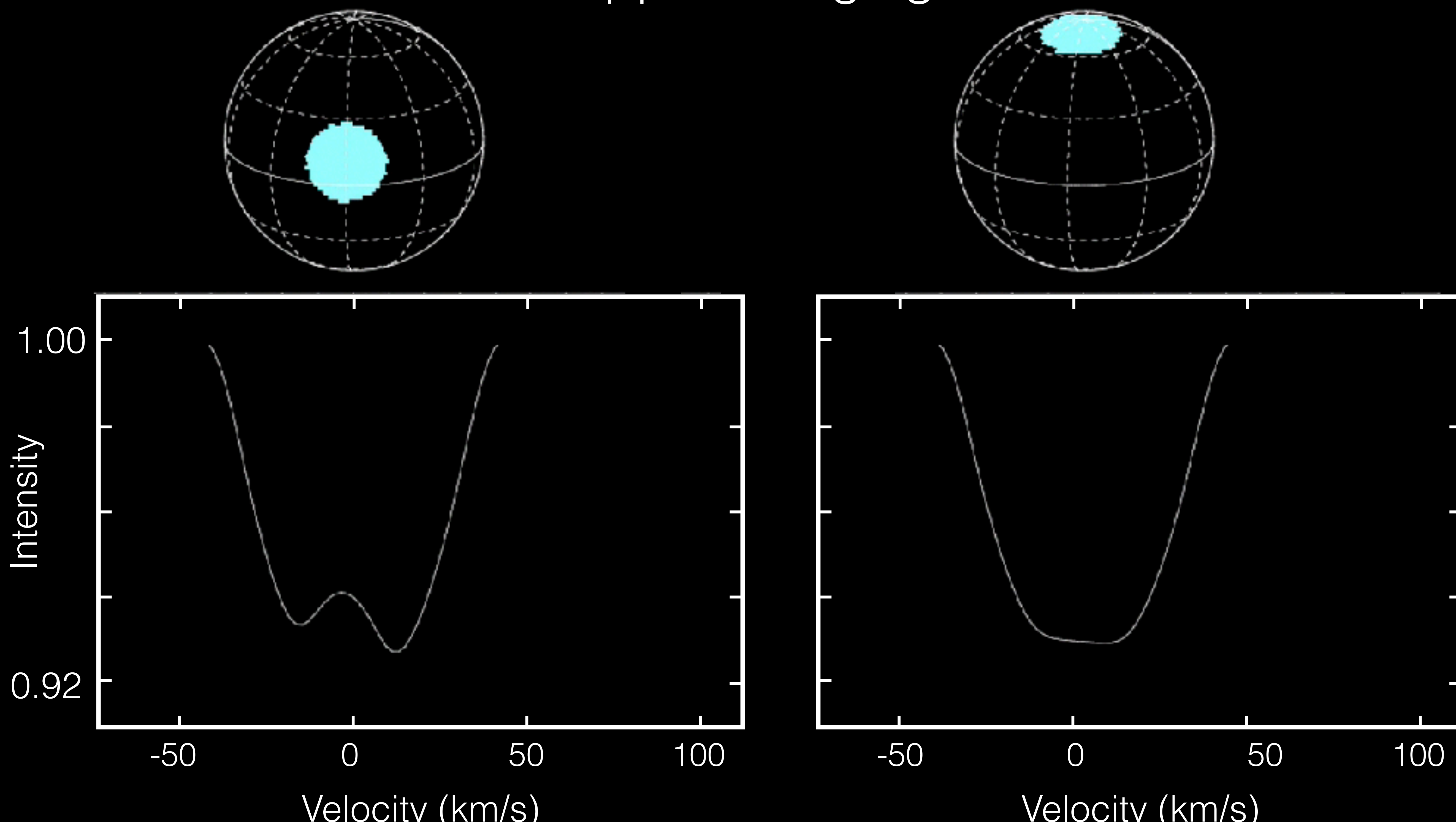
Simulating Electron Cyclotron Maser Emission from Low Mass Stars



Joe Llama

How do we map stellar surface magnetic fields?

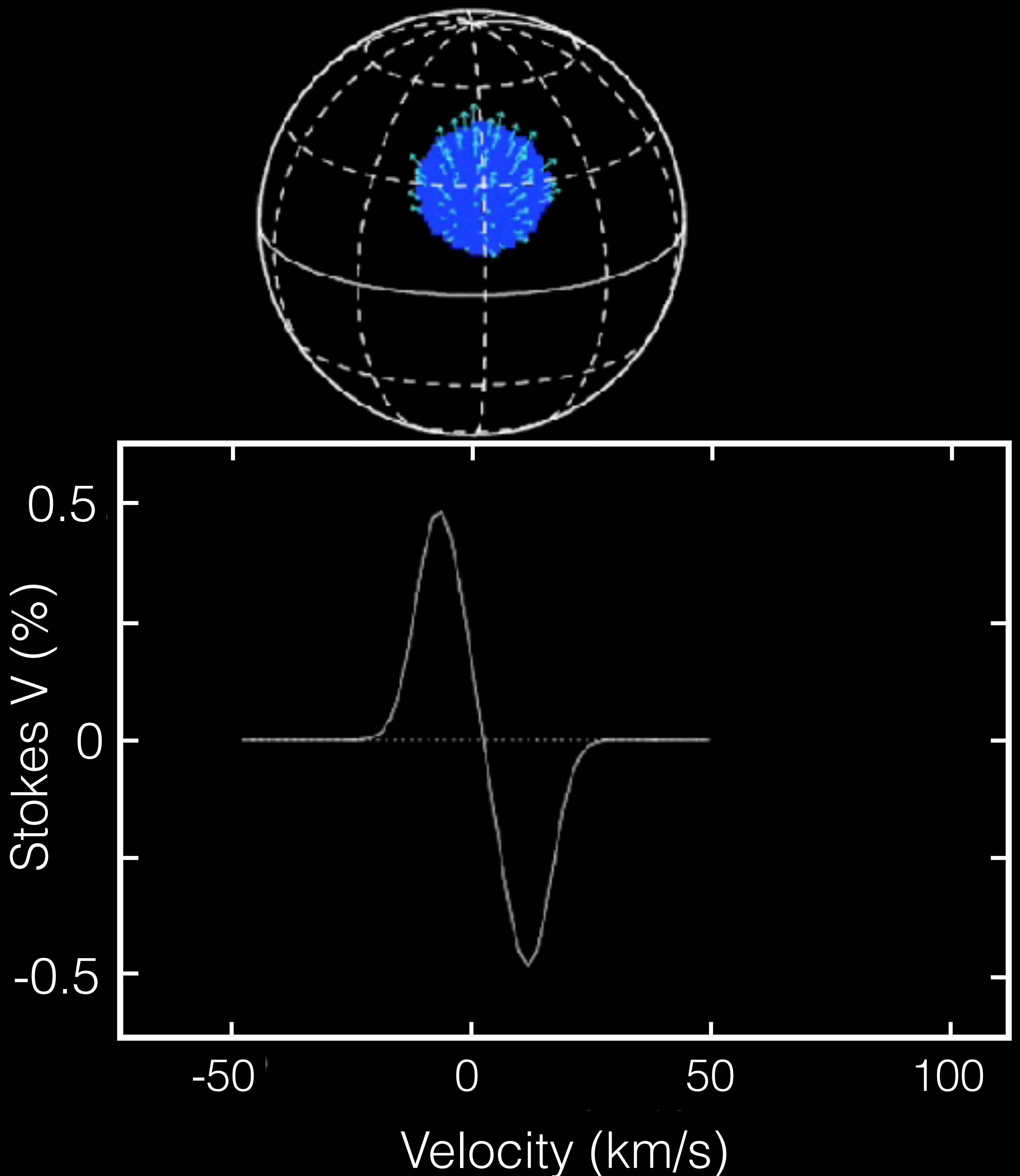
Doppler Imaging



Credit: J-F Donati

How do we map stellar surface magnetic fields?

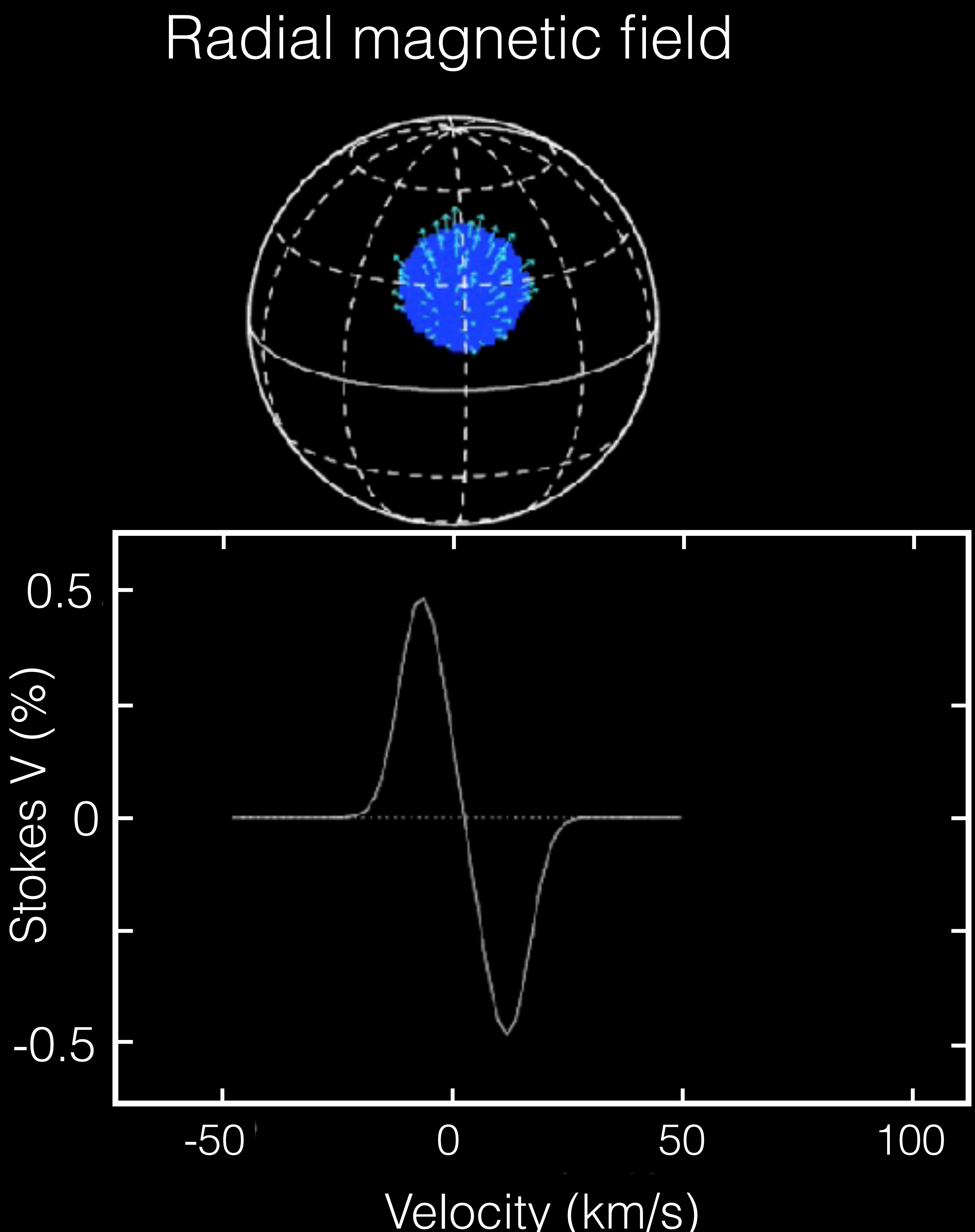
Radial magnetic field

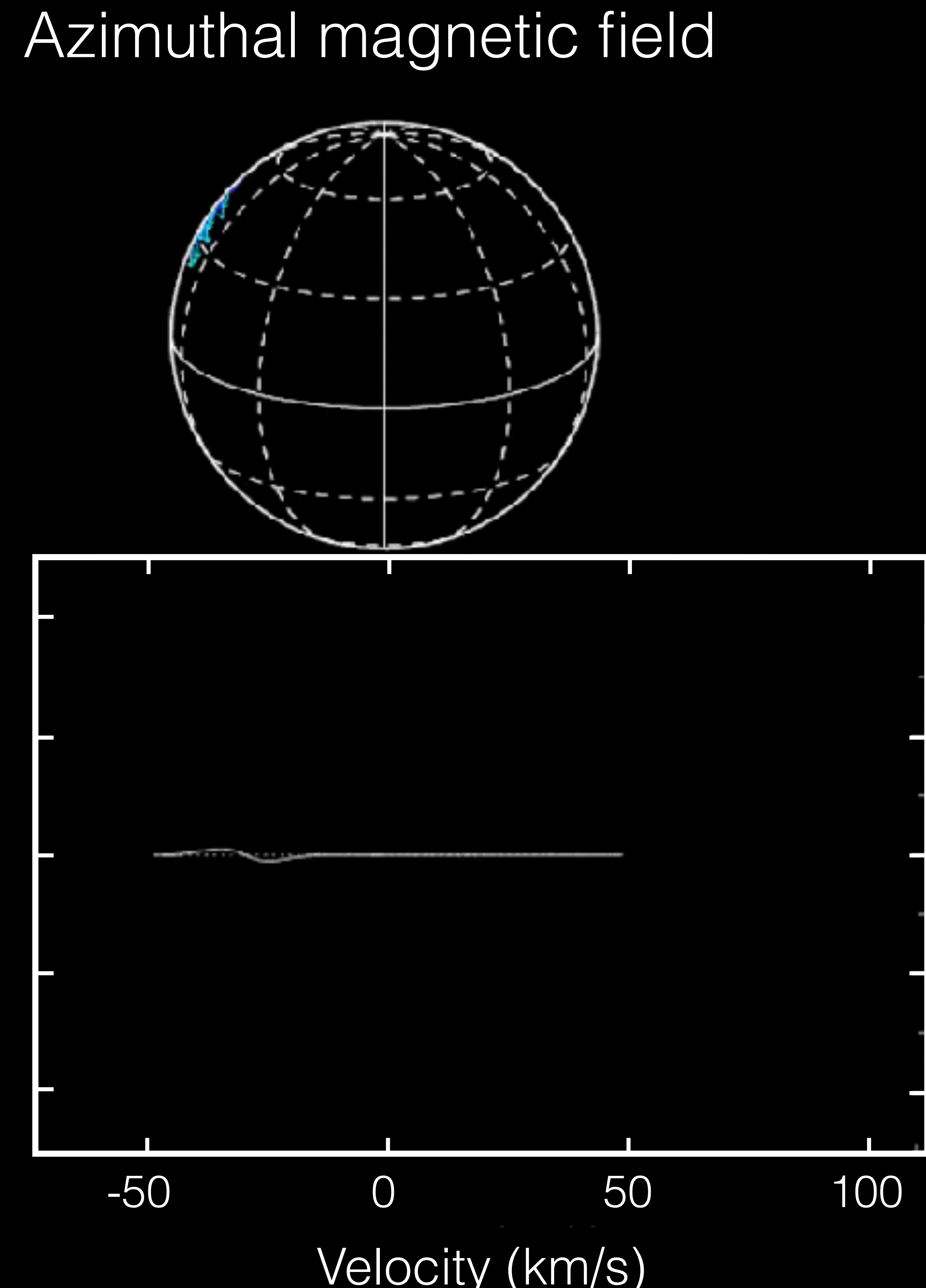


- Zeeman effect: Magnetic field splits lines
- stokes V = ↺ - ↻
- Track Stokes V -> get field along line-of-sight (B_{los}).
- Max amplitude at disk center
- Limitation: Only large scale field is detected

Credit: J-F Donati

How do we map stellar surface magnetic fields?

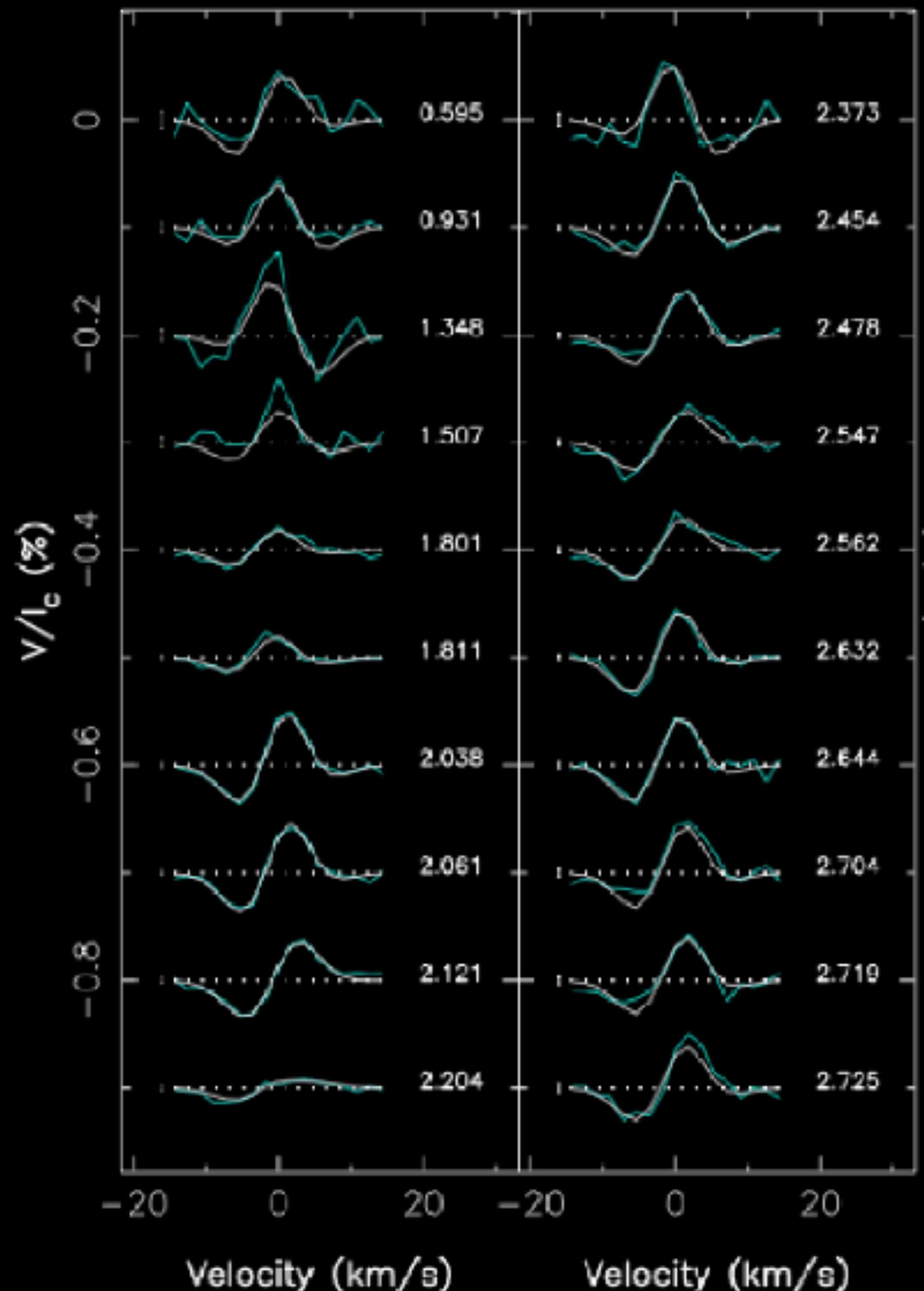




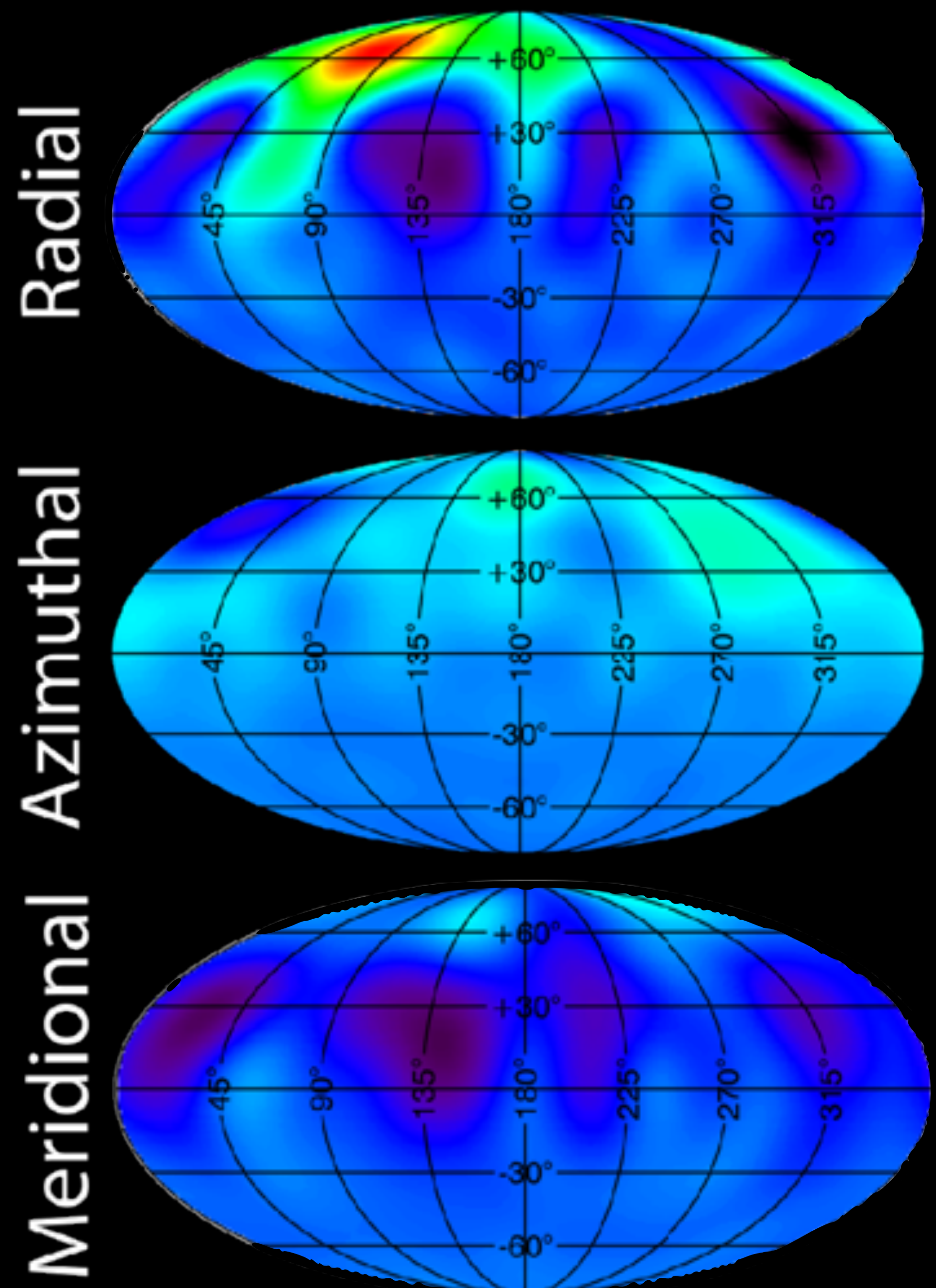
Credit: J-F Donati

How do we map stellar surface magnetic fields?

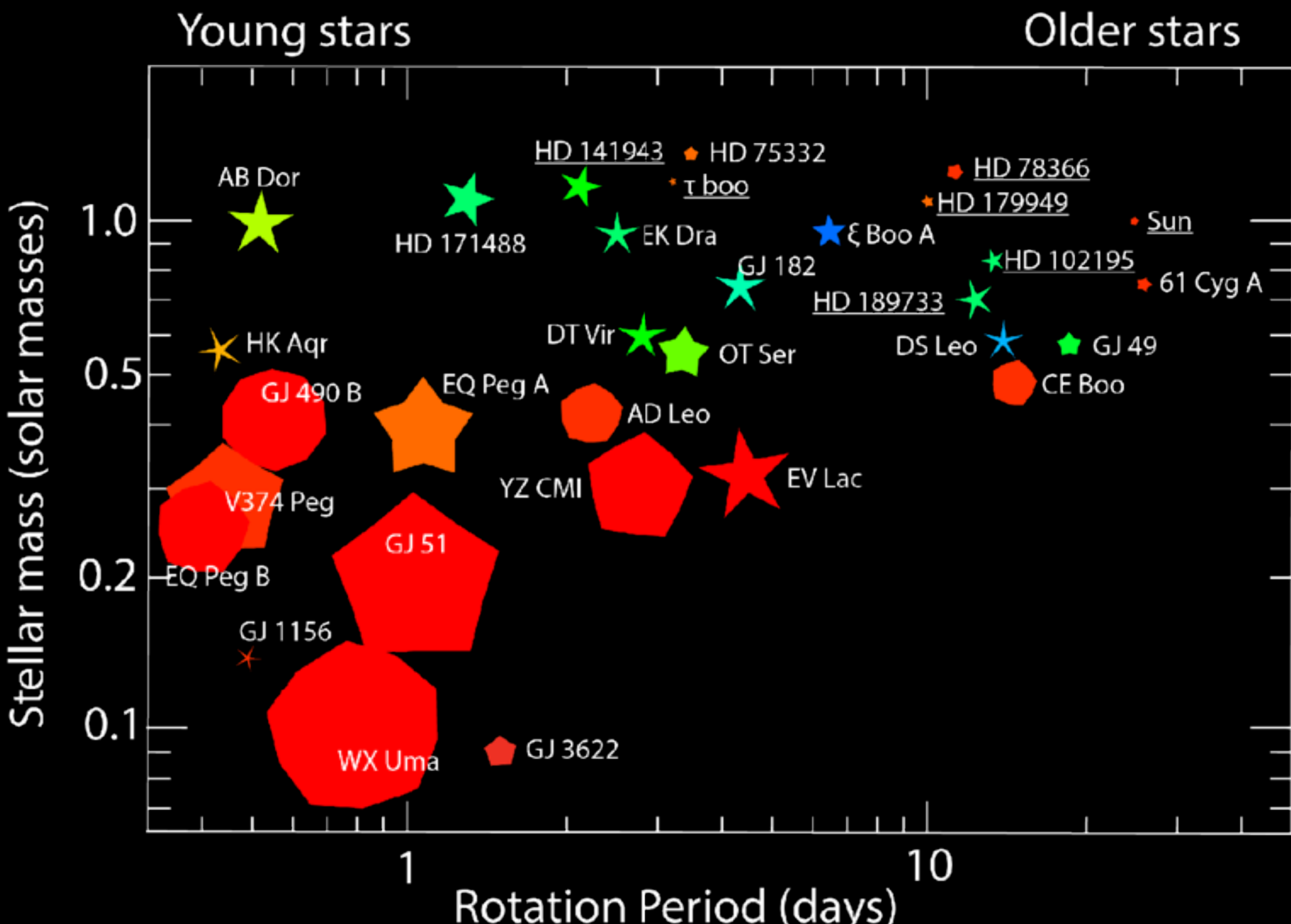
- From Stokes V profile → use inversion techniques to derive B_r, B_ϕ, B_θ



Tau Boo (F7V)
Donati et al. (2008)



The *confusogram* of stellar magnetic fields

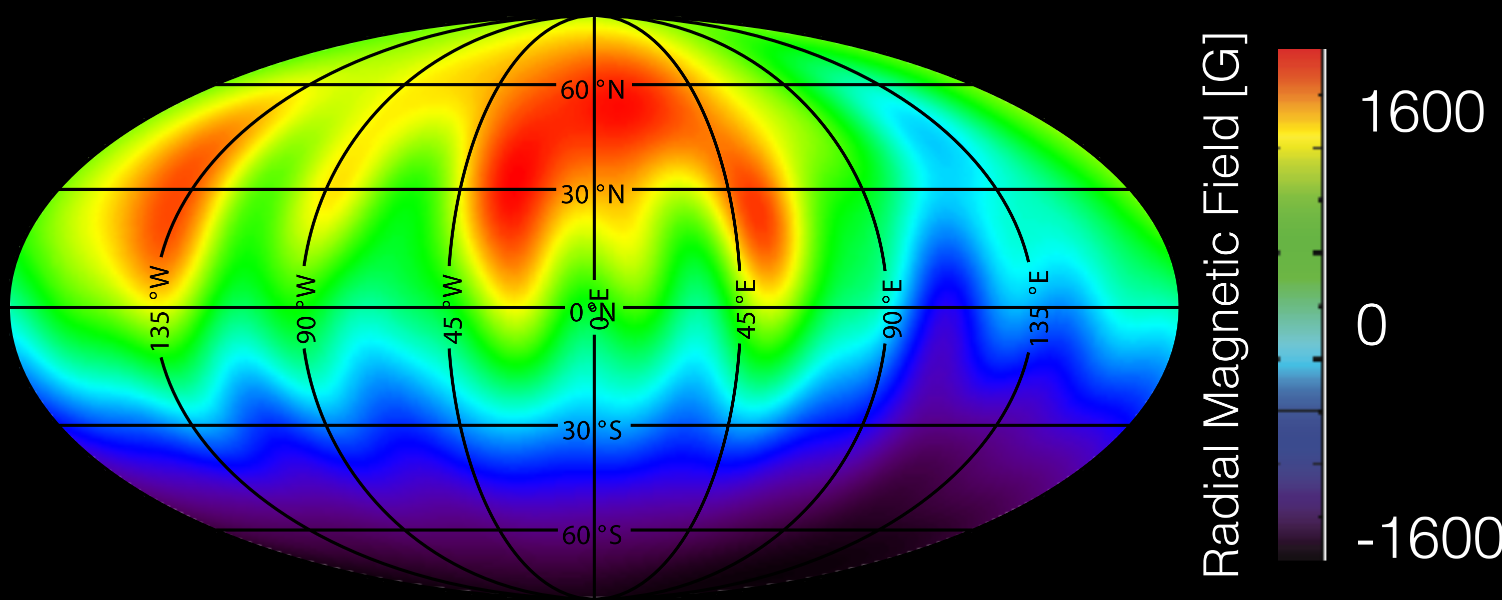


- Size: intensity
- Color:
  poloidal
  toroidal
- Shape:
  ● axisymmetric
  ★ non-axisym.
- Variety of intensities and topologies

Data from: Catala et al. (2007), Donati et al. (2003,2008,2009); Fares et al (2011,2012,2013), Jeffers et al. (2008), Petit et al. (2008,2011), Morgenthaler et al. (2012); Marsden et al. (2011), Moutou et al. (2009)

Modeling Stellar coronae and Winds

V374 Peg



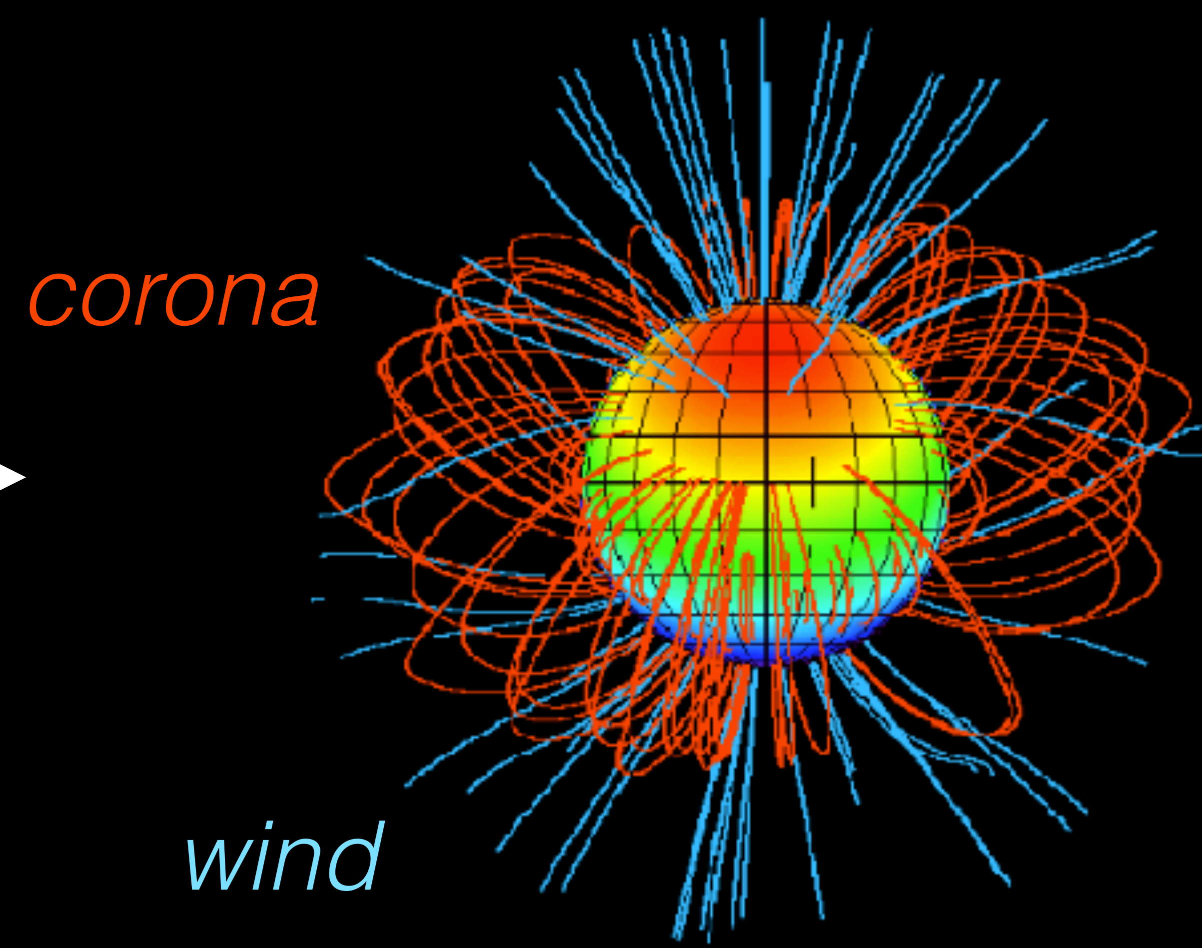
Morin et al. (2008)

3D MHD Modeling

Powell et al. (1999), Toth et al. (2012)
Cohen et al. (2011, 2014a, b, 2017)
Vidotto et al. (2009, 2011, 2012)
Llama et al. (2013)
Garraffo et al. (2015, 2016)

Potential Field Source Surface Model

Altshuler & Newkirk (1969)
Jardine et al. (1999, 2013, 2017)
See et al. (2015, 2016, 2017)
Lang et al. (2012, 2014)
Lehmann et al. (2017)



Stellar Dipole: ECM Emission

- $B_\star$ = 1000 Gauss
- incl = 45°
- T_{cor} = 6×10^6 K

- For ECM emission:

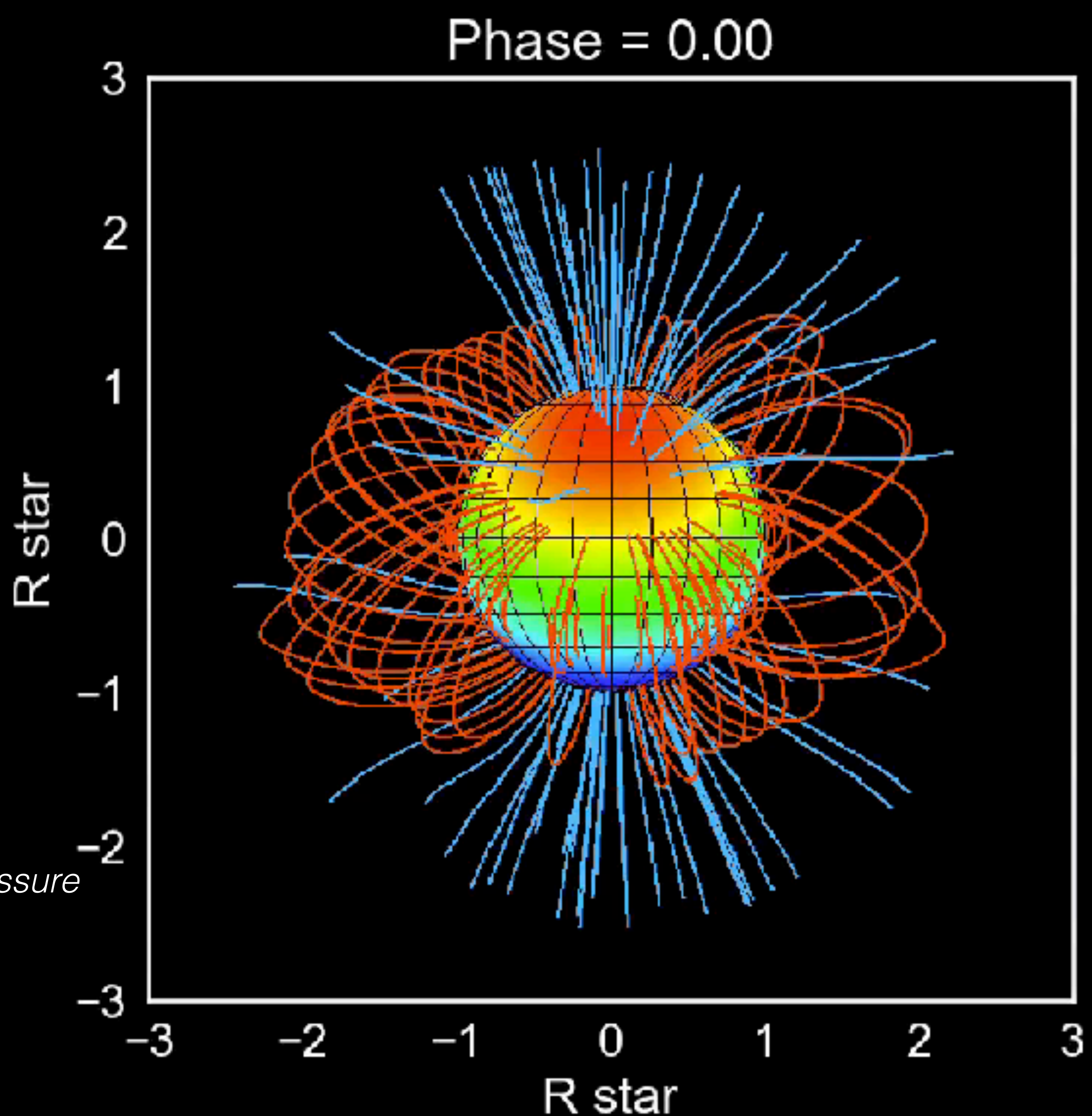
$$\sqrt{\frac{n_e e^2}{m_e \epsilon_0}} < \frac{eB}{m_e}$$

- and

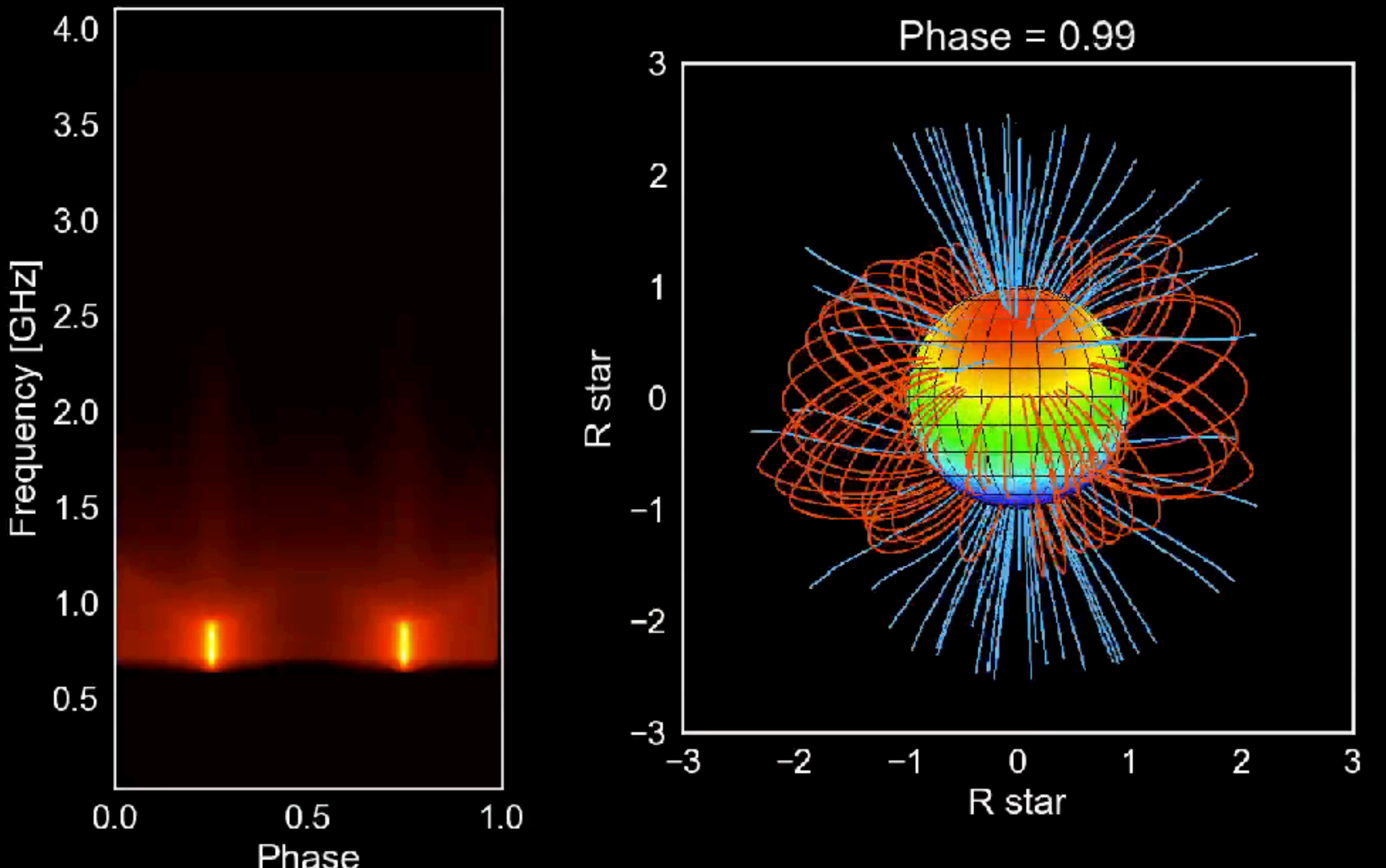
Thermal pressure

$$\beta = \frac{n k_B T}{B^2/(2\mu_0)} < 1$$

Magnetic pressure



Stellar Dipole: ECM Emission



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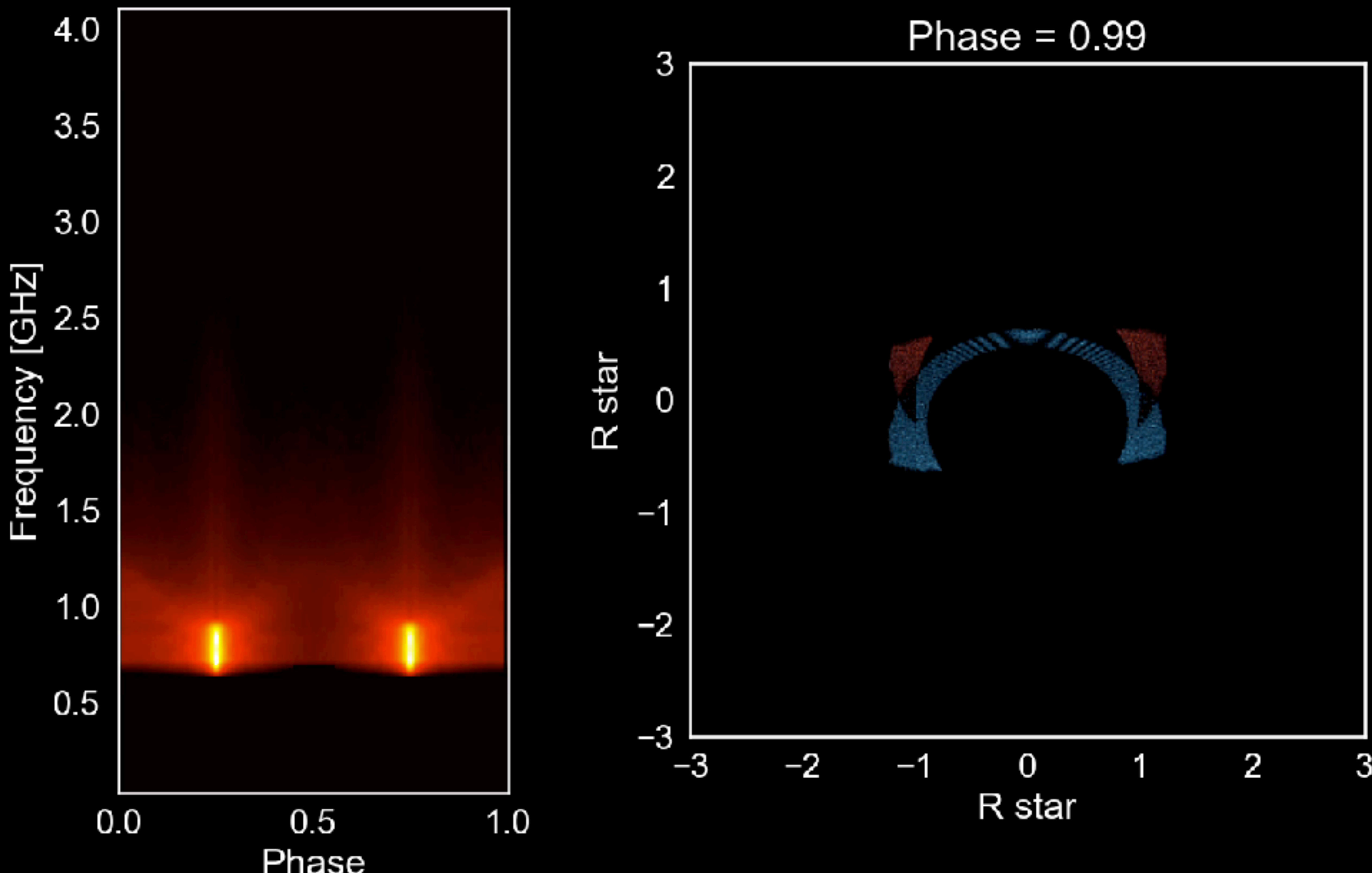

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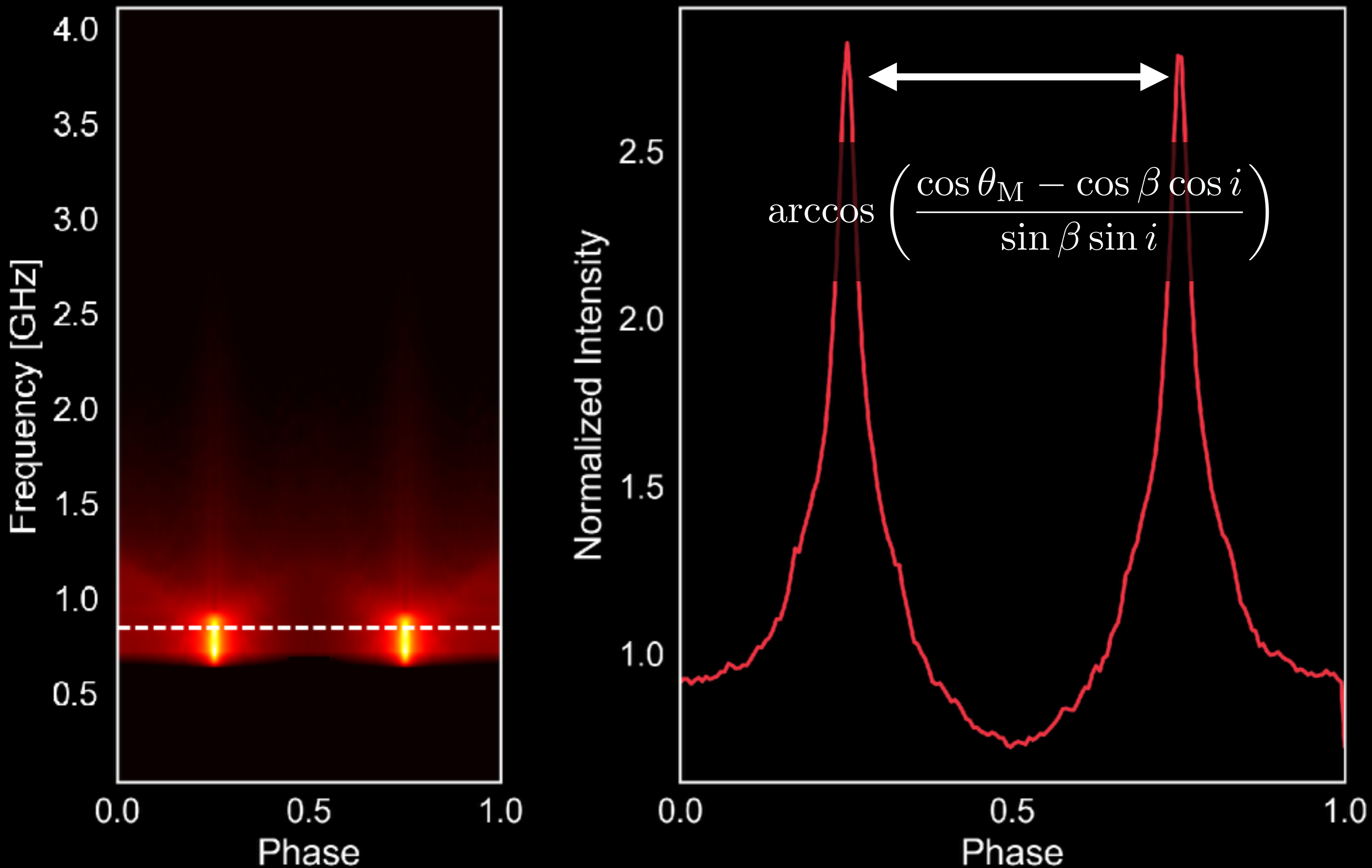


Stellar Dipole: X-ray Emission

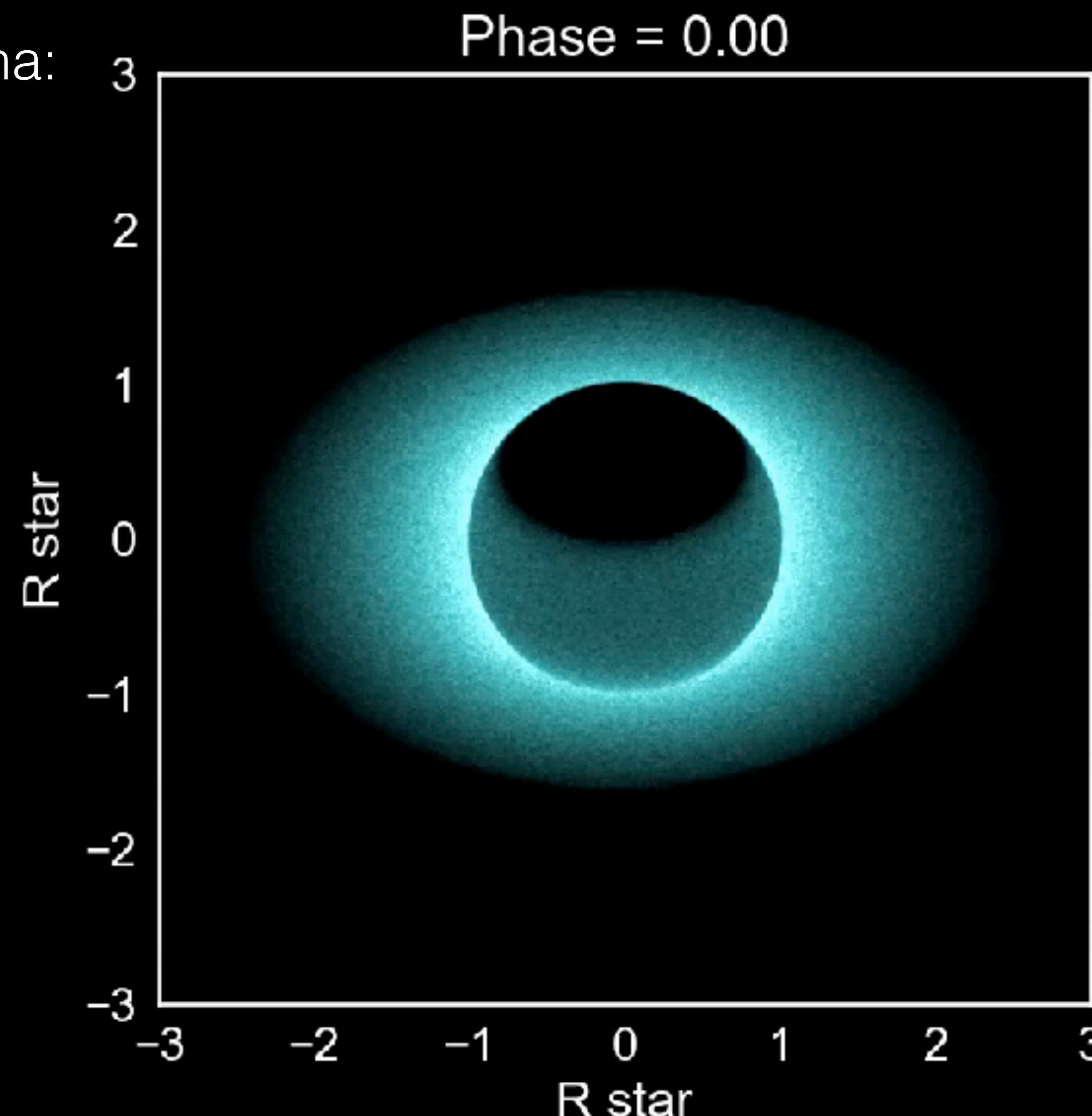
- Isothermal, hydrostatic corona:

$$p = p_0 \exp\left(\frac{m}{T}\int g_s \mathrm{d}s\right)$$

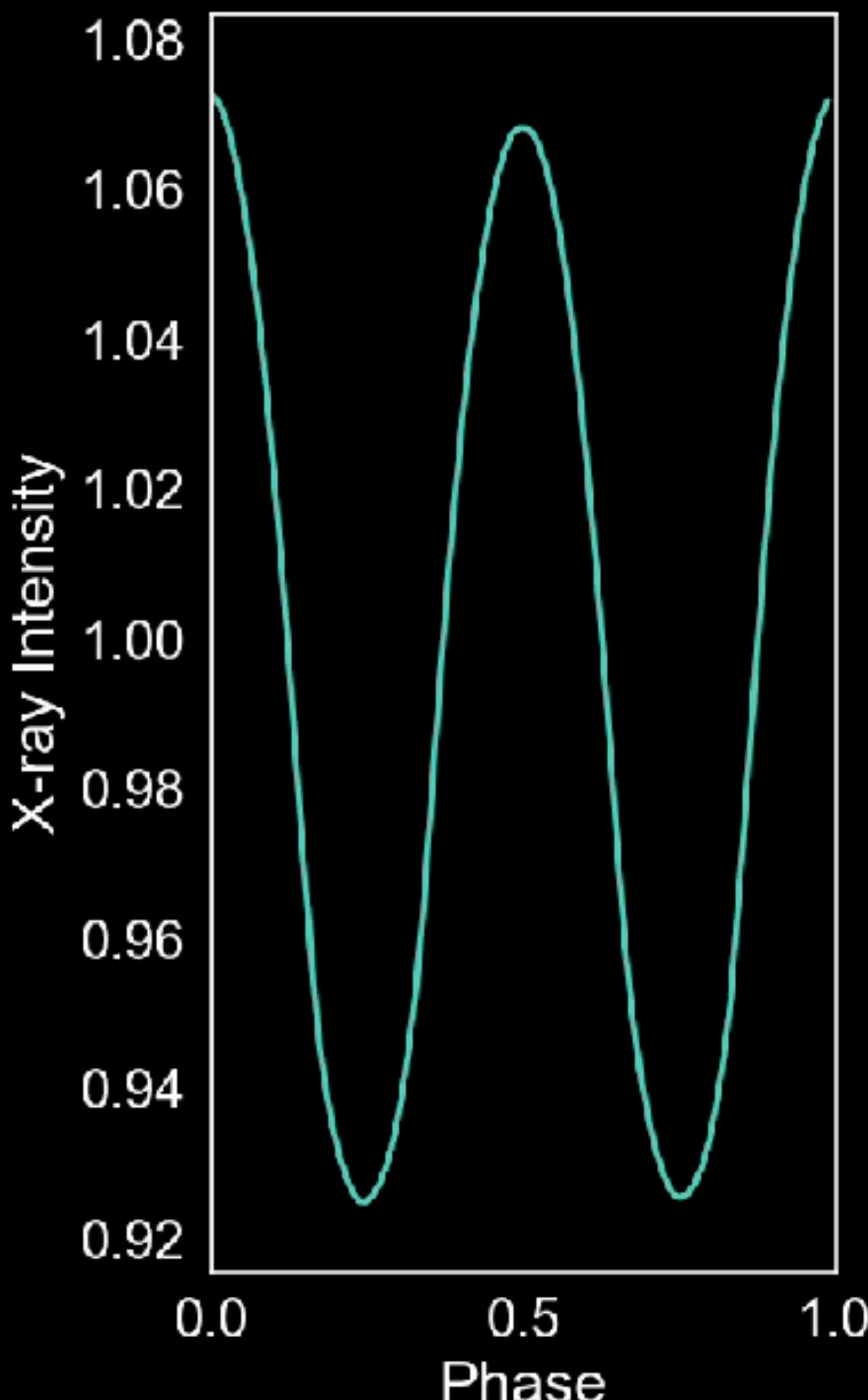
- Base-density scales with magnetic pressure:

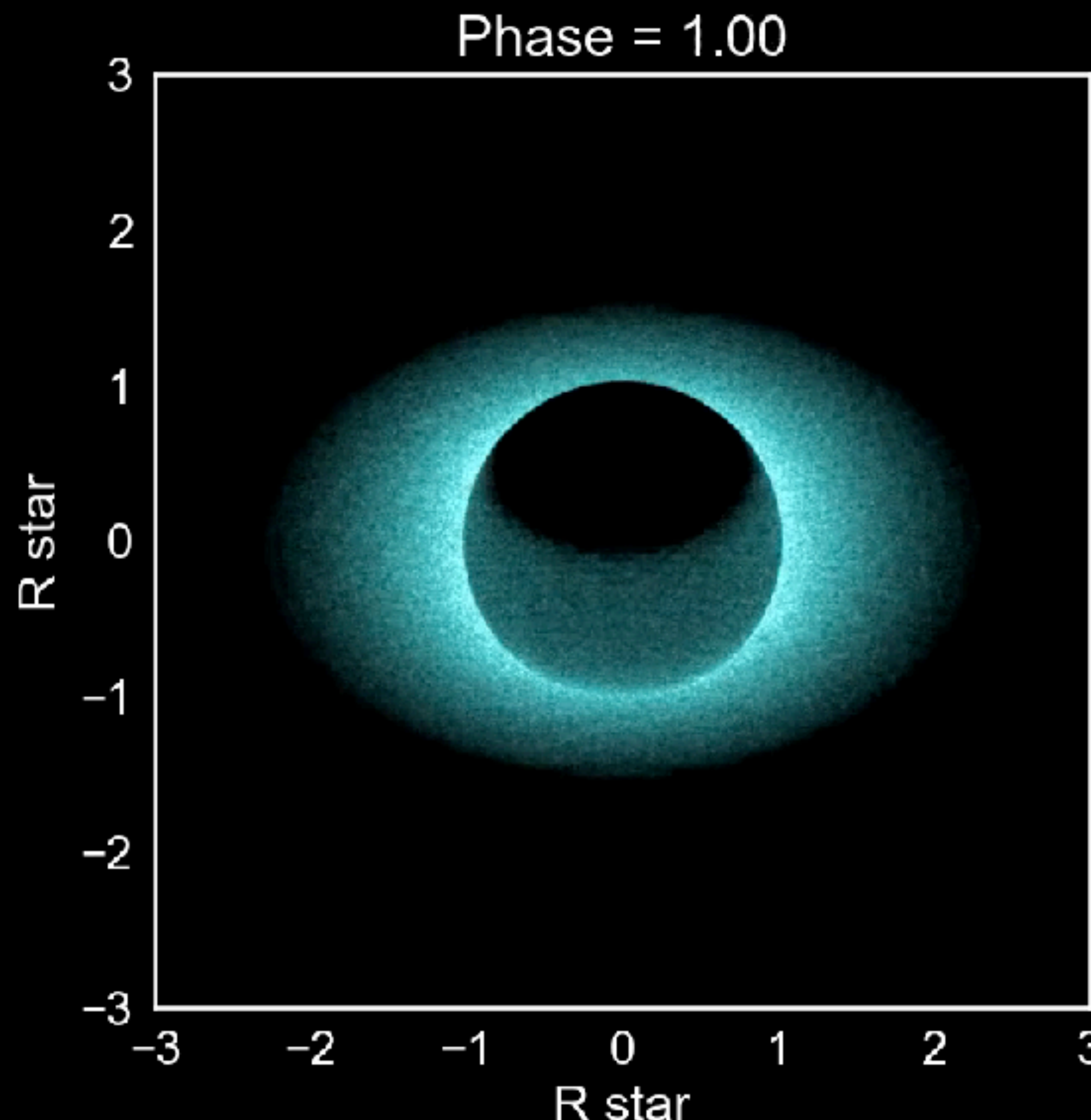
$$p_0(\theta, \phi) = K B_0^2(\theta, \phi)$$

Scales with observed Emission Measure

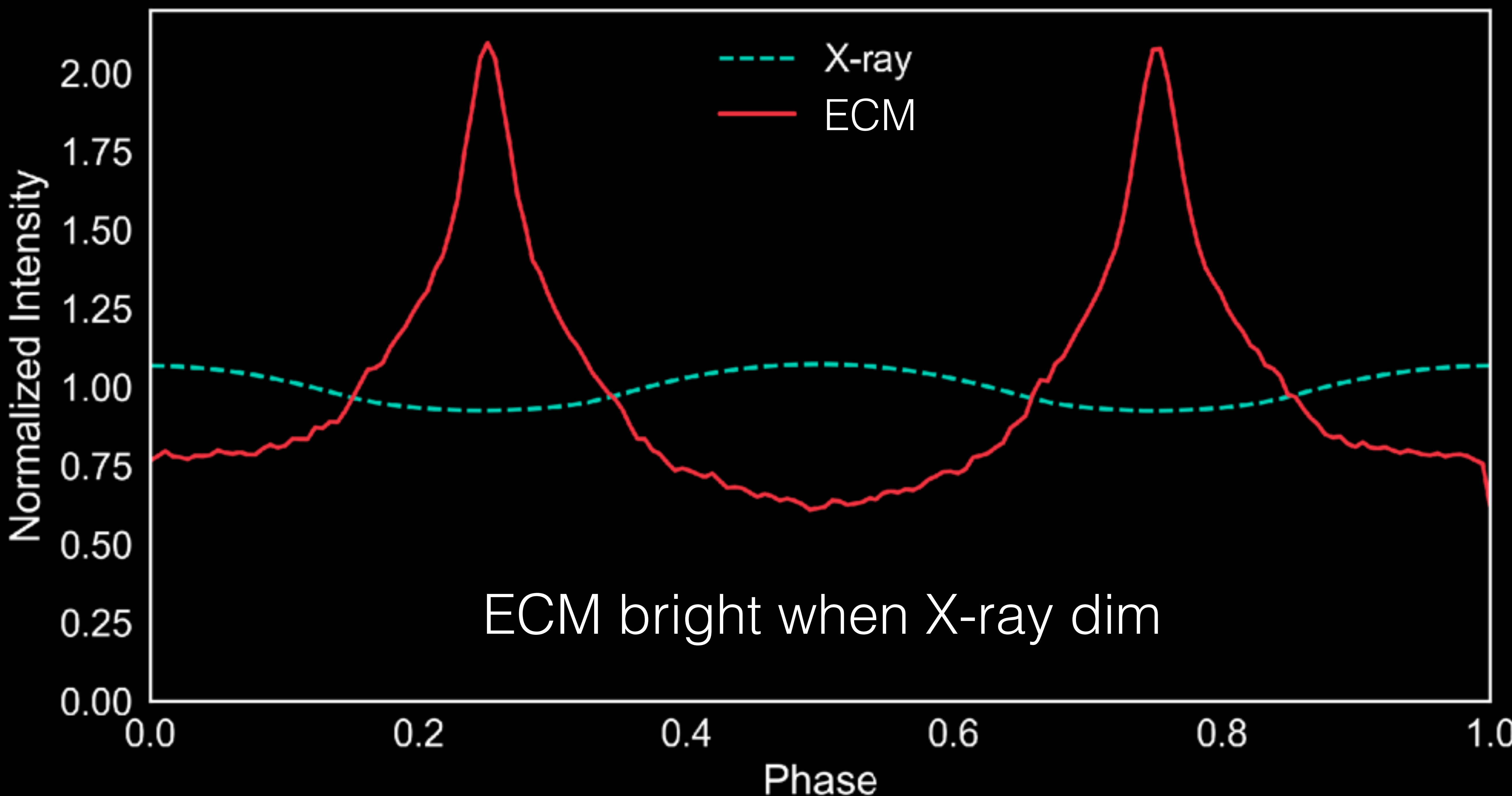


Stellar Dipole: X-ray Emission

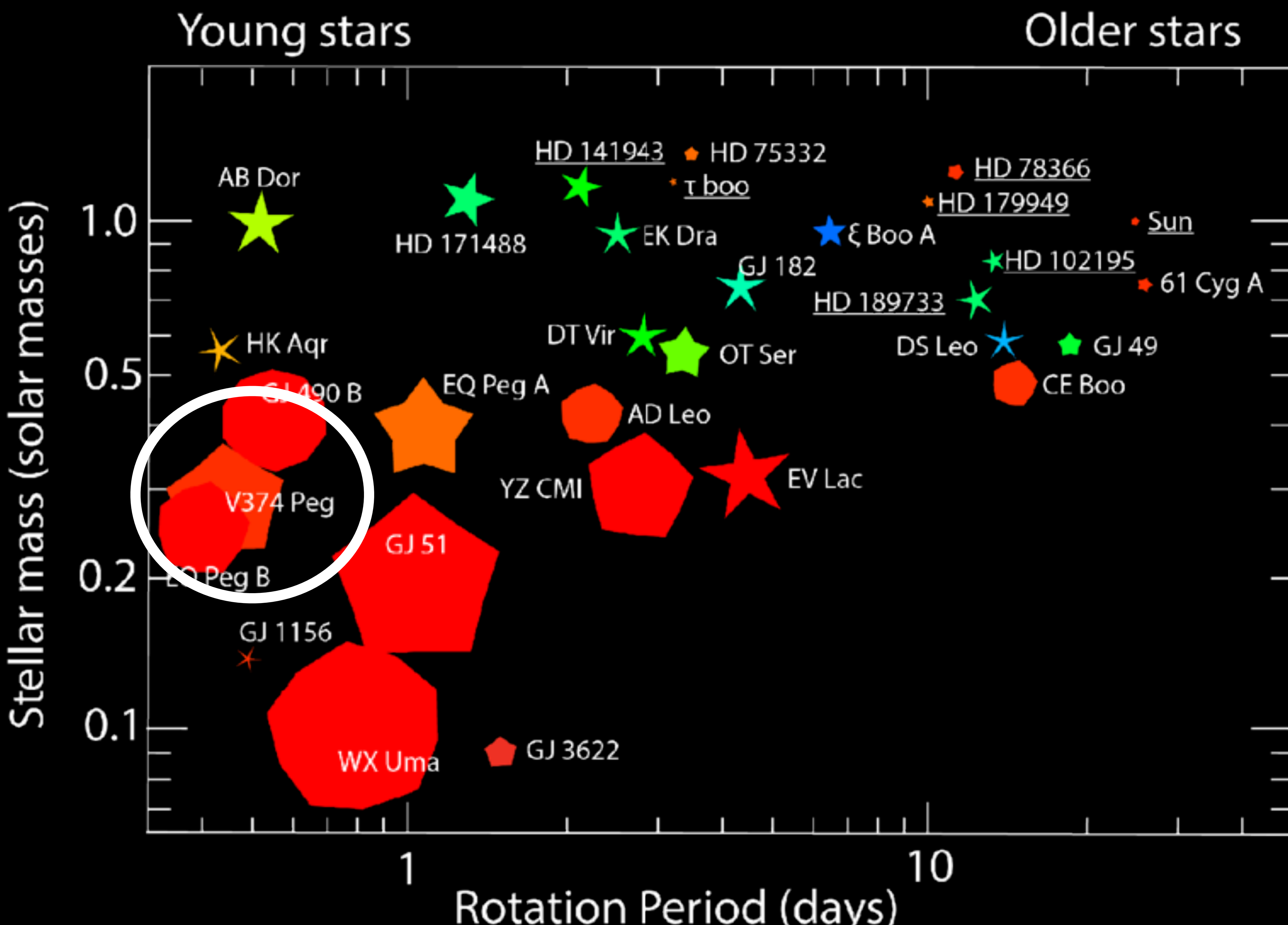




X-ray and ECM light curves



Simulating ECM emission from V374 Peg



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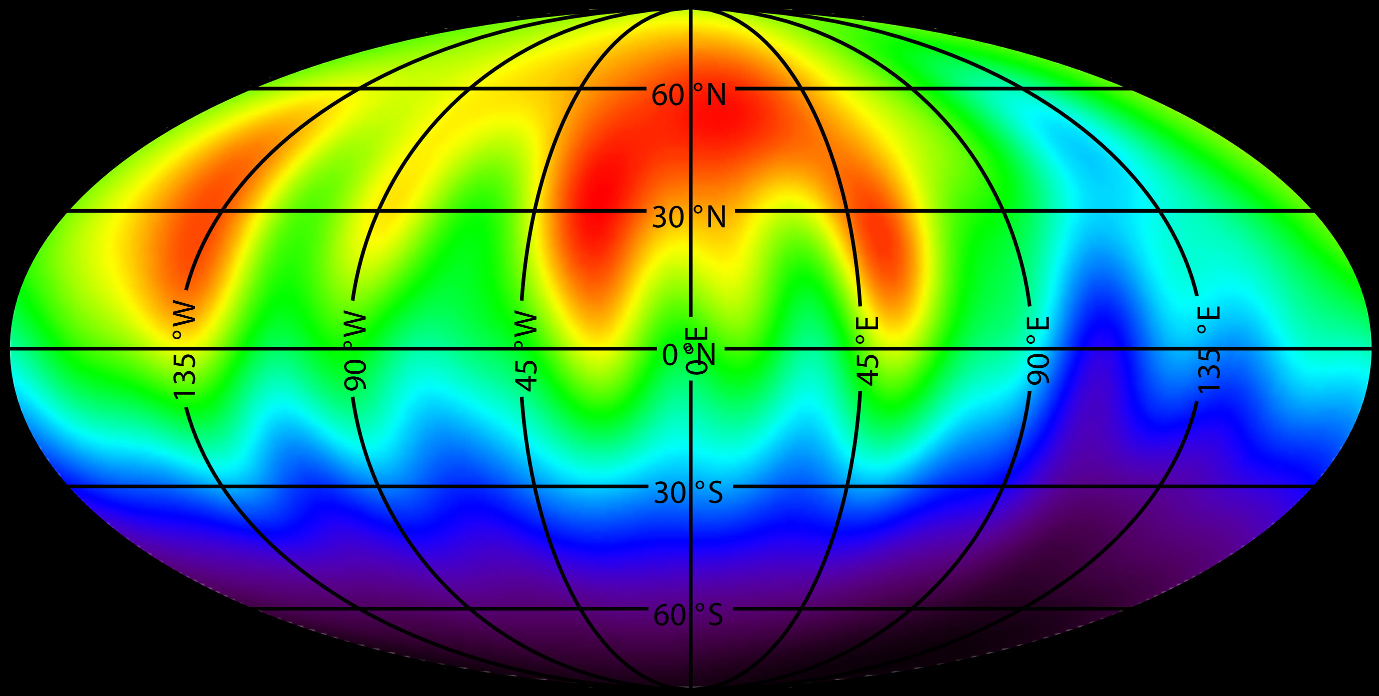
Simulating ECM emission from V374 Peg

- Mass: 0.28 x solar mass
- Radius: 0.28 x solar radius
- Temperature: 3410 K
- Rotation Period: 0.44 days
- Log Lx = 28.44

V374 Peg

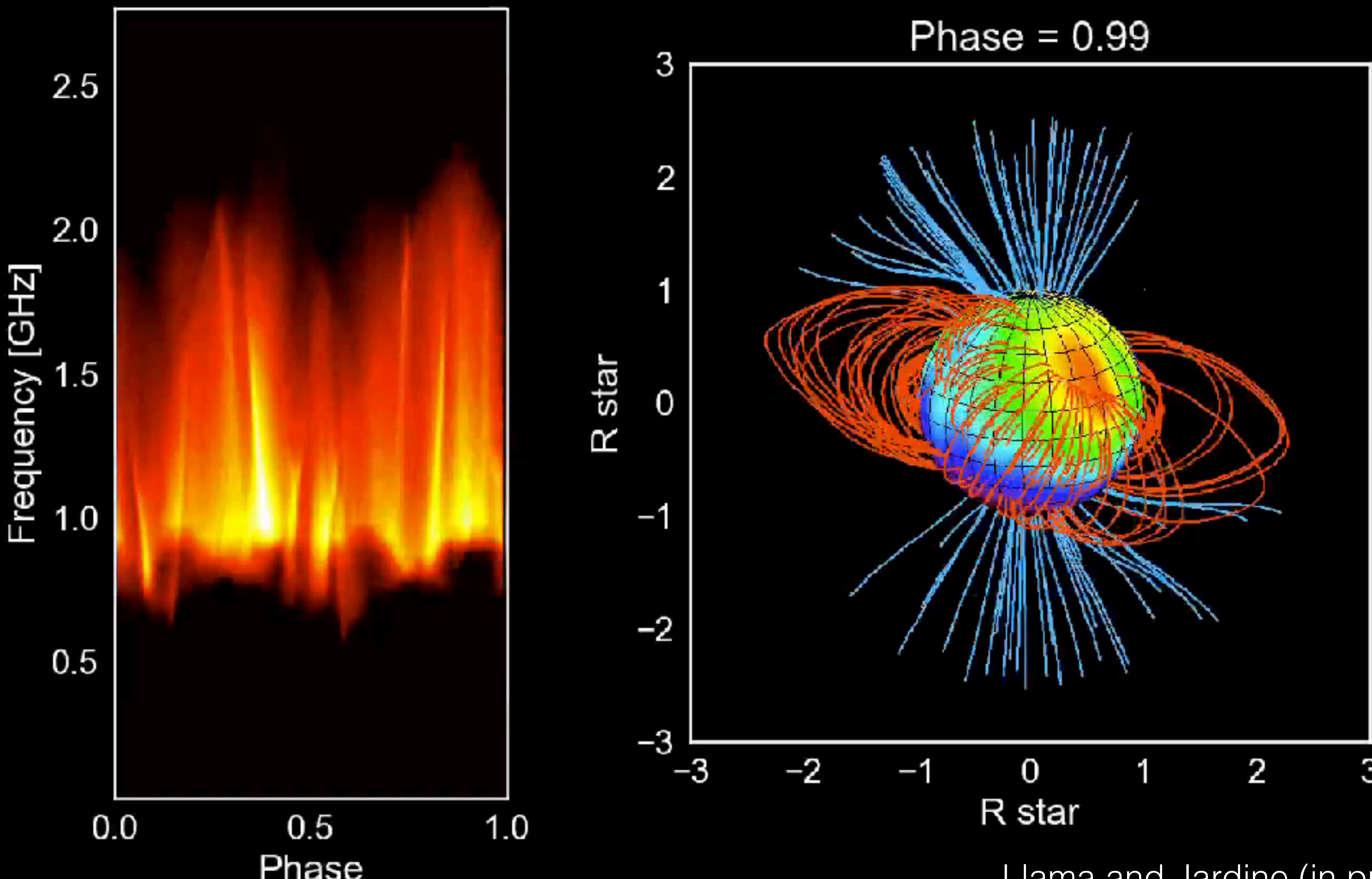


Morin et al. (2008)

$$T_{corona} = 0.11 \times F_X^{0.26} \quad \Rightarrow \quad T_{corona} = 6 \times 10^6 \text{ K}$$

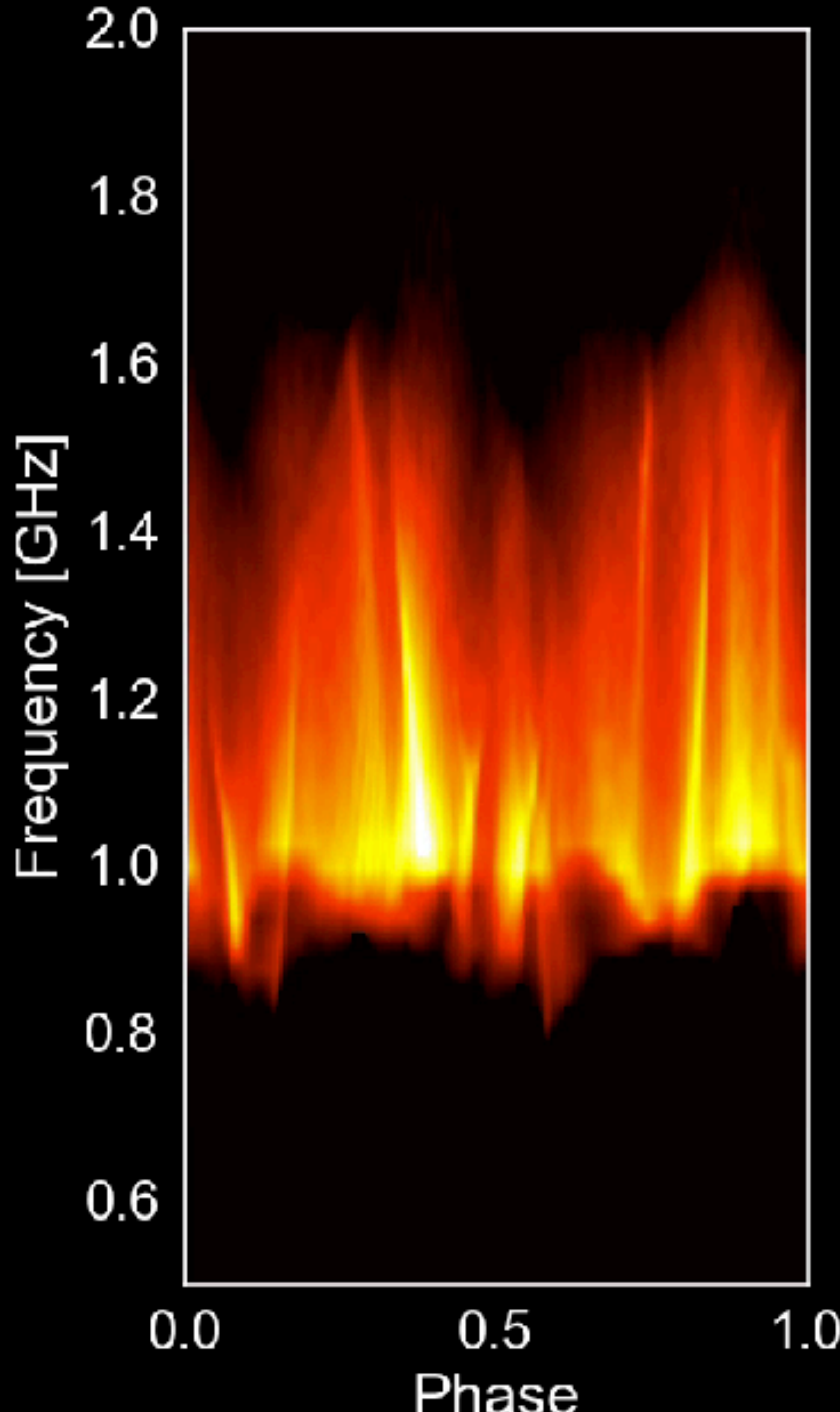
(Johnstone et al. 2015)

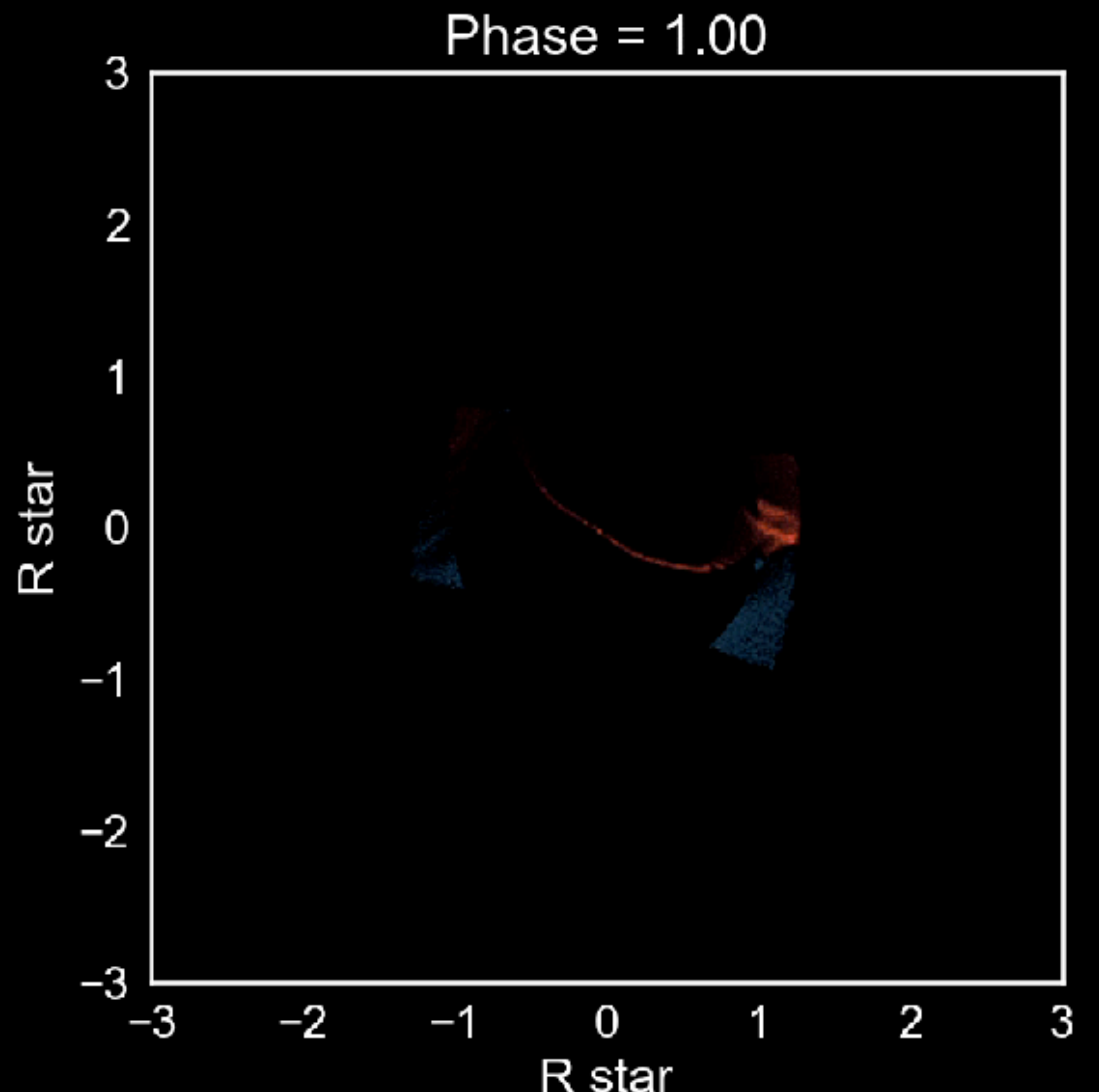
Simulating ECM emission from V374 Peg



Llama and Jardine (in prep)

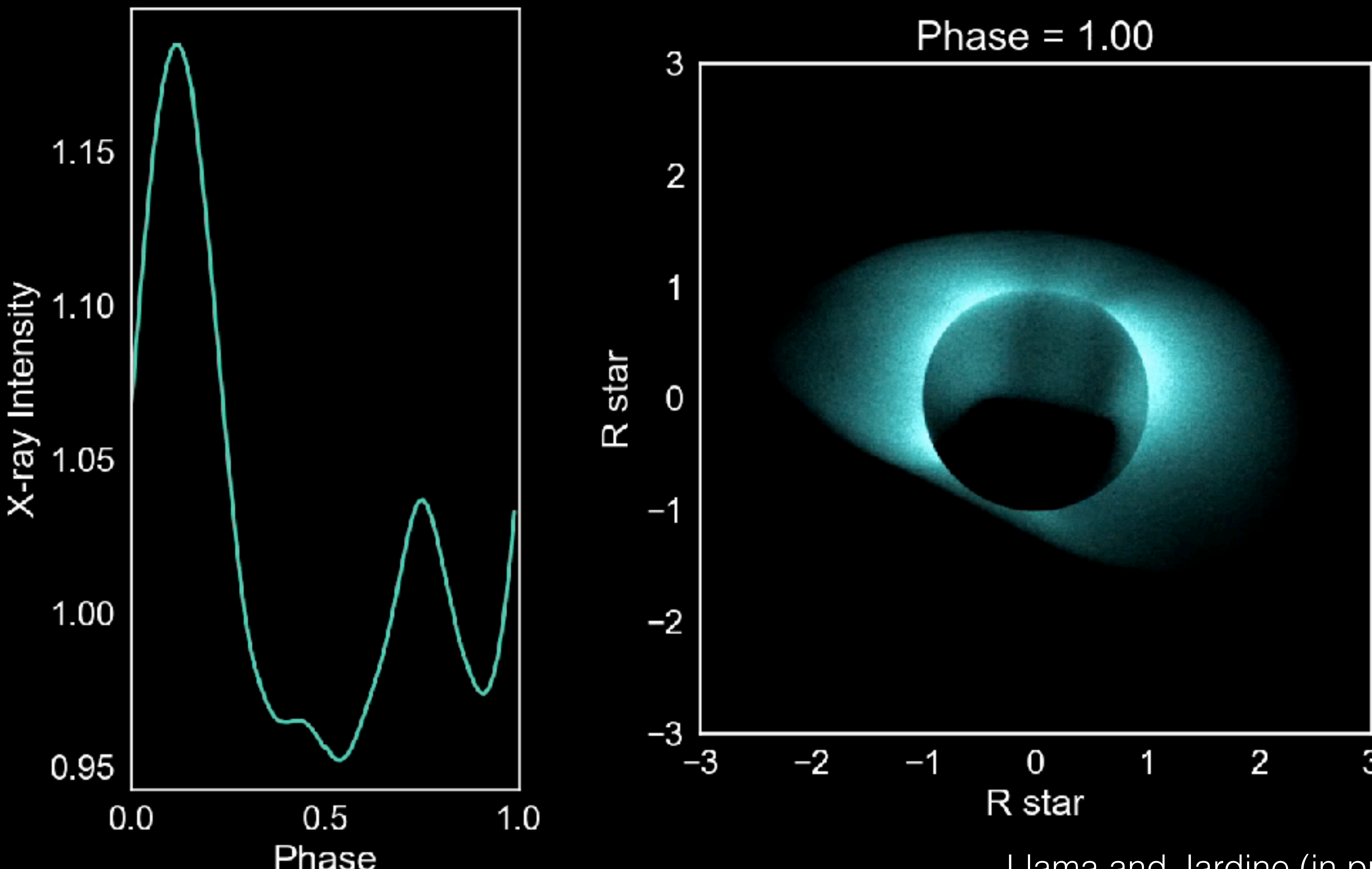
Simulating ECM emission from V374 Peg





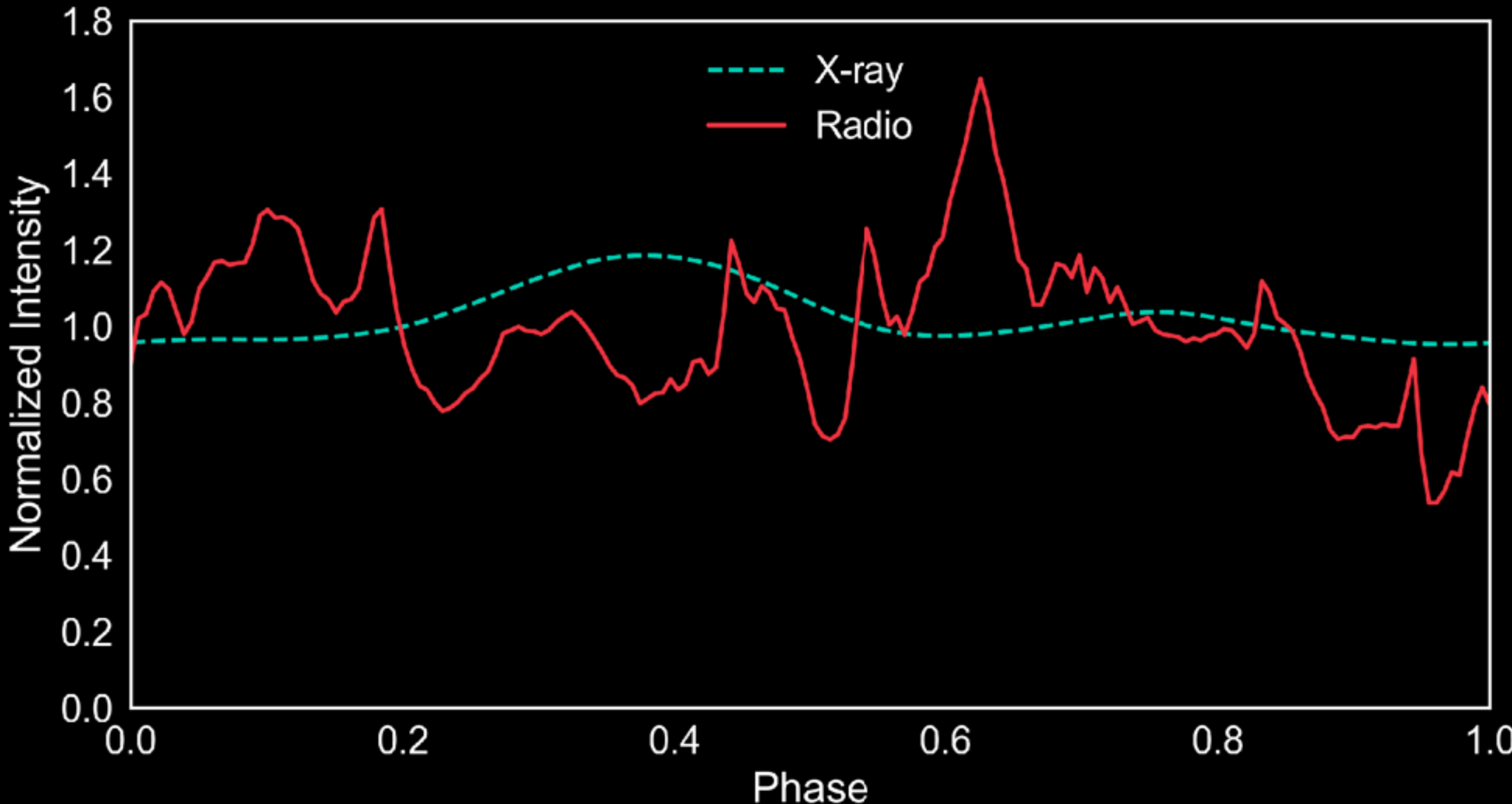
Llama and Jardine (in prep)

Simulating X-ray emission from V374 Peg



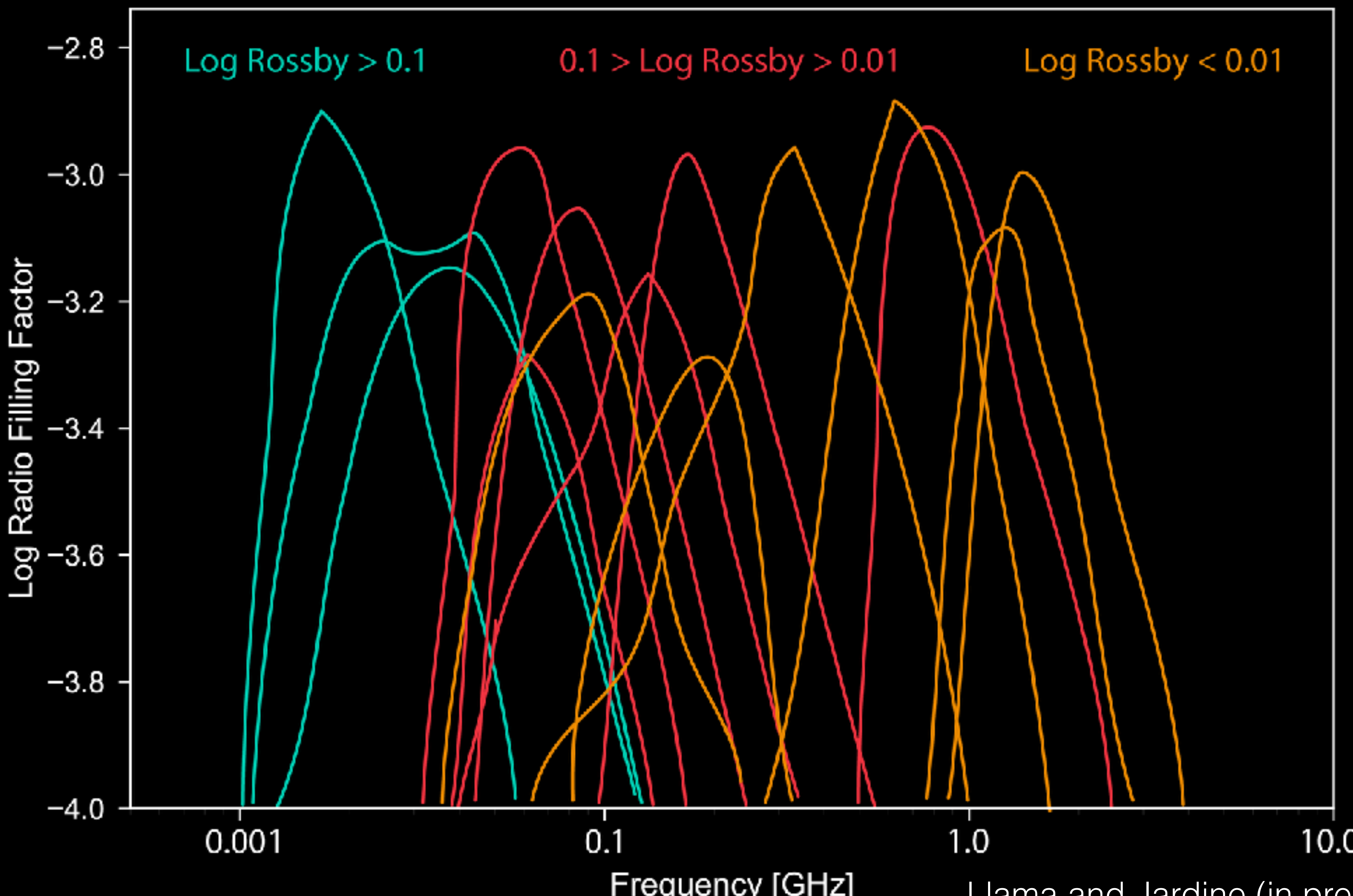
Llama and Jardine (in prep)

Simulating ECM emission from V374 Peg



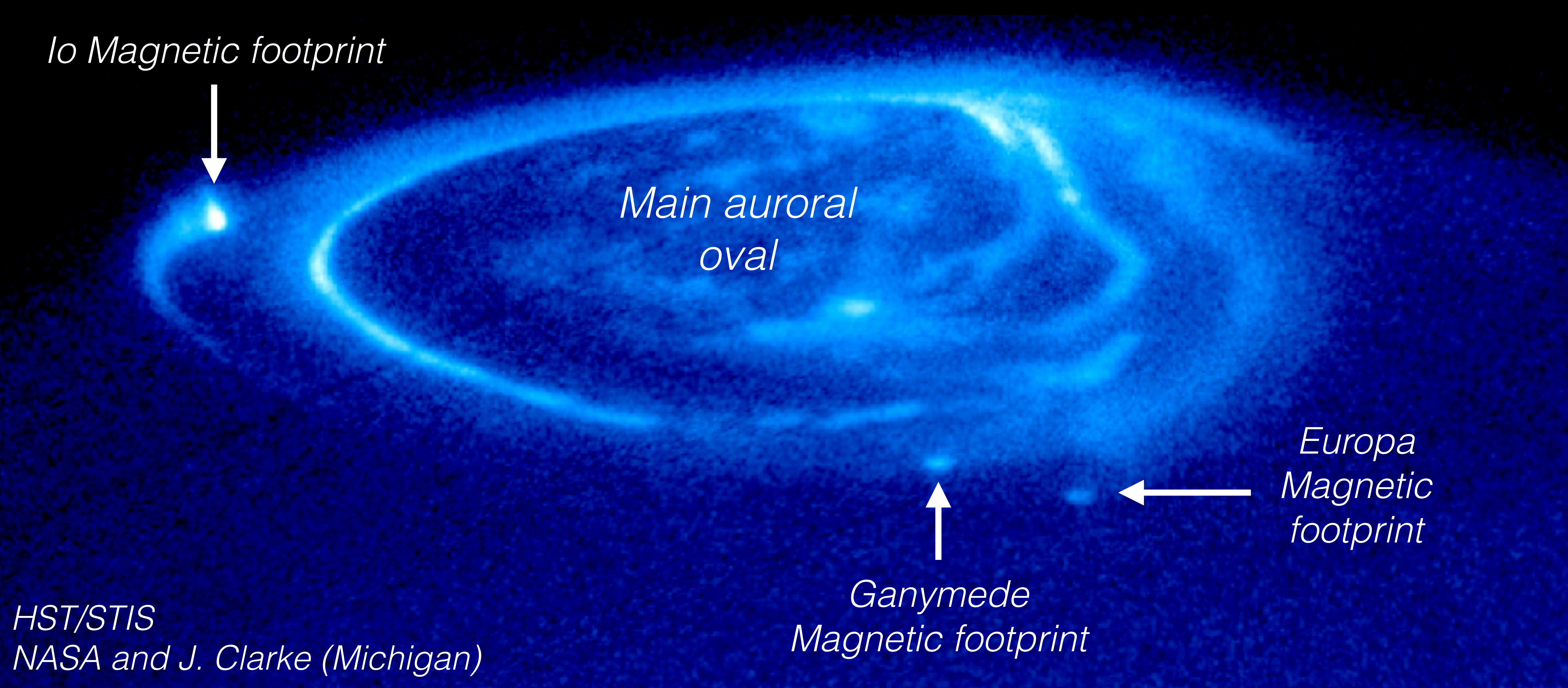
Llama and Jardine (in prep)

Extension to more ZDI stars



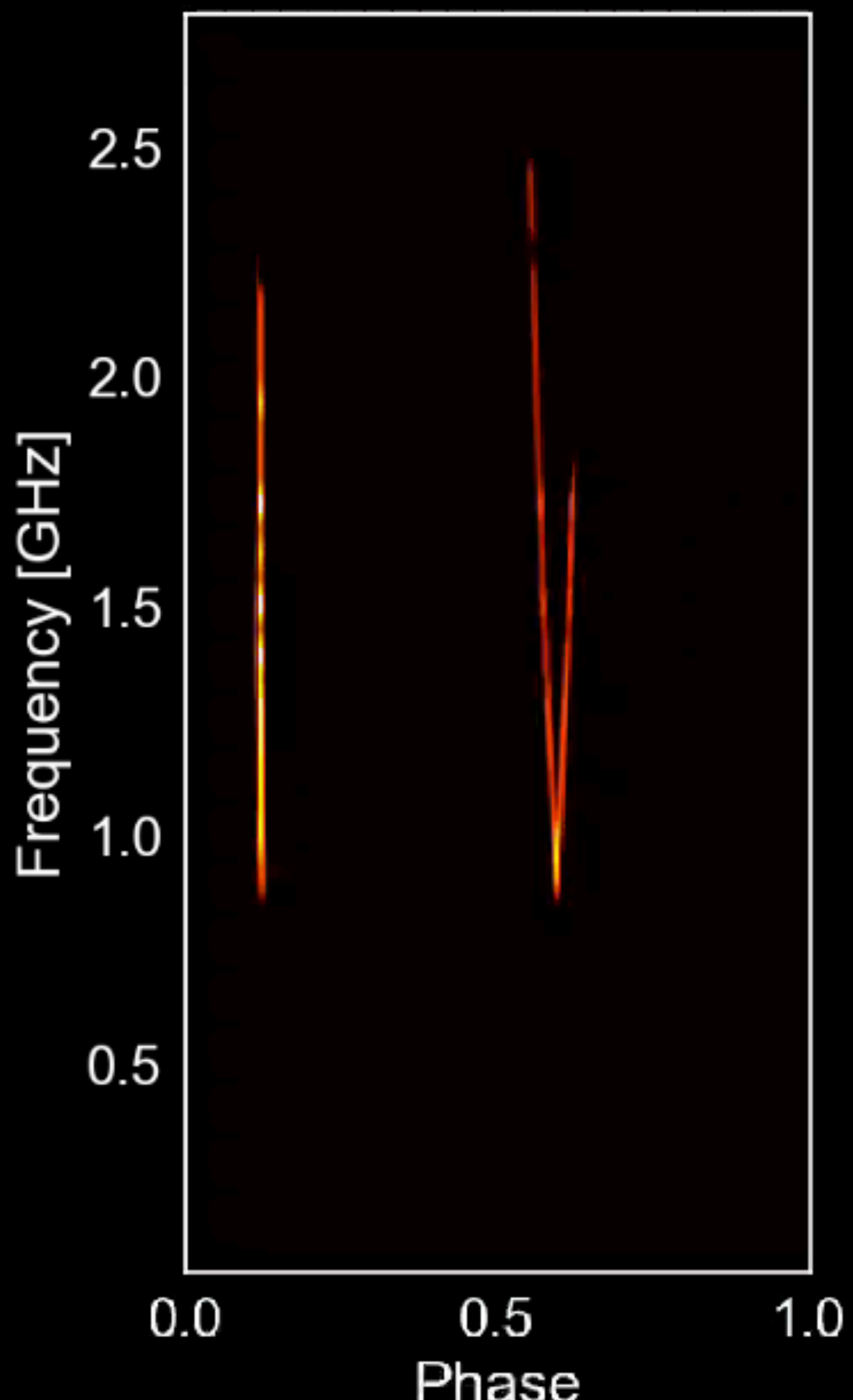
Llama and Jardine (in prep)

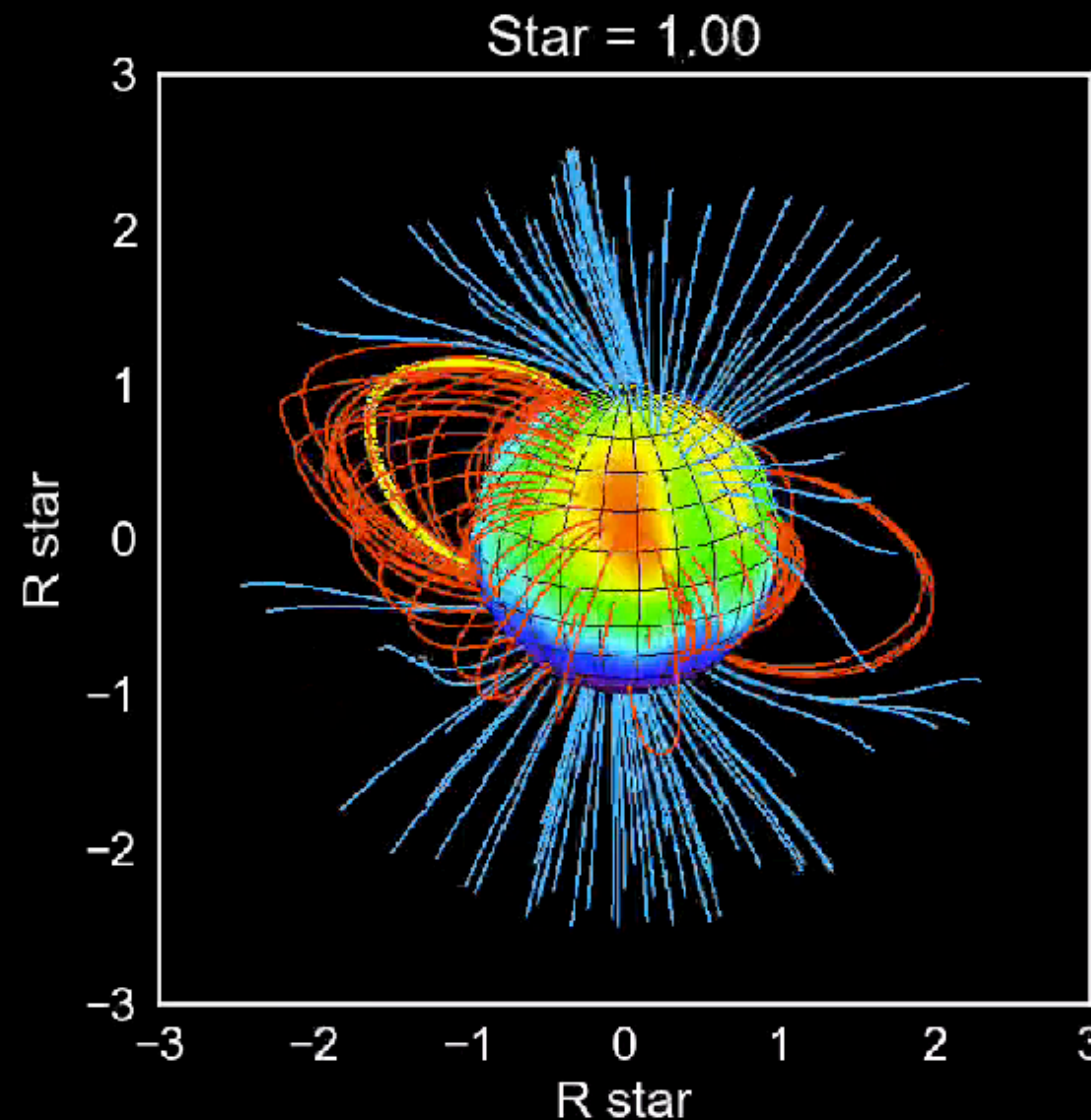
Planet induced ECM



HST/STIS
NASA and J. Clarke (Michigan)

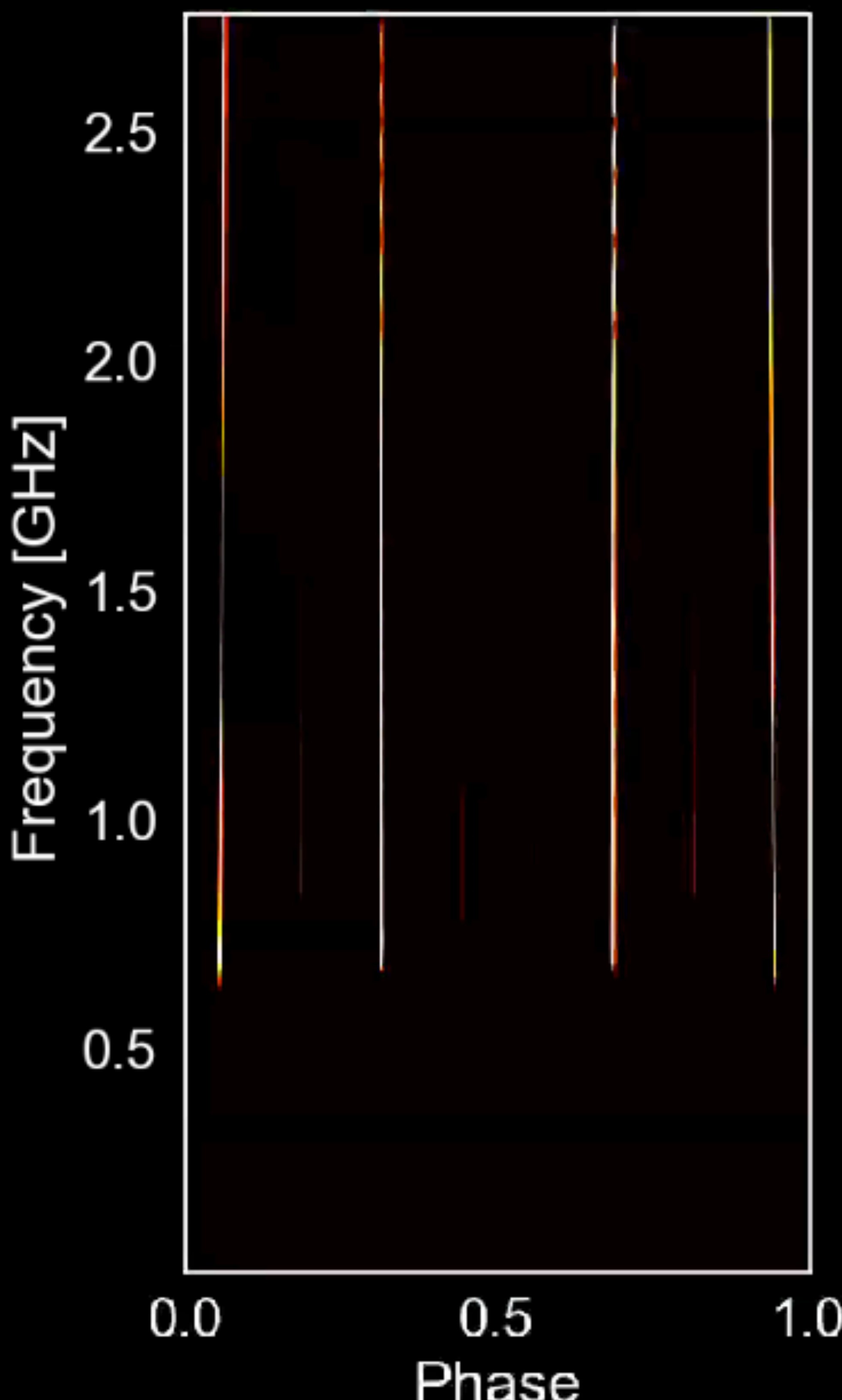
Planet induced ECM

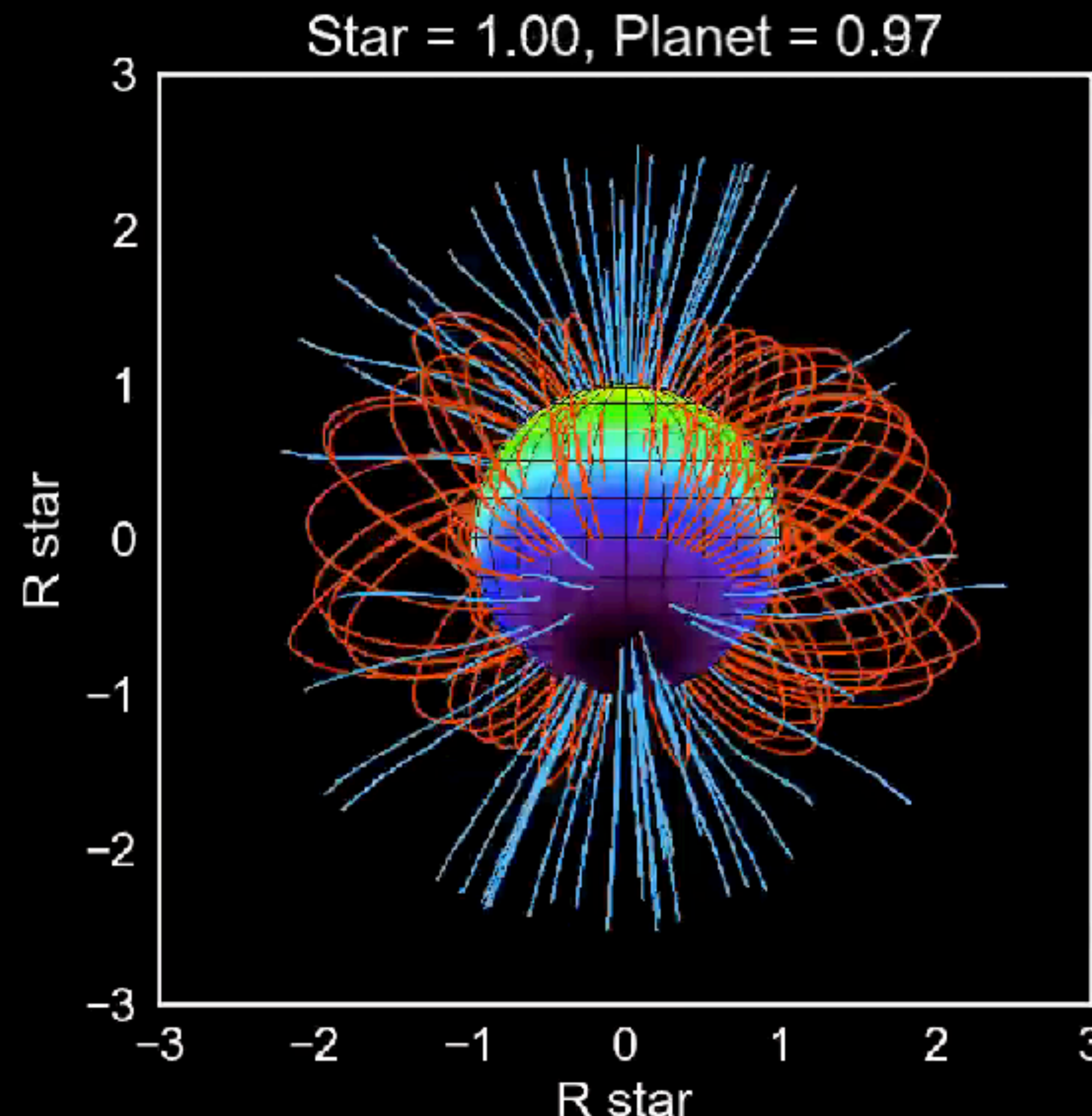




Llama and Jardine (in prep)

Planet induced ECM





Llama and Jardine (in prep)

Summary and Prospects

- Magnetic maps are a useful tool for predicting the radio emission from stars.
- X-ray and ECM light curves are anti-phased.
- Planet induced ECM can vary depending on the orbital configuration of the planet.
- Next steps: Predict light curves for the low-mass stars that have ZDI observations.