Temporal variability of the wind from the star τ Boötis

Belinda Nicholson, PhD Candidate

University of Southern Queensland, Toowoomba, Australia

European Southern Observatory, Garching, Germany

Supervisors: Brad Carter, Aline Vidotto, Leigh Brookshaw

5th BCool Meeting, February 2016

Image: Digitized Sky Survey (©1993 – 1995 California Institute of Technology.)

Understanding winds is important…

- Stellar evolution: Mass loss, angular momentum loss and spin-down.

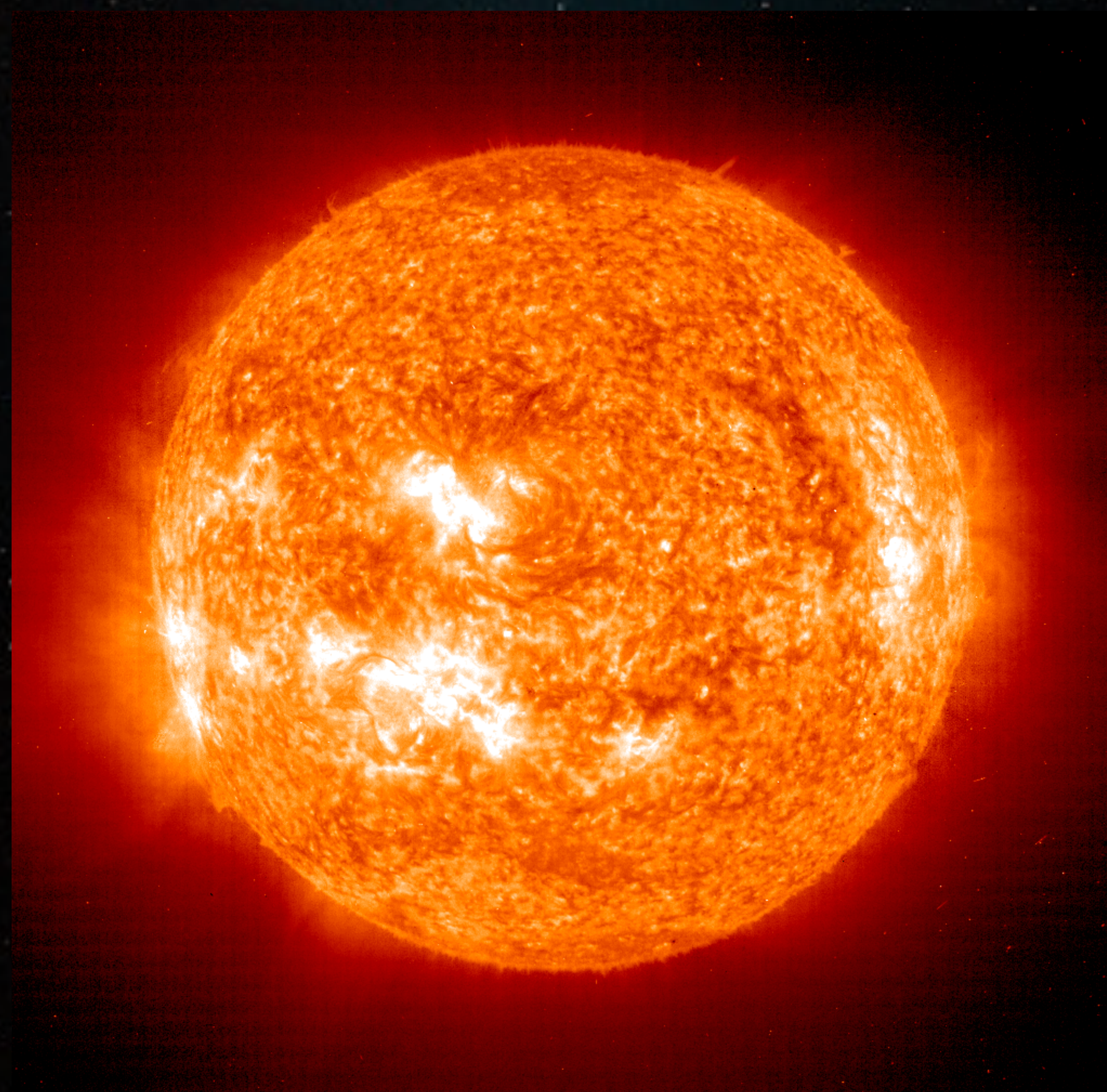
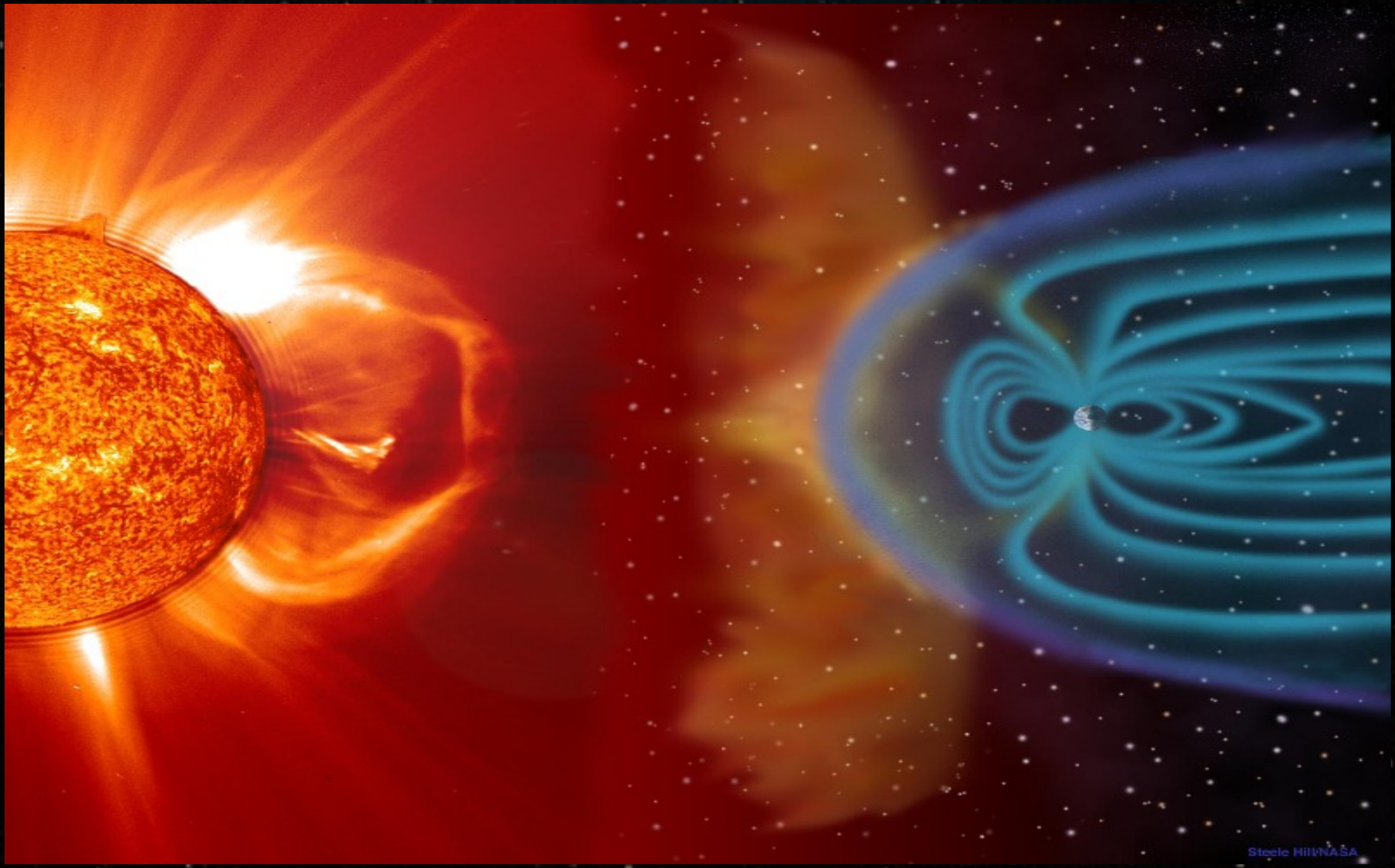


Image Credit: NASA

Understanding winds is important…

- Planet habitability: planetary atmosphere stripping

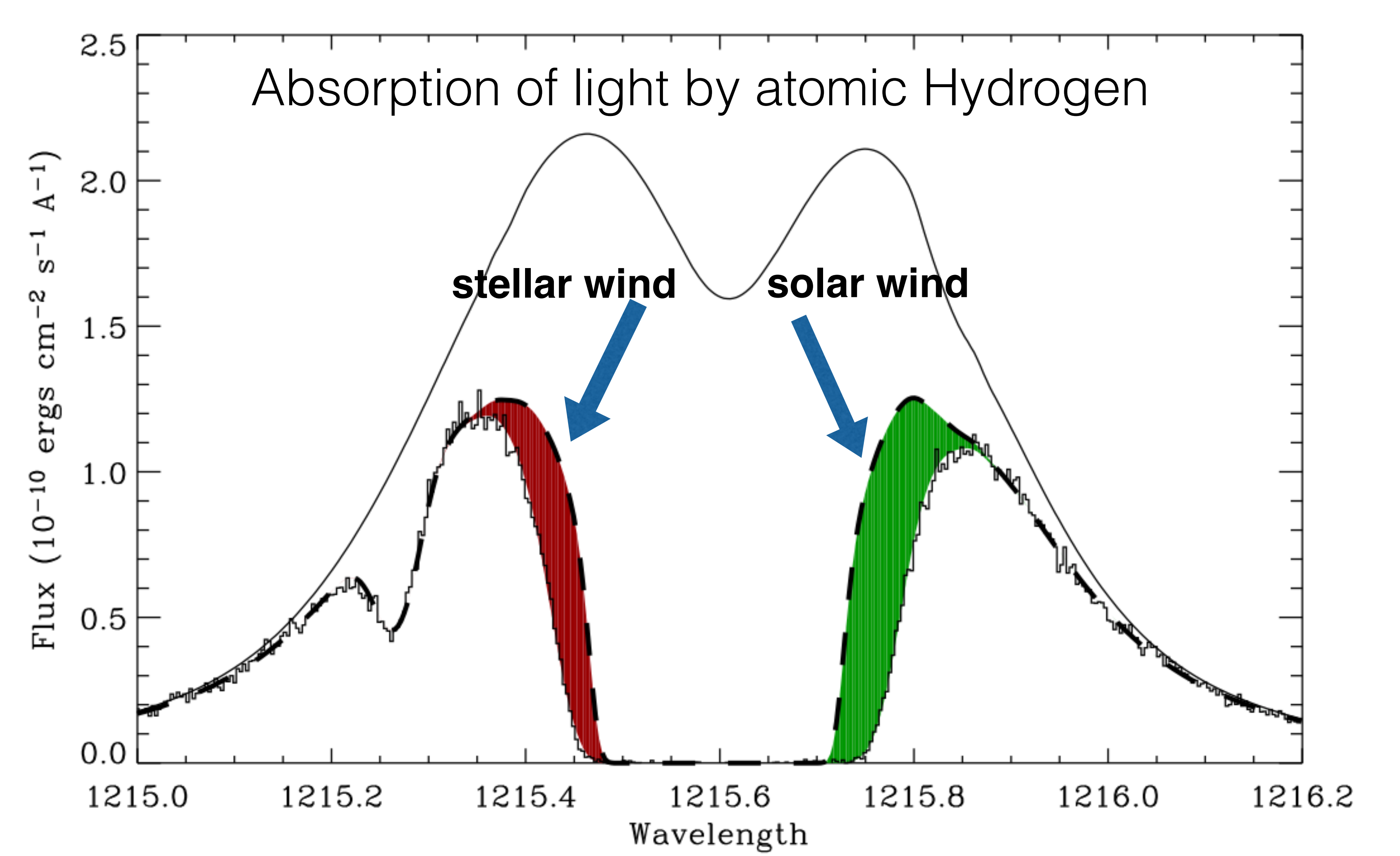


But observing them is hard…

- Can only be observed directly in the most extreme cases:

But observing them is hard…

- Can be observed indirectly:



Wood et al. (2004)

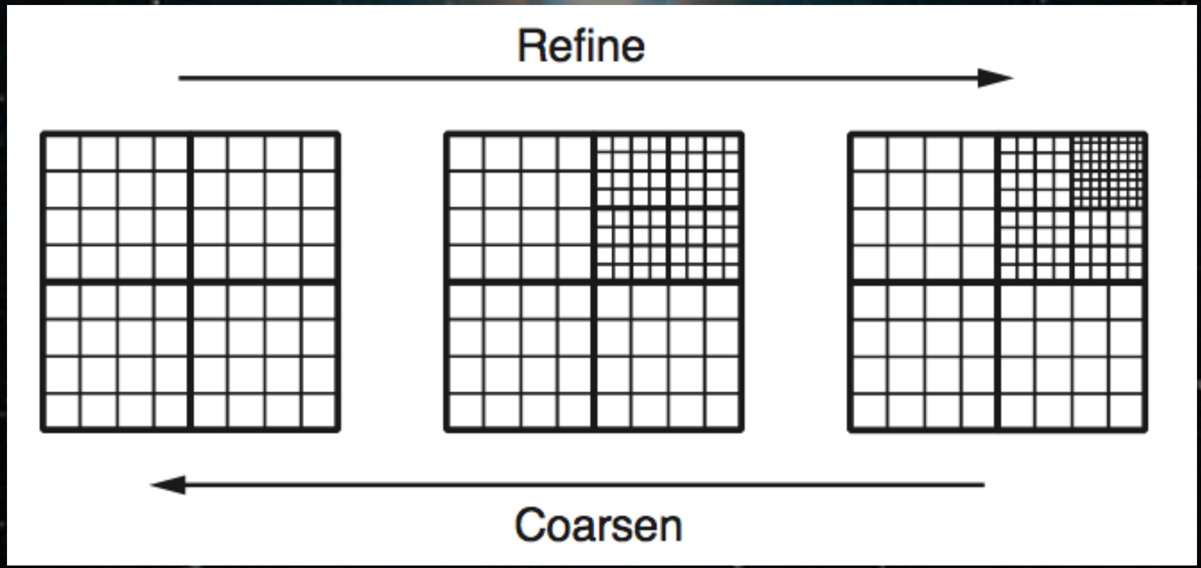
So we model them instead!

Study Aim:

To model the wind of the planet-hosting star τ Boötis (Tau Boo) based on magnetic field information obtained from 8 sets of spectropolarimetric observations taken from May 2009 to January 2015, and estimate the wind properties and its impact on the planet.

Stellar Wind Modelling with BATSRUS

- Block-Adaptive Tree Solar-wind Roe Upwind Scheme (BATS-R-US) is a 3D MHD code created to simulate the solar wind.
- Grid structure that can be refined in areas of interest to save computational resources.



- A modular code that can be adapted to model the wind of other stars.

Stellar Wind Modelling with BATSRUS

Input:

- Stellar parameters
- Radial magnetic field maps, reconstructed using Zeeman Doppler Imaging

Output at each point of the 3D grid:

- Plasma velocity
- Plasma density
- Plasma pressure
- Magnetic field
- Current

τ Boötis (Tau Boo)

An F7V star with a 1:1 tidally-locked, close-in Hot Jupiter with mass 5.6 $M_{Jupiter}$

Parameters for the simulation:

Mass =1.341 M_Sun
Radius =1.46 R_Sun
v sin i = 14.98 km/s
Equatorial Rotation Period = 3.0 days
Coronal Base Temperature = 2 x 10^6 K
Coronal Base Density = 8.36 x 10^{-16} g cm^{-3}

It has been previously shown to have a magnetic cycle of ~740 days

Stellar Wind Modelling with BATSRUS

Input:

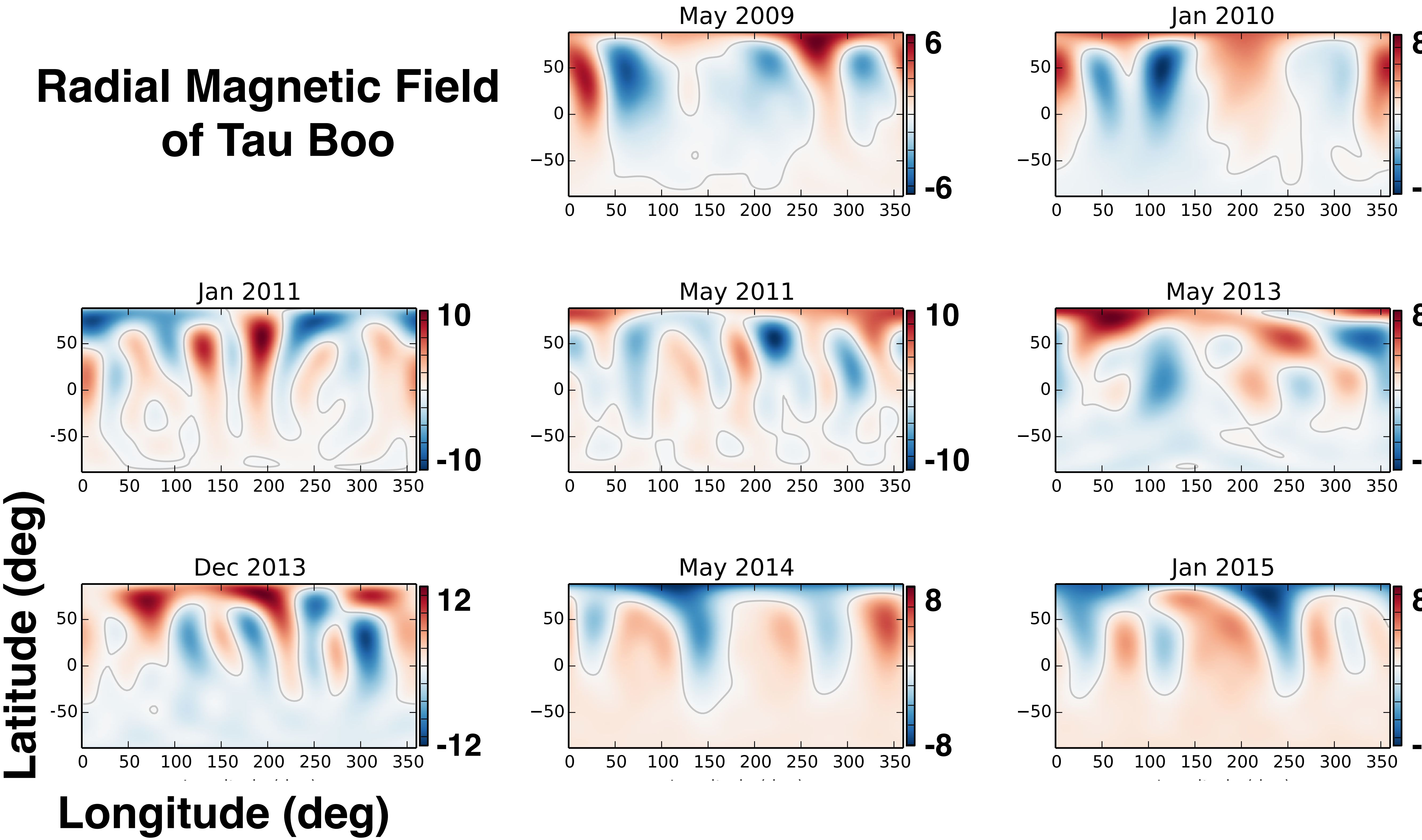
- Stellar parameters

- Radial magnetic field maps, reconstructed using Zeeman Doppler Imaging

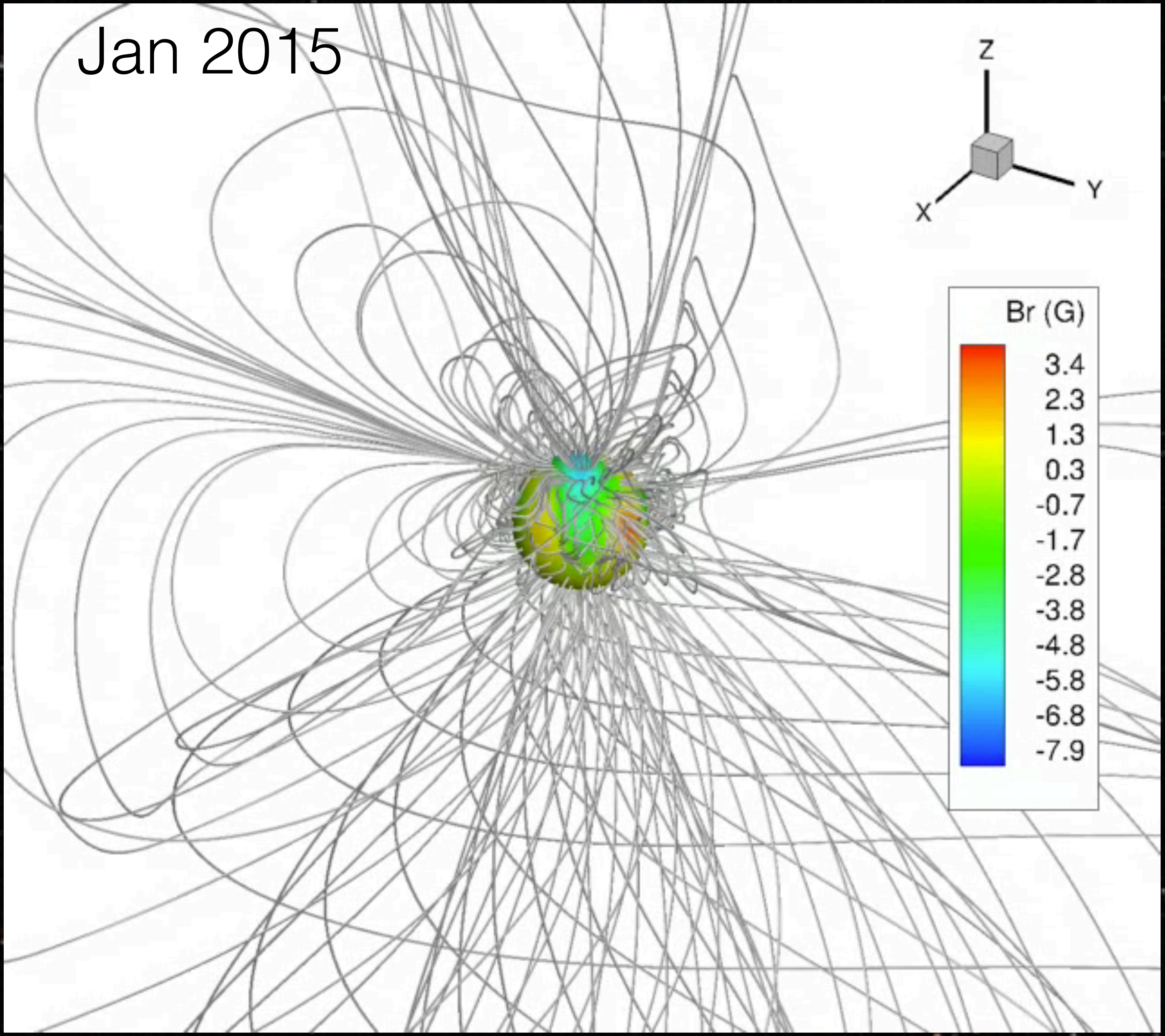
Output at each point of the 3D grid:

- Plasma velocity
- Plasma density
- Plasma pressure
- Magnetic field
- Current

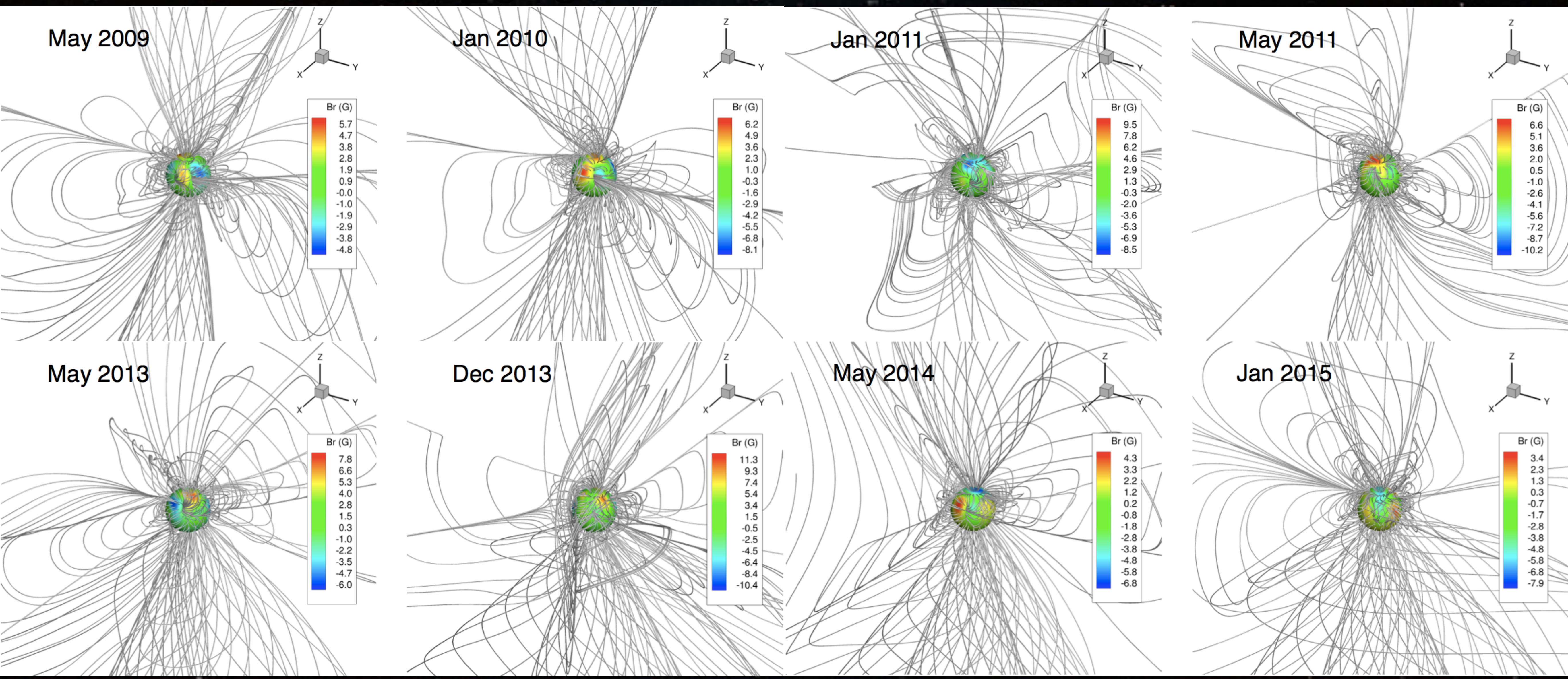
Radial Magnetic Field of Tau Boo



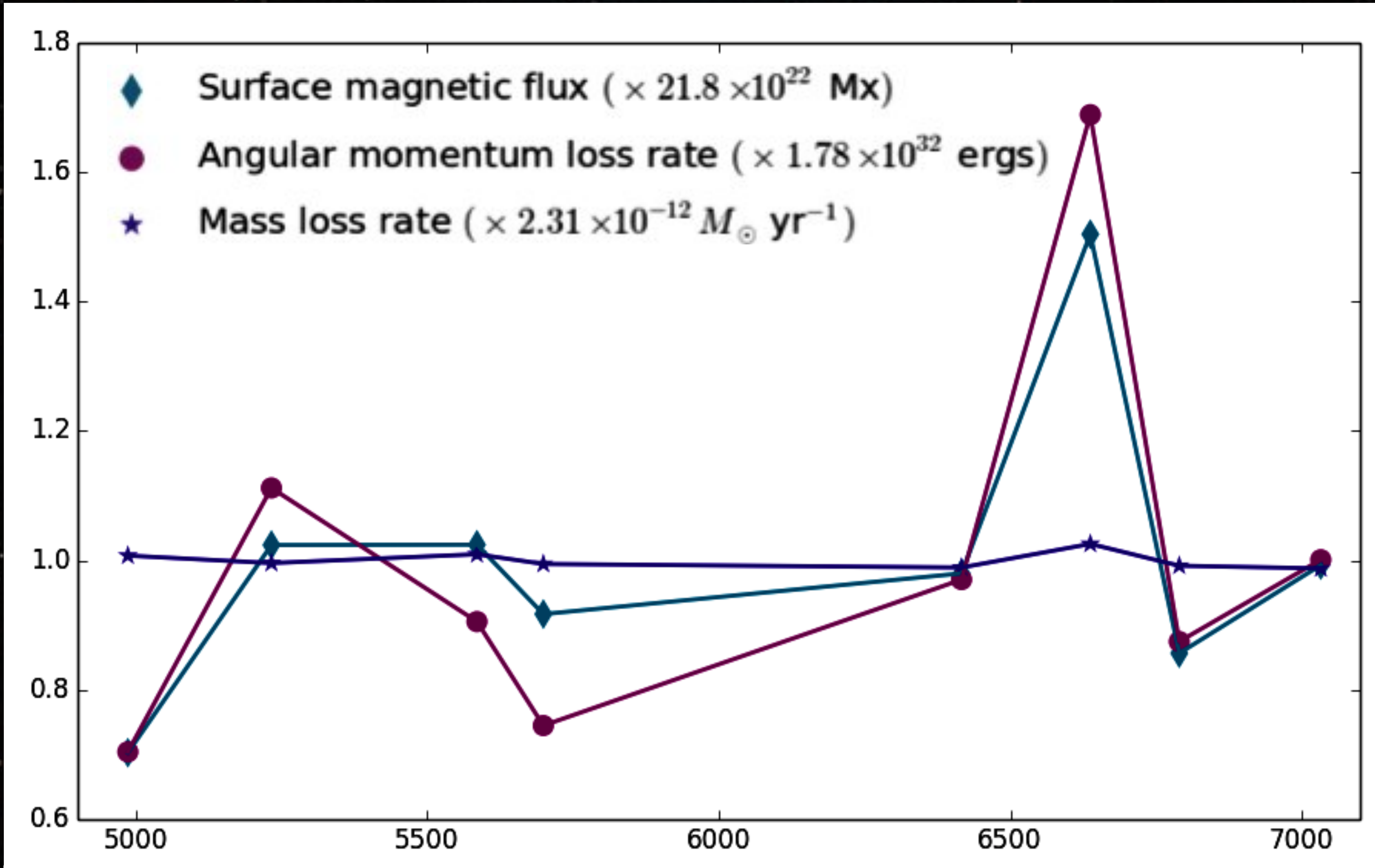
Simulation Results: Extended Global Magnetic Field



Simulation Results: Extended Global Magnetic Field

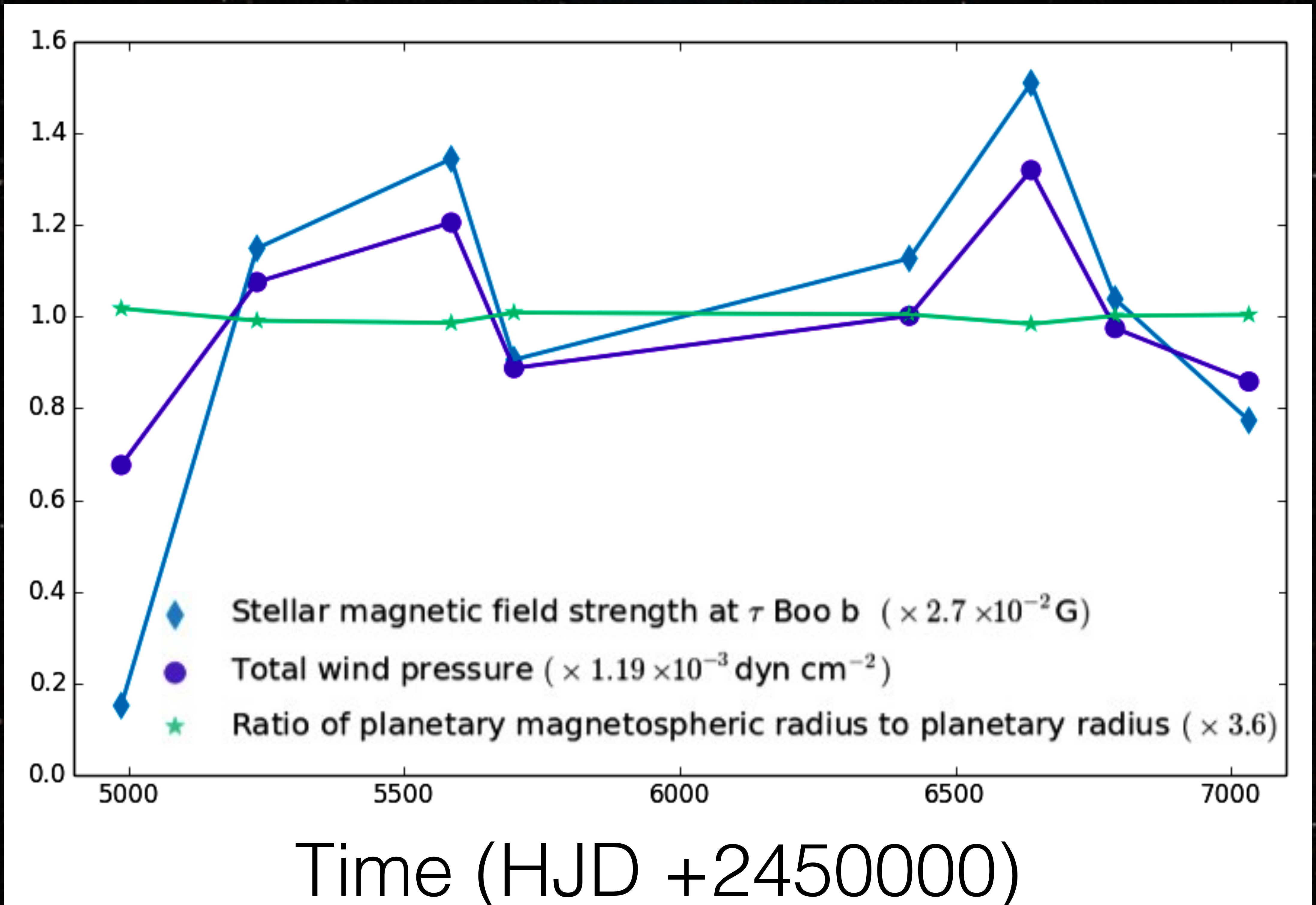


Simulation Results: Global Wind Parameters

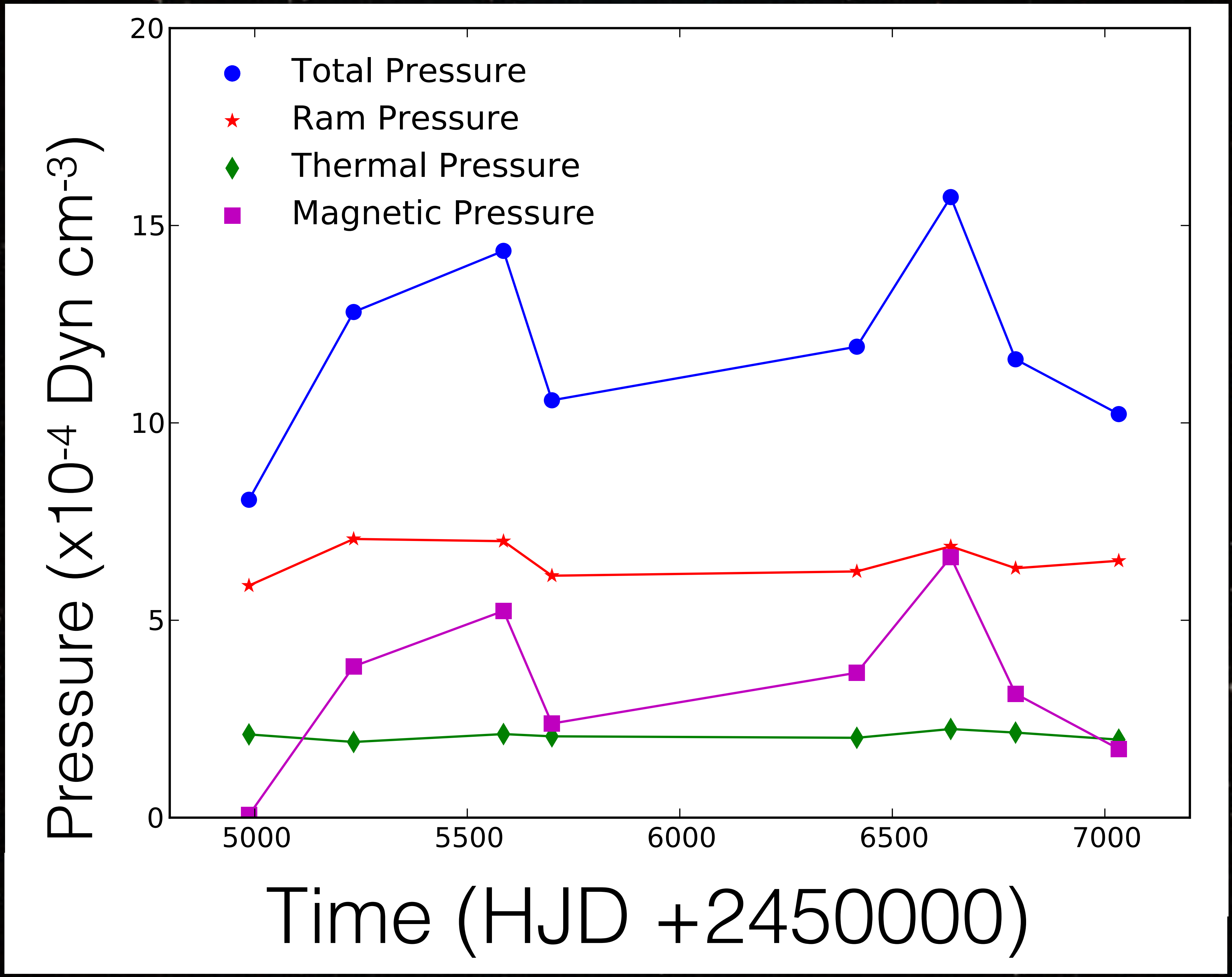


Time (HJD +2450000)

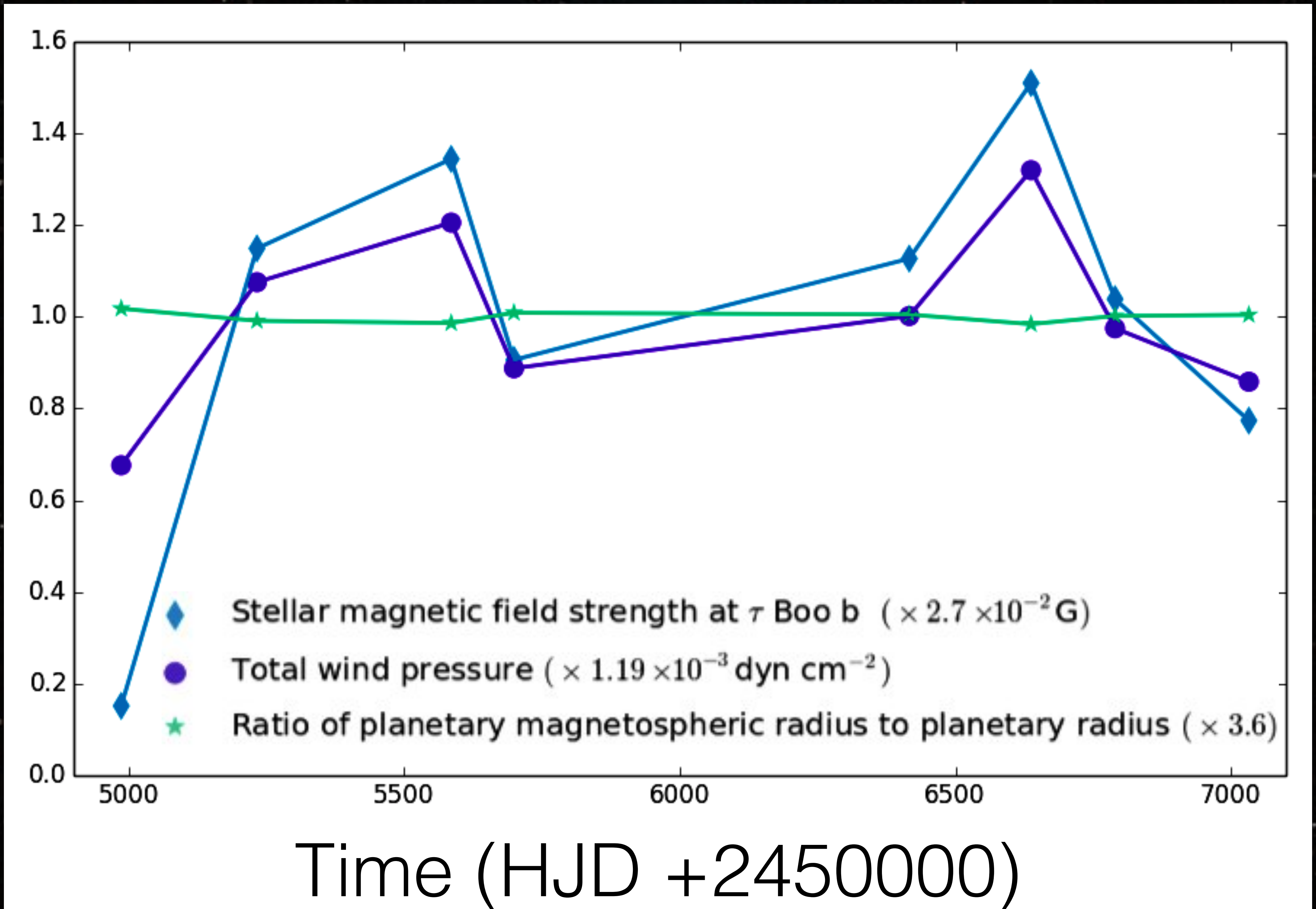
Simulation Results: Wind Around the Planet



Simulation Results: Pressure on the Planet



Simulation Results: Wind Around the Planet



Summary: The Wind of Tau Boo

- Mass loss rates vary only slightly over the cycle.
- Angular momentum loss rates vary with the changing magnetic field of the star
- Whilst the wind environment of the planet is varying greatly, the planet's magnetosphere (assuming it is similar to that of Jupiter) is expected to remain relatively stable