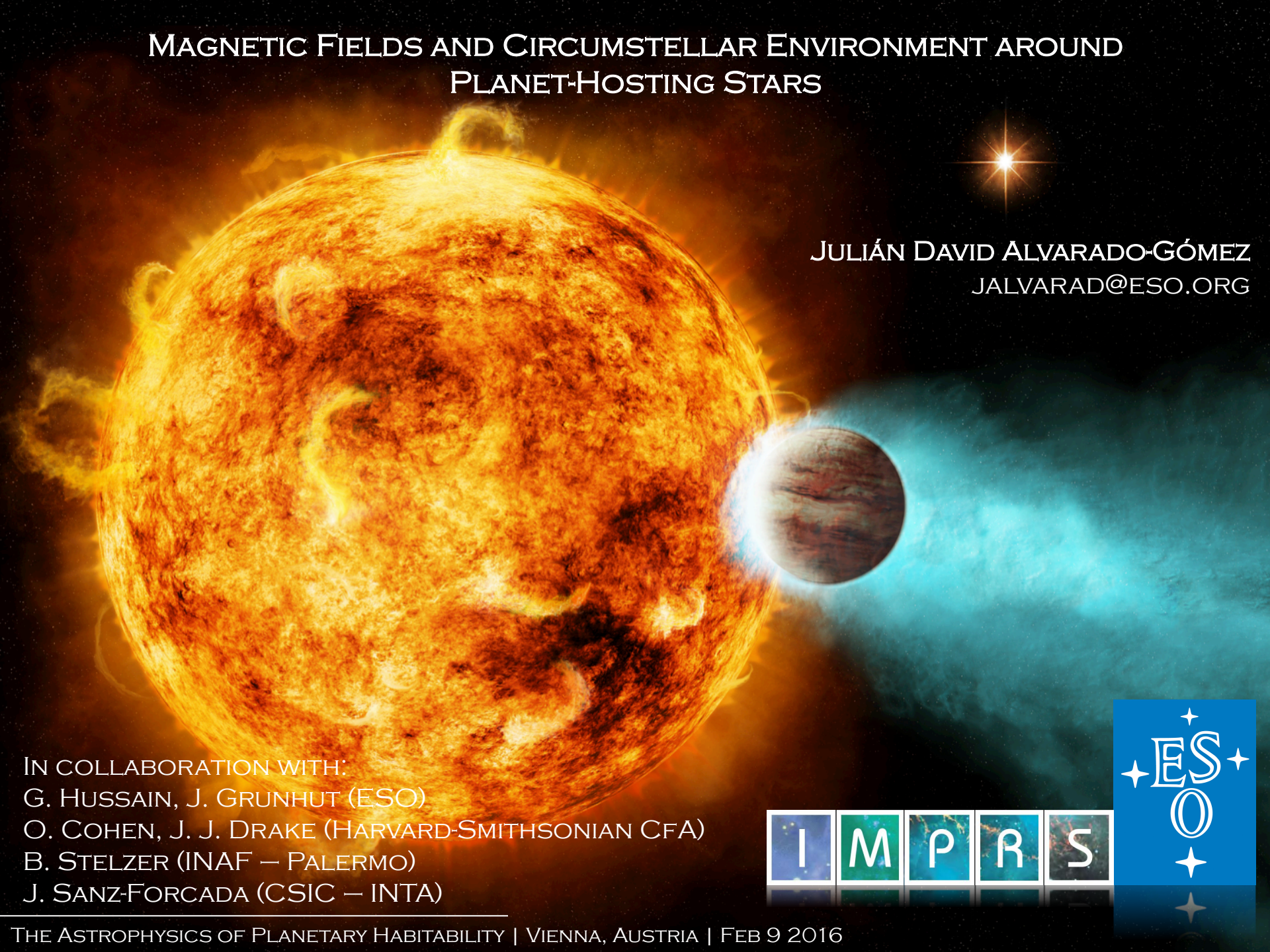
Magnetic Fields and Circumstellar Environment around Planet-Hosting Stars



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The Astrophysics of Planetary Habitability | Vienna, Austria | Feb 9 2016

Outline

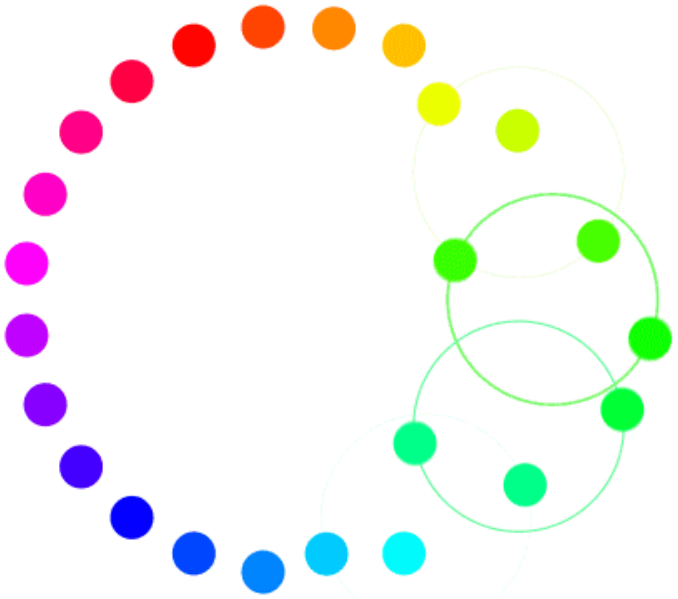
Context and Motivation

Planet-Hosting Systems

Modeling the Environment (SWMF)

Analysis and Results

Further Work



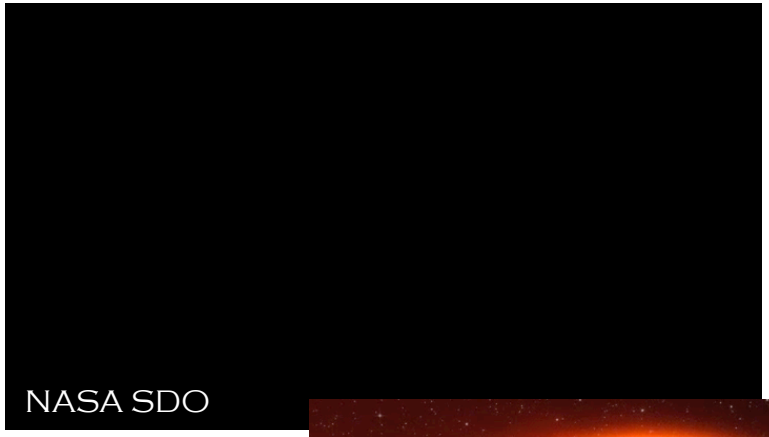
Zeeman Doppler Imaging (ZDI)

Magnetic Field Studies in Late-Type Stars

Context and Motivation

Heliophysics

- Dynamo Theories
- Energy Transport
- Transient Phenomena
- Space Weather
- Heliosphere


NASA SDO

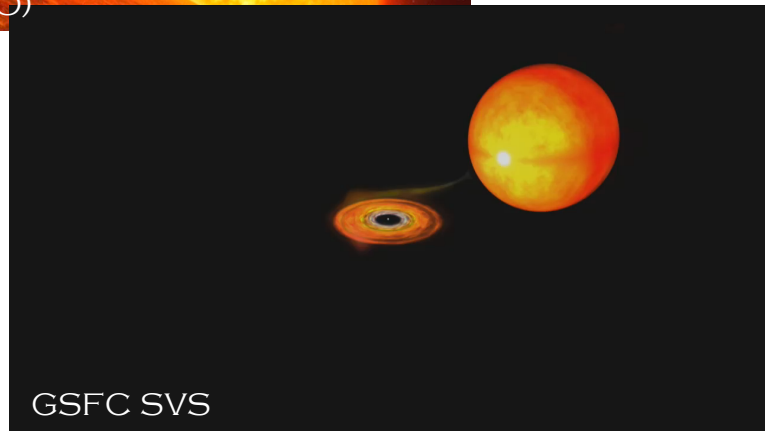
Exo-Planetary Systems

- Detection
- Super/Exo Earths
- Proper Characterization
- Exo-Space Weather
- Astrospheres


L. Calçada (ESO)

Other Regimes

- Spectral Type
- Evolutionary Stages
- "Exotic" Systems


GSFC SVS

Tomographic inversion technique based on time-series of polarized radiation, modulated by rotation.

Usually: Only Stokes V

Requires: Stellar Parameters

Ideally: Combined with DI

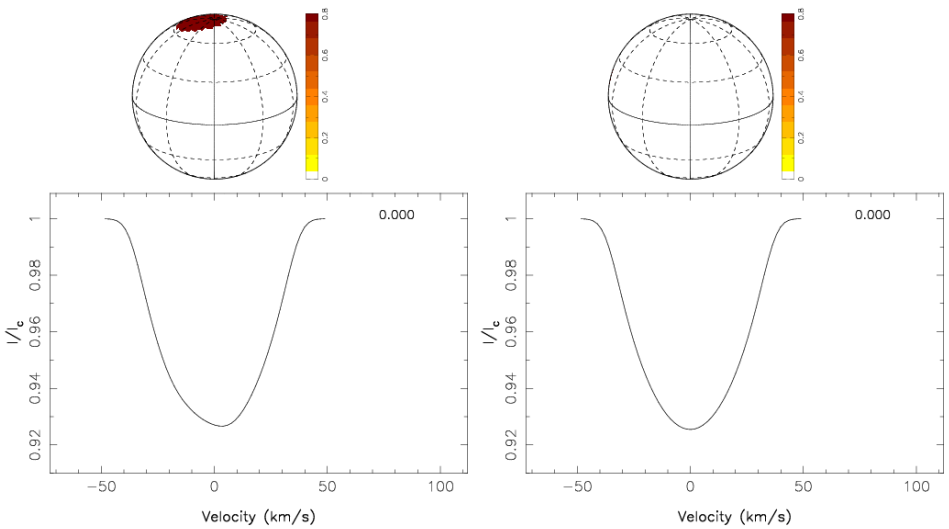
Requires: Good Phase Coverage

Assumes: Static Magnetic Field

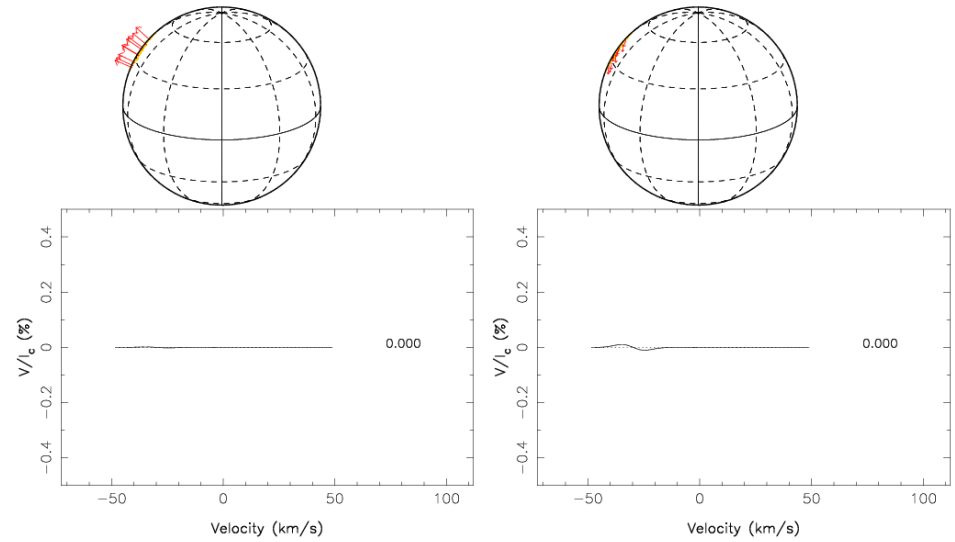
Includes: Regularization function

Recovers: The large-scale magnetic field distribution on the stellar surface (magnetic field maps – ZDI maps)

Brightness mapping (DI)



Magnetic field mapping (ZDI)



Credit: J.F. Donati (IRAP – OMP)

Developed: Fast rotators

Large–Scale Magnetic Field Maps

- Targets: Moderately active, planet–hosting Sun–like stars.
- Data: High–Resolution spectropolarimetric data from HARPSpol@ESO3.6m.
- Result: Surface distribution of the large–scale magnetic field.

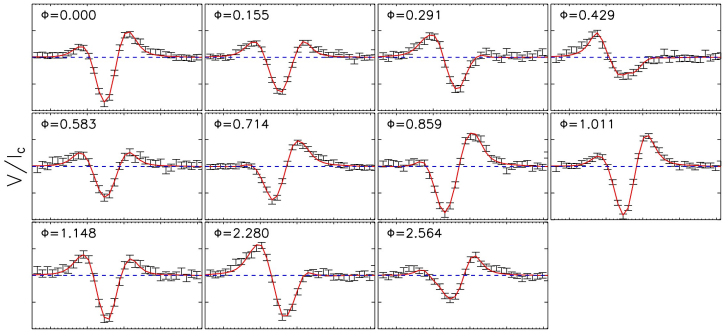
Name	Spectral Type	T_{EFF} [K]	$R_\star$ [$R_\odot$]	$M_\star$ [$M_\odot$]	P_{ROT} [D]	Activity		$M_P$sin(i)	a
						log(R'_{HK})	log(L_X)	[M_{JUP}]	[AU]
HD 1237	G8V	5572	0.86	1.00	7.00	– 4.38	29.02	3.37	0.49
HD 22049	K2V	5146	0.74	0.86	11.68	– 4.47	28.22	1.55	3.39
HD 147513	G5V	5930	0.98	1.07	10.00	– 4.64	28.92	1.21	1.32

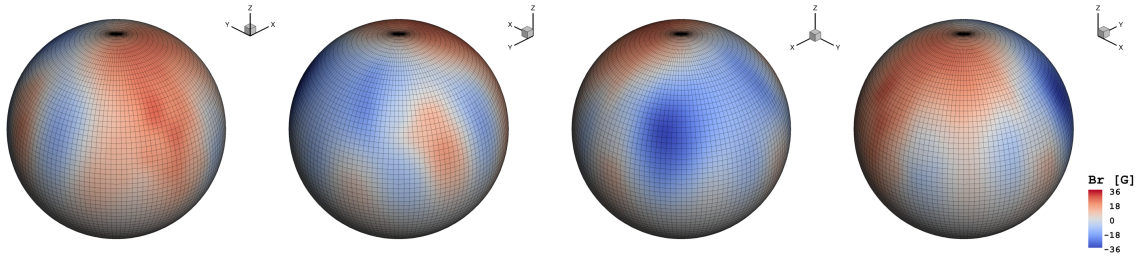
Target systems astrophysical properties.

- References:

HD1237: Naef et al. (2001)
HD 22049: Drake & Smith (1993), Hatzes et al. (2000), Benedict et al. (2006)
HD 147513: Mayor et al. (2004)

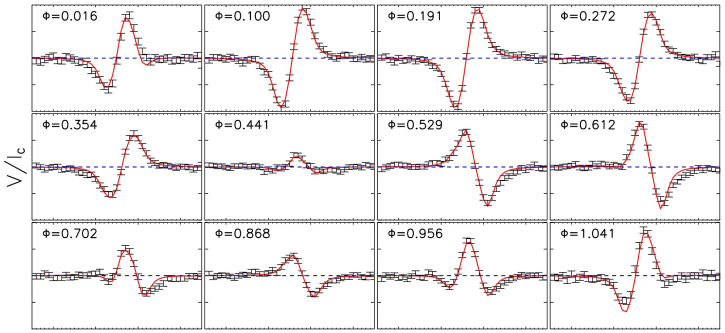
HD 1237 (GJ 3021)

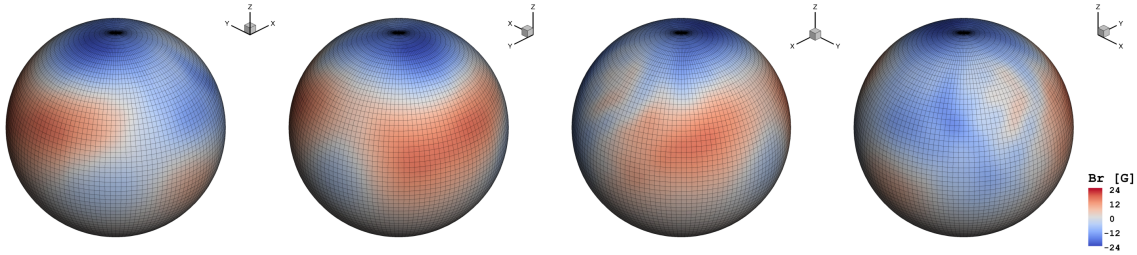




(Alvarado–Gómez et al. 2015)

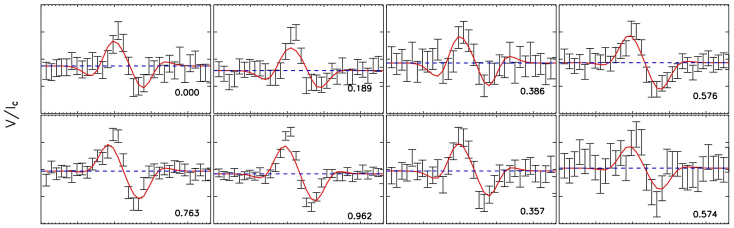
HD 22049 (ε Eridani)

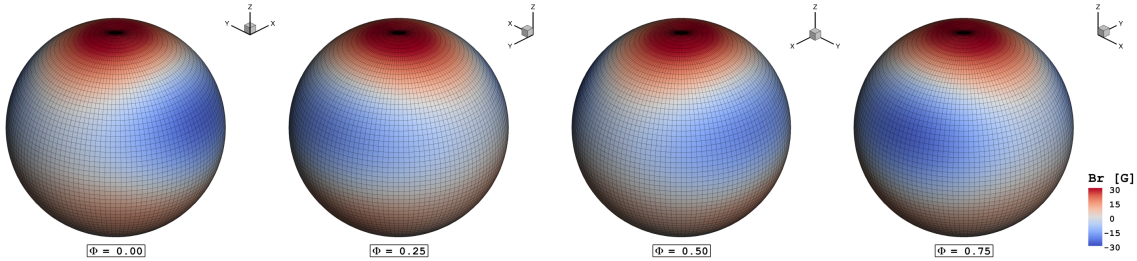




(Piskunov et al. 2011, Jeffers et al. 2014)

HD 147513 (62 G Scorpii)





(Hussain et al. 2015)

Data-driven numerical simulations

Space Weather Modeling Framework (SWMF)

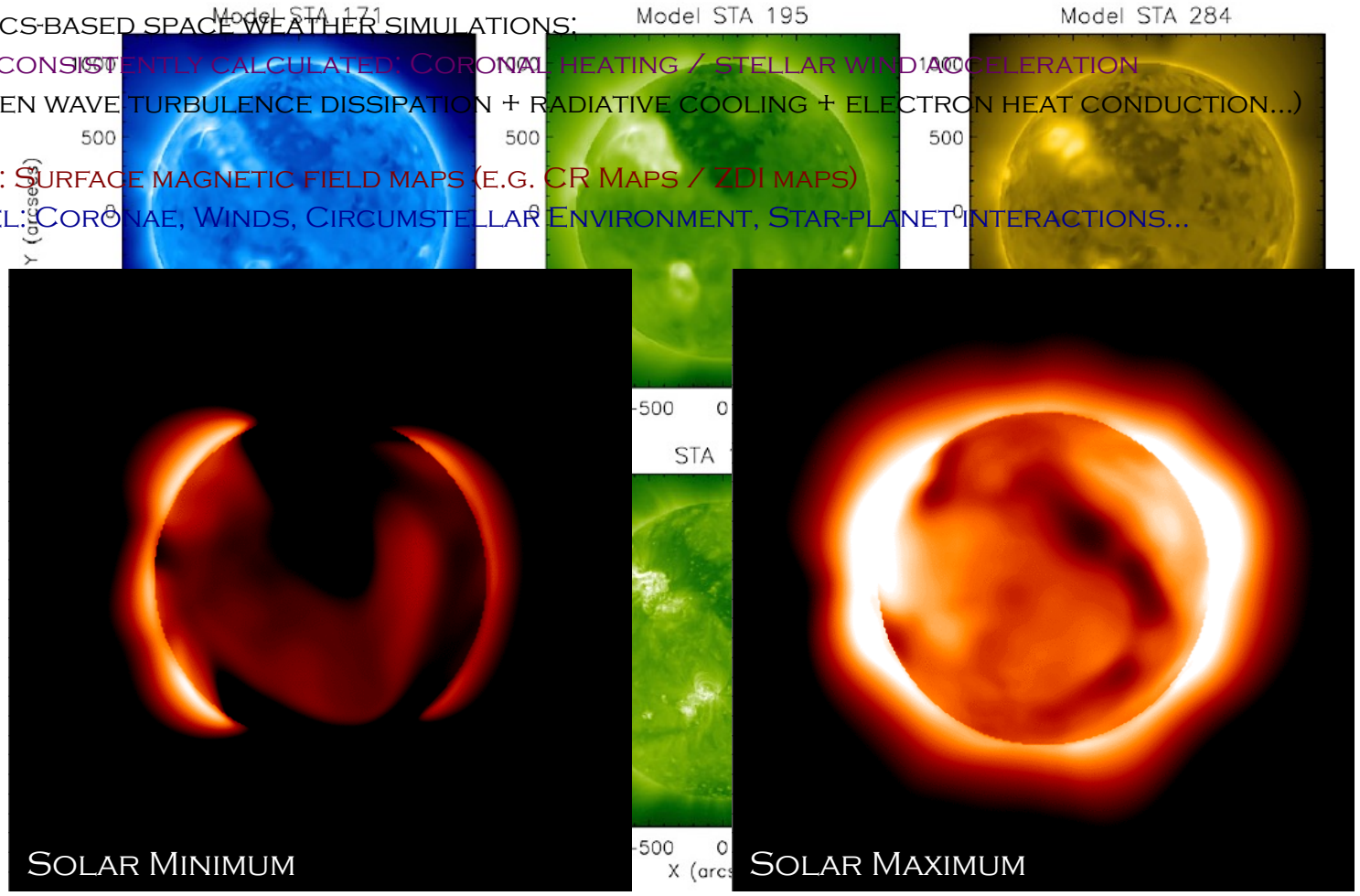
Modeling the Environment (SWMF)

State-of-the-art 3D MHD code used and validated in different Heliophysics domains

High-performance / parallel computing

Physics-based space weather simulations:
Self-consistently calculated: Coronal heating / stellar wind acceleration
(Alfven wave turbulence dissipation + radiative cooling + electron heat conduction...)

Input: Surface magnetic field maps (e.g. CR Maps / ZDI maps)
Model: Coronae, Winds, Circumstellar Environment, Star-planet interactions...



(van der Holst et al. 2014)

3D Coronal Structure

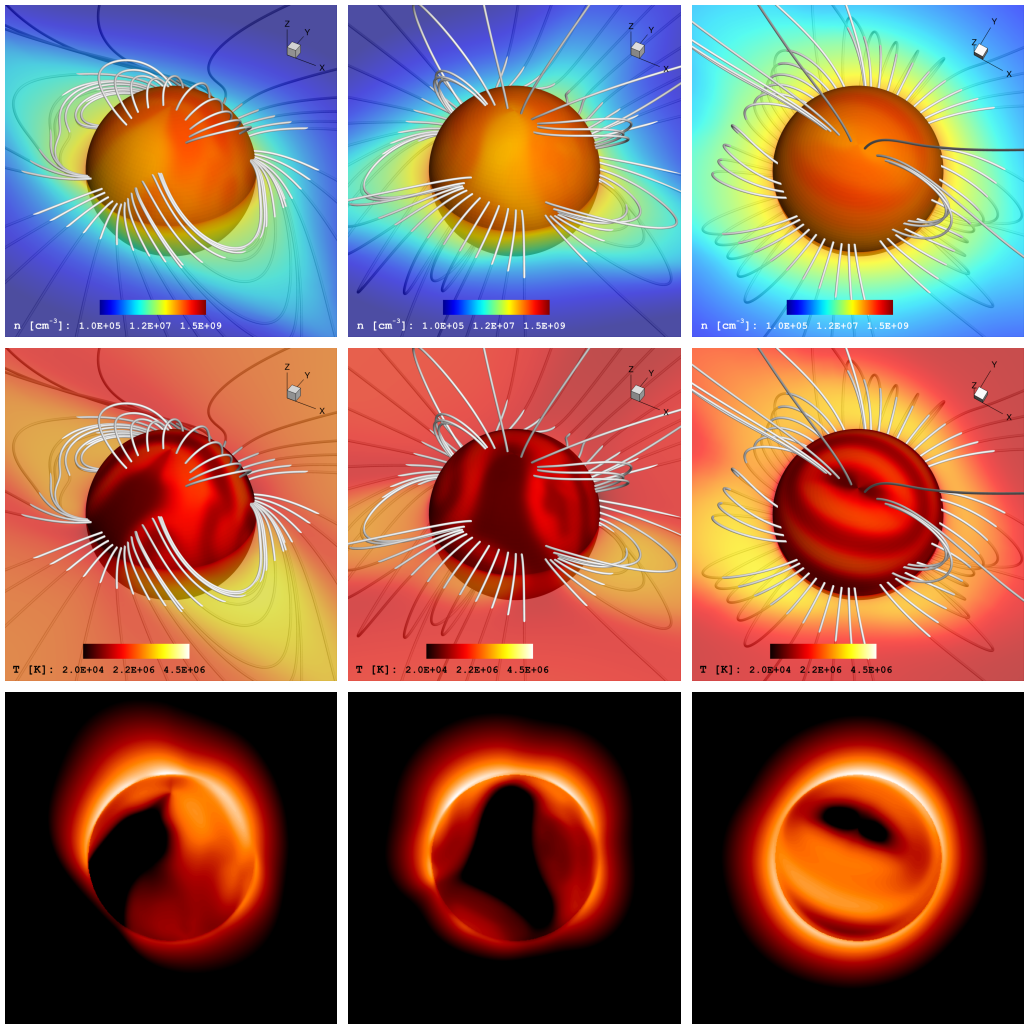
- Coronal features: Field topology
- Coronal thermodynamic conditions: Field strength (Unsigned flux)

HD 1237 | ε Eridani | HD 147513

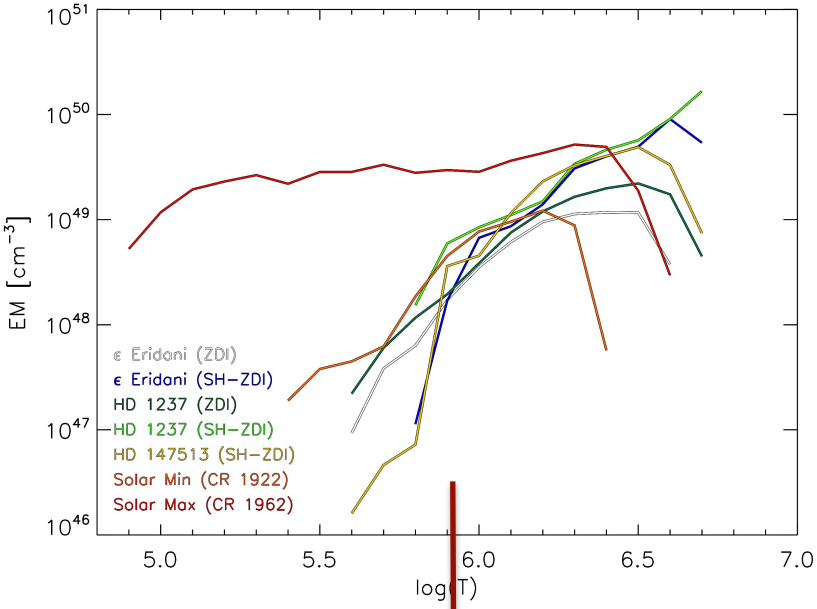
DENSITY

TEMPERATURE

SXR EMISSION



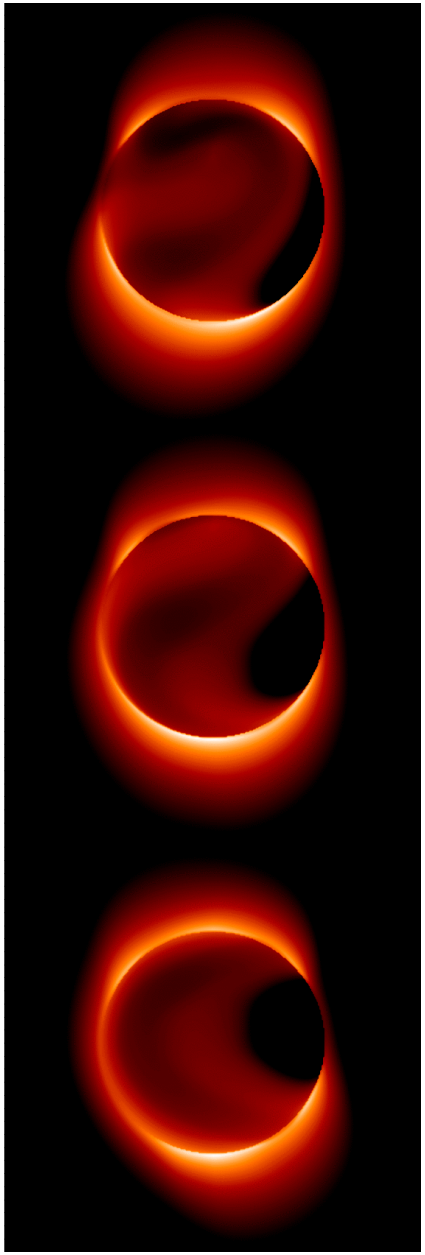
Emission Measure (EM) Distribution

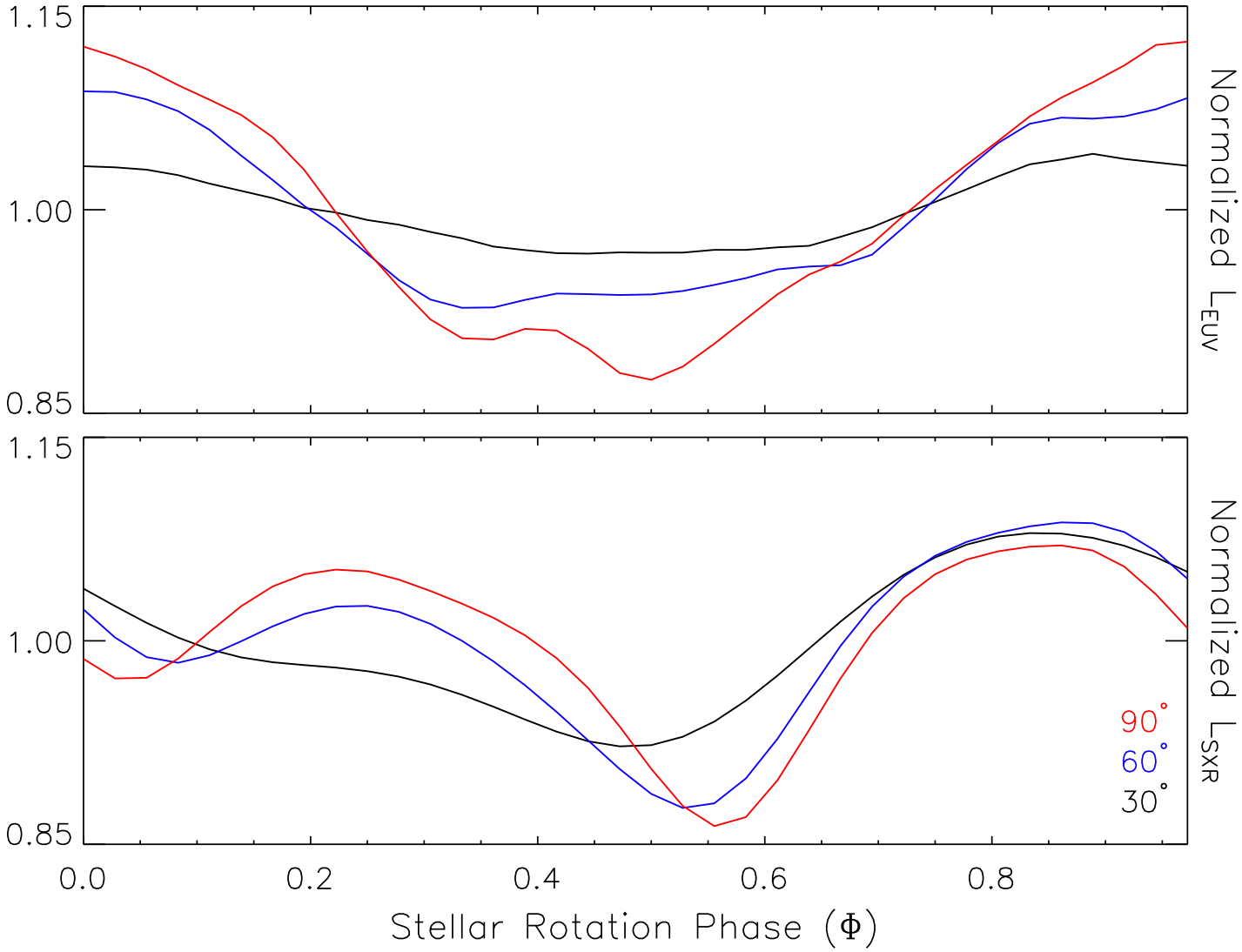


Synthetic Spectra

(Alvarado−Gómez et al. 2016)

Rotational modulation of the high-energy emission





(Alvarado–Gómez et al. 2016)

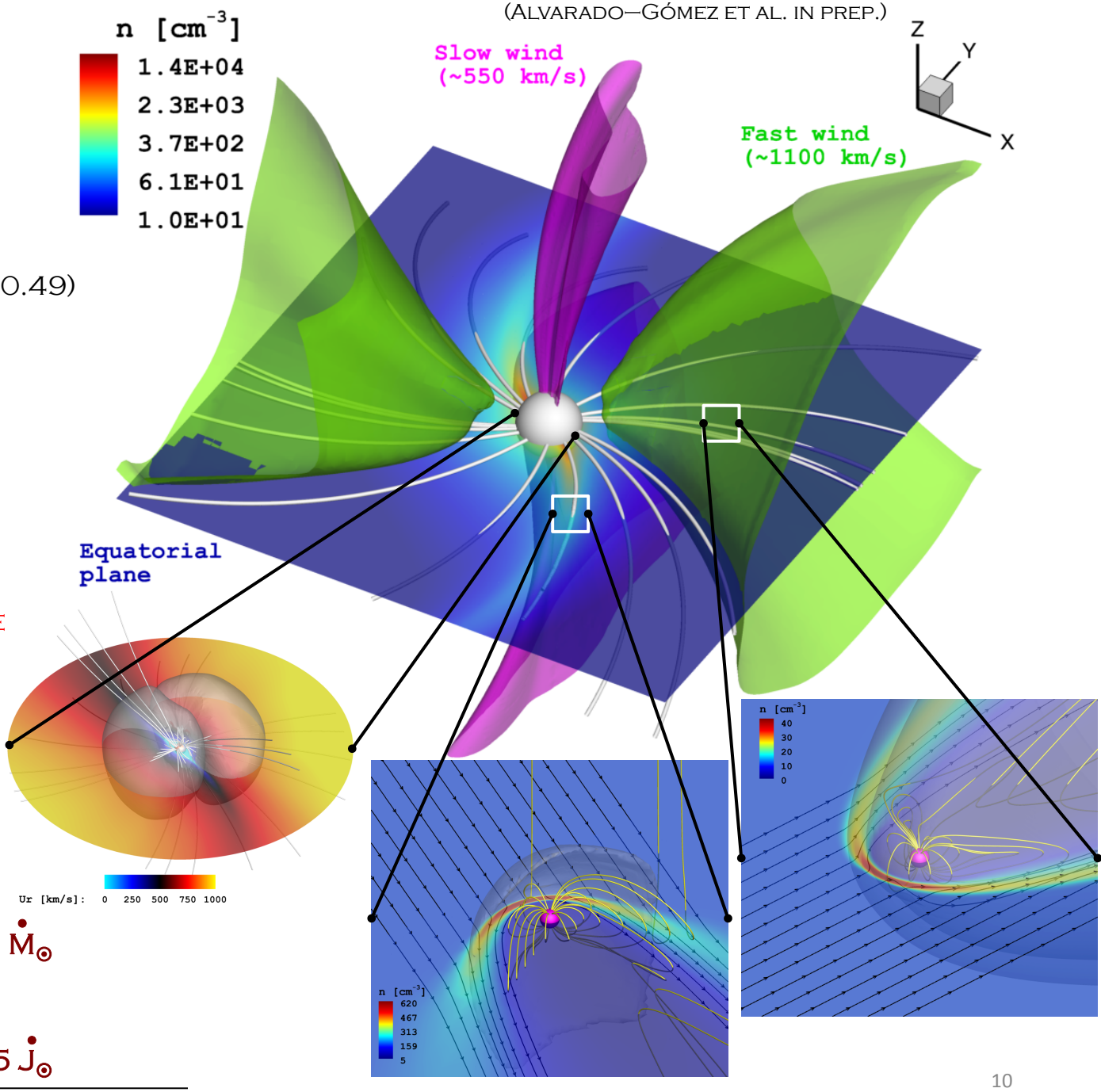
HD 1237 (GJ 3021)

(Alvarado–Gómez et al. in prep.)

Jupiter–mass planet
located at ~ 0.5 AU
(P_{ORB} = 133.7 ± 0.2 days, e = 0.49)
(Naef et al. 2001)

Strong wind-planet
interactions along
the orbit

Potentially detectable
in Radio/MW?

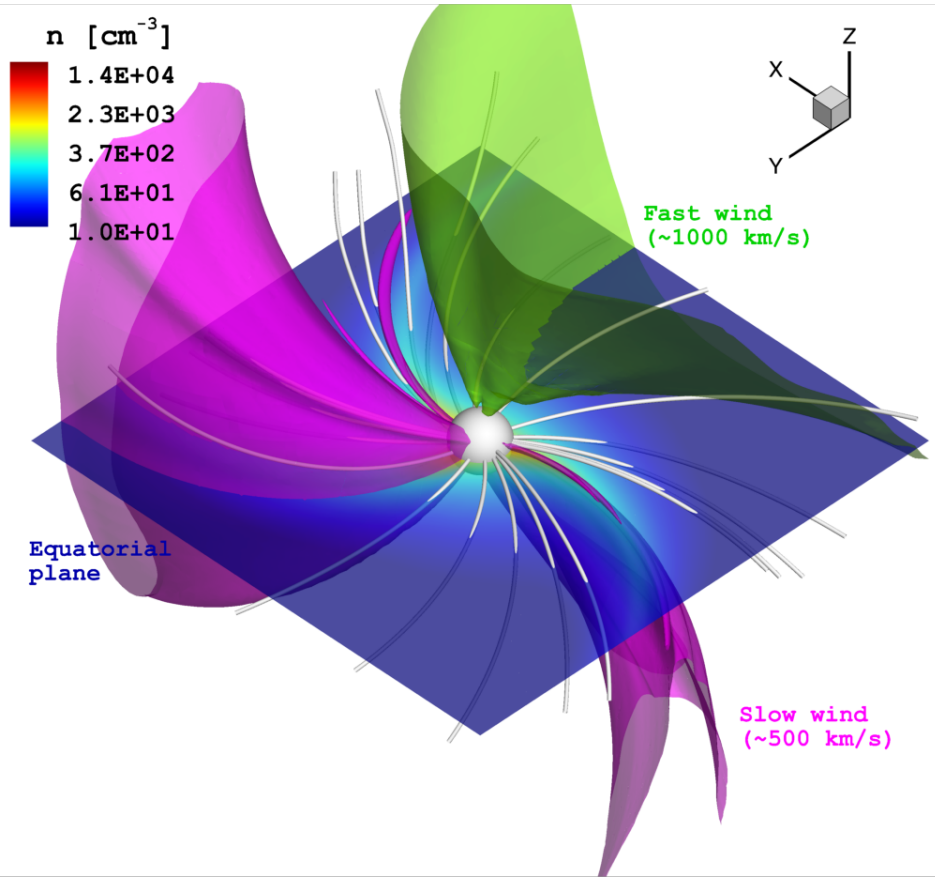


Mass loss: ~2 – 6 $\dot{M}_\odot$

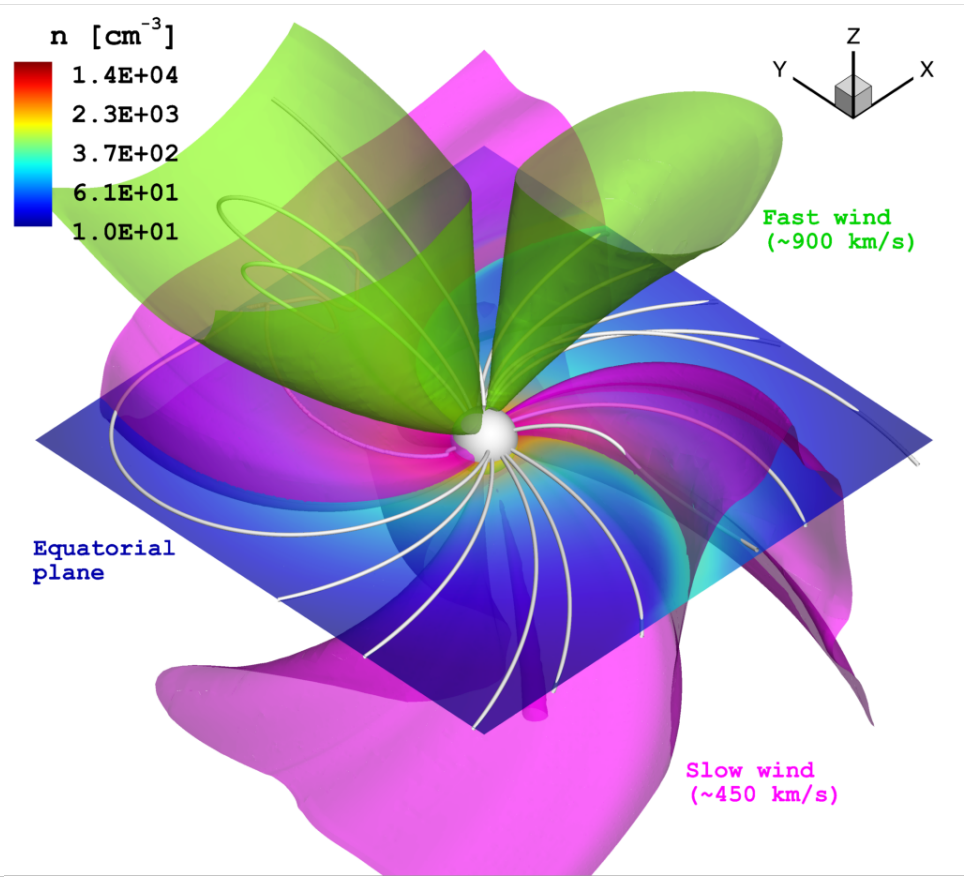
Angular momentum loss: ~5 – 15 $\dot{J}_\odot$

Stellar Wind Structure

HD 22049 (ε Eridani)

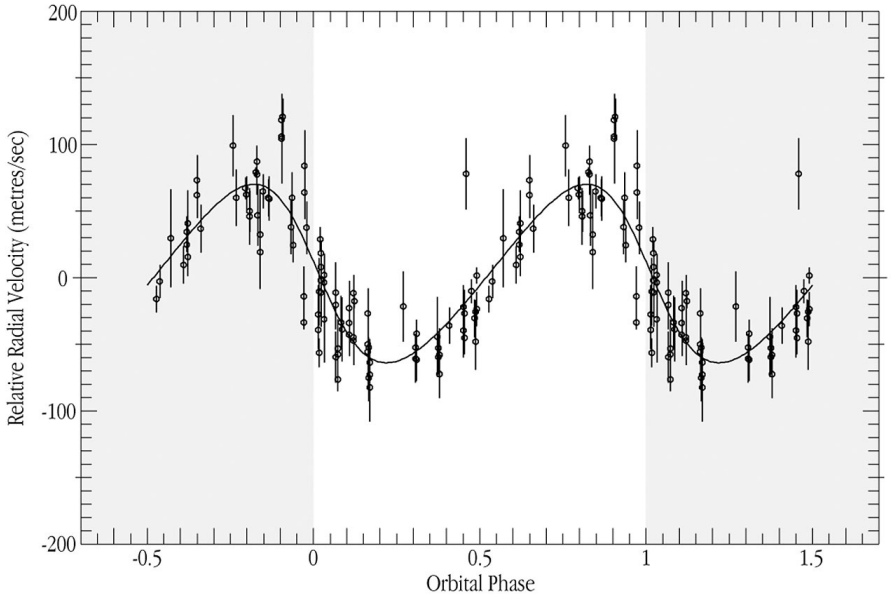


HD 147513 (62 G Scorpii)



(Alvarado–Gómez et al. in prep.)

Mass loss:	$\sim 1 - 4\ \dot{M}_\odot$	$\sim 2\ \dot{M}_\odot$
Angular momentum loss:	$\sim 1 - 5\ \dot{J}_\odot$	$\sim 6\ \dot{J}_\odot$

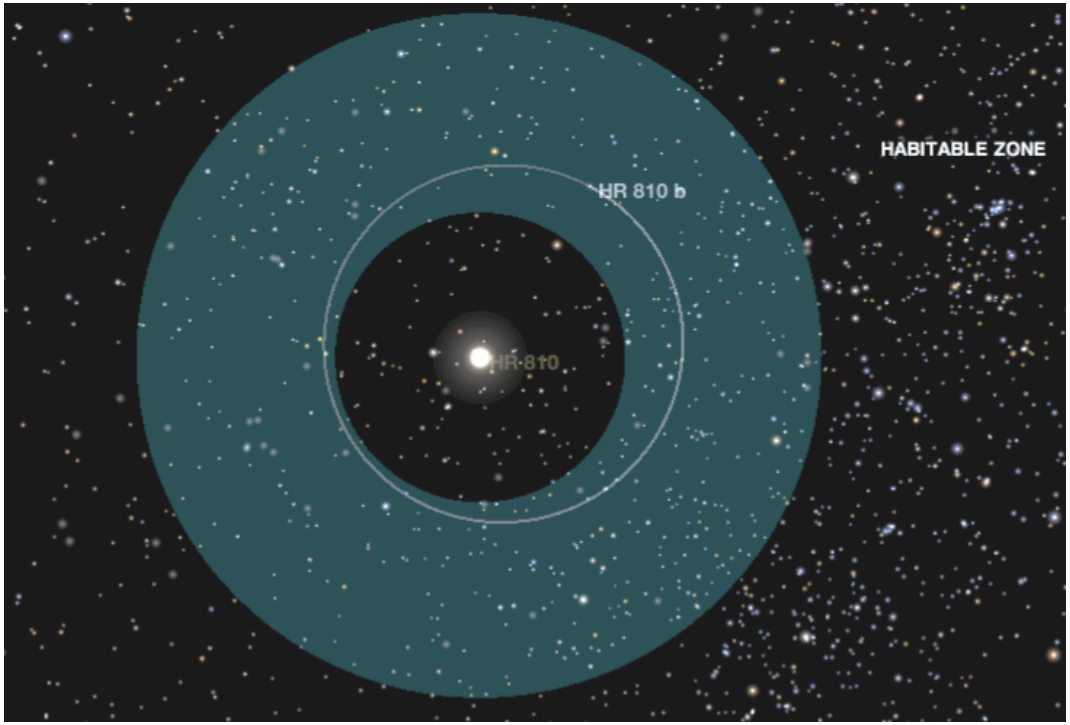


Kürster et al. (2000) – Butler et al. (2006)

ι Horologii b (HR 810b)

First exoplanet discovered with an ESO instrument

Planet Quest – NASA JPL



Properties:

$M_P \sin(i) = 2.05 \pm 0.2\ M_{\text{Jup}}$

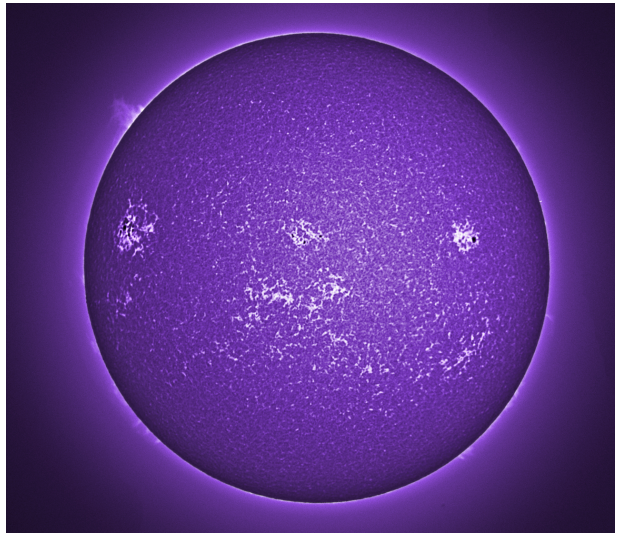
$a = 0.924 \pm 0.016$ AU

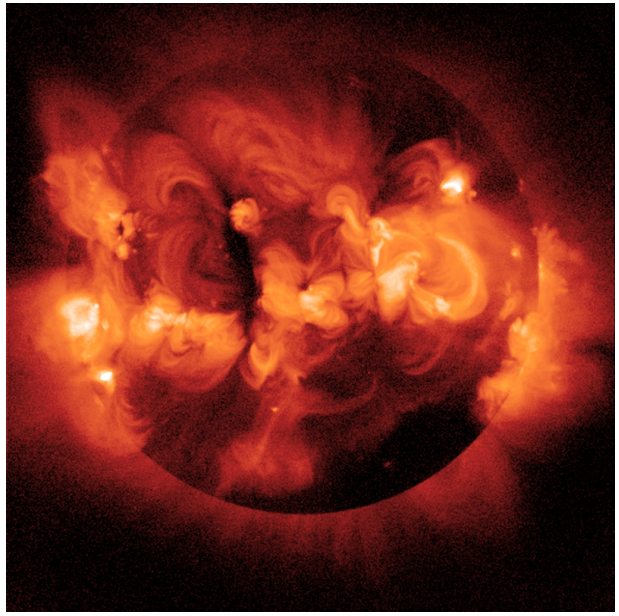
$P_{orb} = 302.8 \pm 2.3$ days

$e = 0.14 \pm 0.13$

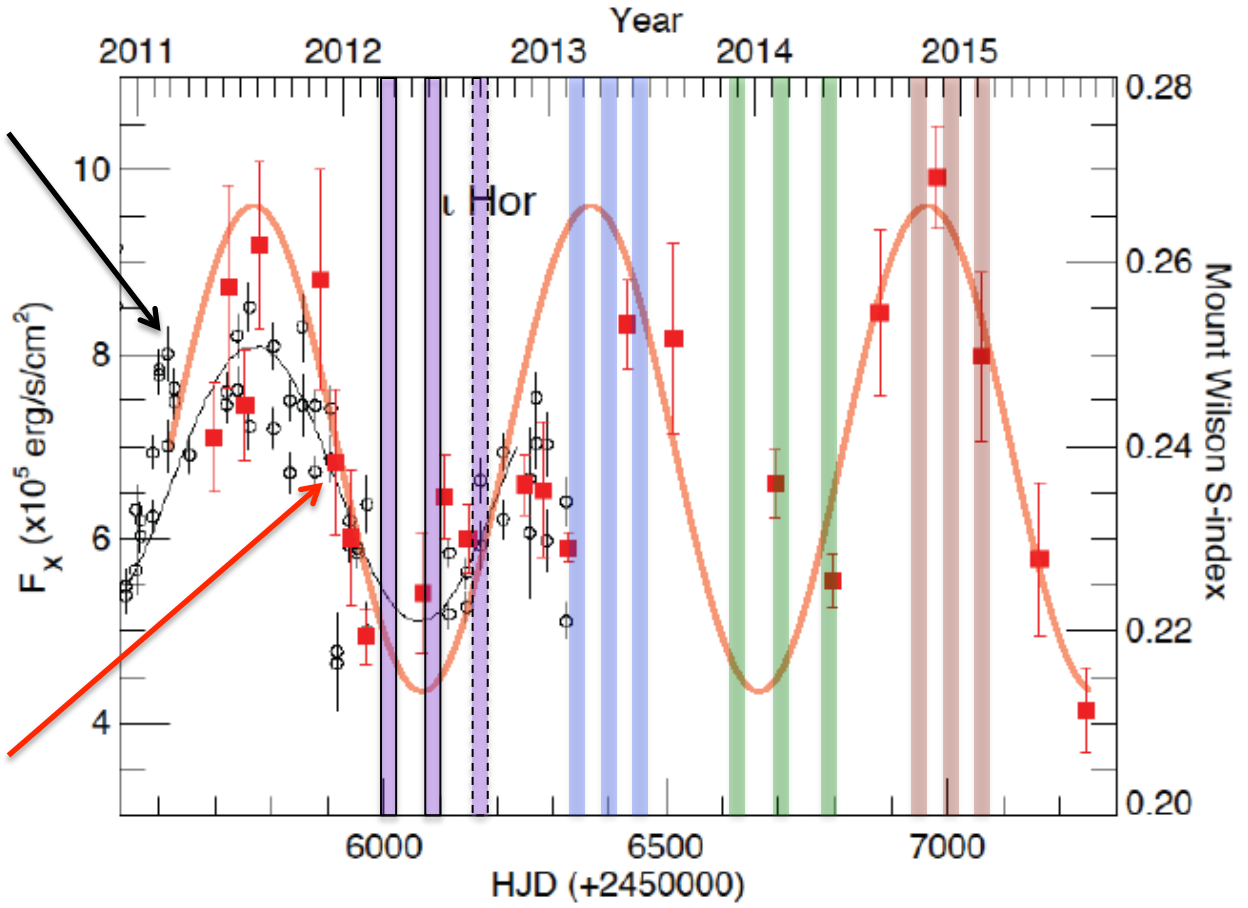
RMS = 27 m/s (19 m/s)

ι Horologii (HR 810) Activity Cycle



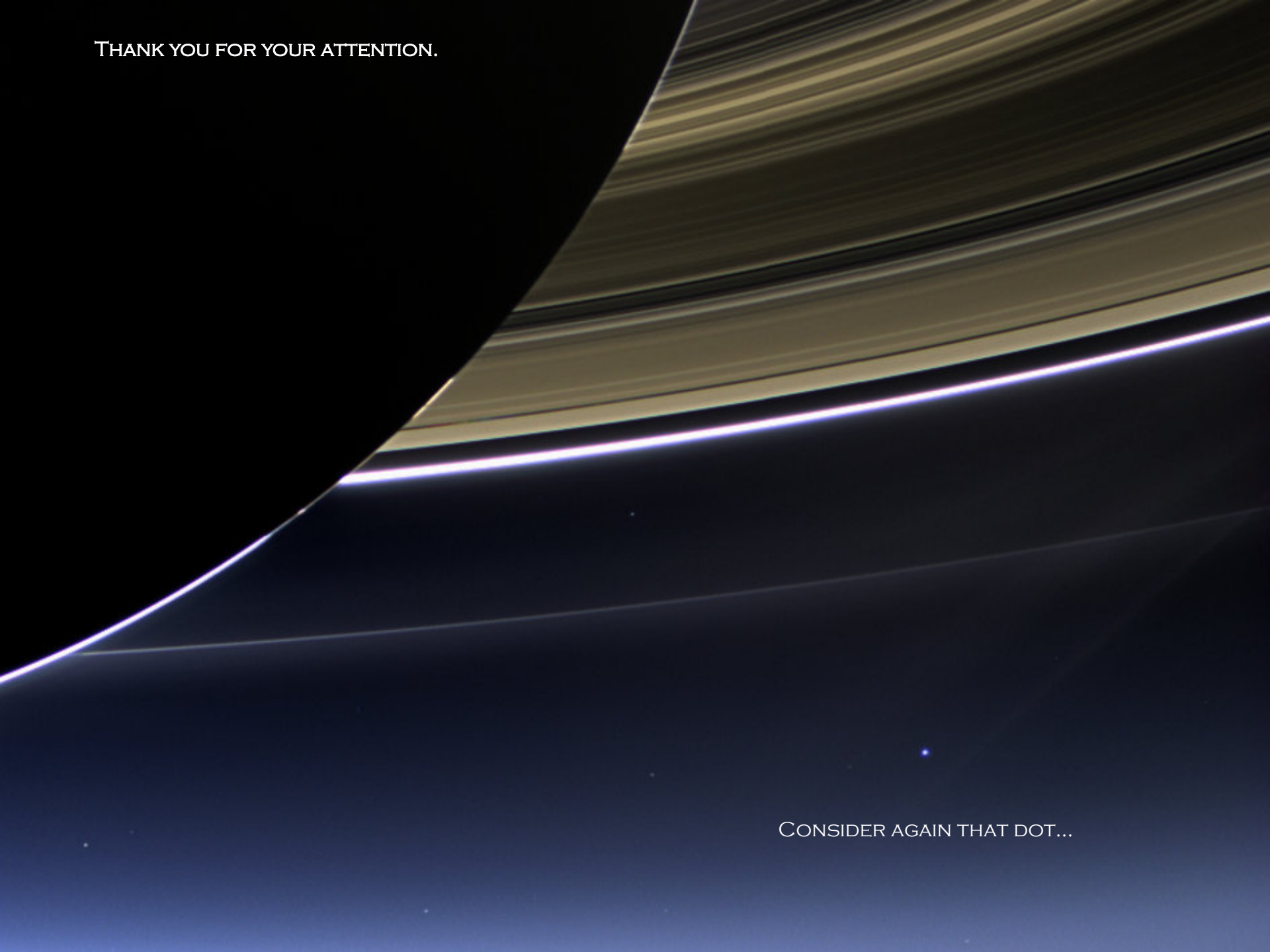


Adapted from Sanz-Forcada et al. (2013)



☑ P96 ☑ P97 ☐ P98 ☐ P99

(ST: G0V – Age: ~600-700 Myr)


Thank you for your attention.
Consider again that dot...