Simulating the Environment around Planet-Hosting Stars

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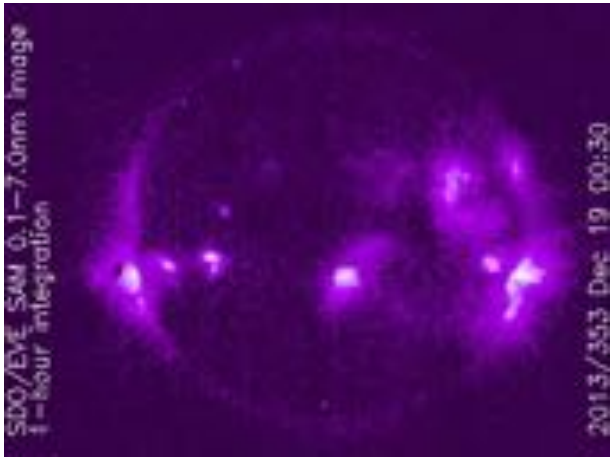
Motivation: Understand the effects of stellar magnetic fields on the surrounding environment

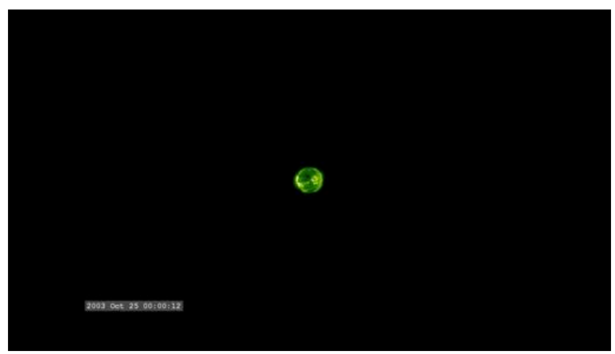
High-Energy Emission

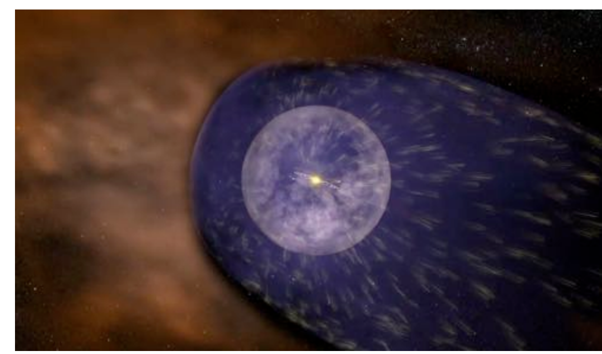
Coronal Structure + Stellar Wind + Planetary Environment



Transient Phenomena (Flares/CMEs)

Astrospheres





Advanced Observational Techniques ⟷ Detailed Numerical Simulations

This Study:

Targets: Moderately active, planet–hosting Sun–like stars

Data: High–Resolution spectropolarimetric time-series from HARPSpol@ESO3.6m

Technique: Zeeman-Doppler Imaging (ZDI)

Result: Surface distribution of the large–scale magnetic field

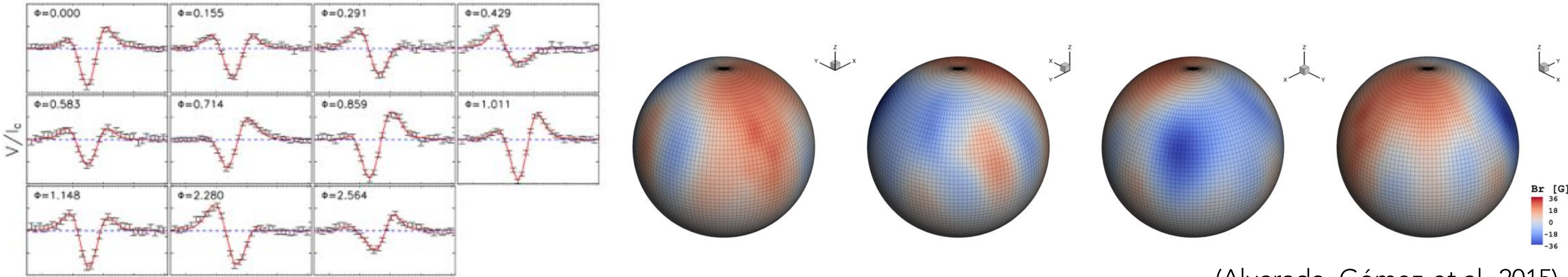
Name	Spectral Type	T_{EFF} [K]	$R_\star$ [$R_\odot$]	$M_\star$ [$M_\odot$]	P_{ROT} [d]	Activity $\log(R'_{HK})$	Activity $\log(L_X)$	$M_p\sin(i)$ [$M_{♃}$]	a [AU]
HD 1237	G8V	5572	0.86	1.00	7.00	– 4.38	29.02	3.37	0.49
HD 22049	K2V	5146	0.74	0.86	11.68	– 4.47	28.22	1.55	3.39
HD 147513	G5V	5930	0.98	1.07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

Target systems astrophysical properties.

References:

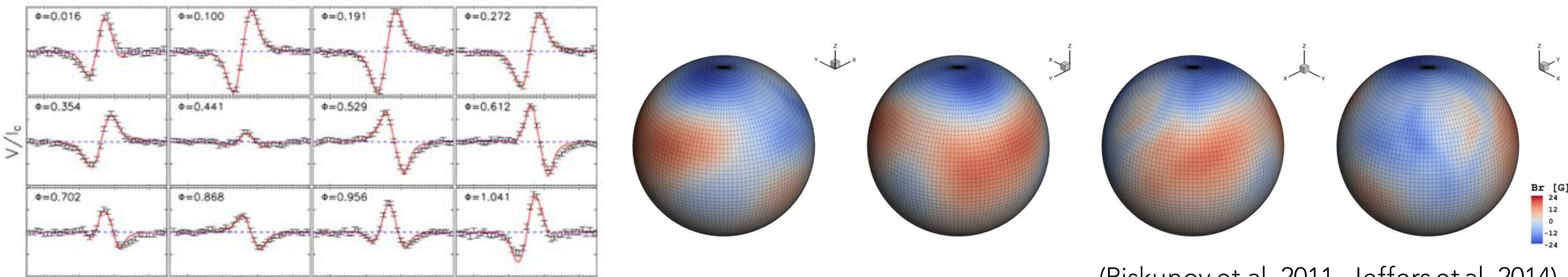
HD1237 (GJ 3021): Naef et al. (2001)
HD 22049 (ε Eridani) : Drake & Smith (1993), Hatzes et al. (2000), Benedict et al. (2006)
HD 147513 (62 G Scorpii): Mayor et al. (2004)

HD 1237 (GJ 3021)



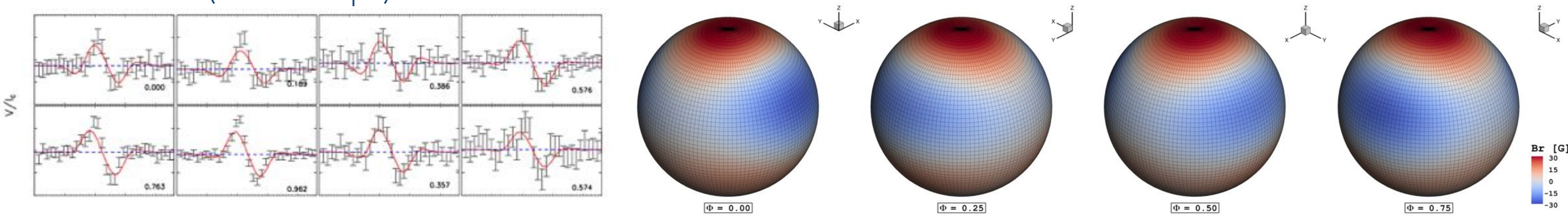
(Alvarado–Gómez et al. 2015)

HD 22049 (ε Eridani)



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

HD 147513 (62 G Scorpii)



(Hussain et al. 2016)

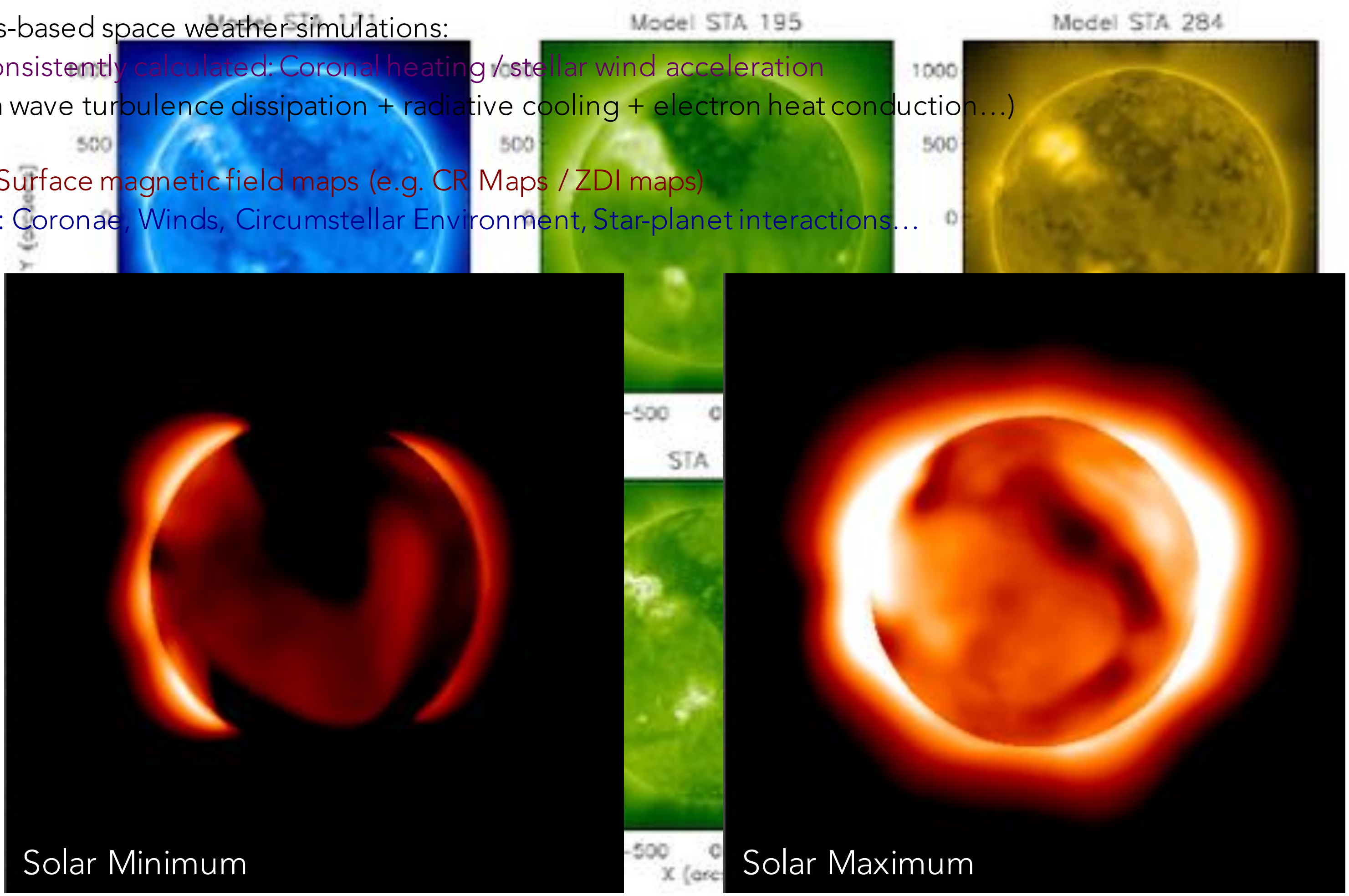
Space Weather Modeling Framework (SWMF)

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

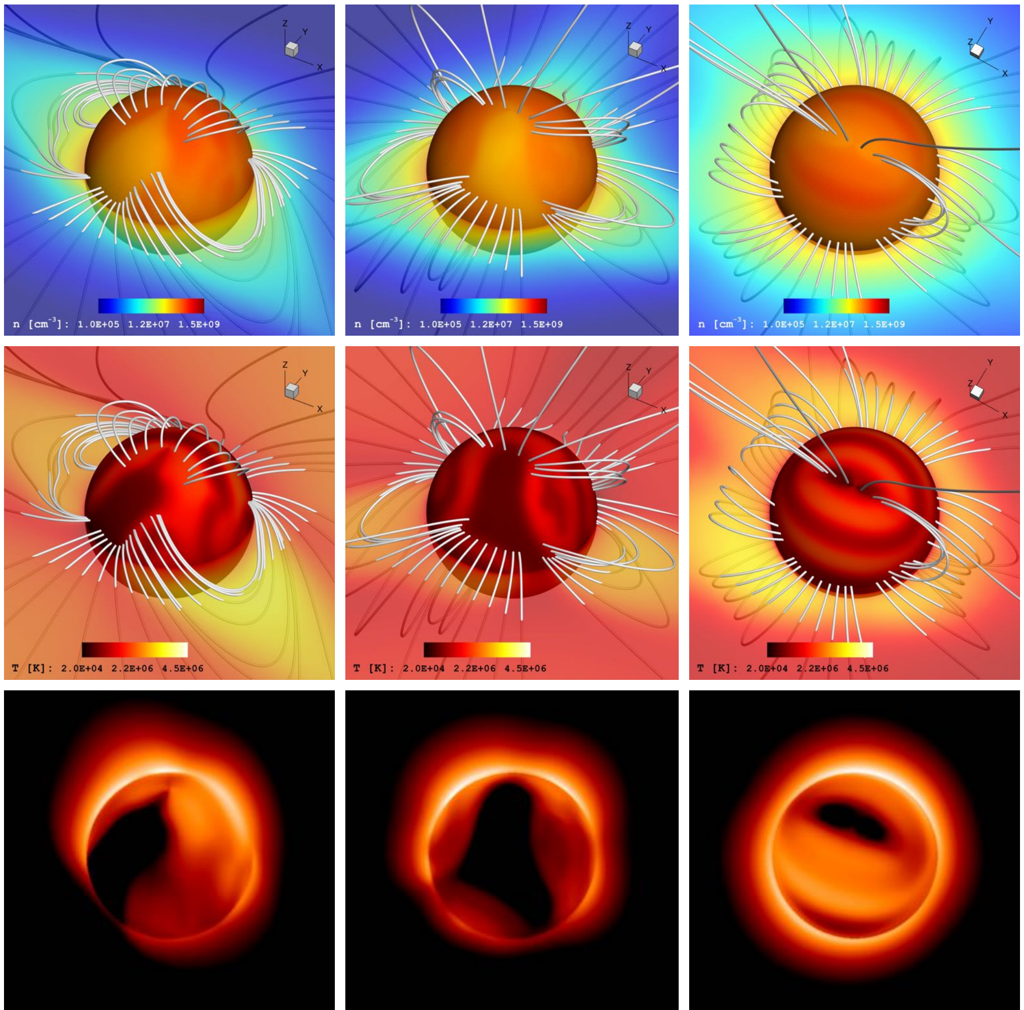
Coronal thermodynamic conditions: Field strength (Unsigned flux)

HD 1237 | ε Eridani | HD 147513

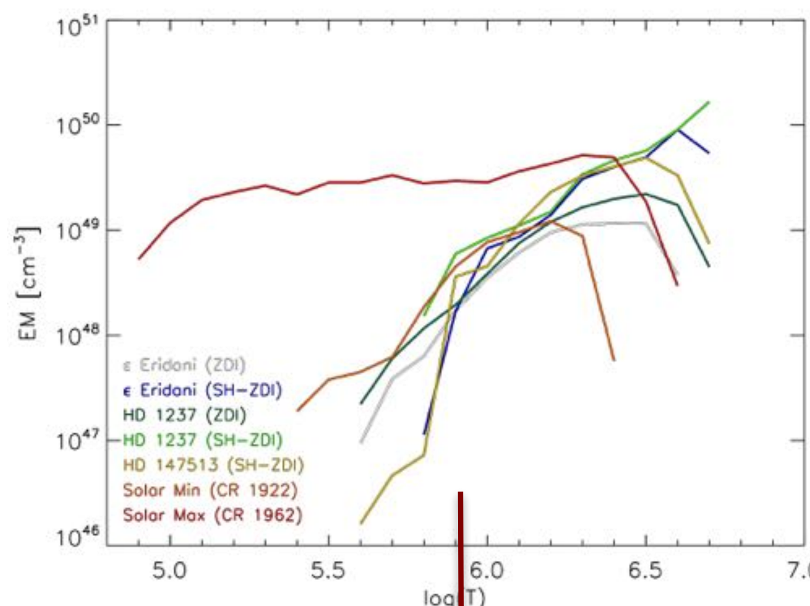
DENSITY

TEMPERATURE

SXR EMISSION



Emission Measure (EM) Distribution

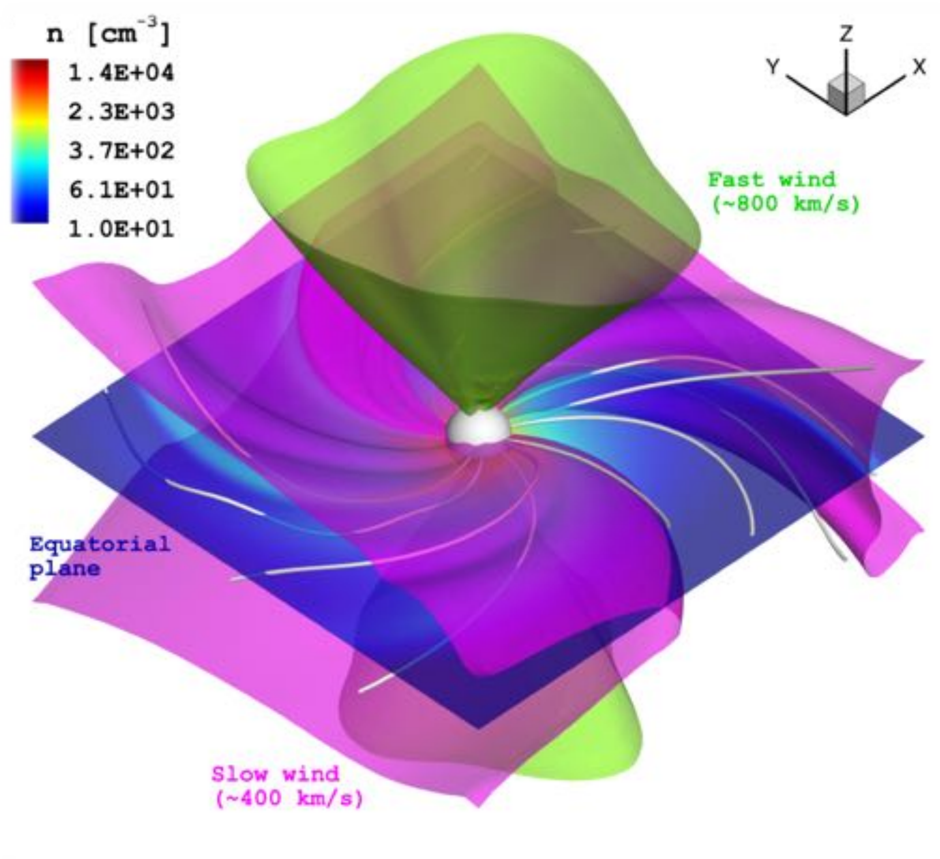


Synthetic Spectra

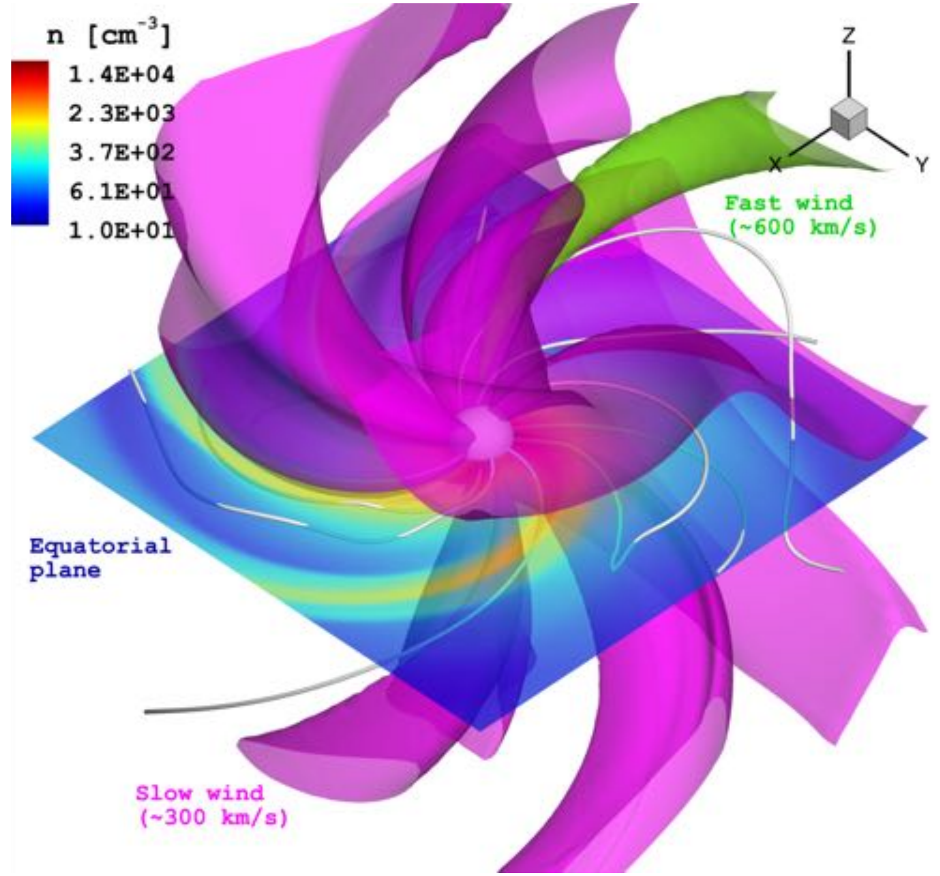
(Alvarado–Gómez et al. 2016a)

Solar Wind Structure

Solar Minimum



Solar Maximum



Alvarado–Gómez et al. (2016b, submitted)

Fast-wind from the poles
(Coronal Holes)

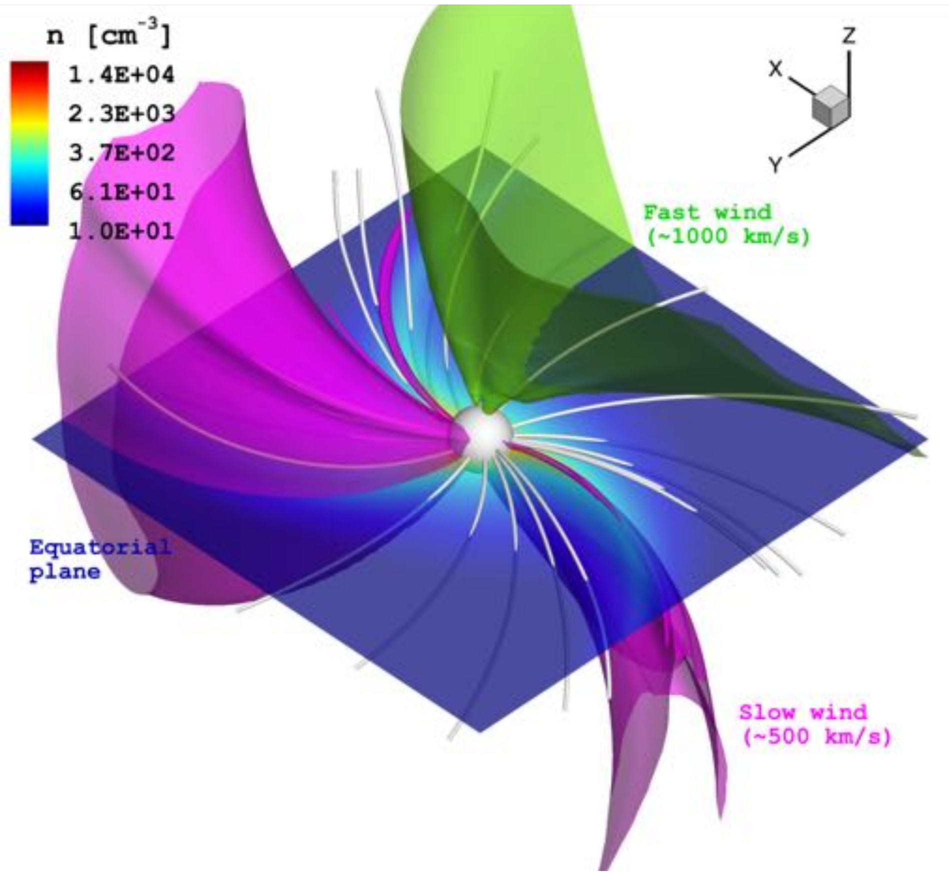
Slow-wind along the Equatorial plane
("Ballerina Skirt")

Slow-wind dominates the structure
(closed-field regions)

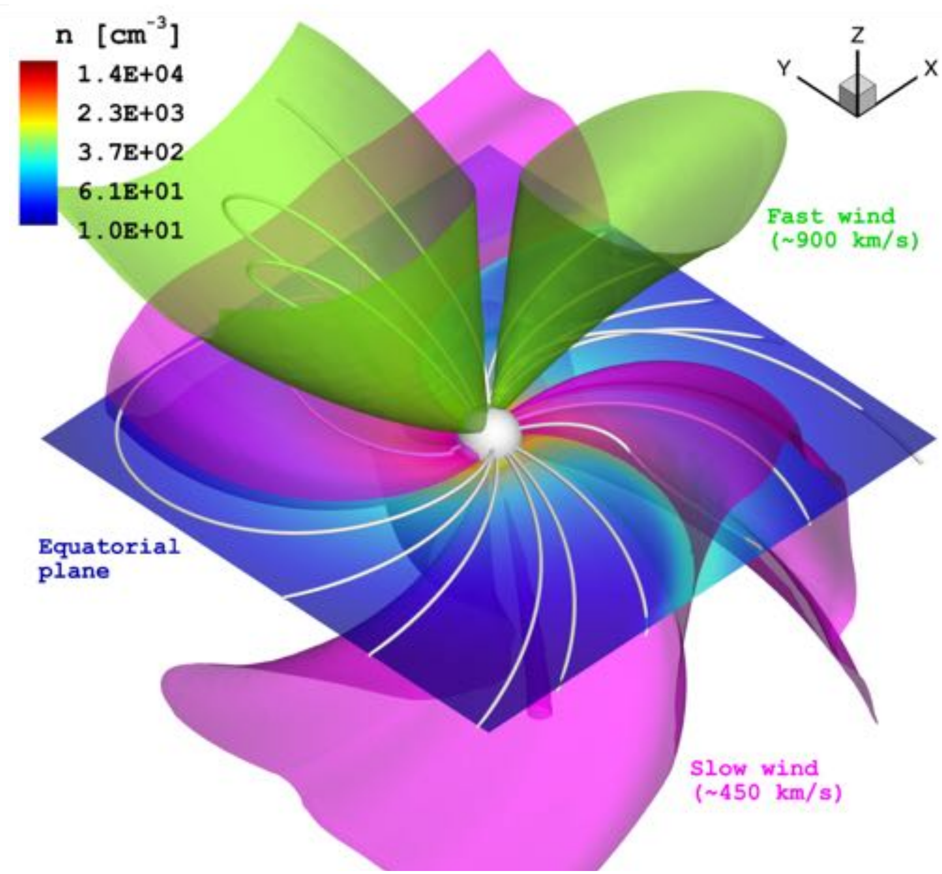
Almost no fast wind regions
Increased complexity

Stellar Wind Structure

HD 22049 (ε Eridani)



HD 147513 (62 G Scorpii)



Alvarado–Gómez et al. (2016b, submitted)

Mass loss: ~1 – 5 $\dot{M}_\odot$ ~6 $\dot{M}_\odot$

Angular momentum loss: ~1 – 12 $\dot{J}_\odot$ ~ 4 $\dot{J}_\odot$

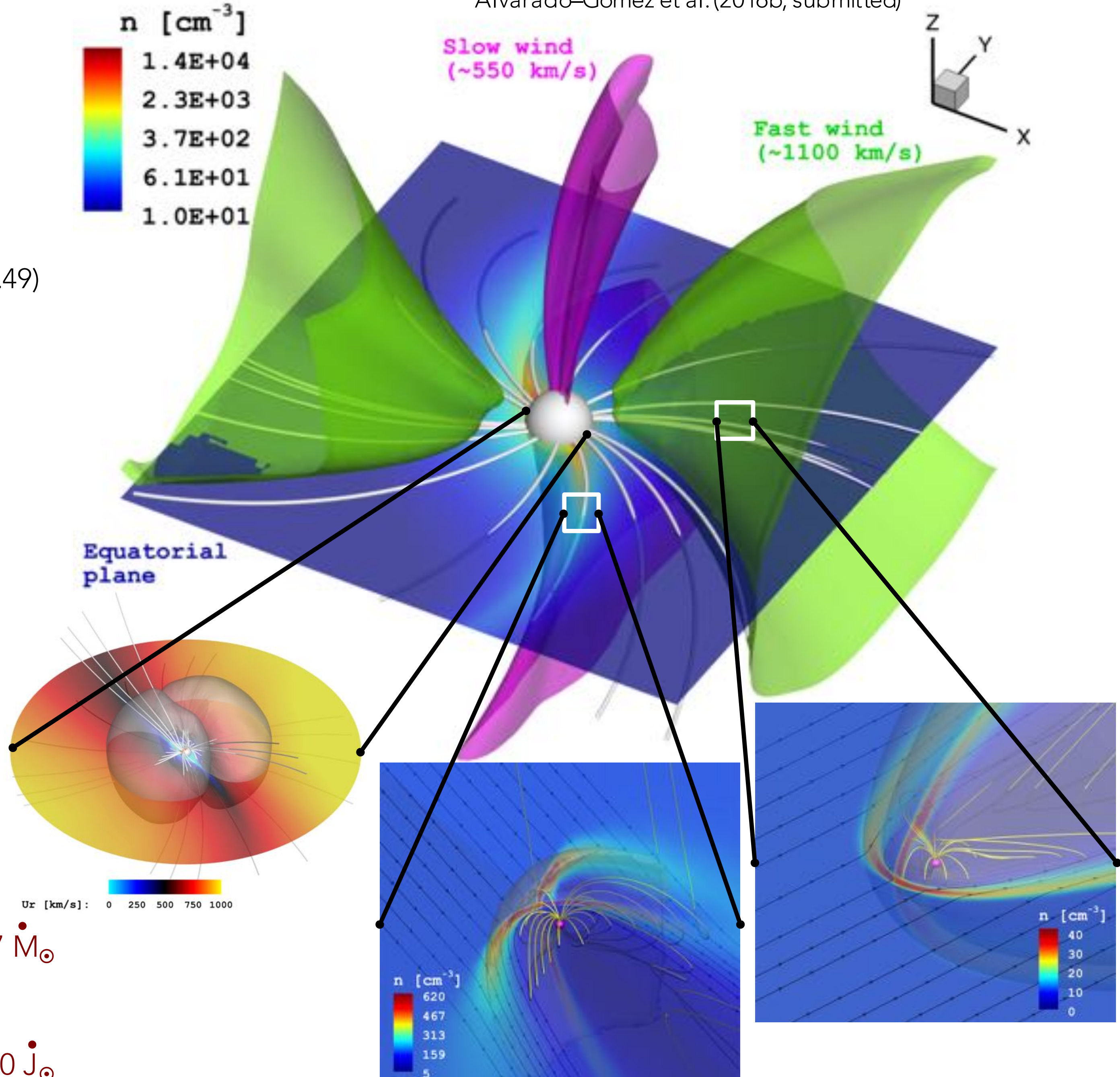
HD 1237 (GJ 3021)

Alvarado–Gómez et al. (2016b, submitted)

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
(F^R ~ 12 mJy)

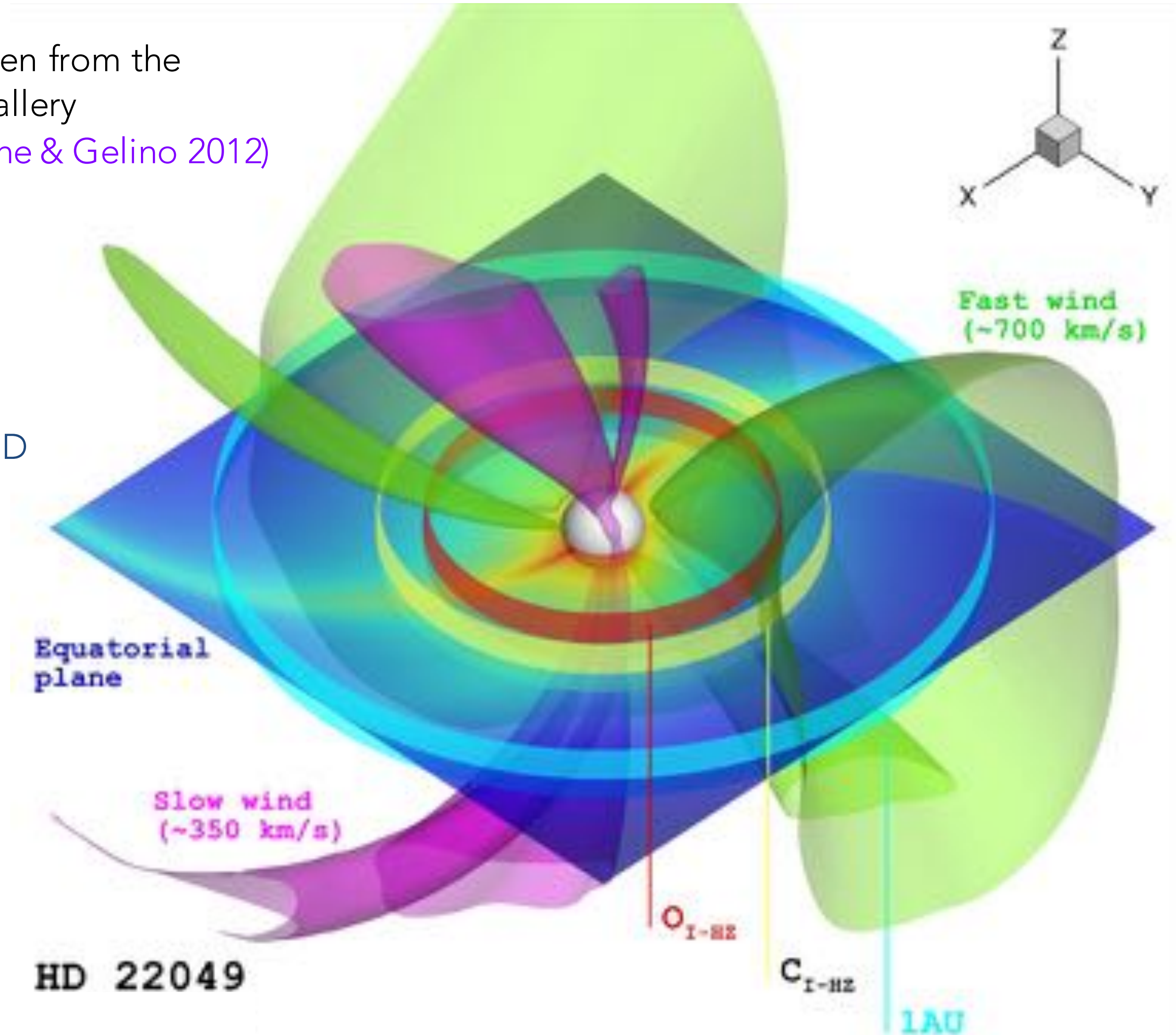


Mass loss: ~3 – 7 $\dot{M}_\odot$

Angular momentum loss: ~7 – 60 $\dot{J}_\odot$

Inner HZs boundaries taken from the Habitable Zone Gallery
(http://www.hzgallery.org/ - Kane & Gelino 2012)

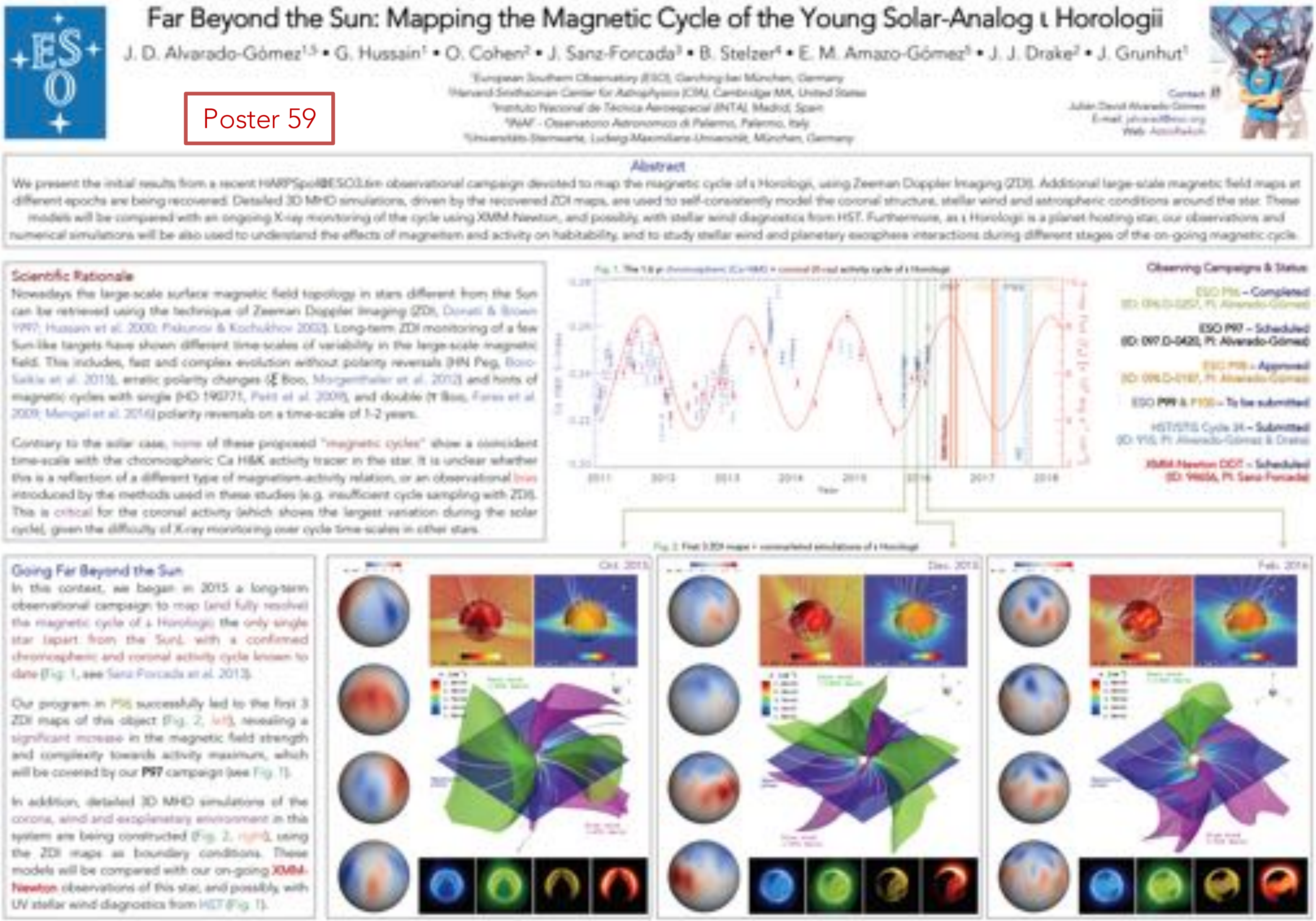
MHD Characterization of the 3D structure of the stellar wind.



Alvarado-Gómez et al. (2016b, submitted)

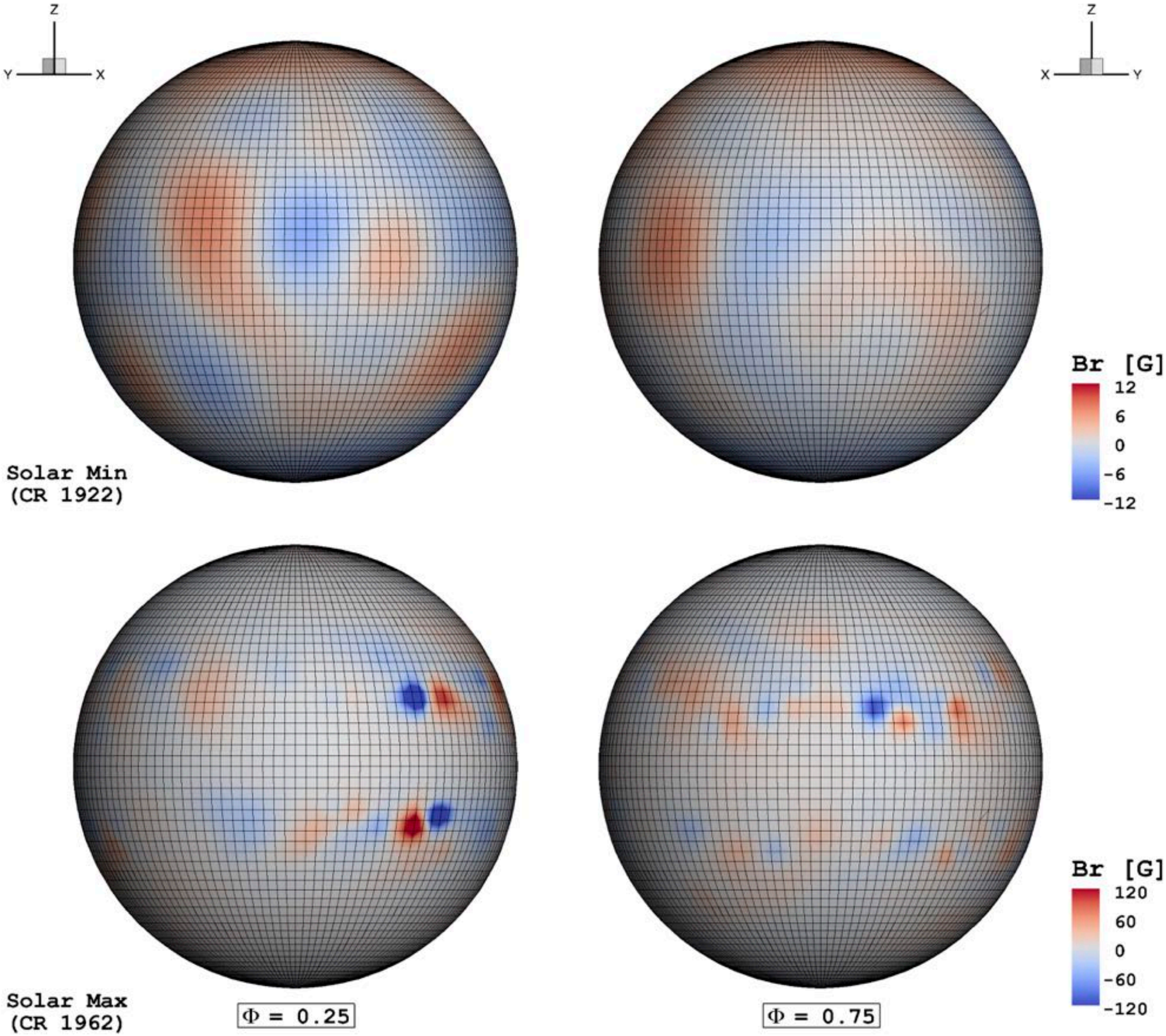
Dynamical determination of the HZ inner boundary

- Stellar wind properties
- Host-star activity level
- Planetary magnetospheric shielding


Far Beyond the Sun: Mapping the Magnetic Cycle of the Young Solar-Analog ι Horologii
J. D. Alvarado-Gómez • G. Hussain • O. Cohen • J. Sanz-Forcada • B. Stelzer • E. M. Amazo-Gómez • J. J. Drake • J. Grunhut
Abstract
Scientific Rationale
Observing Campaigns & Status
Going Far Beyond the Sun

Poster 59

MDI/SOHO Synoptic Magnetograms (Carrington Maps)



Observations: High-Resolution Spectropolarimetry

NARVAL@TBL

D = 2 m | R ~ 65000
λ ~ 370 – 1050 nm

ESPaDOnS@CFHT

D = 3.6 m | R ~ 70000
λ ~ 370 – 1050 nm

HARPSpol@ESO-3.6m

D = 3.6 m | R ~ 120000
λ ~ 378 – 691 nm

Future instruments/upgrades:

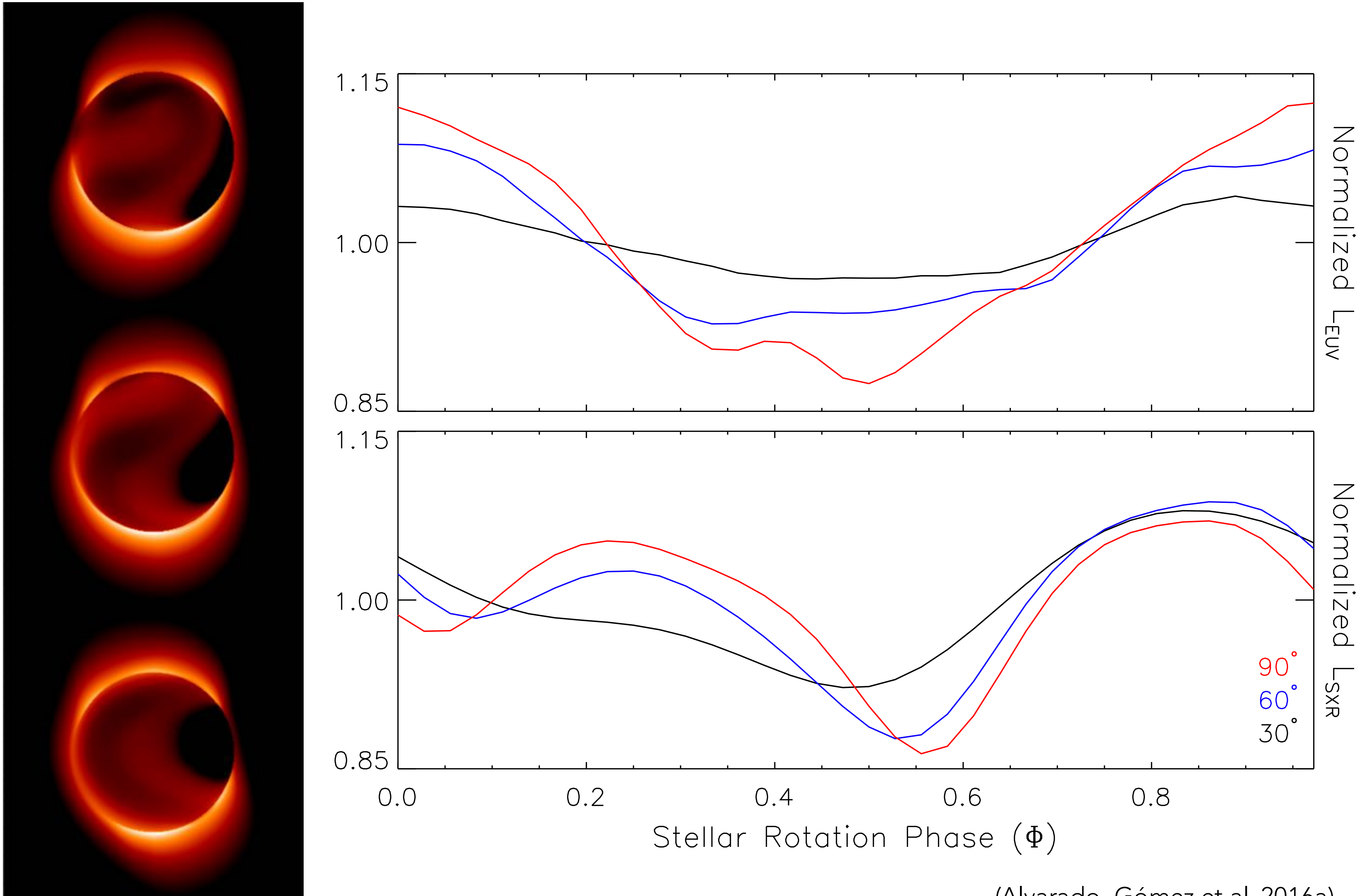
NEO NARVAL

RV precision < 3 m/s
First Light: ~ 2018

SPiRou

R ~ 75000 | λ ~ 0.98 – 2.35 μm
RV precision ~ 1 m/s
First Light: ~ 2017

Rotational modulation of the high-energy emission



(Alvarado–Gómez et al. 2016a)

Astrospheres: Mass loss – Activity Relation

Mass loss rates estimates only for 10 Sun - like (G-K type) stars

Apparent correlation between mass loss and x-ray activity (Physical Units!)

Open questions: 2 regimes? (π^1 UMa) – Models in the high activity end? – Binarity?