La Physique Stellaire avec ANDES/ELT, ArmazoNes high Dispersion Echelle Spectrograph

Andrea Chiavassa
+ E. Alecian, L. Bigot, A. Domiciano De Souza, N. Nardetto, P. Tisserand

ANDES

LAGRANGE

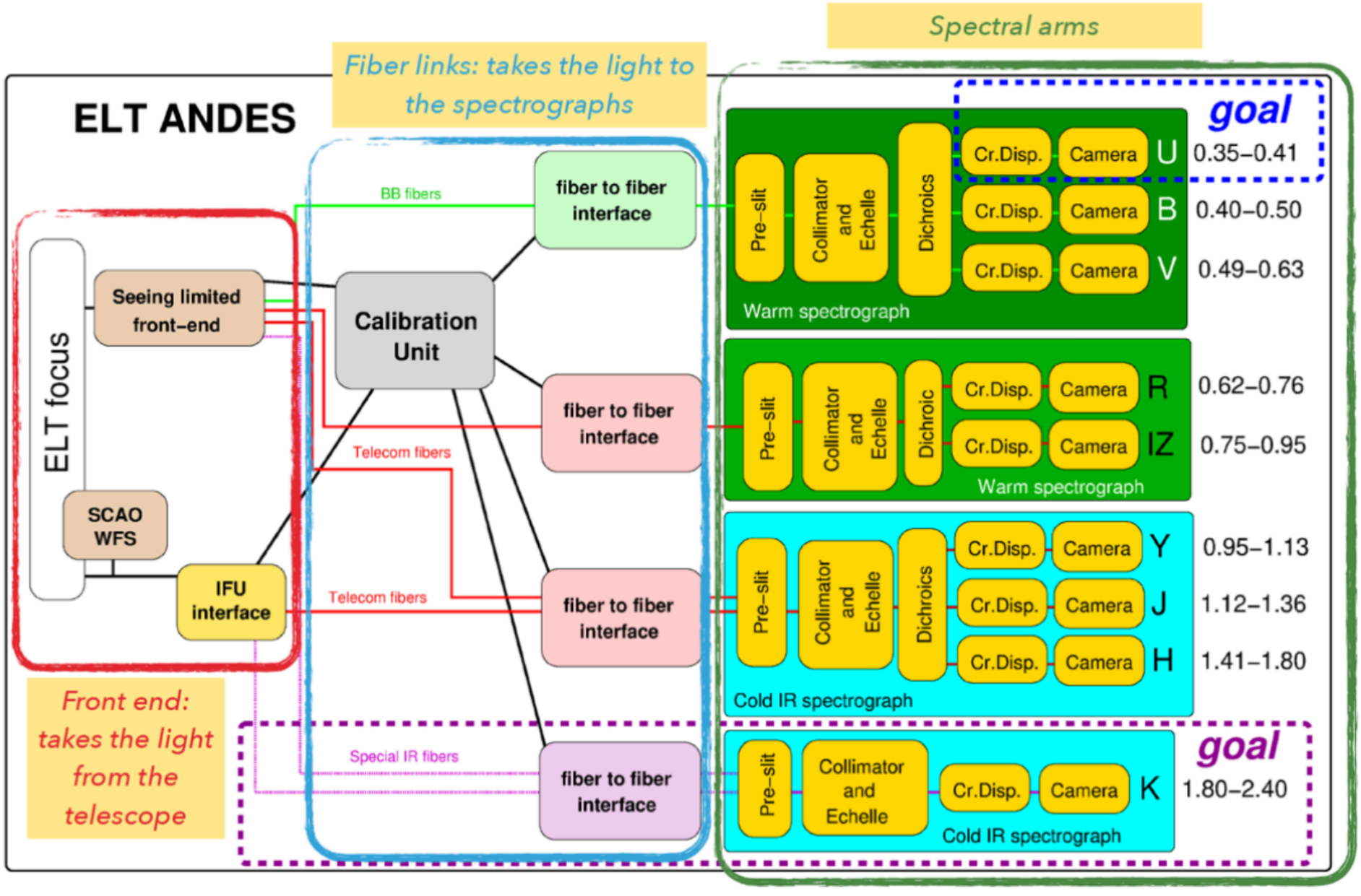
Observatoire de la CÔTE d'AZUR

ANDES: the instrument and its current status

Science working groups and french contribution

French Stellar Physics science cases

ANDES: ArmazoNes high Dispersion Echelle Spectrograph



Wavelength range: 0.35 – 2.40 μm
Simultaneous acquisition at R
Precision in RV: 1 m/s (goal 0.1 m/s)
Precision in λ calibration: 1 m/s (goal 0.02m/s)

Current status

Phase B | Phase C | Phase D

2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031

Phase A 2016-2018

ESO Council Approval Dec 2021

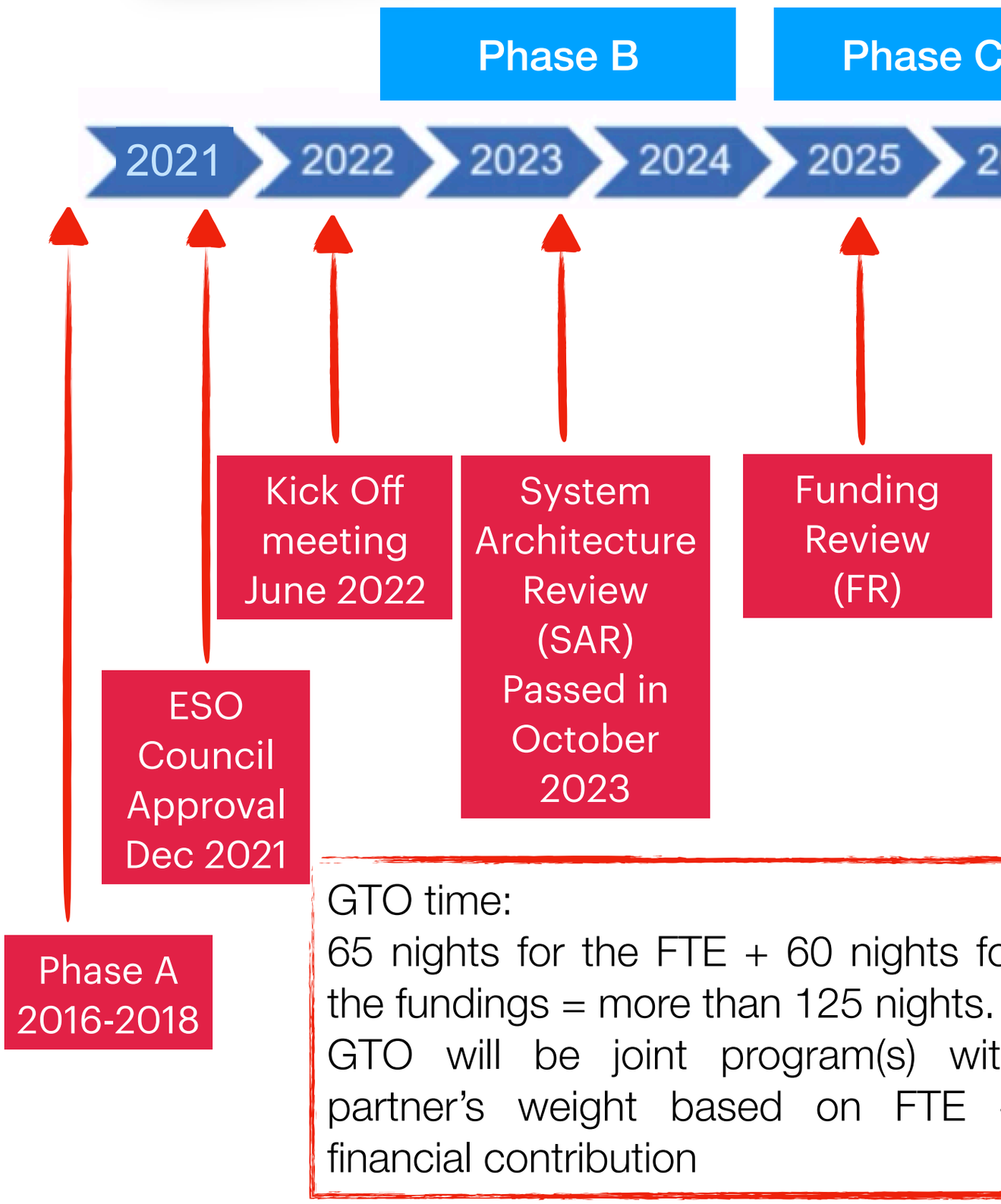
Kick Off meeting June 2022

System Architecture Review (SAR) Passed in October 2023

Consortium 13 countries
Leading INAF - Italy
French contribution:

- Science
- Calibration Unit
- SCAO/Coronagraph
- Management Team
- Data Software

Current status



GTO time:
65 nights for the FTE + 60 nights for the fundings = more than 125 nights.
GTO will be joint program(s) with partner's weight based on FTE + financial contribution

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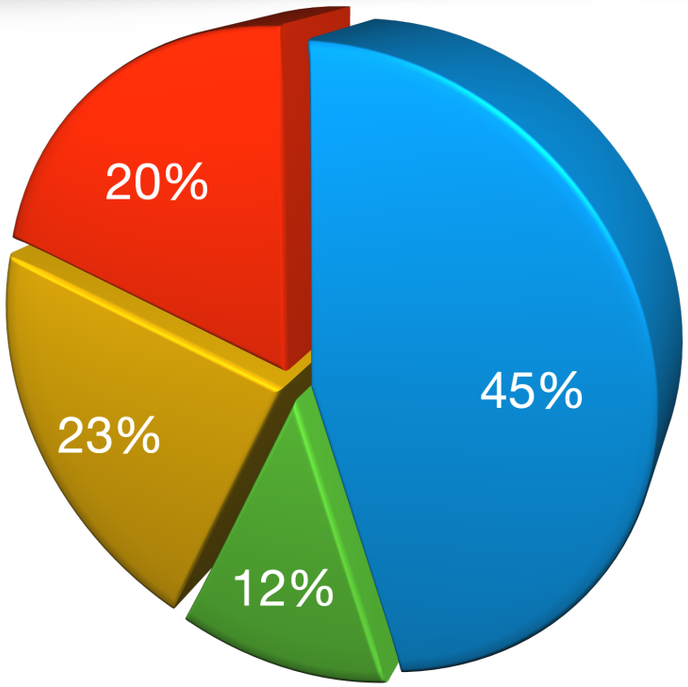

100 members in 4 Working Groups.

4 scientific papers submitted in Nov 2023 to Experimental Astronomy

WG1 45 me.

Exoplanets: characterization of Exoplanet atmosphere - detection of signature of life

Protoplanetery discs: dynamics - chemistry - physical conditions in the inner regions

I. Boisse (LAM), X. Bonfils (IPAG), A. Chiavassa (Lagrange), F. Debras (IRAP), M. Turbet (LMD)
PAPER: arXiv:2311.17075

WG2 23 me.

Stellar populations: metal enrichment and dynamics of extragalactics star cluster - resolved stellar populations

Stellar astrophysics: abundance of solar-type and cooler dwarfs in galactic disc bulge - halo and nearby dwarfs: tracing metal enrichment of Pop III stars in nearby universe

A. Chiavassa (Lagrange)
PAPER: arXiv:2311.16320

WG3 20 me.

Intergalactic medium: signature of reionization and early enrichment of ISM - IGM observed in high-z quasar spectra **Super massive black hole:** low-mass end

Galaxy evolution: massive early type galaxies epochs of formation and assembly

P. Noterdaeme (IAP)
PAPER: arXiv:2311.16803

WG4 12 me.

Fundamental physics: variation of fundamental constants - α, mp/me, Sandage test

P. Noterdaeme (IAP)
PAPER: arXiv:2311.16274

Science working groups

WG2 23 me.

Stellar populations: metal enrichment and dynamics of extragalactics star cluster - resolved stellar populations

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A. Chiavassa (Lagrange)

The discovery space of ELT-ANDES. Stars and stellar populations

Ian U. Roederer[IUR1,IUR2*], Julián D. Alvarado-Gómez[JAG], Carlos Allende Prieto[CAP1,CAP2], Vardan Adibekyan[VA], David Aguado[DA1,DA2], Pedro J. Amado[PJA], Eliana M. Amazo-Gómez[EMAG], Martina Baratella[MBA1,MBA2], Sydney A. Barnes[SAB], Thomas Bensby[TB], Lionel Bigot[LB], Andrea Chiavassa[AC], Armando Domiciano de Souza[AD], Camilla Juul Hansen[CJH], Silva P. Järvinen[SPJ], Andreas J. Korn[AJK], Sara Lucatello[SL], Laura Magrini[LM], Roberto Maiolino[RM], Paolo Di Marcantonio[PM], Alessandro Marconi[AMa], José R. De Medeiros[JRM], Alessio Mucciarelli[AM1,AM2], Nicolas Nardetto[NNa], Livia Origlia[LO], Celine Peroux[CP], Katja Poppenhäger[KP1, KP2], Cristina Rodríguez-López[CRL], Donatella Romano[DR], Stefania Salvadori[SN], Patrick Tisserand[PT], Kim Venn[KV1], Gregg Wade[GAW], Alessio Zanutta[AZ]

PAPER: arXiv:2311.16320

6 science cases in WG2 ANDES paper (17 cases in total)

1 science case in WG1 paper

+ 4 other expressions of interest

French community mailing list:
physique_stellaire_andes@oca.eu
Including more than 20 people in 7 laboratories

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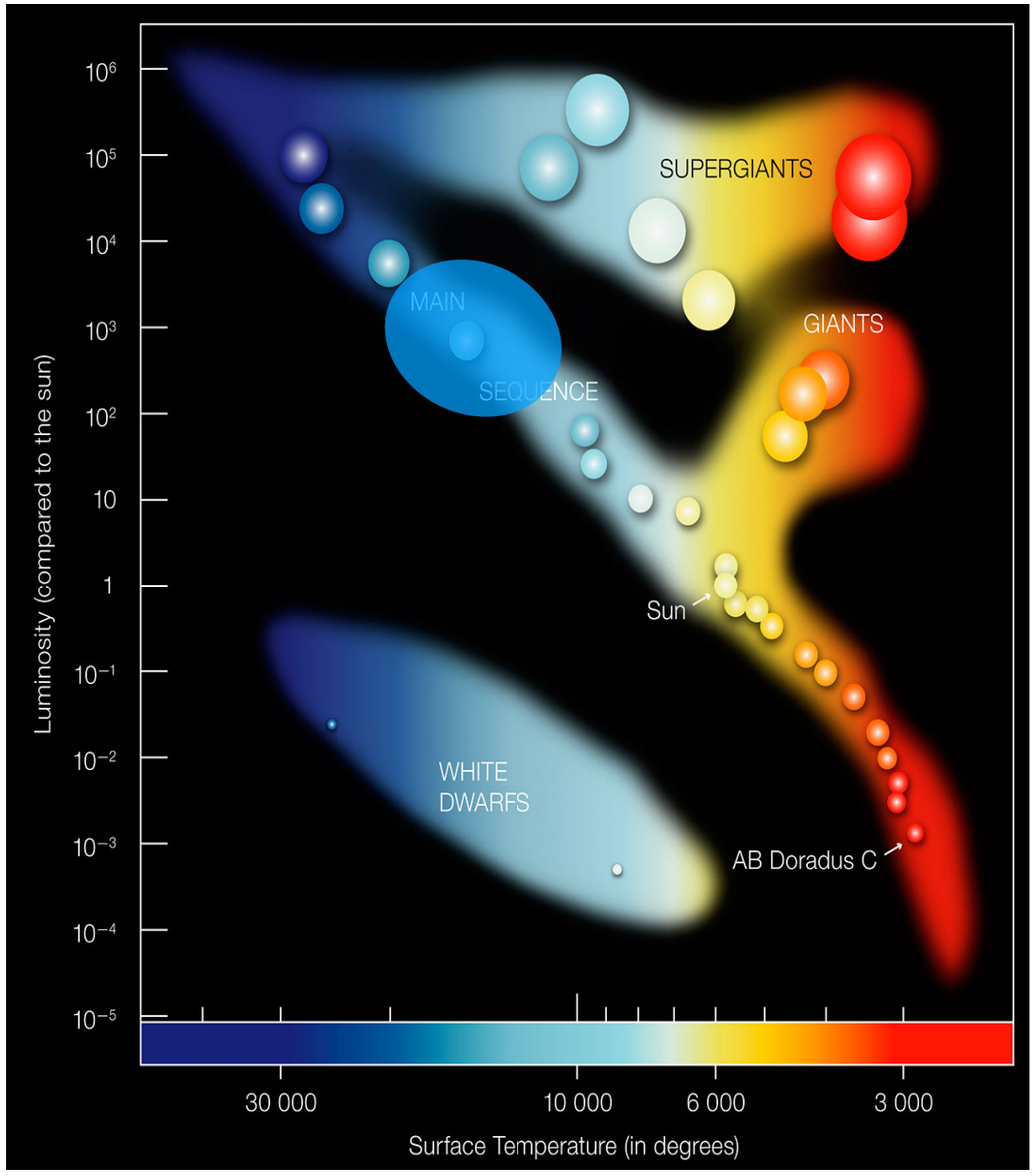

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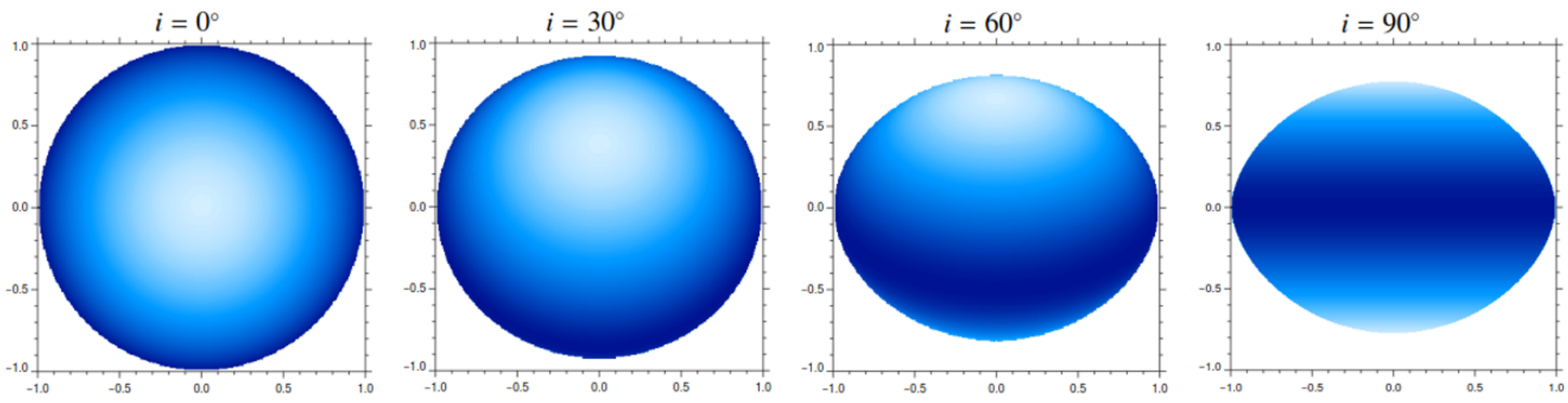
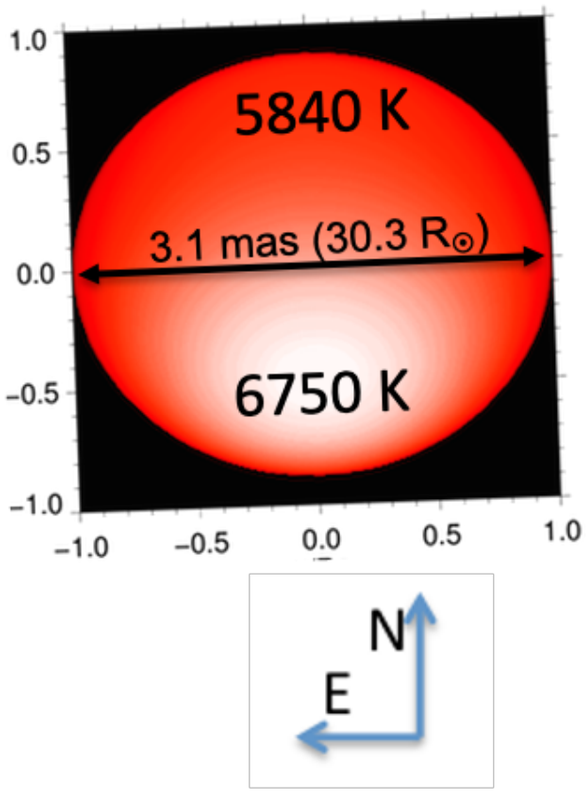
Other subtle effects of rotation in spectral lines: gravity darkening

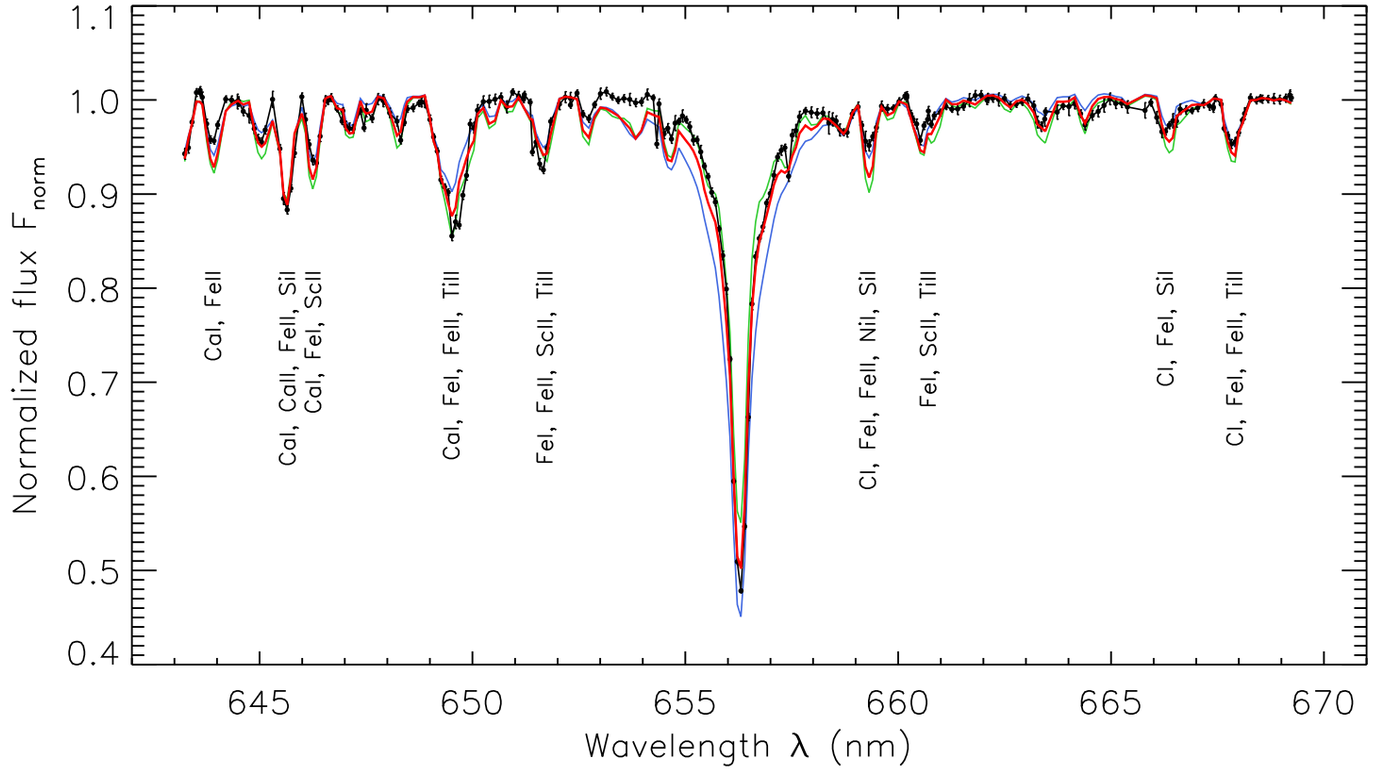


Gravity darkening (flux of the rotating star becomes dependent on the latitude)

Domiciano De Souza et al. 2002



Domiciano De Souza et al. 2018



Need: High resolution (~10^4) spectra with high signal-to-noise ratio S/N (~400)

People interested: A. Domiciano De Souza

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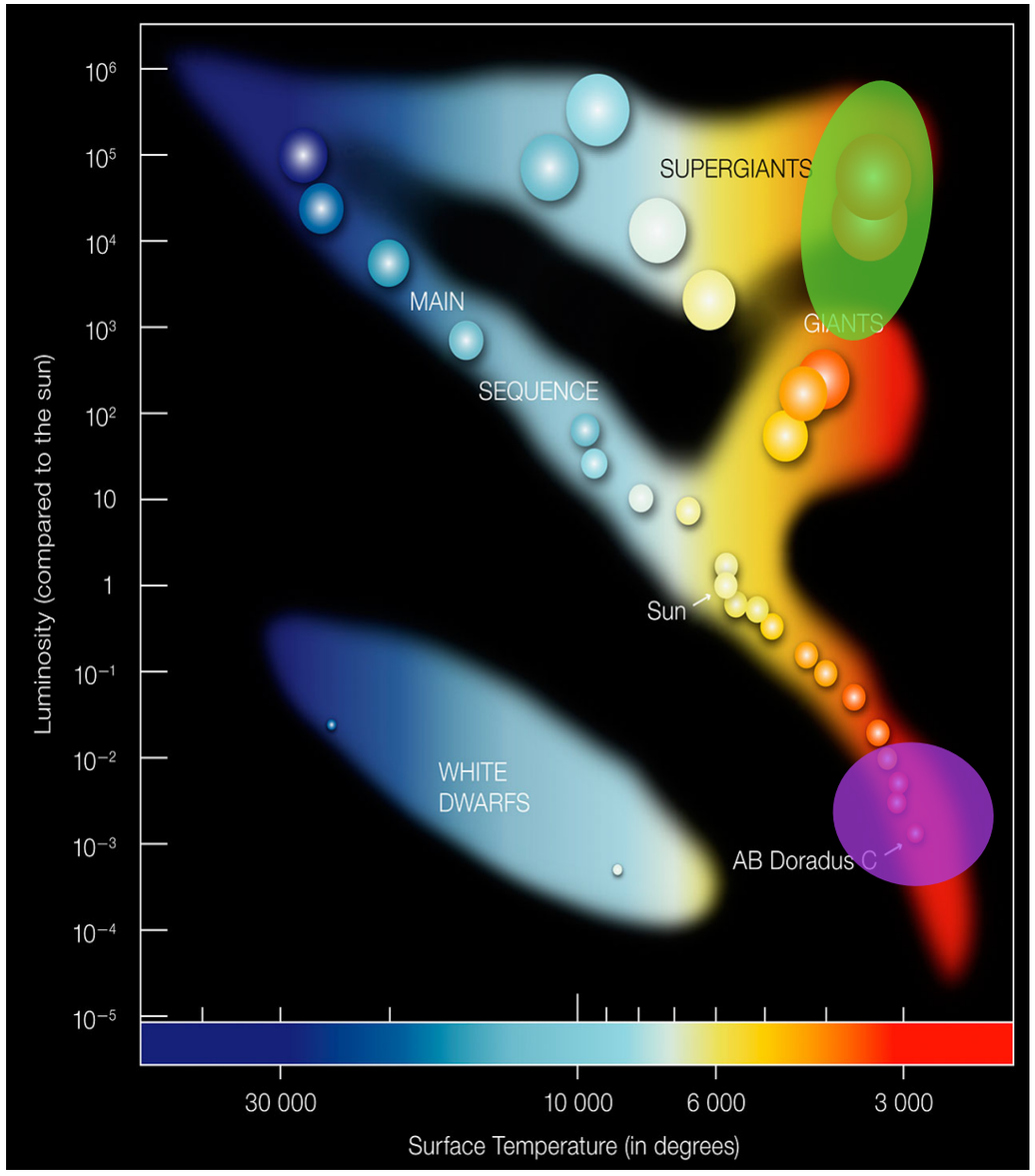

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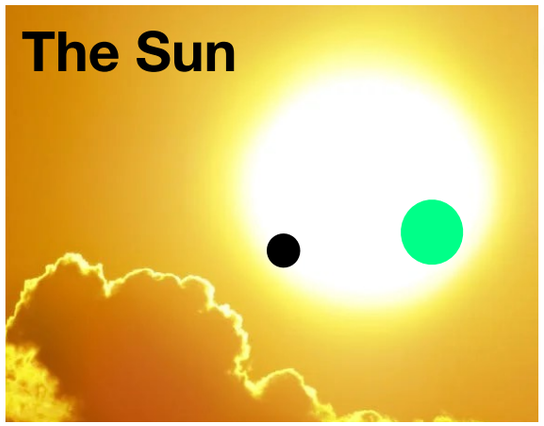
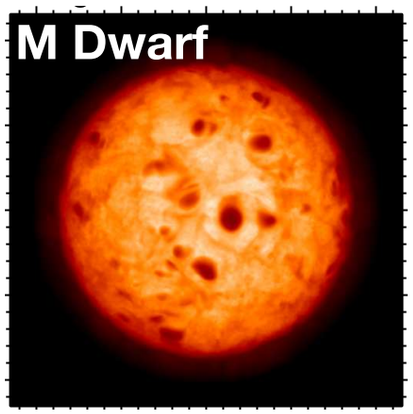
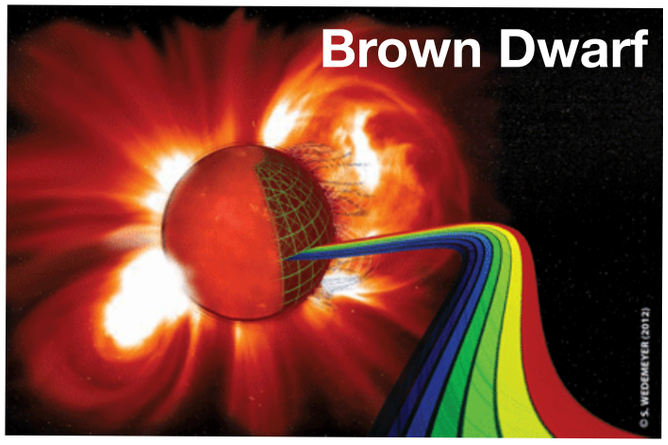
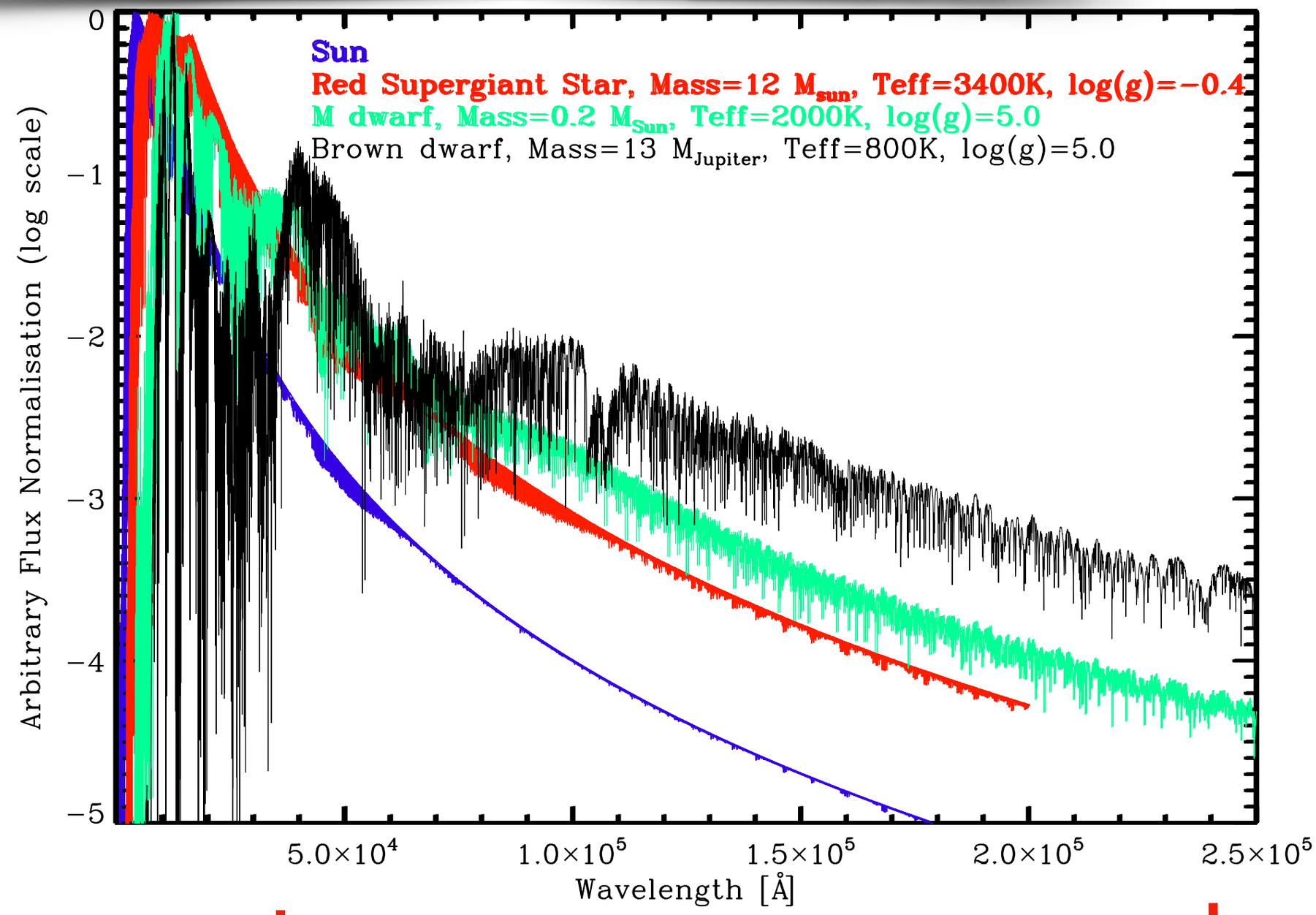
(Evolved) cool stars







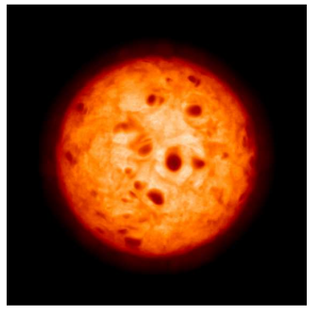


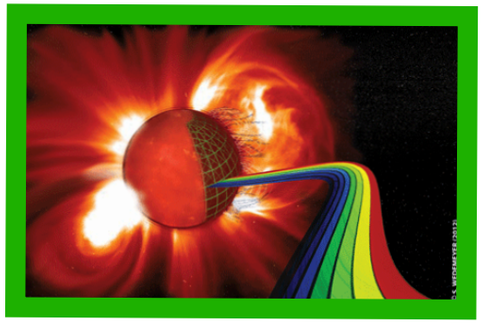
The Sun is here!

ANDES wavelength range

(Evolved) cool stars

Cool dwarf stars

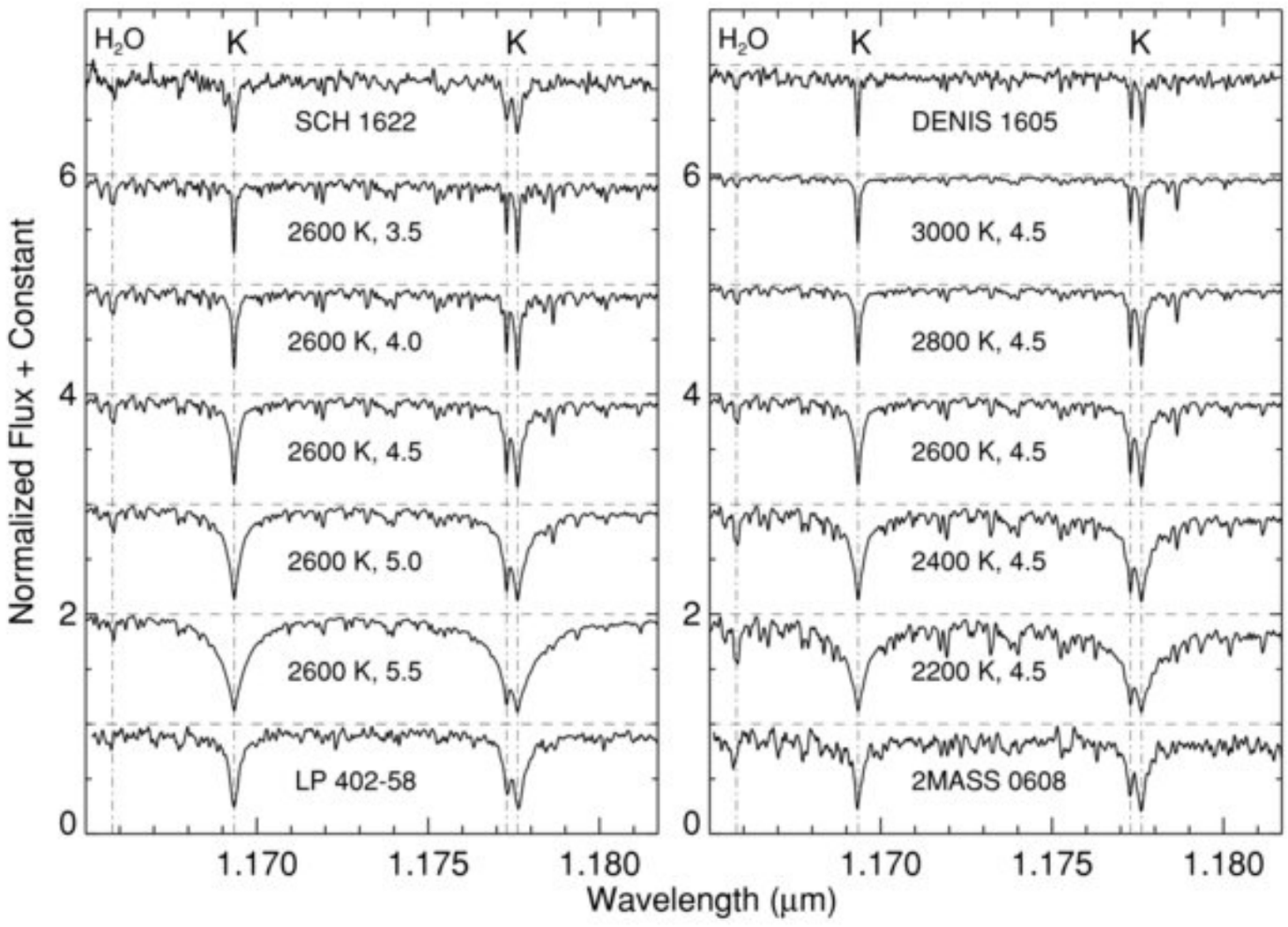




High-resolution spectroscopy provides detailed information, which complements photometric observations (synergy with PLATO and ARIEL).

Atmospheric parameters of the star, in particular its chemical composition, or the presence of significant velocity fields, accretion from circumstellar material, or strong magnetic fields.

NIRSPEC spectra (Rice et al. 2010)

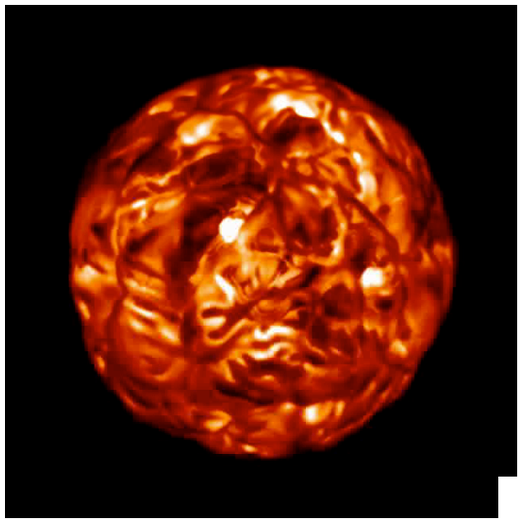


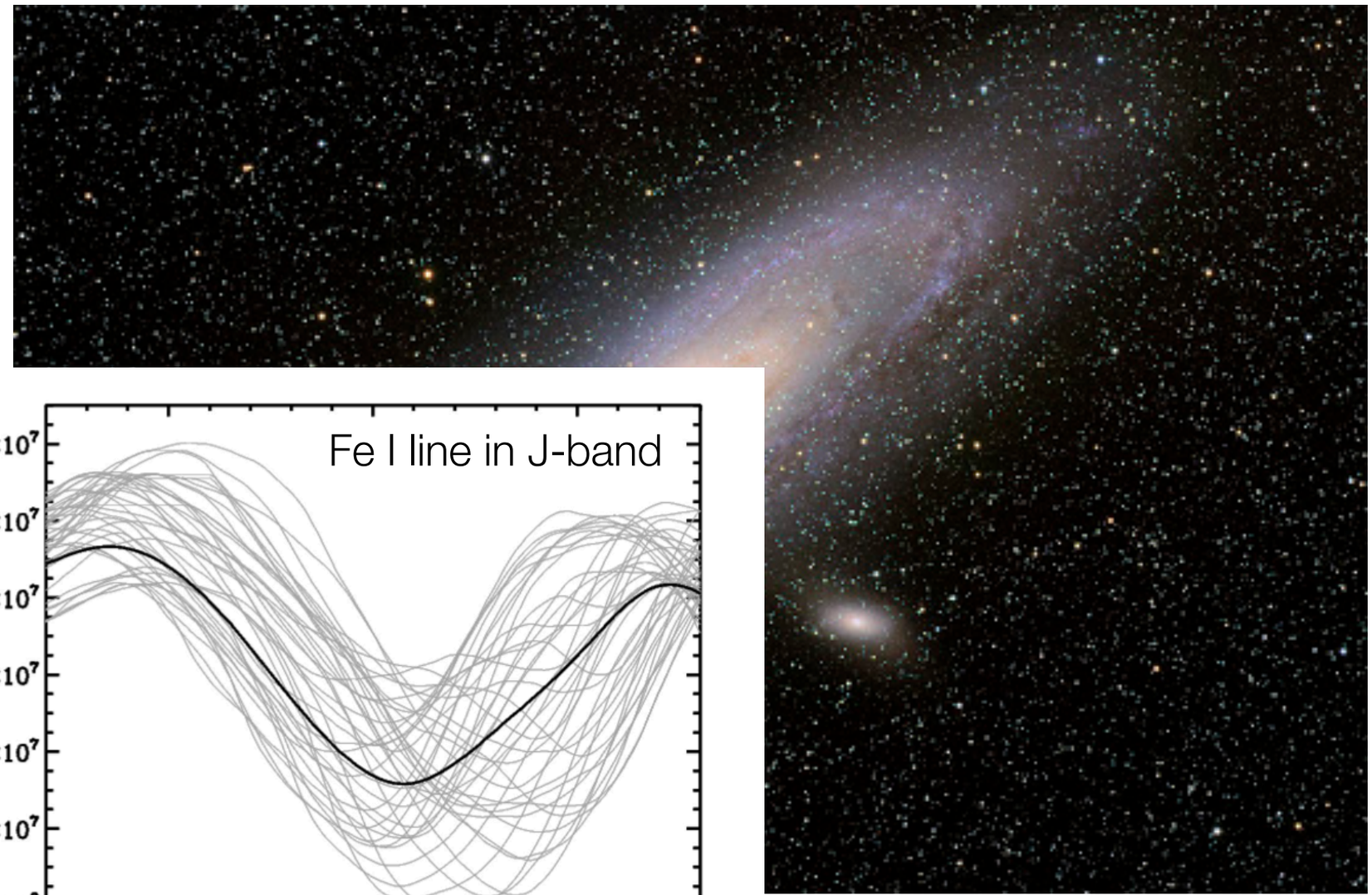
Strong sensitivity of potassium lines and H_2O absorption

People interested: C. Reylé, A. Chiavassa

(Evolved) cool stars

Cool evolved stars





Dynamics and chemical composition in nearby Galaxies (Davies et al. 2017)

People interested: A. Chiavassa, P. Kervella

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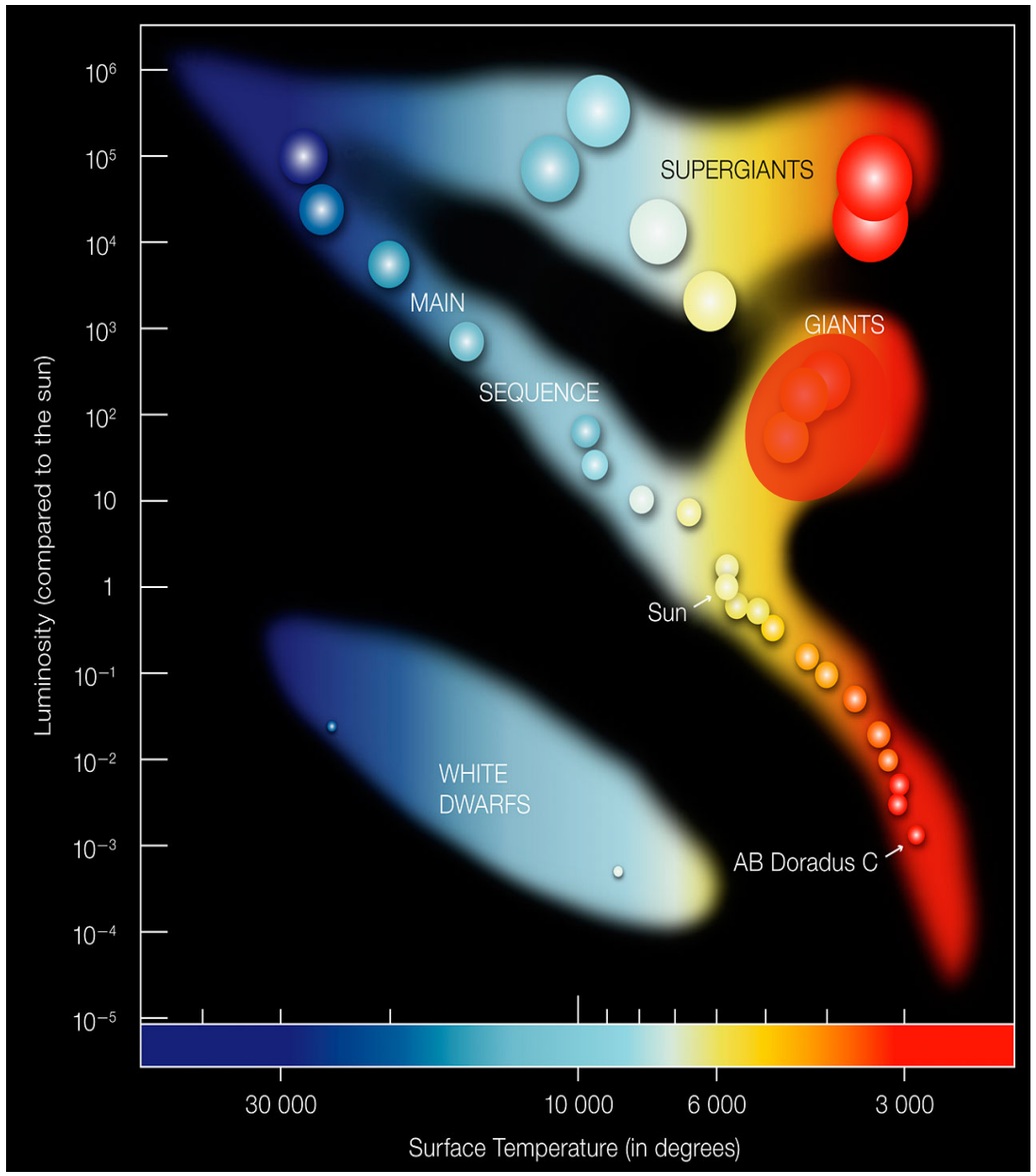

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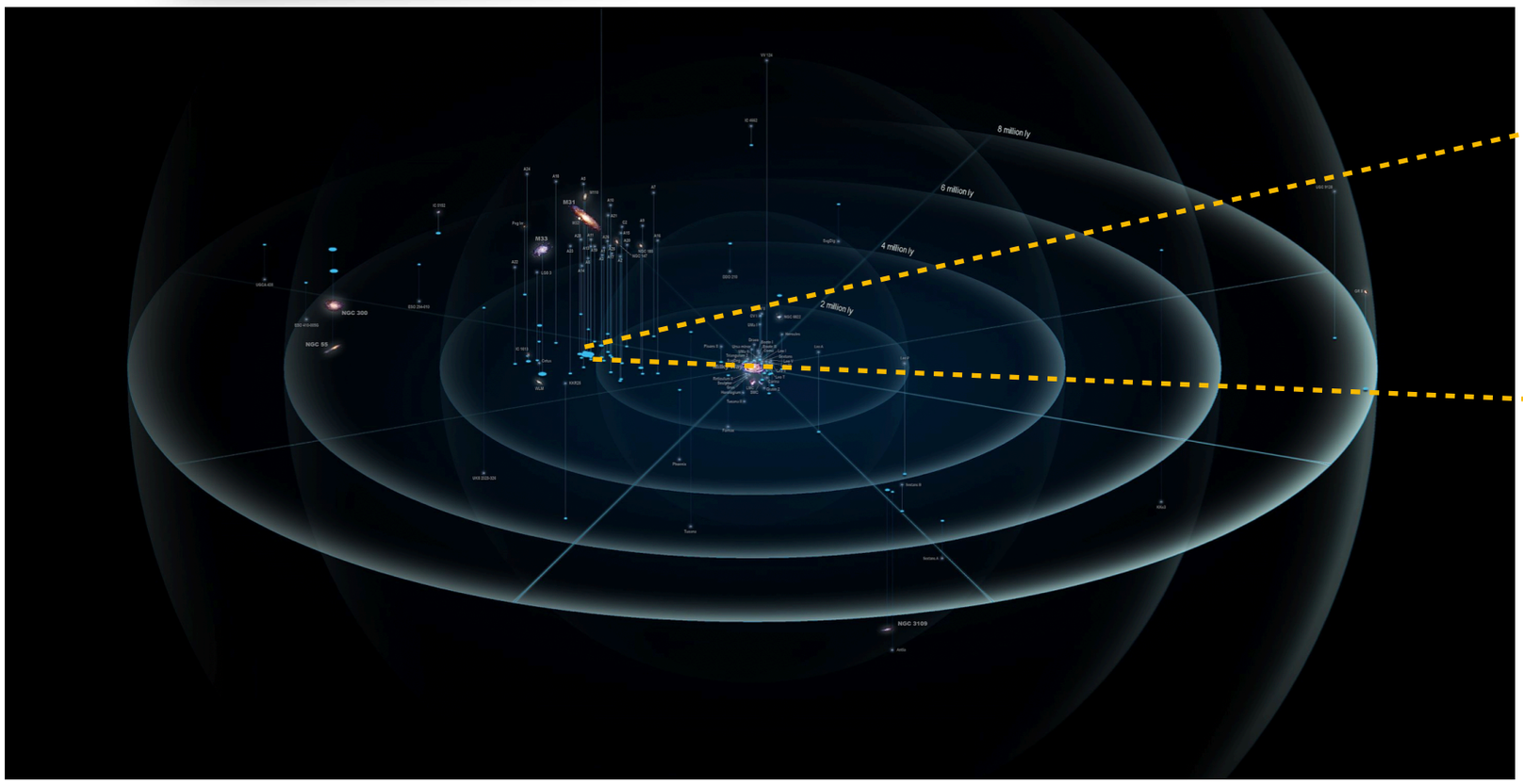
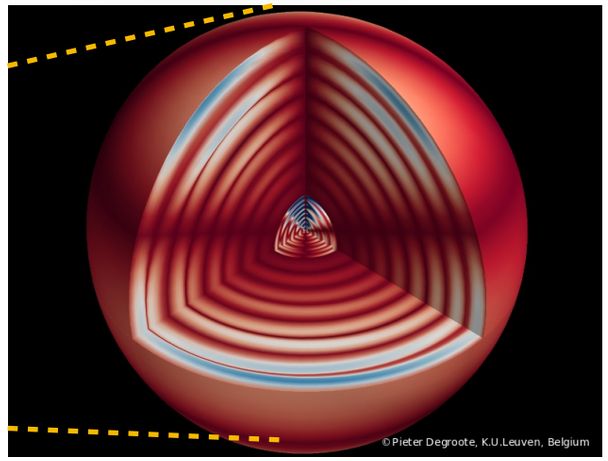
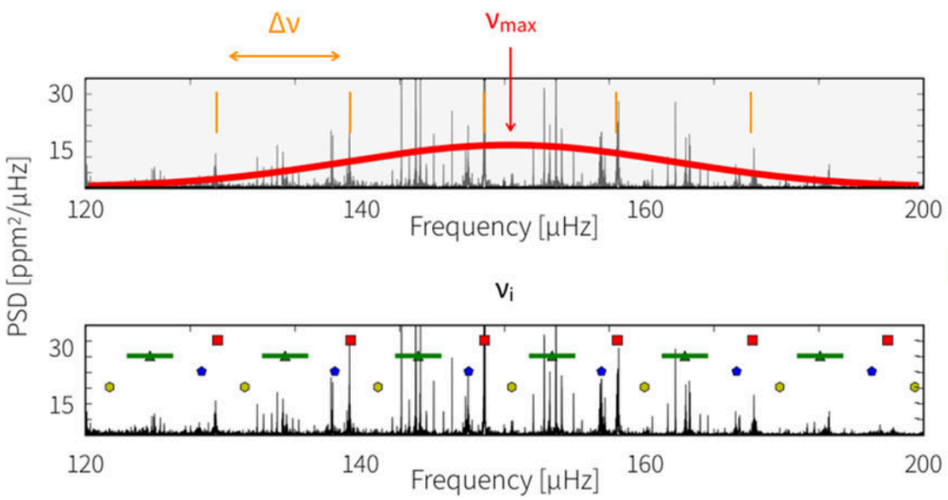
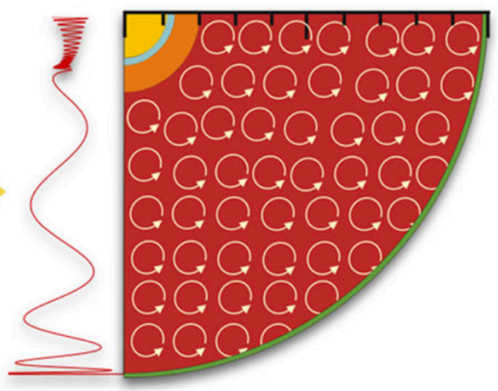
Extragalactic Asteroseismology with ANDES ?

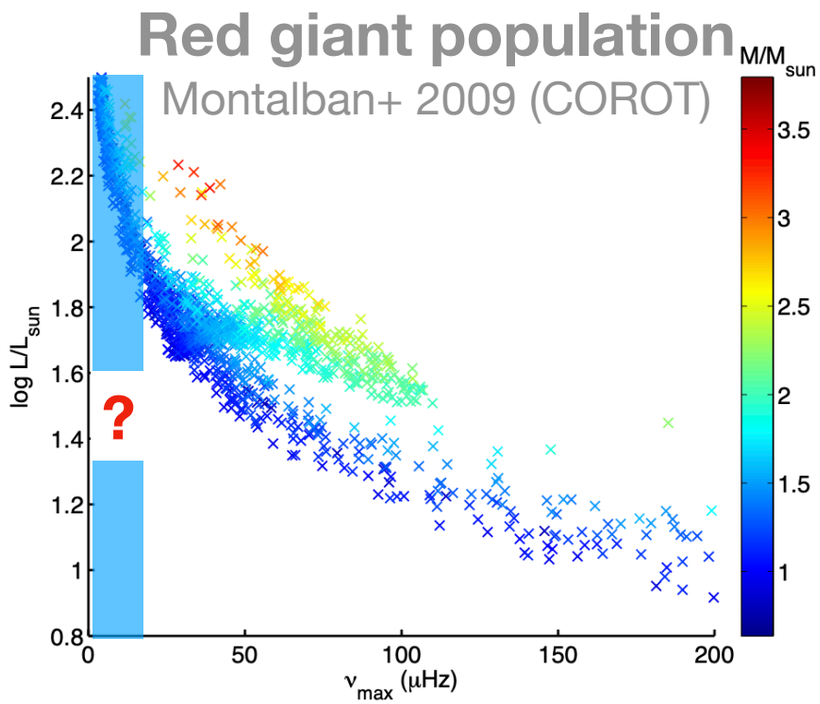






Miglio+ 2021





Stellar Age determination?

Needs to resolve mode linewidths to have periods spacings (e.g. Mosser+ 2018)

Several month/year time series!

—> need to estimate the feasibility (collected photons), length of time series, cost …

People interested: L. Bigot, O. Creevey

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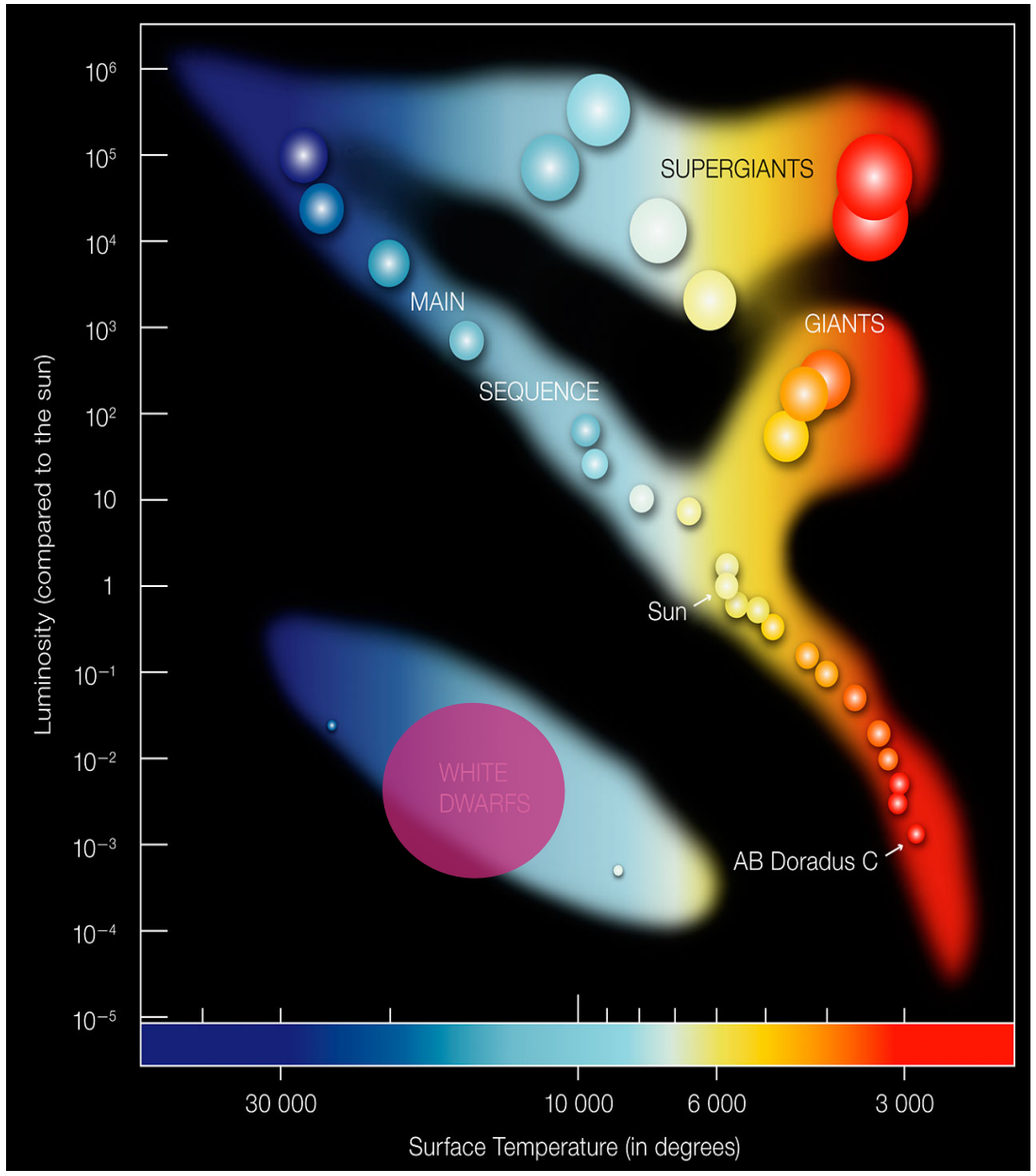

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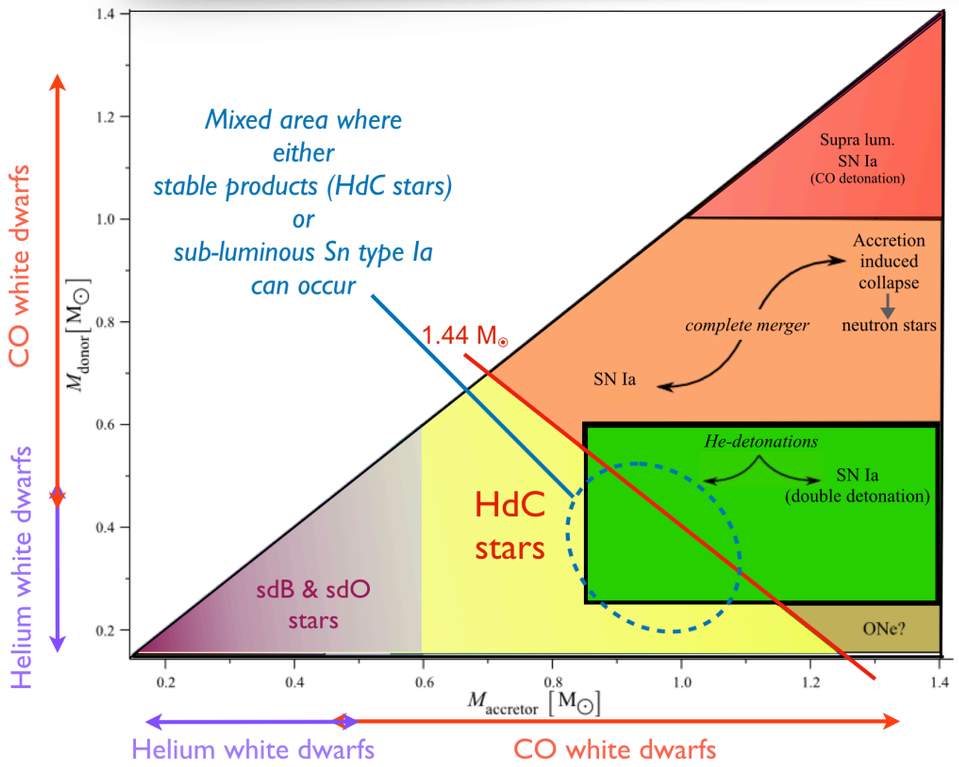
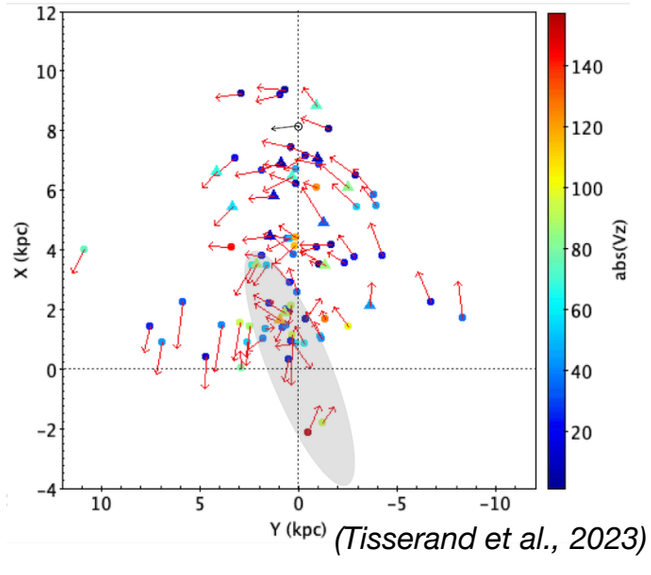
Where are the products of White Dwarf mergers whose total masses are below the Chandrasekhar limit?



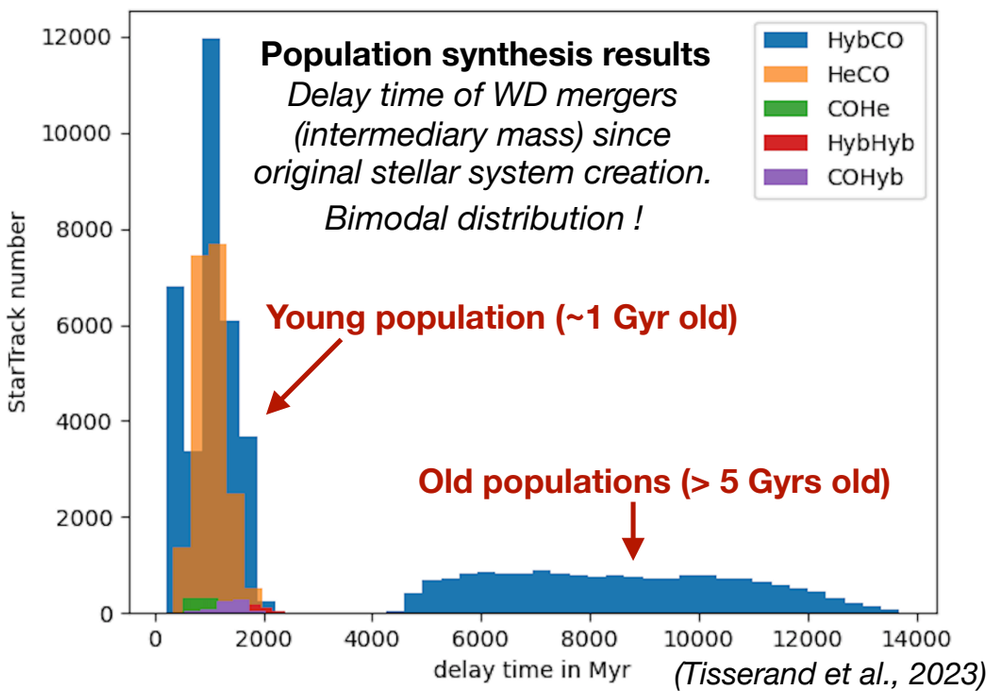
Hydrogen-deficient carbon rich (HdC) stars are supergiant stars (-5 < M_V < -2 mag) that full-fill all the requirements to be such products.

Thanks to Gaia DR3, we shown that they belong to all 3 old Galactic substructures: Halo, Bulge, Thick disk.
But also a few were found with dynamical properties typical of the thin disk.



(Tisserand et al., 2023)

ANDES spectroscopic survey of Bulge, Halo and Magellanic HdC stars encompassing the entire luminosity-temperature grid.



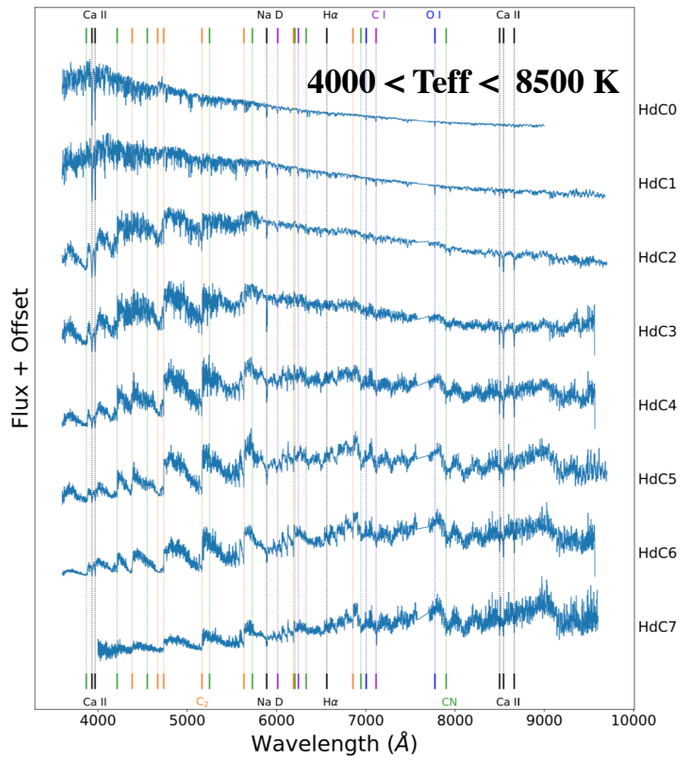
(Tisserand et al., 2023)

<u>Large abundance variety expected</u>: need of high-resolution spectroscopy observations to rigorously test our hypothesis regarding the origin of HdC stars and to define the contours of their evolutionary trajectory. To date, the few abundance analysis focused on nearby HdC stars located particularly within the thick disk region.

LMC: SF burst [0.5 - 2] Gyrs ago

Furthermore, high $^{18}O/^{16}O$ isotopic ratios, close to unity, i.e., 500 times larger than the Sun was measured in HdC stars (Clayton et al. 2007).

K band in the near-IR is imperative to observe the CO bands at R~100000 to disentangle information with carbon molecules (CN, C2..)



(Crawford et al., 2023)

People interested: P. Tisserand

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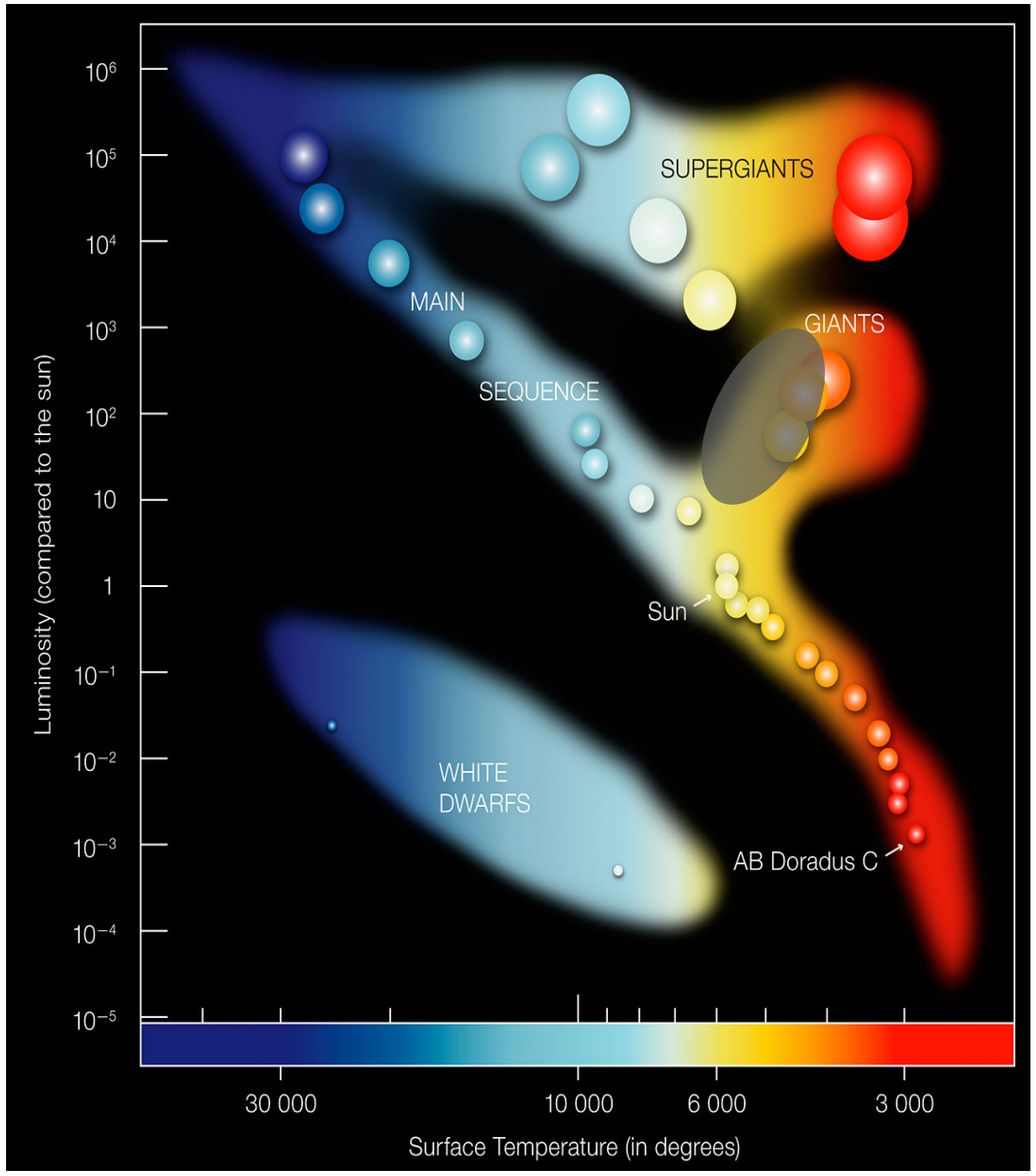

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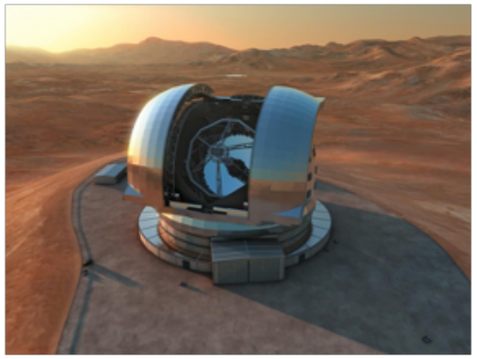
Calibrating properties of Cepheid variables for the cosmic distance ladder

Gaia → PL relation of Classical MW Cepheids (CC) → Distance to 42 galaxies with CC+SN1a → SN1a → Ho

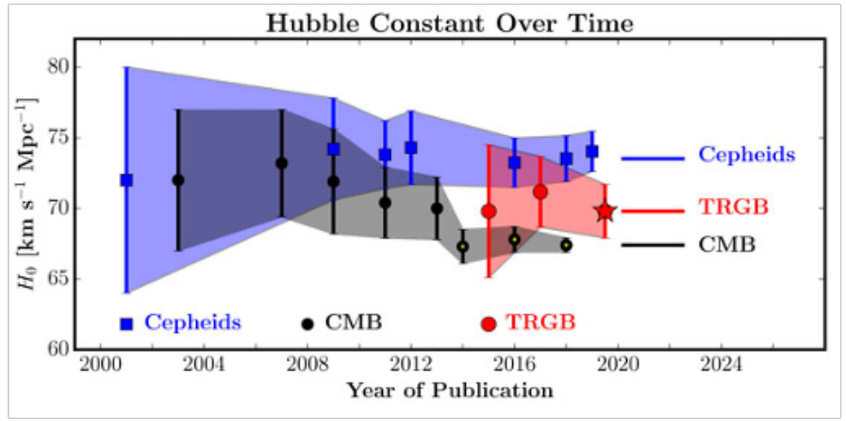
[Riess+21]
1.4% precision



ANDES MOSAIC

Synergy

PLZ in Local Group
< 5Mpc with ANDES



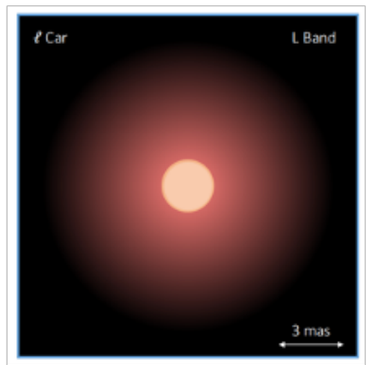
Hubble tension

Parallax of pulsation in Local Group Galaxies

+

« Extragalactic stellar physics »

- **Tomography of the atmosphere *versus* Z**
- **Circumstellar environment *versus* Z**
- **Galactic Archeology**
- **Same approach possible for RR Lyrae**



ANR *Unlockpfactor (2023-2028)*
(PI: Nardetto)

People interested: N. Nardetto

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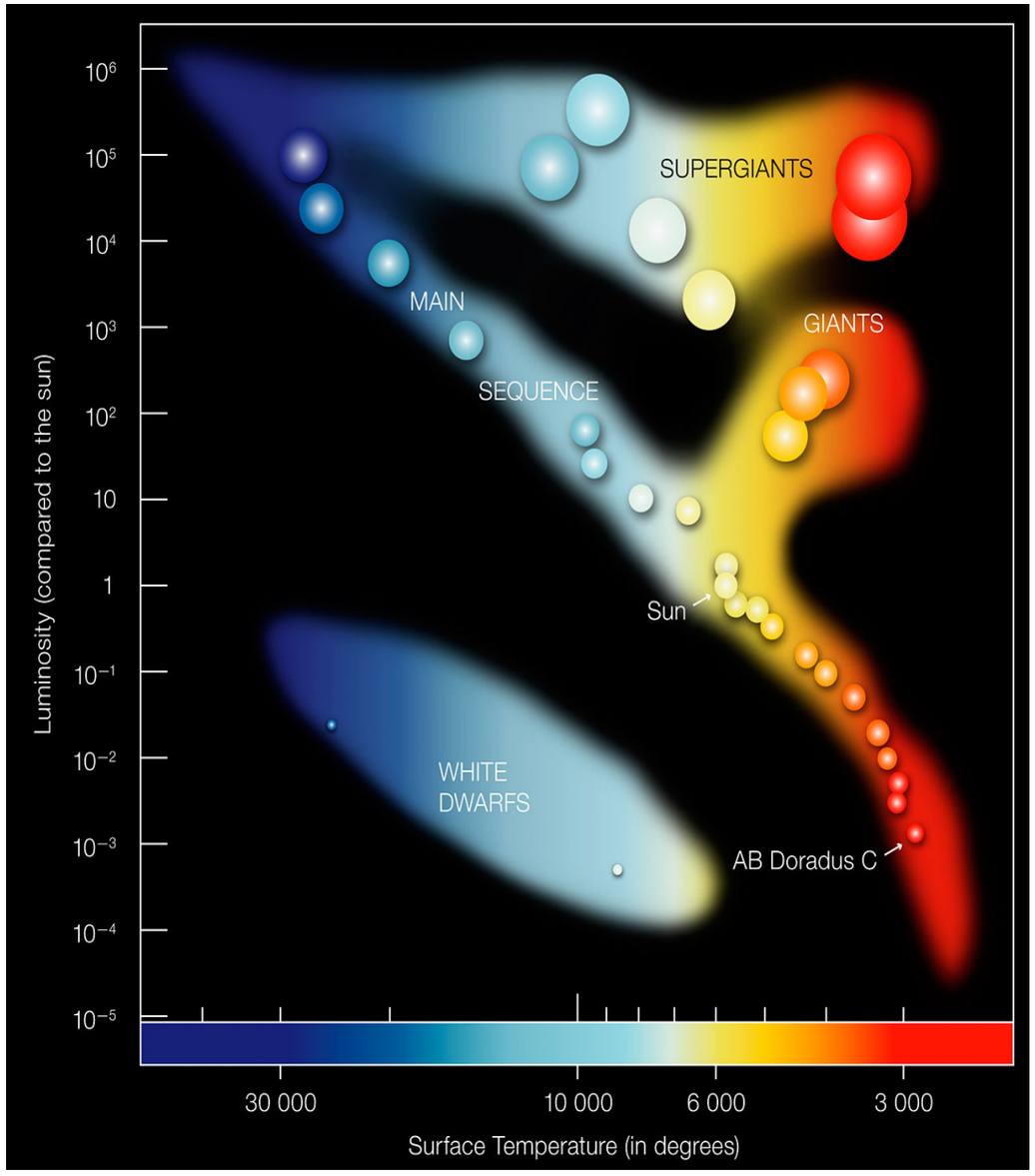

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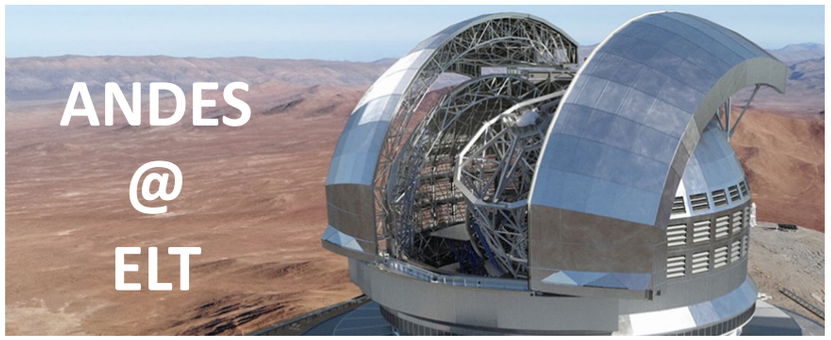
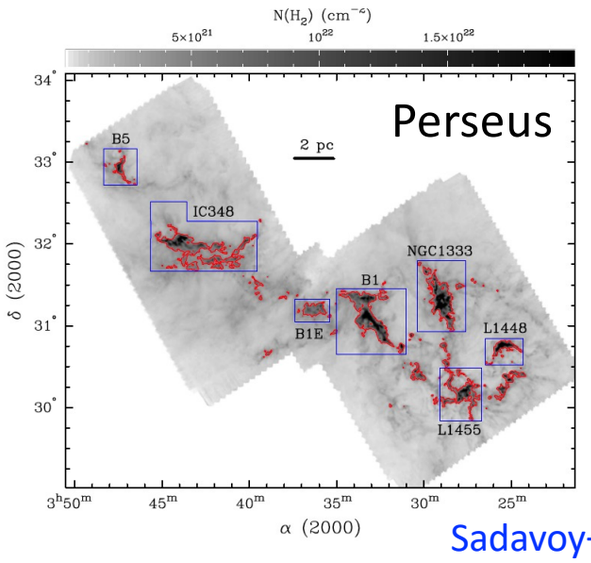
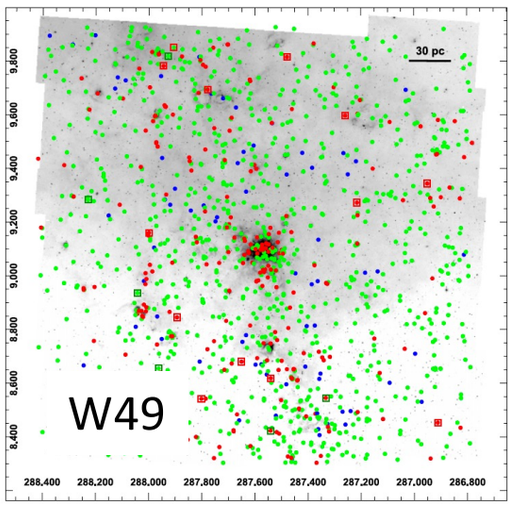
Magnetism of newborn protostars with ANDES



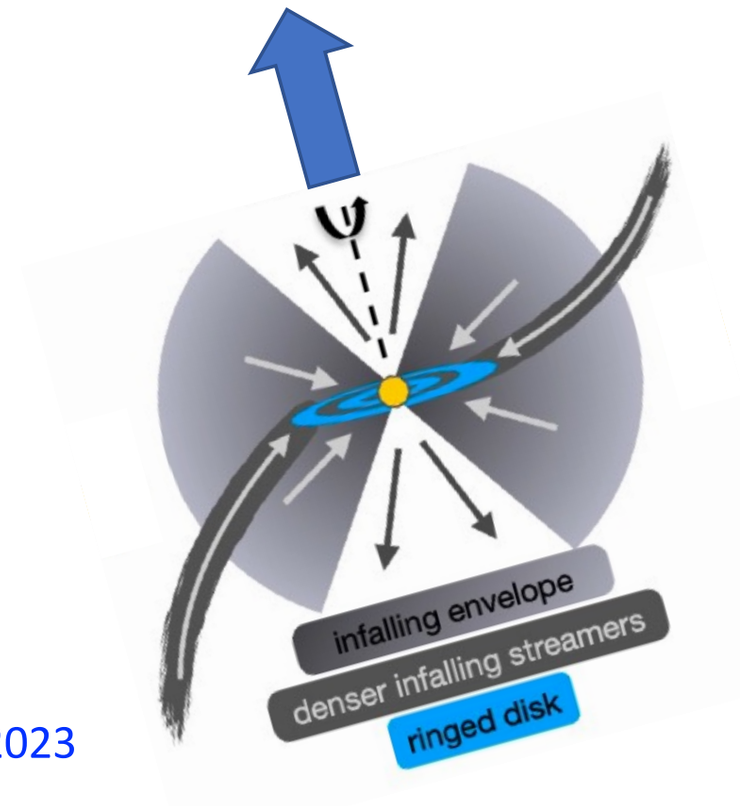
100s low-mass and massive protostars



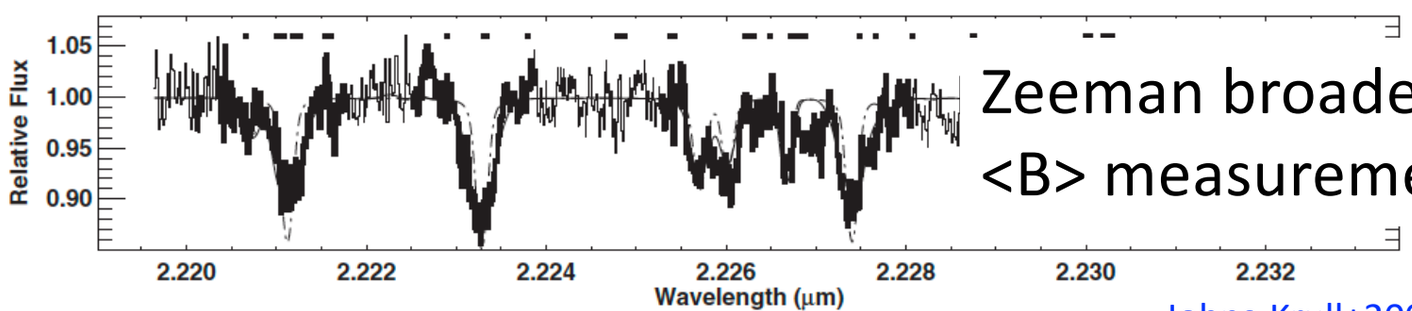
Sadavoy+2014



Saral+2015



Pineda+2023



Zeeman broadening
<B> measurements

Johns-Krull+2009

People interested: E. Alecian, V. Le Gouellec

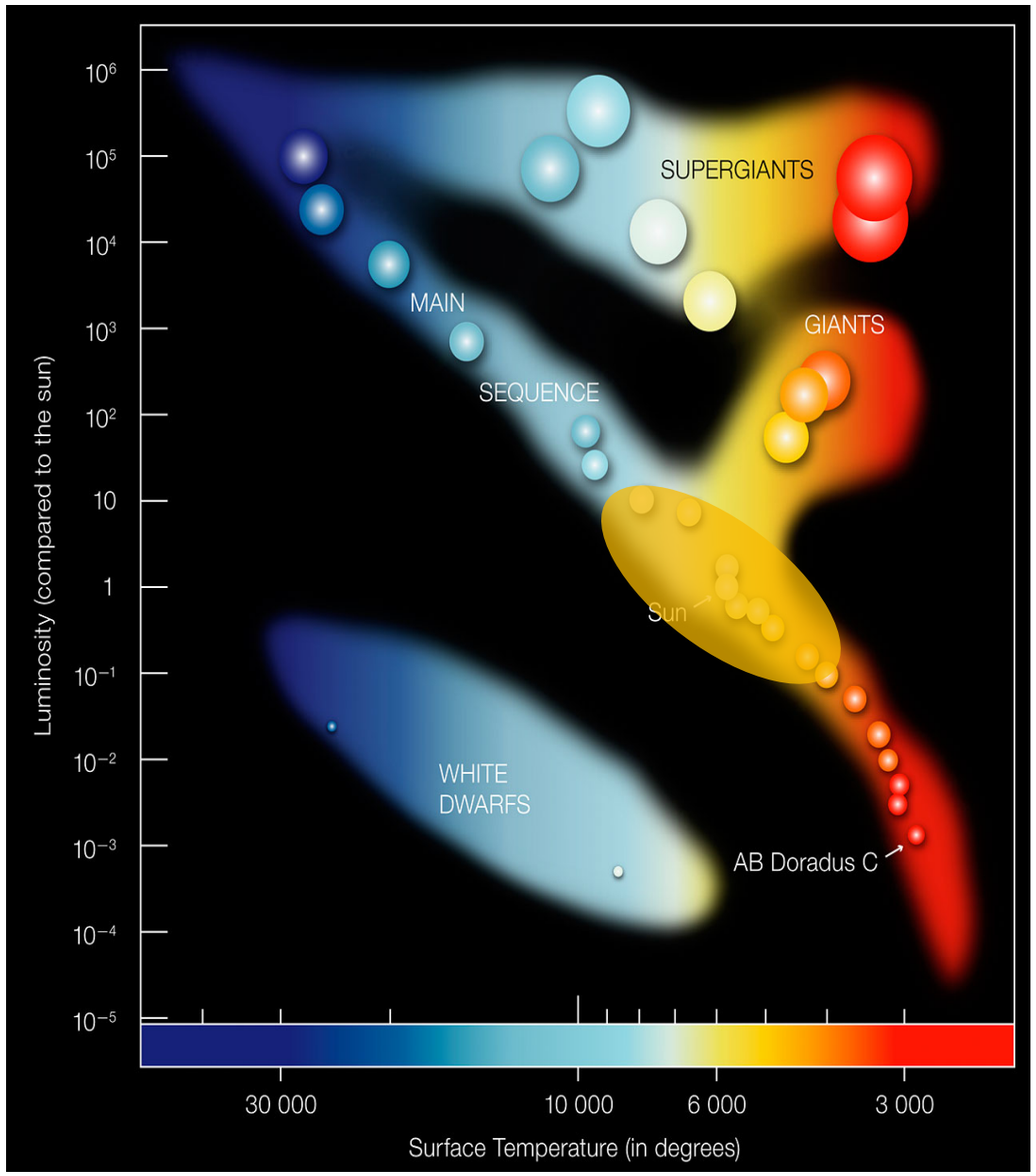
Science cases in Stellar Physics

Gravity darkening: a new measure of stellar rotation (Science paper)

White Dwarf mergers (Science paper)

Stellar contamination to planet characterisation (Science paper)

Detection and characterisation of the photosphere of protostars (Expression of interest)



Evolved stars in other Galaxies (Science paper)

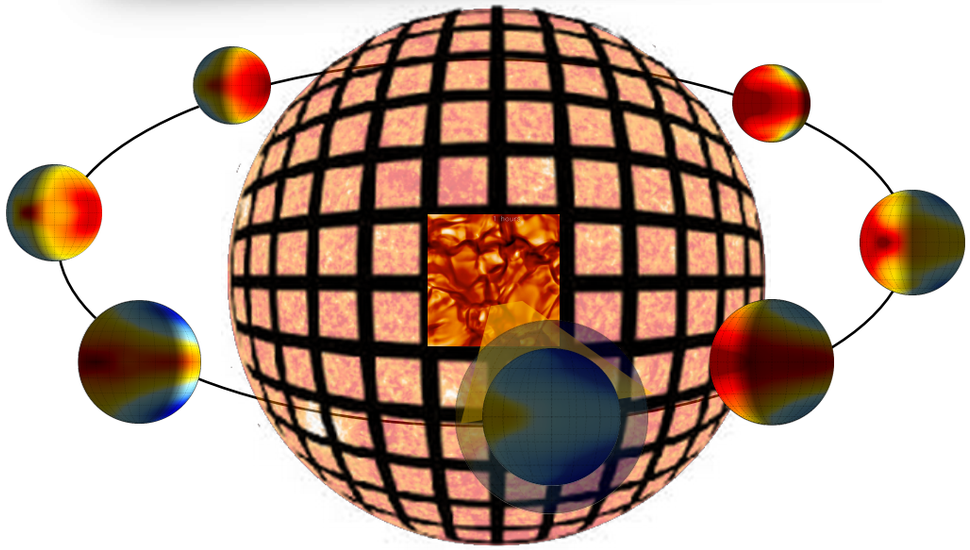
Study of red supergiant surfaces and radial velocity measurements of distant stars (Expression of interest)

Asteroseismology of stellar populations across the Milky Way and beyond (Science paper)

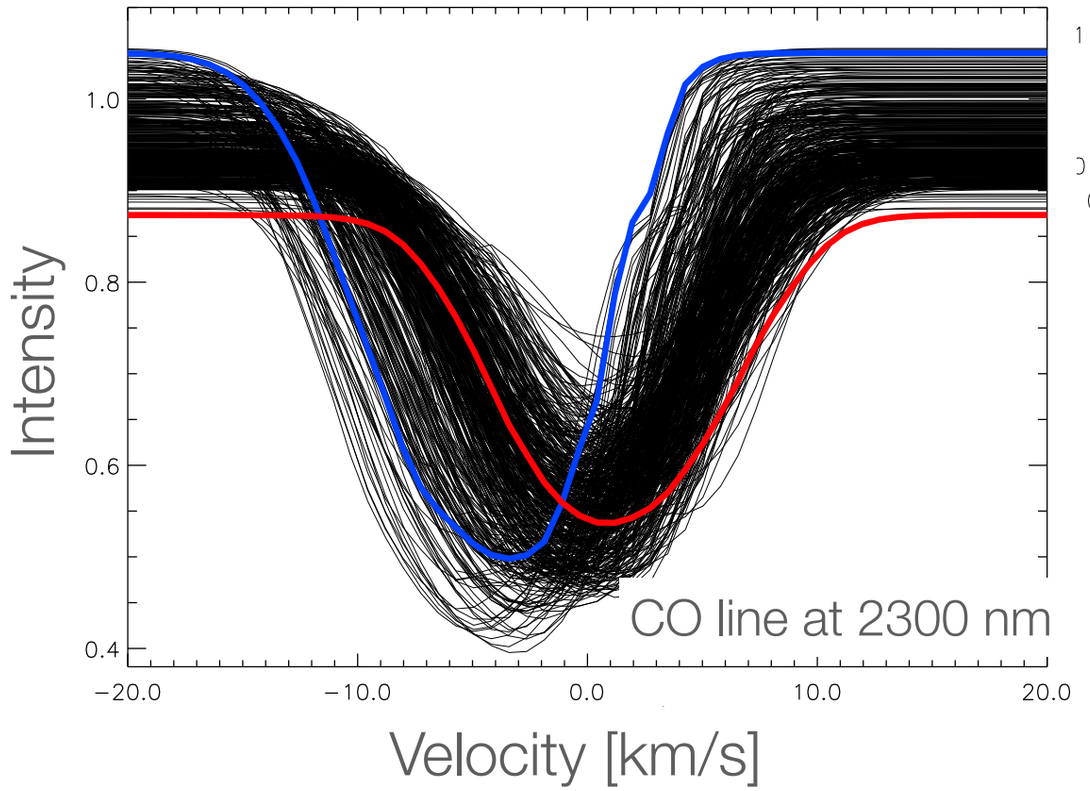
Calibrating properties of Cepheid variables for the cosmic distance ladder (Science paper)

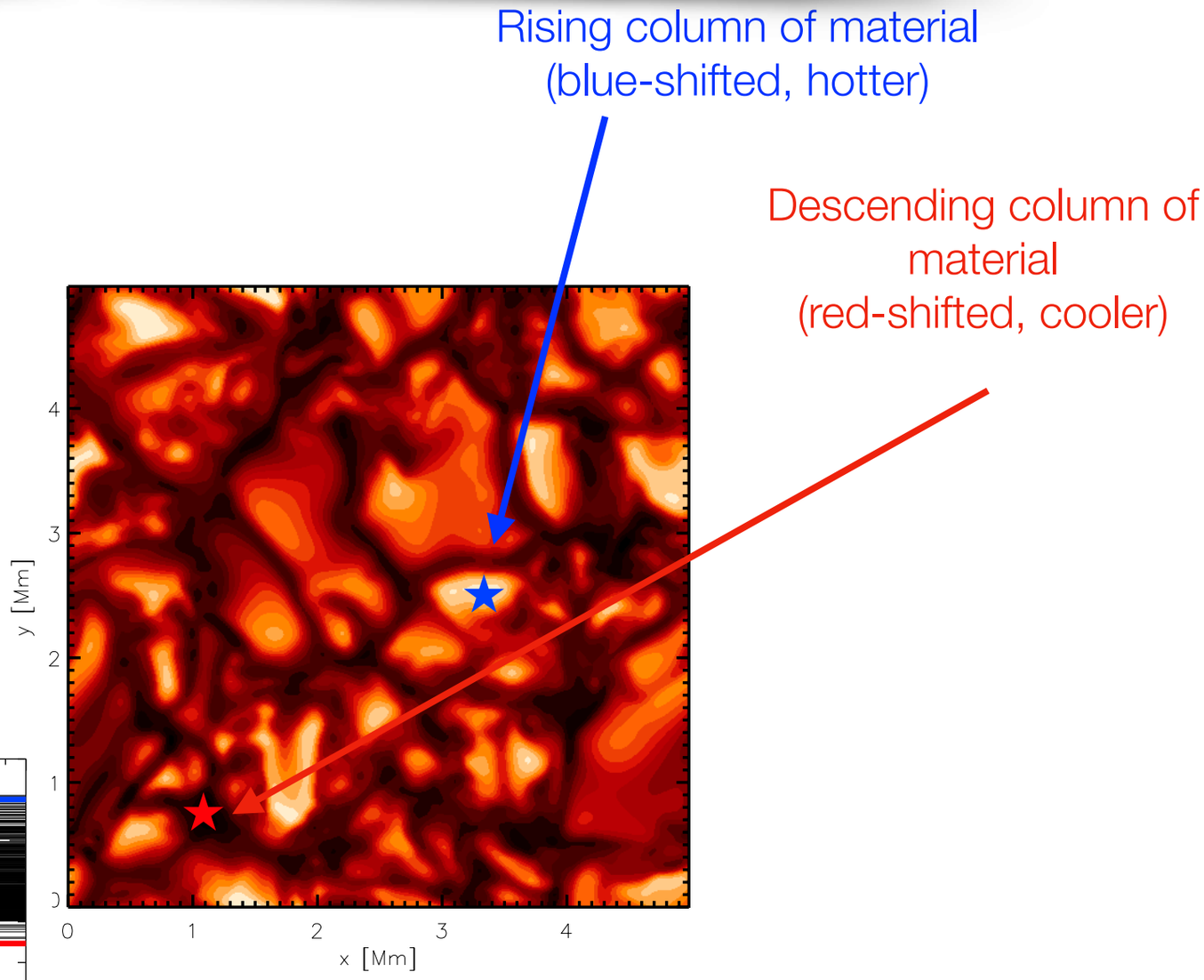
Characterisation of M dwarf stars (Expression of interest)

Stellar contamination to planet characterisation



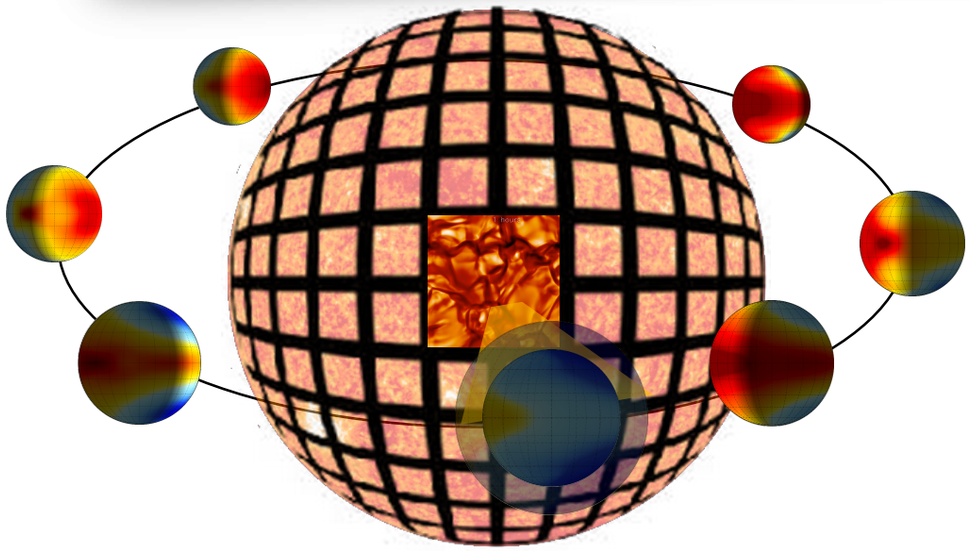
3D radiative hydrodynamical simulations of stellar convection





People interested: A. Chiavassa, L. Bigot

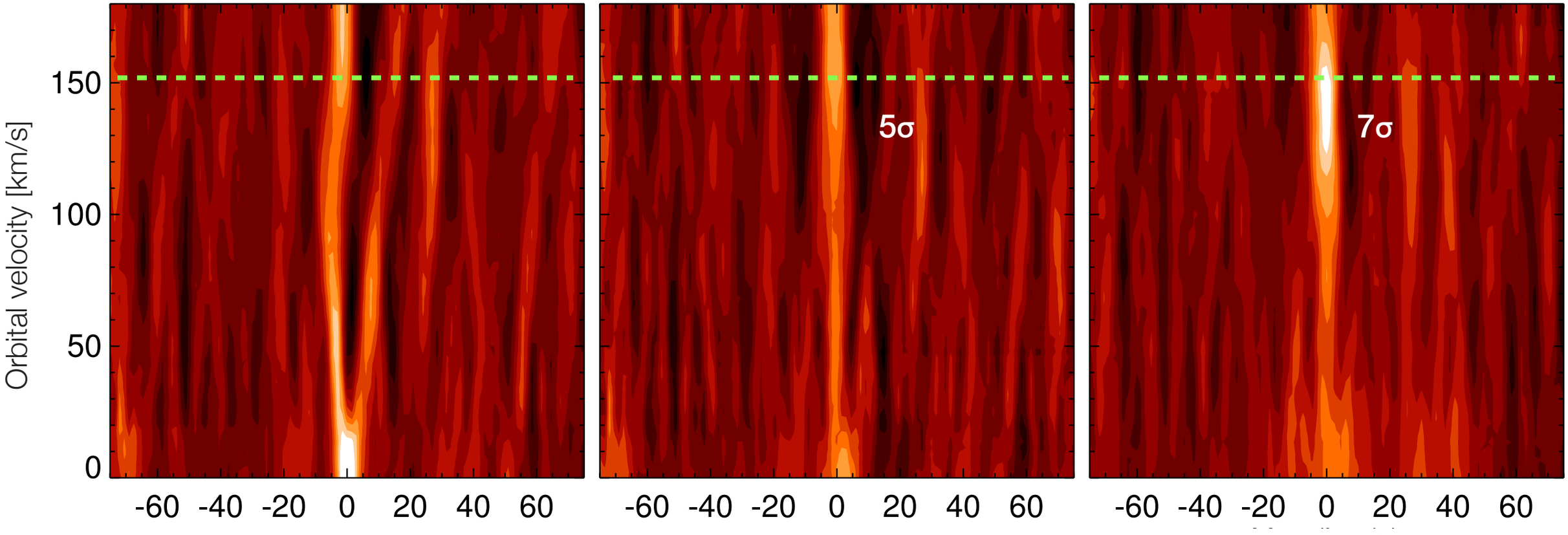
Stellar contamination to planet characterisation



Uncorrected

Brogi et al. 2016
(parametric & fitted star)

Flowers et al. 2019
(with 3D stellar spectra)



People interested: A. Chiavassa, L. Bigot

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Eso webpage: https://elt.eso.org/instrument/ANDES/
Exposure Time Calculation: https://andes.inaf.it/instrument/exposure-time-calculator/
References: Marconi et al. 2020 (ESO Messenger No.182), Marconi et al. 2022 (SPIE, 12184, id. 1218424)