I A F E
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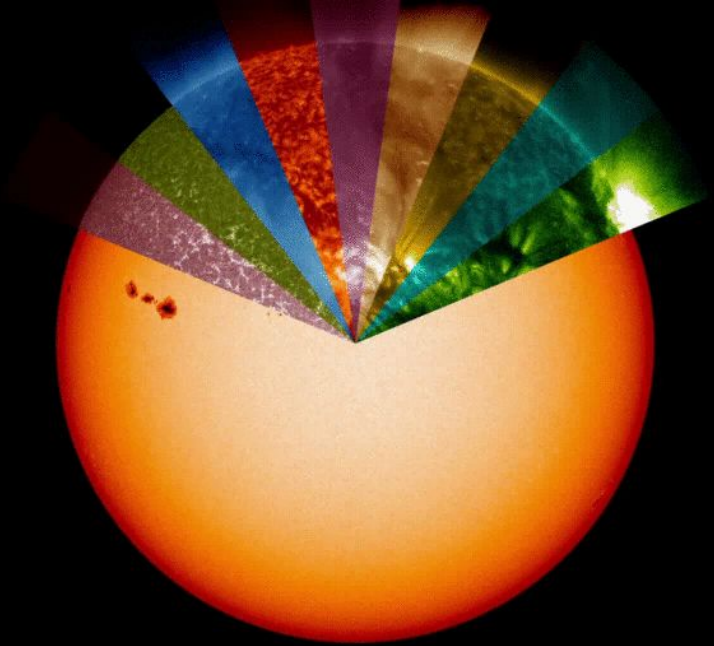
universidad de buenos aires - exactas
departamento de física

Magnetic activity cycleS in solar-type stars and beyond…

Andrea Buccino

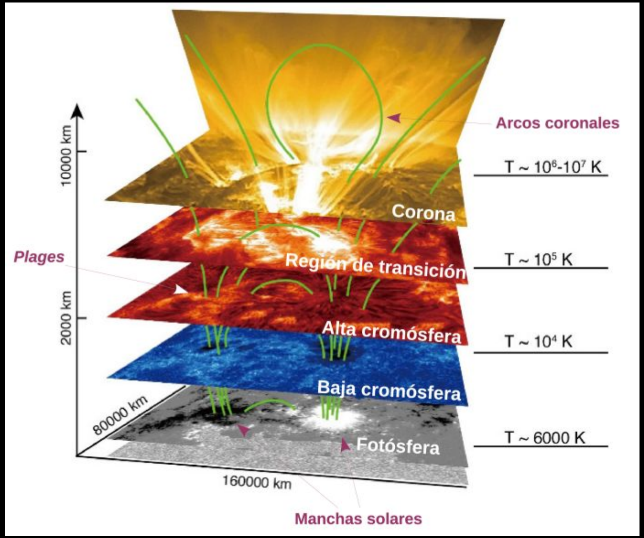
Flares and CMEs
Credito de imagen: NASA/SDO/Goddard

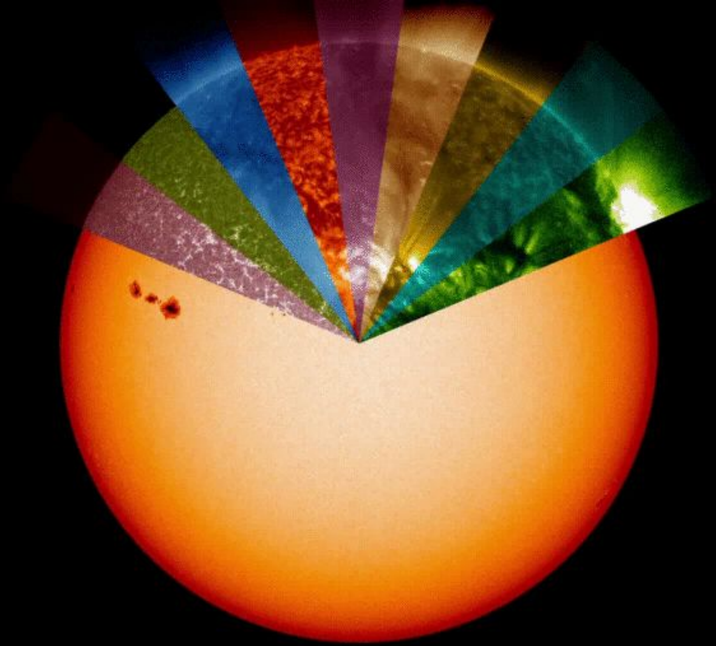
Solar Activity



Crédito de imagen:
NASA/SDO/Goddard

Solar Activity





Crédito de imagen:
NASA/SDO/Goddard

Solar activity

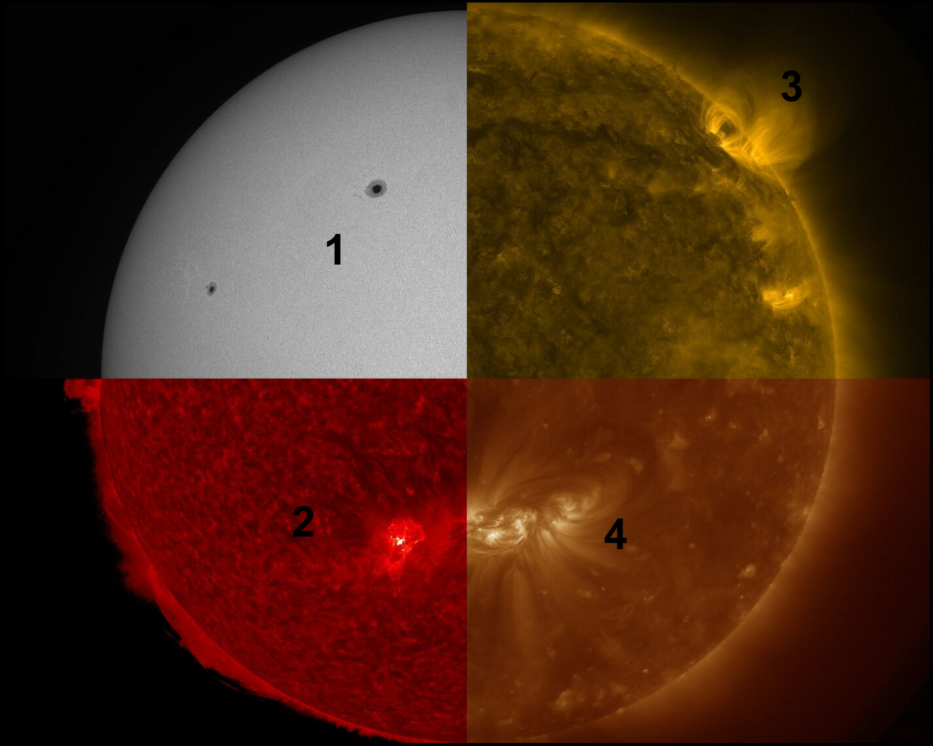
Images obtained from the Atmospheric Imaging Assembly (AIA) on board of the Solar Dynamics Observatory (SDO) during November, 11th. 2010.

1 Photosphere, centered at 4500 A

2 Cromosphere, centered at 304 A

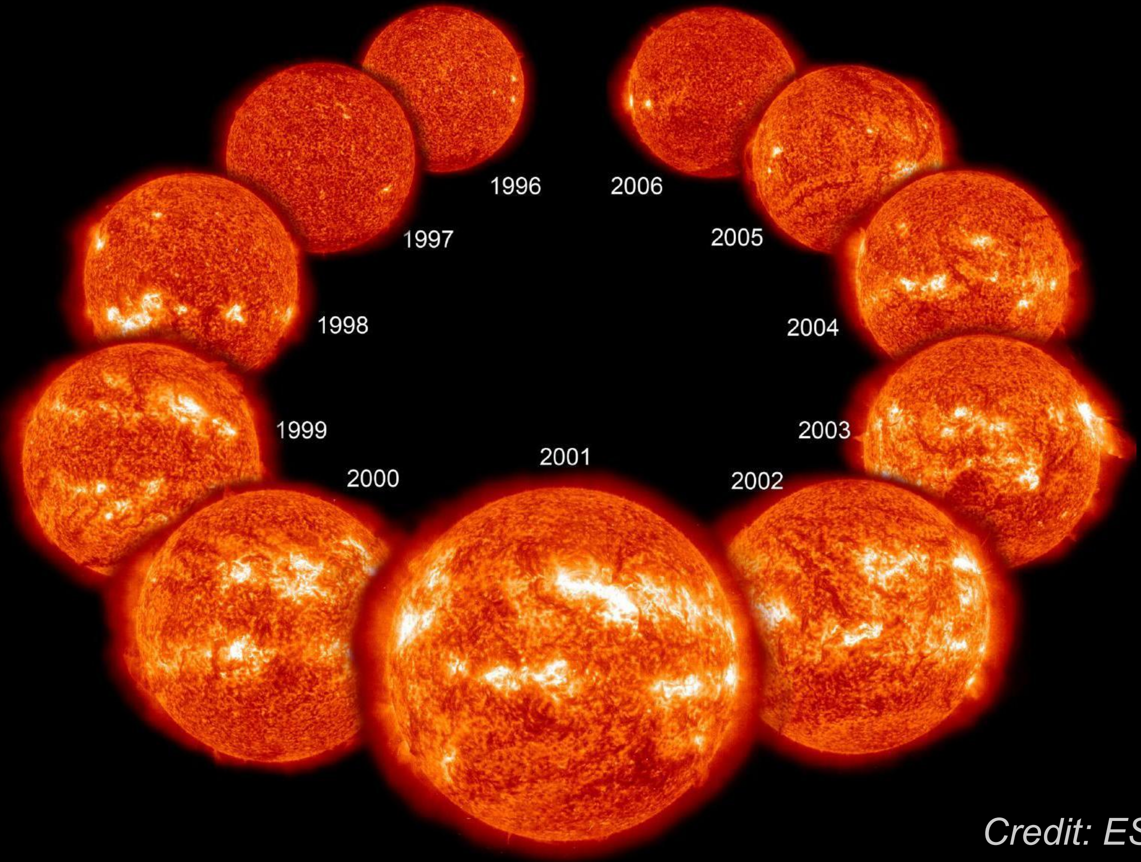
3 Coronal loops, centered at 171 A

4 Corona, centered at 193 A



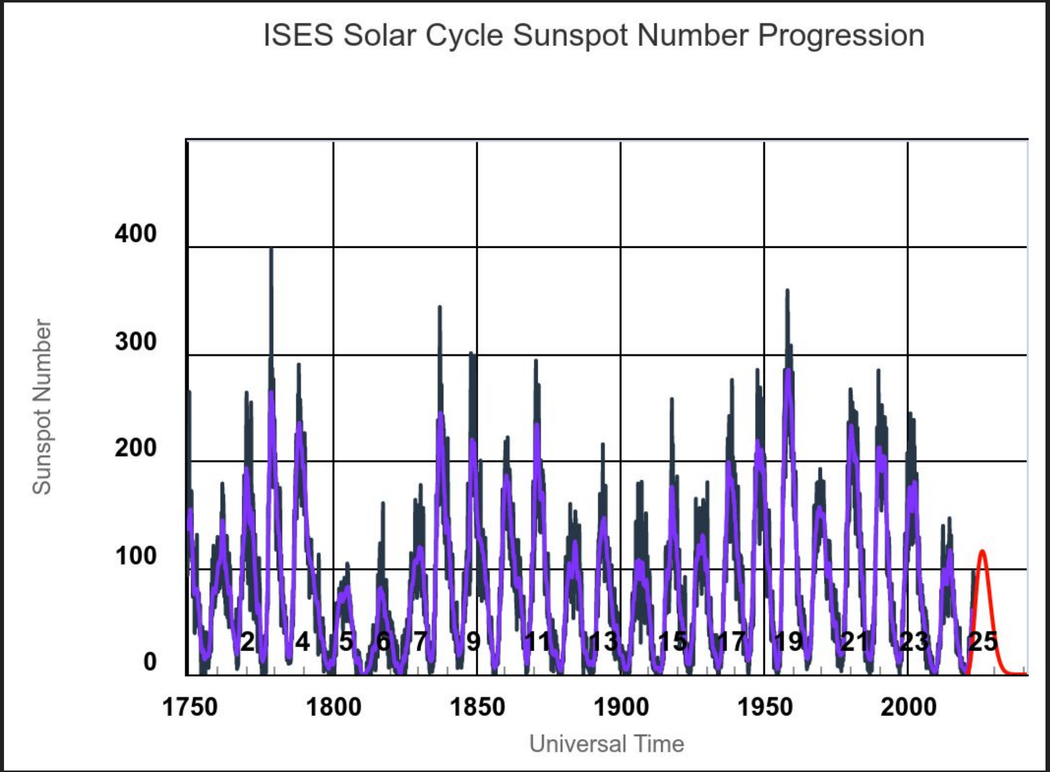
Gentileza del Grupo de Física Solar

Solar Cycle



Credit: ESA/NASA/SOHO

Sunspots-Solar Cycle



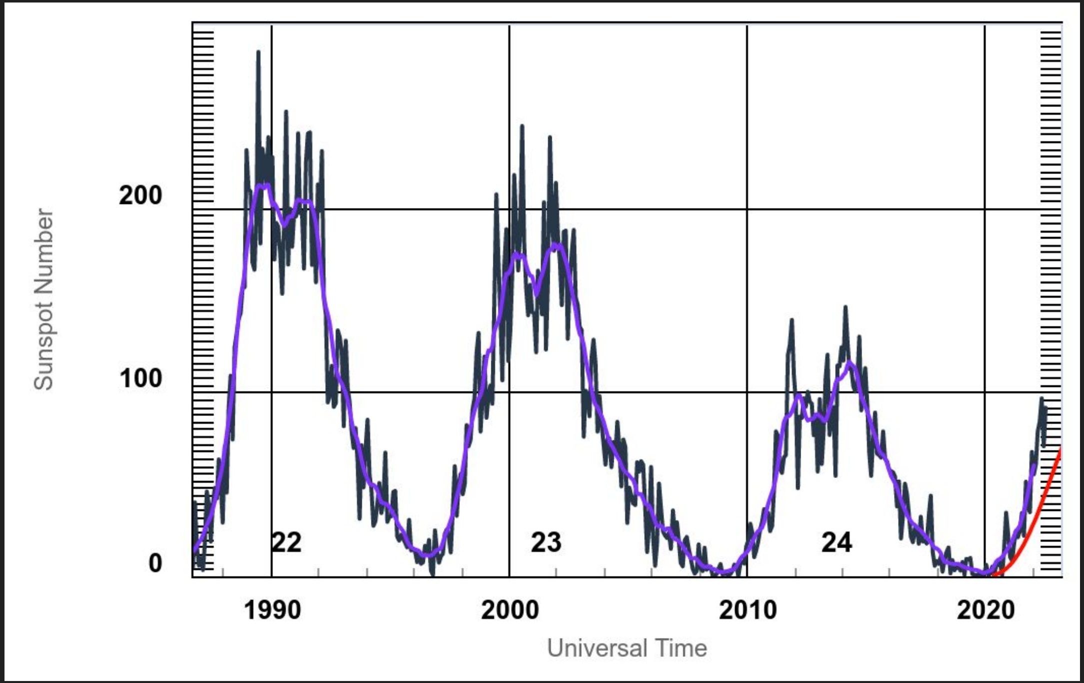
Fuente: https://www.swpc.noaa.gov/

Short activity cycle 11-yr length (not exact, 9-13 years).

Variable amplitude.

~80-yr cycle modulates the regular 11-yr cycle.

Solar cycle



Short activity cycle 11-yr length (not exact, 9-13 years).

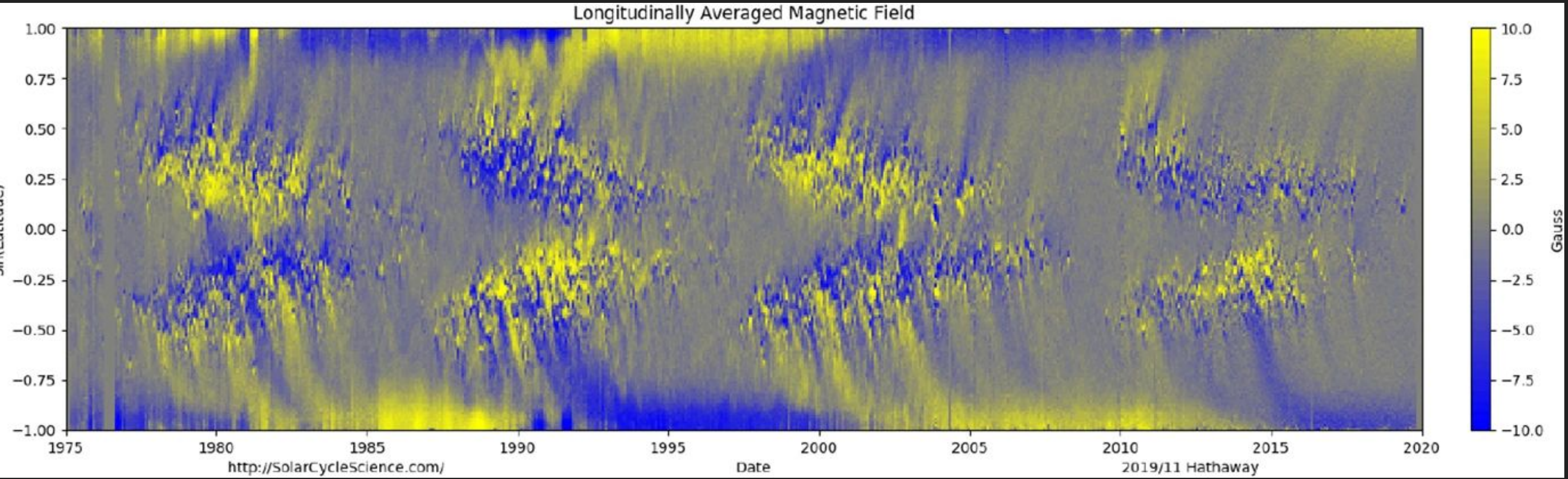
Variable amplitude.

~80-yr cycle modulates the regular 11-yr cycle.

Bi-annual oscillations along the 11 yr-cycle.

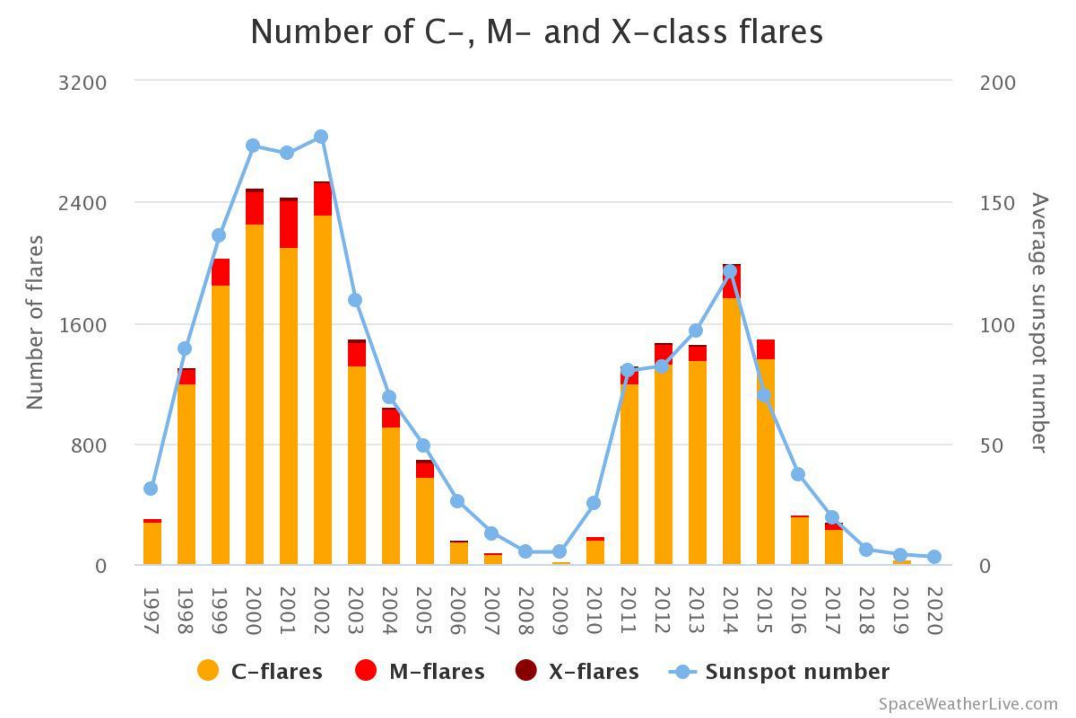
Fuente: https://www.swpc.noaa.gov/

Solar magnetic cycle



Zonally-averaged time–latitude magnetogram of the radial component of the solar surface magnetic field. The low-latitude component is associated with sunspots. Note the polarity reversal of the high-latitude magnetic field, occurring approximately at time of sunspot maximum (courtesy of D. Hathaway, Solar Cycle Science; see http://www.solarcyclescience.com/solarcycle.html)

Flares during the solar cycle



Short activity cycle 11-yr length (not exact, 9-13 years).

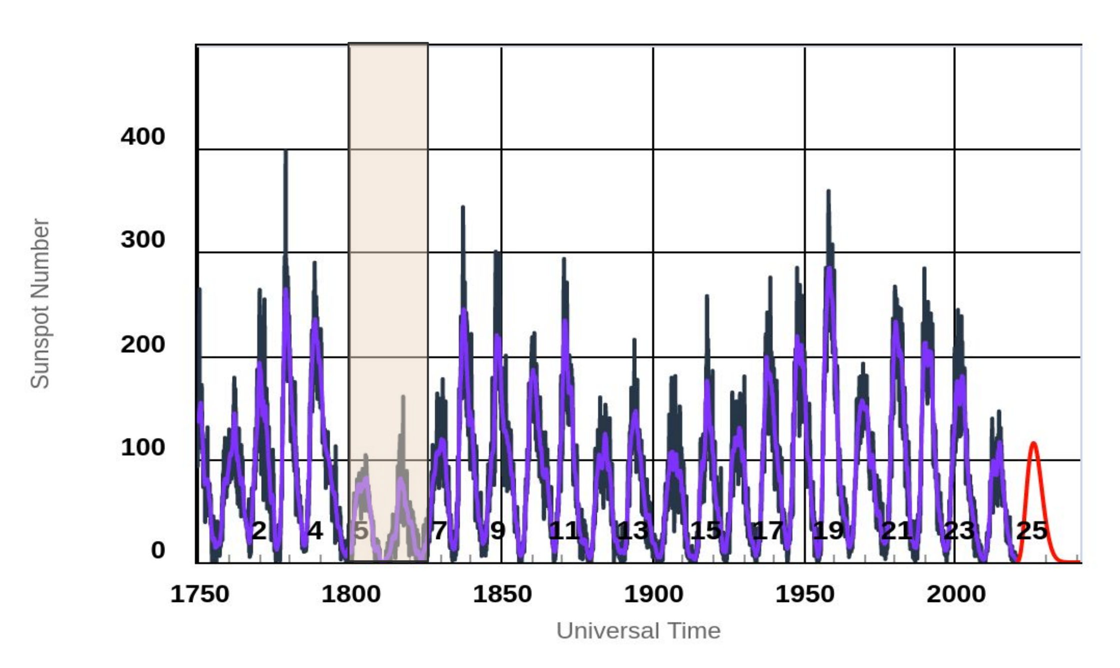
Variable amplitude.

~80-yr cycle modulates the regular 11-yr cycle.

Number of flares follow the solar cycle.

Datos de NOAA SWPC
https://www.spaceweatherlive.com/

Solar cycle



Fuente: https://www.swpc.noaa.gov/

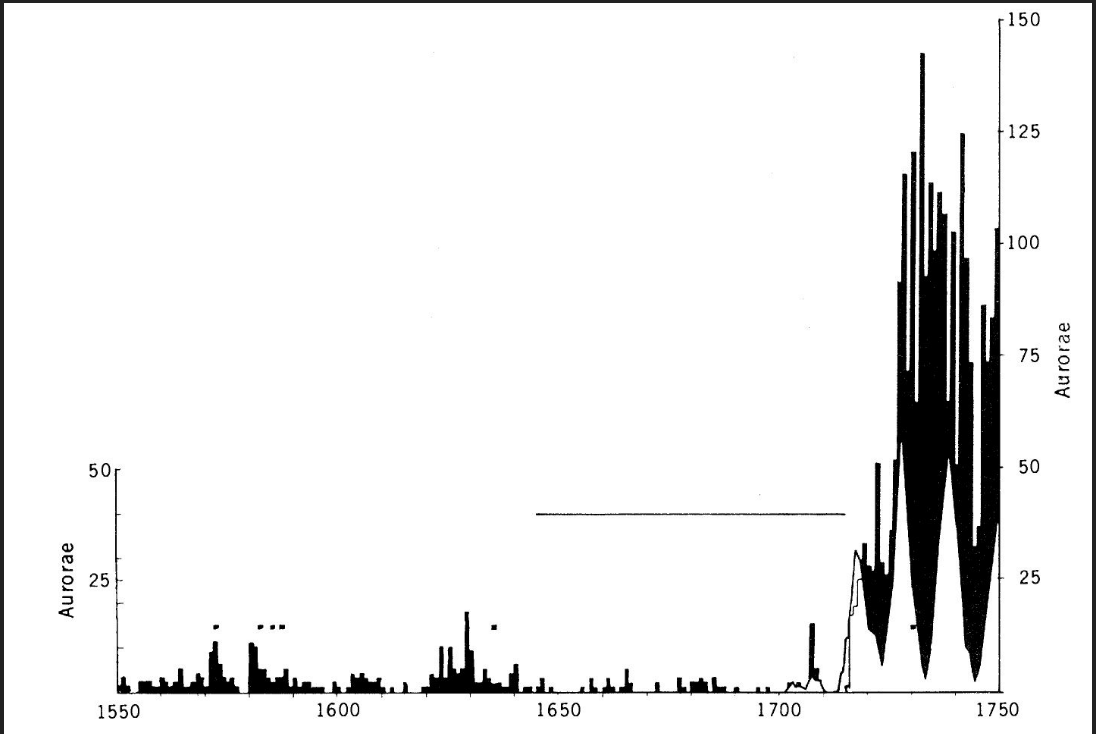
Short activity cycle 11-yr length (not exact, 9-13 years).

Variable amplitude.

~80-yr cycle modulates the regular 11-yr cycle.

Dalton Minimum (low-level activity cycle) between 1790-1830.

Solar cycle- Maunder minimum



Eddy (1976, Science, 192, 1189)

Maunder minimum between 1645 and 1715, pronounced decrease in the spot number followed by a decrease in aurora borealis reports.

Solar Cycle-Mínimo de Maunder

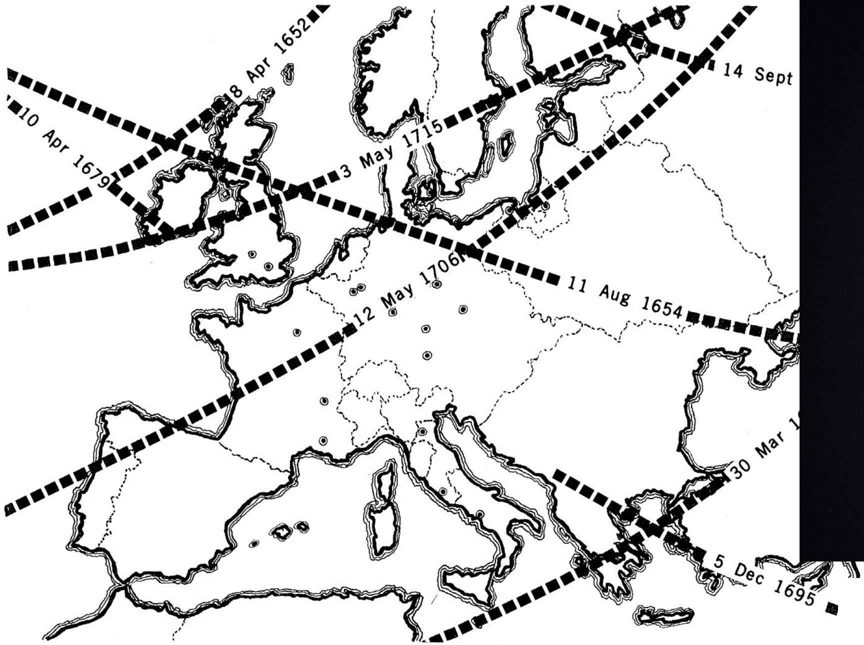


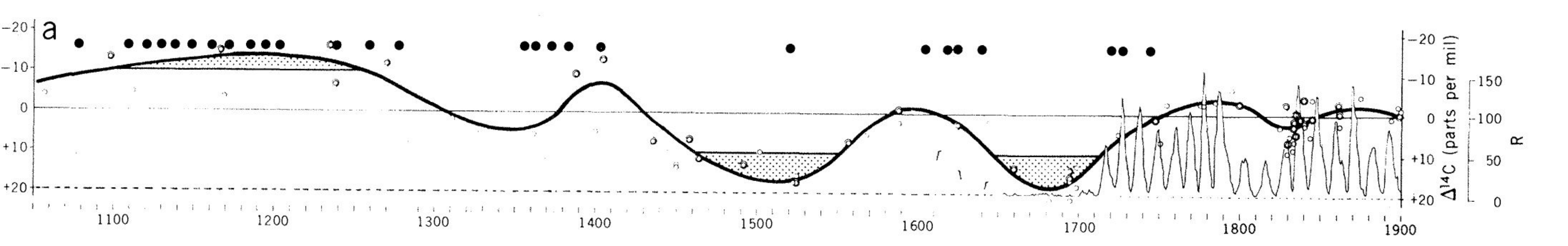
Fig. 7. Paths of totality for solar eclipses in Europe, from 1640 to 1715, from Oppolzer (*65*). S
of observatories which reported eclipse observations in the period are shown as double circl

Eddy (1976, Science, 192, 1189)

Franco Meconi, 2 de julio 2019

Besides this ring, there appeared also rays of a much fainter light in the form of a rectangular cross. . . . The longer and brighter branch of this cross lay very nearly along the ecliptic, the light of the shorter was so weak that I did not constantly see it.

Solar cycle- Maunder minimum

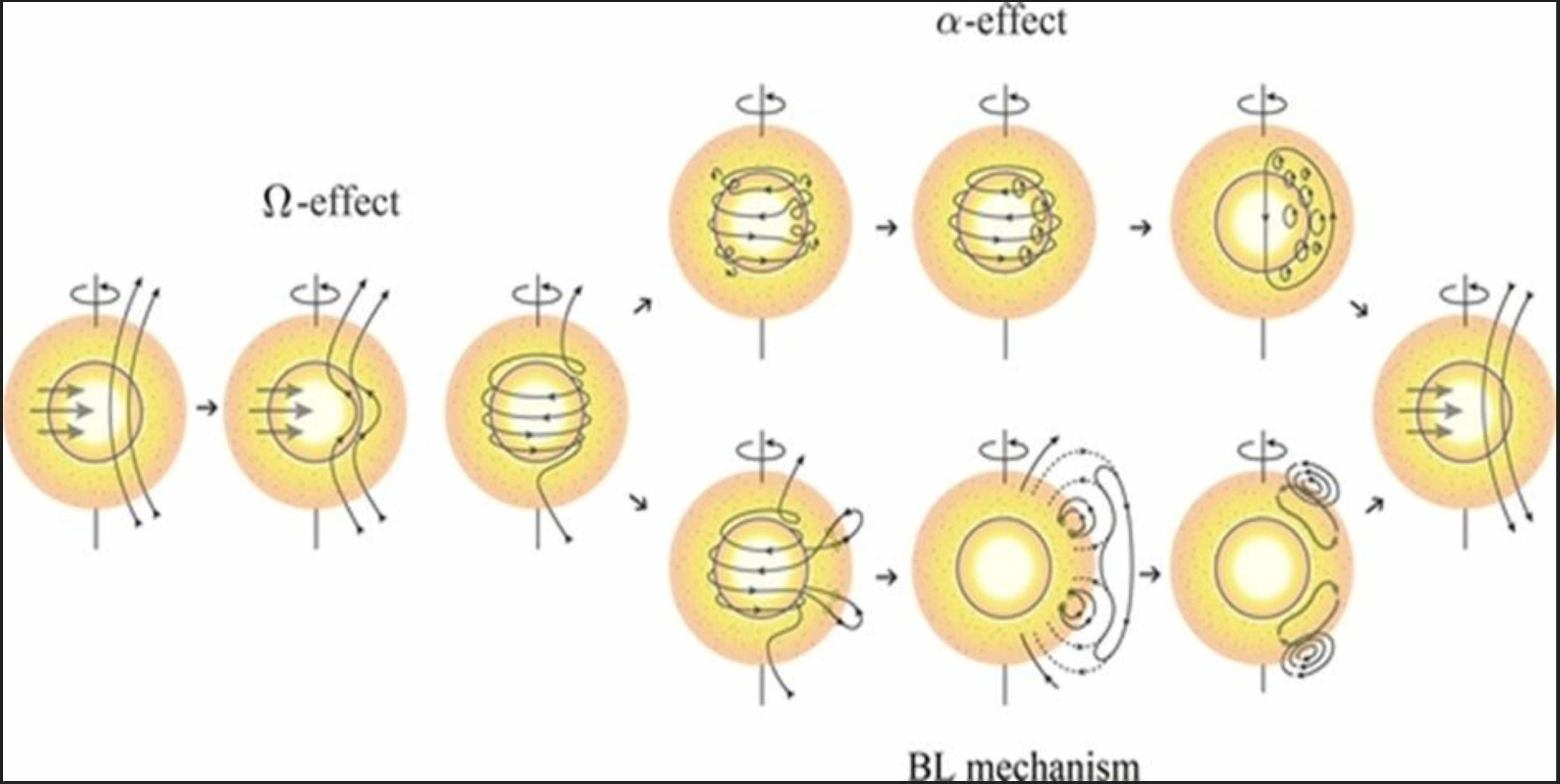


Eddy (1976, Science, 192, 1189)

Reconstructed solar activity from ^{14}C relative abundance in tree rings.

When the Sun is active, some of the galactic cosmic rays are prevented from reaching the Earth. Then, less than the normal amount of ^{14}C is produced in the atmosphere and less is found in tree rings formed then.

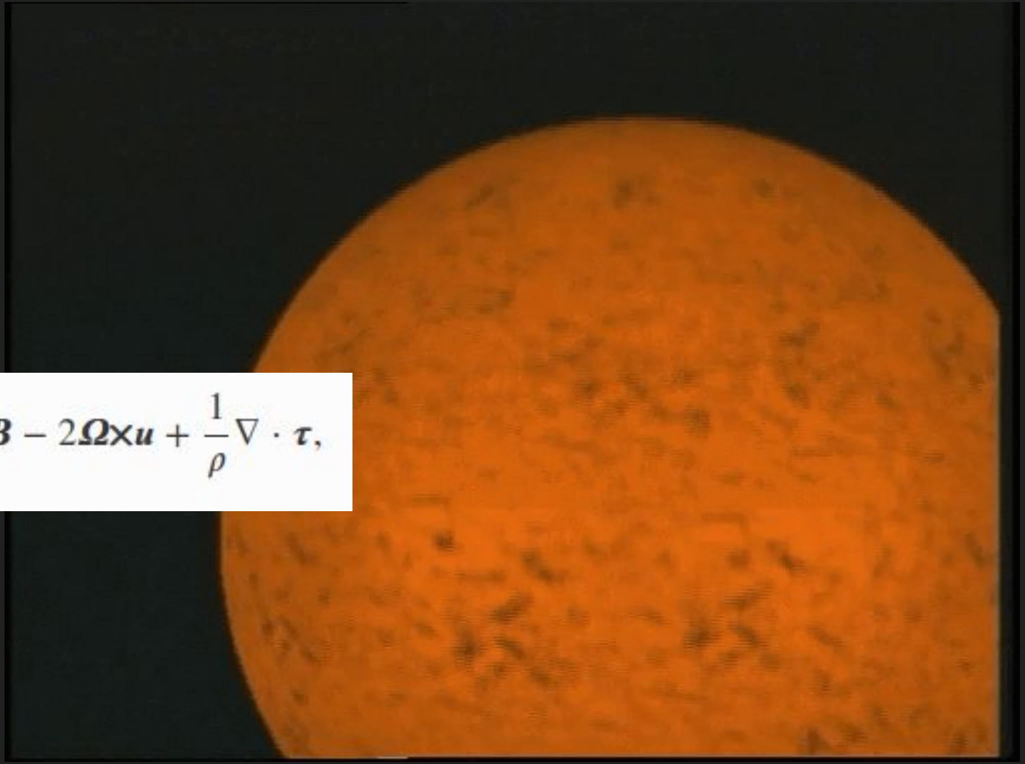
Solar dynamo



Dínamo solar

$$\frac{\partial \boldsymbol{B}}{\partial t} = \nabla \times (\boldsymbol{u} \times \boldsymbol{B} - \eta \nabla \times \boldsymbol{B}),$$

$$\frac{\partial \boldsymbol{u}}{\partial t} + (\boldsymbol{u} \cdot \nabla)\boldsymbol{u} = -\frac{1}{\rho}\nabla p + \boldsymbol{g} + \frac{1}{4\pi\rho}(\nabla \times \boldsymbol{B}) \times \boldsymbol{B} - 2\boldsymbol{\Omega}\times\boldsymbol{u} + \frac{1}{\rho}\nabla \cdot \boldsymbol{\tau},$$



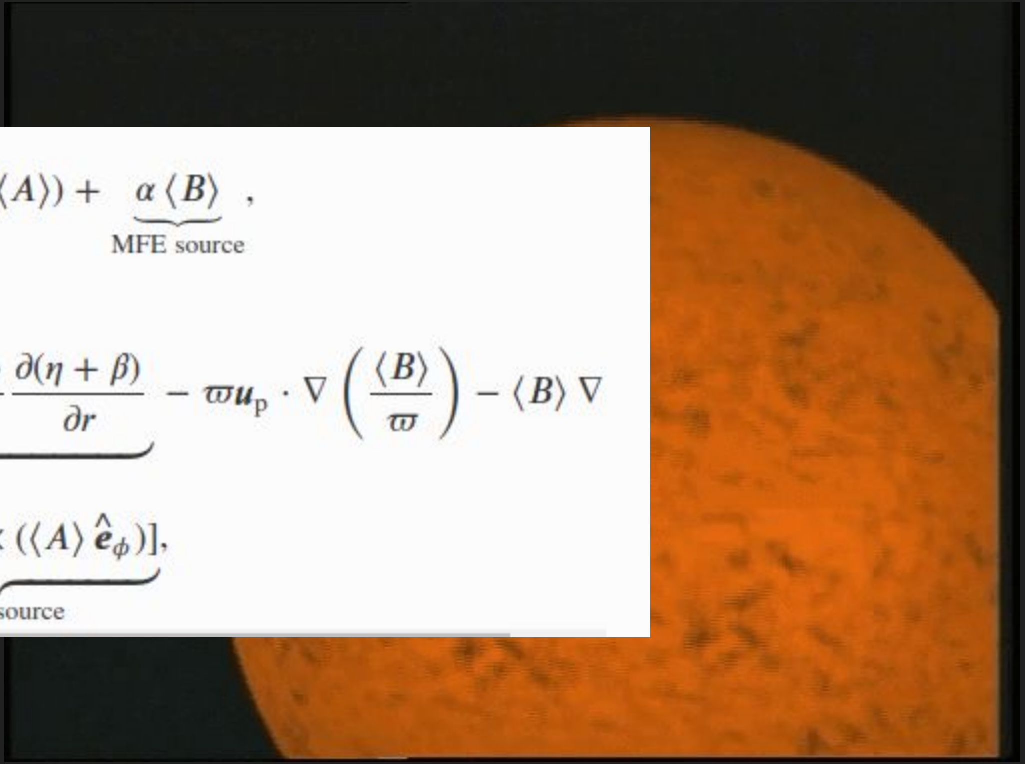
Dínamo solar

$$B(r,\theta,t) = \nabla\times(A(r,\theta,t)\hat{e}_\varphi) + B(r,\theta,t)\hat{e}_\varphi.$$

$$\frac{\partial\langle A\rangle}{\partial t} = \underbrace{(\eta+\beta)\left(\nabla^2 - \frac{1}{\varpi^2}\right)\langle A\rangle}_{\text{turbulent diffusion}} - \frac{\boldsymbol{u}_\mathrm{p}}{\varpi}\cdot\nabla(\varpi\langle A\rangle) + \underbrace{\alpha\langle B\rangle}_{\text{MFE source}},$$

$$\frac{\partial\langle B\rangle}{\partial t} = \underbrace{(\eta+\beta)\left(\nabla^2 - \frac{1}{\varpi^2}\right)\langle B\rangle + \frac{1}{\varpi}\frac{\partial\varpi\langle B\rangle}{\partial r}\frac{\partial(\eta+\beta)}{\partial r}}_{\text{turbulent diffusion}} - \varpi\boldsymbol{u}_\mathrm{p}\cdot\nabla\left(\frac{\langle B\rangle}{\varpi}\right) - \langle B\rangle\nabla$$

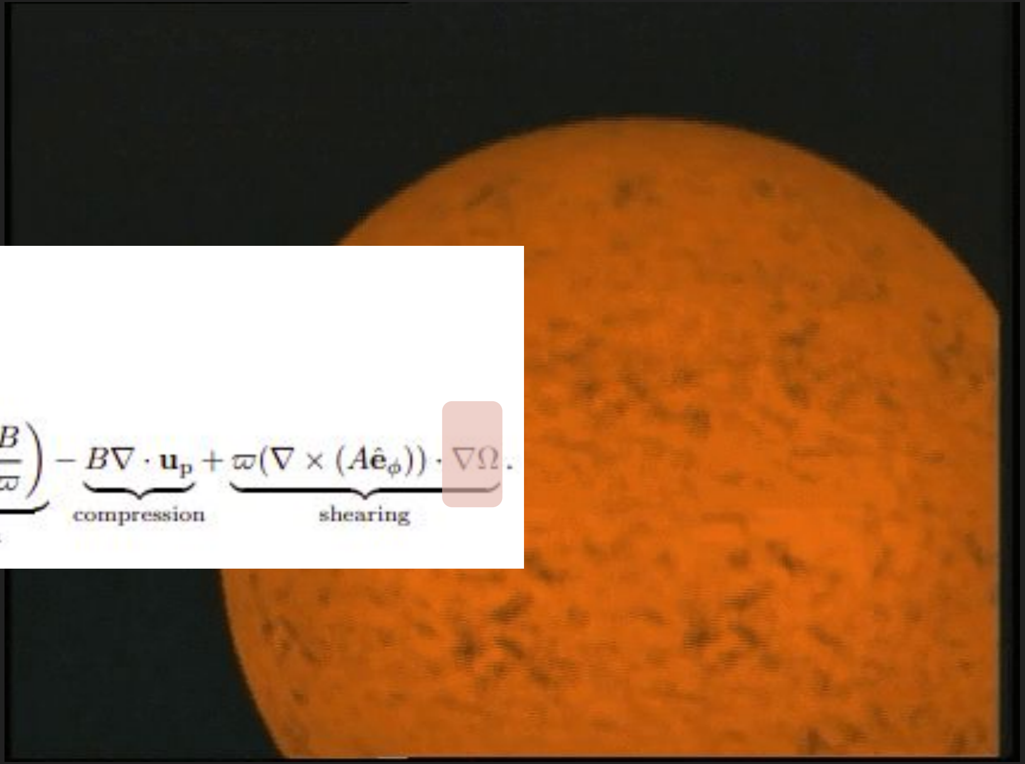
$$+ \underbrace{\varpi(\nabla\times(\langle A\rangle\hat{\boldsymbol{e}}_\phi))\cdot\nabla\Omega}_{\text{shearing}} + \underbrace{\nabla\times[\alpha\nabla\times(\langle A\rangle\hat{\boldsymbol{e}}_\phi)]}_{\text{MFE source}},$$



Charbonnaeu, P. (2020, LRSP, 17, 4)

Dínamo solar

$$B(r, \theta, t) = \nabla \times (A(r, \theta, t)\hat{e}_\varphi) + B(r, \theta, t)\hat{e}_\varphi.$$



$$\frac{\partial A}{\partial t} = \underbrace{\eta\left(\nabla^2 - \frac{1}{\varpi^2}\right)A}_{\text{resistive decay}} - \underbrace{\frac{\mathbf{u}_\mathrm{p}}{\varpi}\cdot\nabla(\varpi A)}_{\text{advection}},$$

$$\frac{\partial B}{\partial t} = \underbrace{\eta\left(\nabla^2 - \frac{1}{\varpi^2}\right)B}_{\text{resistive decay}} + \underbrace{\frac{1}{\varpi}\frac{\partial(\varpi B)}{\partial r}\frac{\partial \eta}{\partial r}}_{\text{diamagnetic transport}} - \underbrace{\varpi\mathbf{u}_\mathrm{p}\cdot\nabla\left(\frac{B}{\varpi}\right)}_{\text{advection}} - \underbrace{B\nabla\cdot\mathbf{u}_\mathrm{p}}_{\text{compression}} + \underbrace{\varpi(\nabla\times(A\hat{\mathbf{e}}_\phi))\cdot\nabla\Omega}_{\text{shearing}}.$$

Charbonnaeu, P. (2020, LRSP, 17, 4)

Dínamo solar

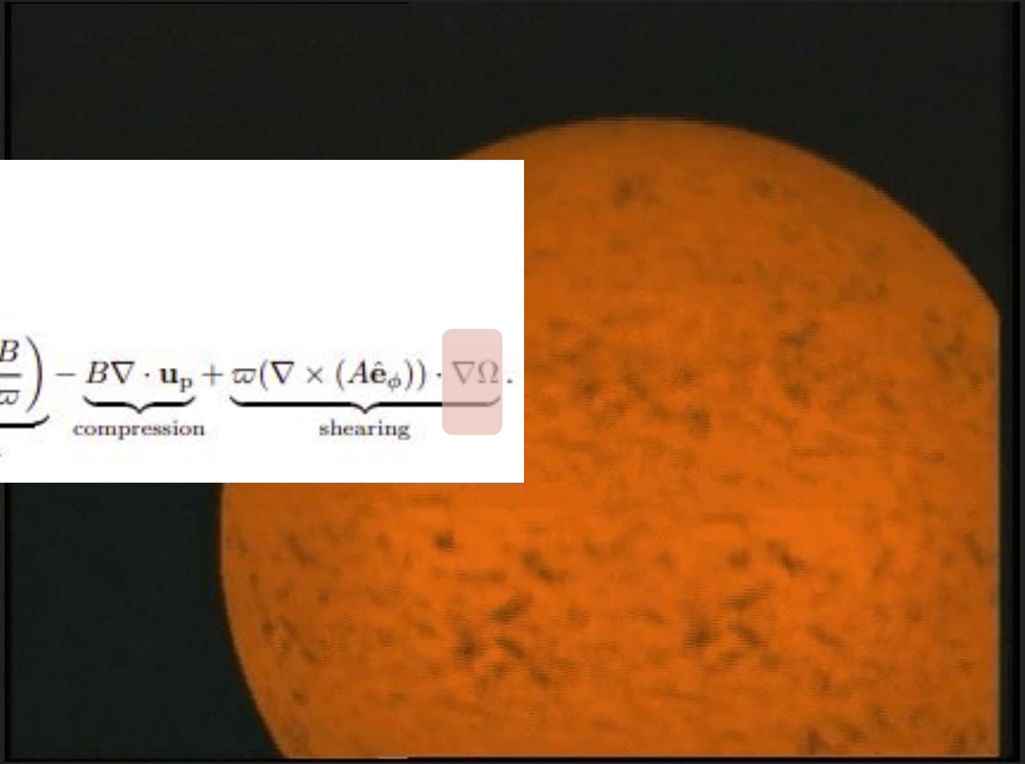
$$B(r,\theta,t) = \nabla \times (A(r,\theta,t)\hat{e}_\varphi) + B(r,\theta,t)\hat{e}_\varphi.$$

$$\frac{\partial A}{\partial t} = \underbrace{\eta\left(\nabla^2 - \frac{1}{\varpi^2}\right)A}_{\text{resistive decay}} - \underbrace{\frac{\mathbf{u}_p}{\varpi}\cdot\nabla(\varpi A)}_{\text{advection}},$$

$$\frac{\partial B}{\partial t} = \underbrace{\eta\left(\nabla^2 - \frac{1}{\varpi^2}\right)B}_{\text{resistive decay}} + \underbrace{\frac{1}{\varpi}\frac{\partial(\varpi B)}{\partial r}\frac{\partial \eta}{\partial r}}_{\text{diamagnetic transport}} - \underbrace{\varpi\mathbf{u}_p\cdot\nabla\left(\frac{B}{\varpi}\right)}_{\text{advection}} - \underbrace{B\nabla\cdot\mathbf{u}_p}_{\text{compression}} + \underbrace{\varpi(\nabla\times(A\hat{\mathbf{e}}_\phi))\cdot\nabla\Omega}_{\text{shearing}}.$$

$$\frac{\partial\langle \boldsymbol{B}\rangle}{\partial t} = \nabla \times (\langle \boldsymbol{u}\rangle \times \langle \boldsymbol{B}\rangle + \mathcal{E} - \eta\nabla\times\langle \boldsymbol{B}\rangle),$$

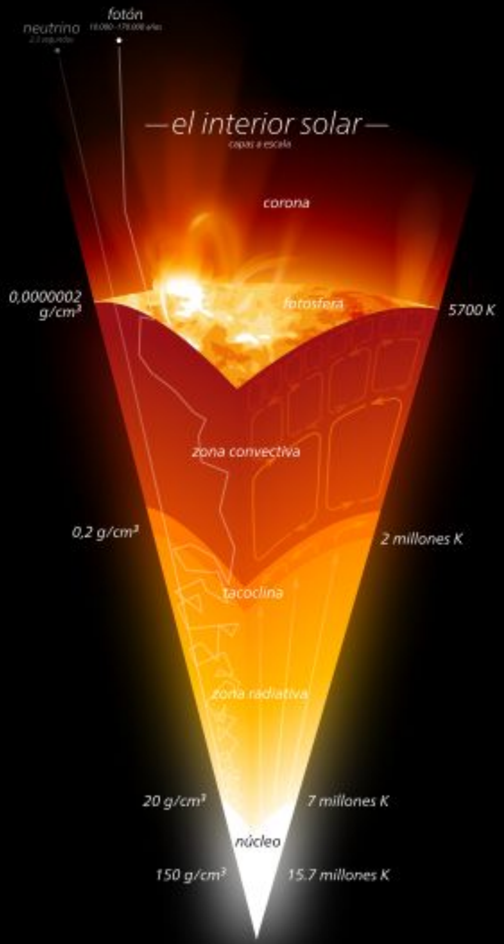
$$\mathcal{E} = \langle \boldsymbol{u}' \times \boldsymbol{B}' \rangle$$

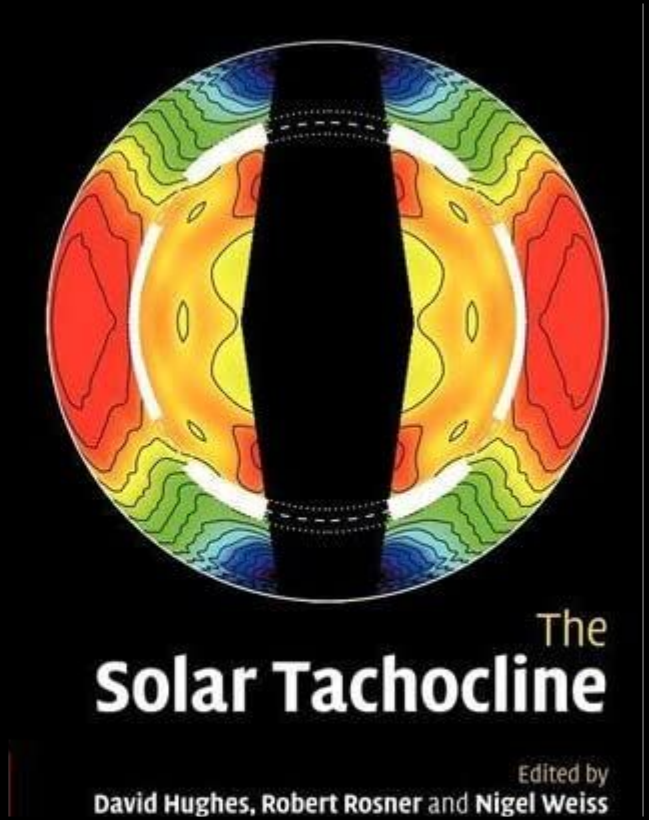


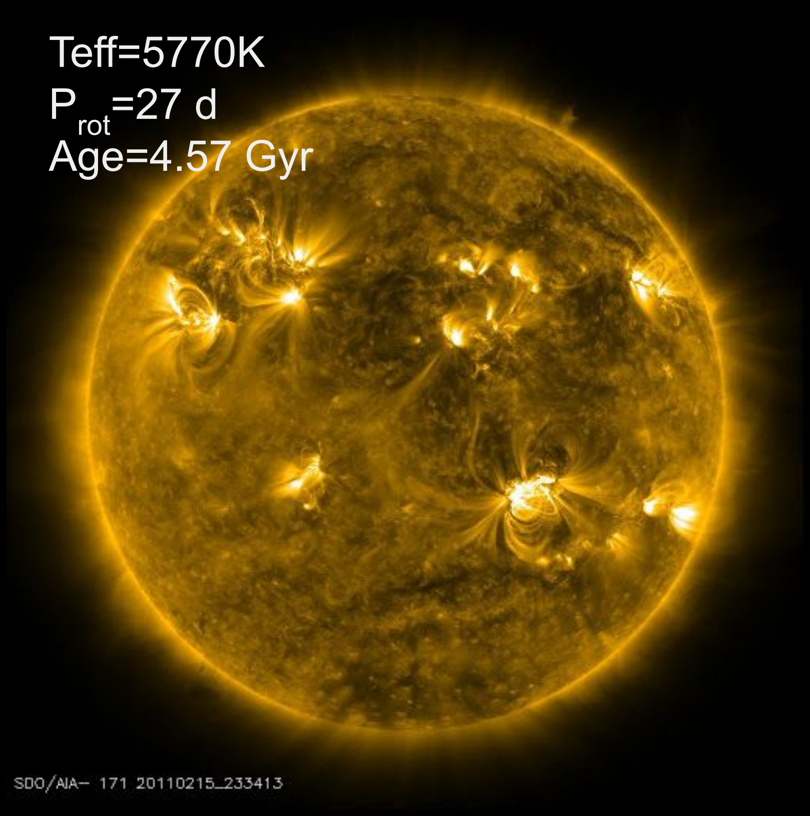
FALTA

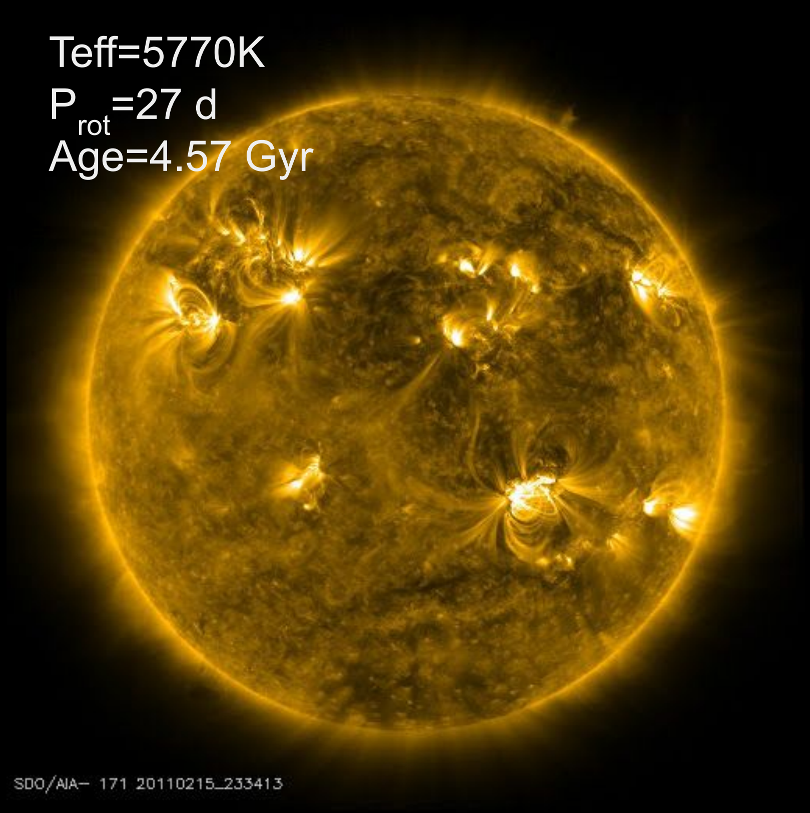
Charbonnaeu, P. (2020, LRSP, 17, 4)

Interior solar






Teff=5770K
P_{rot}=27 d
Age=4.57 Gyr
SDO/AIA- 171 20110215_233413



Variation of stellar parameters: Rotation period, age, temperature, internal structure

Do solar type-stars always present activity cycles?

Do solar type-stars always present activity cycles?

How do stellar parameters affect stellar activity cycles?

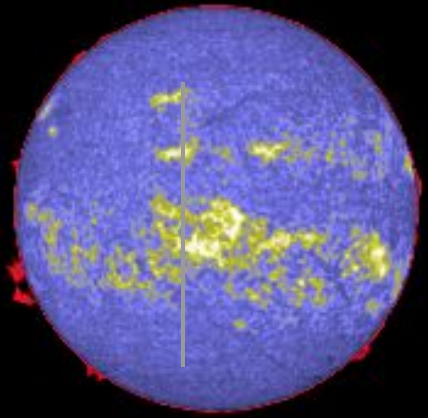
Do solar type-stars always present activity cycles?

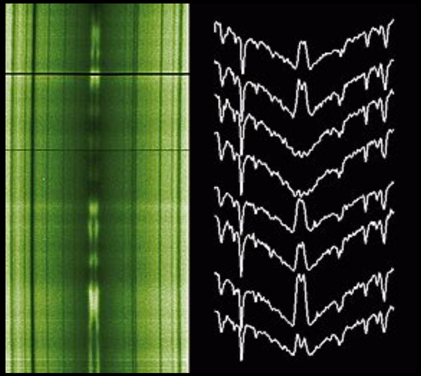
How do stellar parameters affect stellar activity cycles?

Do non solar type-stars present activity cycles?

Stellar activity indexes

Imagen falso color en
línea Ca II K (3934 A)





Stellar activity indexes

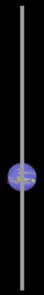
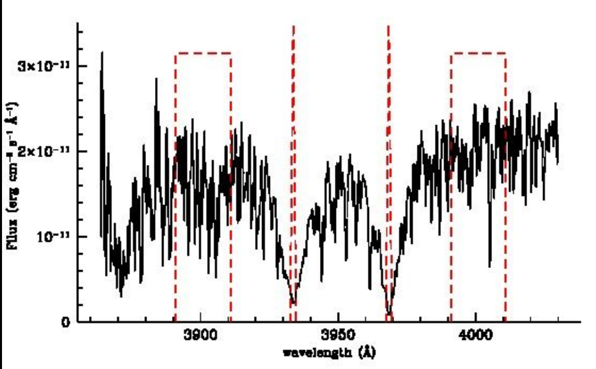


Imagen falso color en
línea Ca II K (3934 A)

Espectro CASLEO 18 Scorpii



Mount Wilson index

$$S = \beta \frac{F_H + F_K}{F_R + F_V}$$

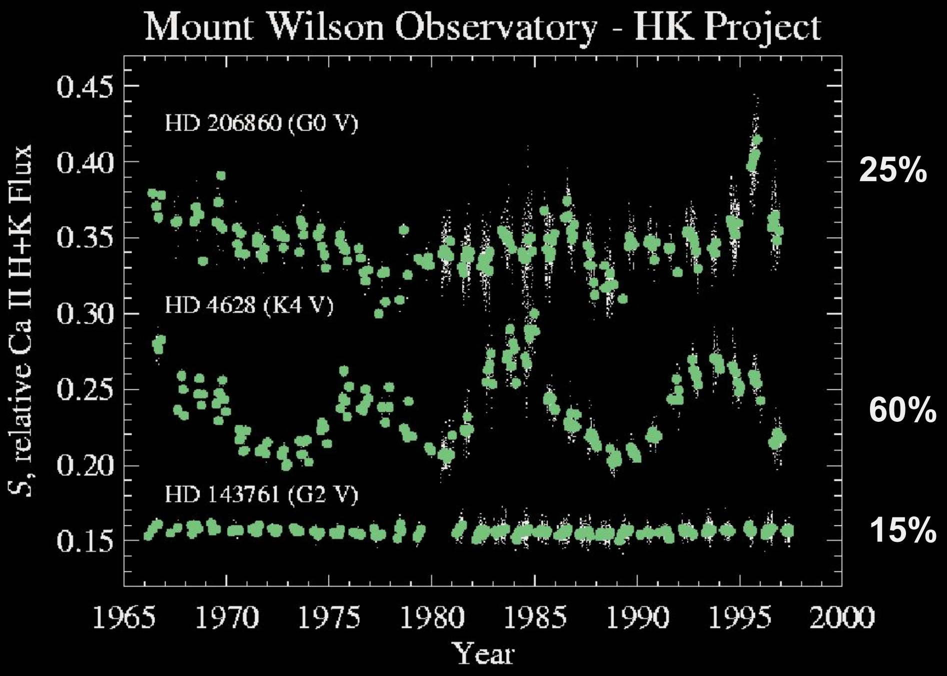
What do we know about long-term activity in solar-type stars?

HK Project

From 1966 to 2003, daily observations at Mount Wilson Observatory (California, USA)

A 2.5m telescope, exclusively measuring fluxes in the Ca II H (396.8 nm) and K (393.3 nm) lines and the near continuum with a spectrophotometer.

400,000 measurements of S from 2,200 stars F to K.



Astronomy & Astrophysics manuscript no. magnetic˙cycles
July 28, 2011

The HARPS search for southern extra-solar planets⋆

XXXI. Magnetic activity cycles in solar-type stars: statistics and impact on precise radial velocities

C. Lovis[1], X. Dumusque[1,2], N. C. Santos[2,3,1], F. Bouchy[4,5], M. Mayor[1], F. Pepe[1], D. Queloz[1], D. Ségransan[1], and S. Udry[1]

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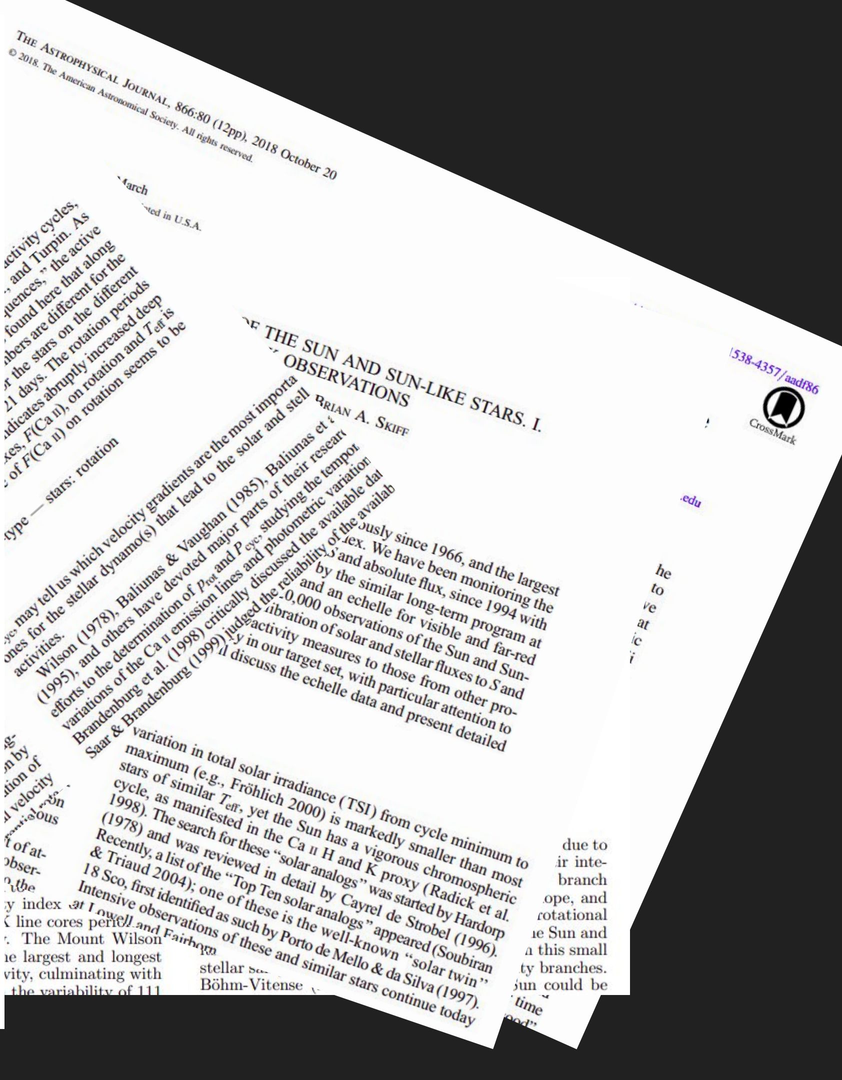
[5] Observatoire de Haute-Provence, CNRS/OAMP, F-04870 St. Michel l'Observatoire, France

Received 26 July 2011 / Accepted ...

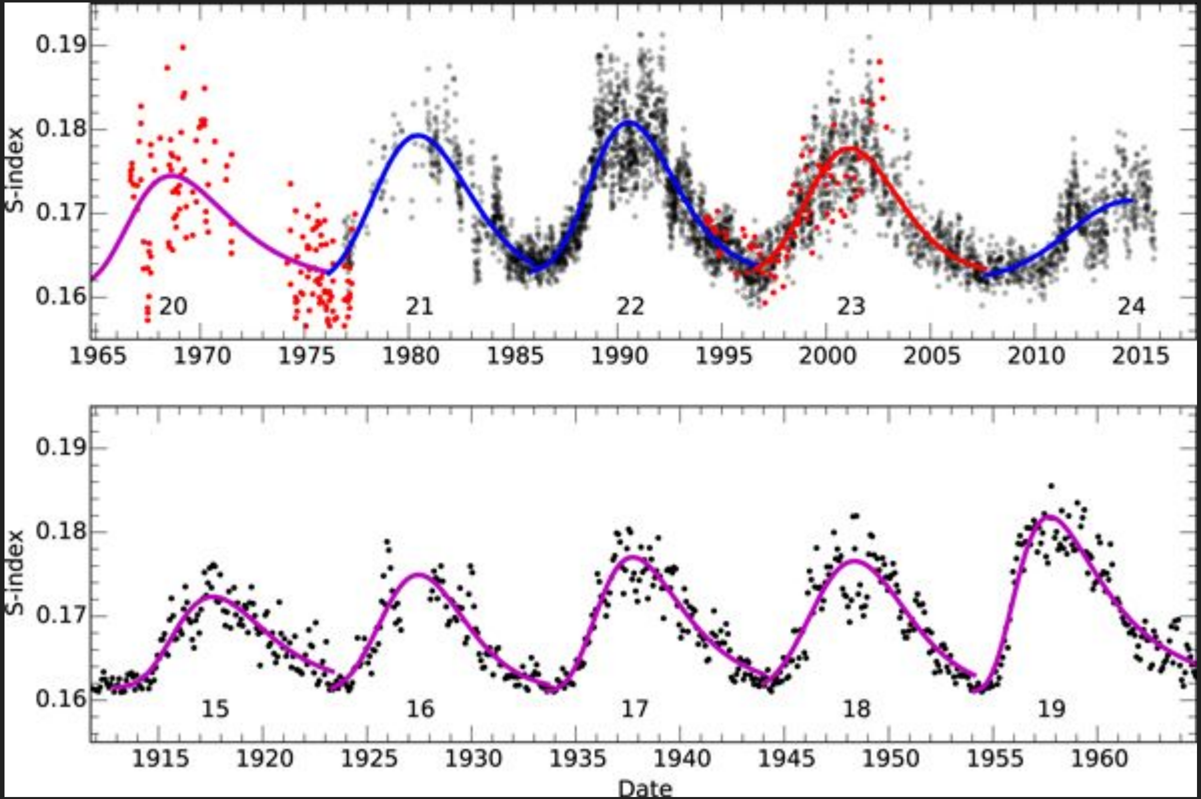
ABSTRACT

Context. Searching for extrasolar planets through radial velocity measurements relies on the stability of stellar photospheres. Several phenomena are known to affect line profiles in solar-type stars, among which stellar oscillations, granulation and magnetic activity through spots, plages and activity cycles.
Aims. We aim at characterizing the statistical properties of magnetic activity cycles, and studying their impact on spectroscopic measurements such as radial velocities, line bisectors and line shapes.
Methods. We use data from the HARPS high-precision planet-search sample comprising 304 FGK stars followed over about 7 years. We obtain high-precision Ca II H&K chromospheric activity measurements and convert them to R'_{HK} indices using an updated calibration taking into account stellar metallicity. We study R'_{HK} variability as a function of time and search for possible correlations with radial velocities and line shape parameters.
Results. The obtained long-term precision of ~0.35% on S-index measurements is about 3 times better than the canonical Mt Wilson survey, which opens new possibilities to characterize stellar activity. We classify stars according to the magnitude and timescale of the Ca II H&K variability, and identify activity cycles whenever possible. We find that 39±8% of old solar-type stars in the solar neighborhood do not show any activity cycles (or only very weak ones), while 61±8% do have one. Non-cycling stars are almost only found among G dwarfs and at mean activity levels $\log R'_{HK} < -4.95$. Magnetic cycle amplitude generally decreases with decreasing activity level. A significant fraction of stars exhibit small variations in radial velocities and line shape parameters that are correlated with activity cycles. The sensitivity of radial velocities to magnetic cycles increases towards hotter stars, while late K dwarfs are almost insensitive.
Conclusions. Activity cycles do induce long-period, low-amplitude radial velocity variations, at levels up to ~25 m s^{-1}. Caution is therefore mandatory when searching for long-period exoplanets. However, these effects can be corrected to high precision by detrending the radial velocity data using simultaneous measurements of Ca II H&K flux and line shape parameters.

Key words. Planetary systems – Stars: activity – Stars: chromospheres – Line: profiles – Techniques: radial velocities – Techniques: spectroscopic



Mount Wilson index in the Sun



Egeland et al. (2017, ApJ, 835, 25)

Fresh paper on stellar activity cycles

THE ASTRONOMICAL JOURNAL, 163:183 (9pp), 2022 April
https://doi.org/10.3847/1538-3881/ac5683

CrossMark

Five Decades of Chromospheric Activity in 59 Sun-like Stars and New Maunder Minimum Candidate HD 166620

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Abstract

We present five decades of chromospheric activity measurements in 59 Sun-like stars as time series. These include and extend the 35 yr of stellar chromospheric activity observations by the Mount Wilson Survey (1966–2001), and continued observations at Keck by the California Planet Search (1996–). The Mount Wilson Survey was studied closely in 1995, and revealed periodic activity cycles similar to the Sun's 11 yr cycle. The California Planet Search provides more than five decades of measurements, significantly improving our understanding of these stars' activity behavior. We have curated the activity measurements in order to create contiguous time series, and have classified the stellar sample according to a predetermined system. We have analyzed 29 stars with periodic cycles using the Lomb–Scargle periodogram, and present best-fit sinusoids to their activity time series. We report the best-fit periods for each cycling star, along with stellar parameters ($T_{\rm eff}$, log(g), vsin(i), etc.) for the entire sample. As a first application of these data, we offer a possible Maunder minimum candidate, HD 166620.

Unified Astronomy Thesaurus concepts: Stellar activity (1580); Maunder minimum (1015); Stellar chromospheres (230); Magnetic fields (994); Solar cycle (1487)

Supporting material: figure set, machine-readable tables

Beyond solar-type stars…

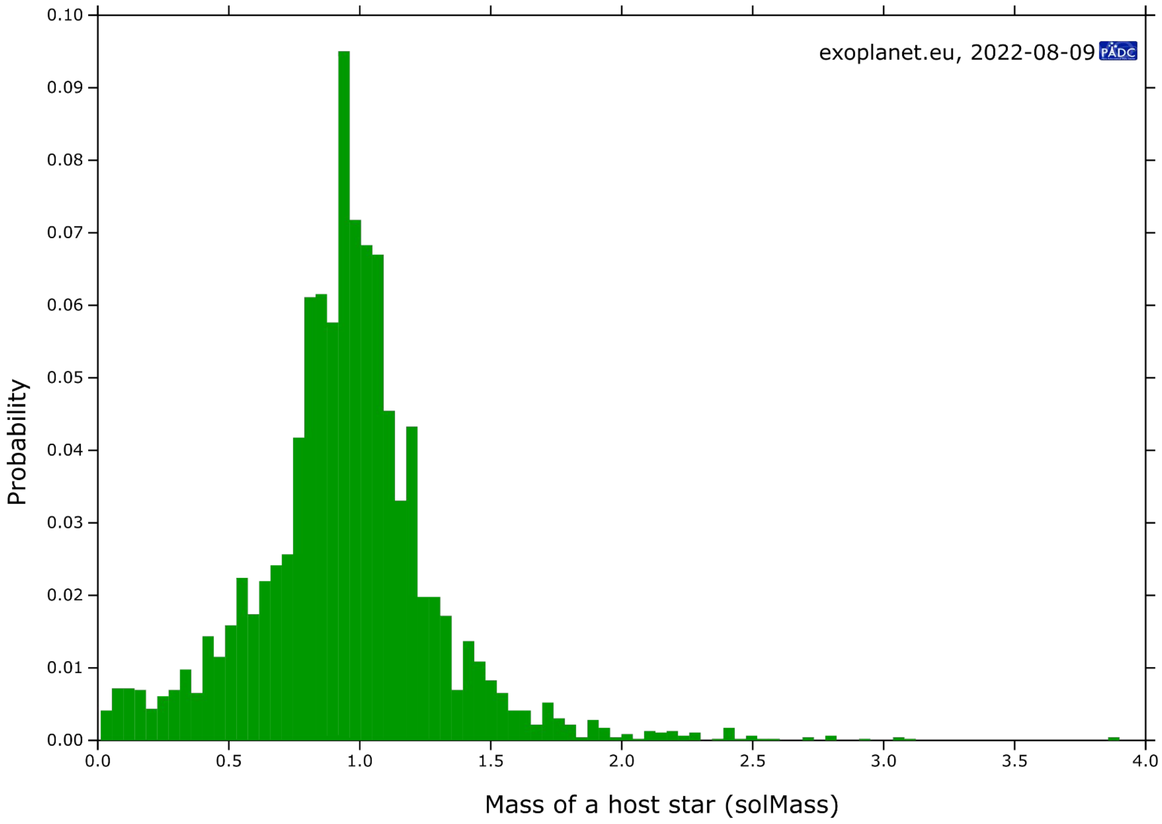
Beyond solar-type stars…

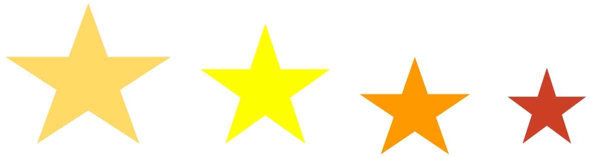
1. Easy to detect terrestrial habitable planets around them.

2. Remarkable short-term variations in stellar luminosity due to flares.

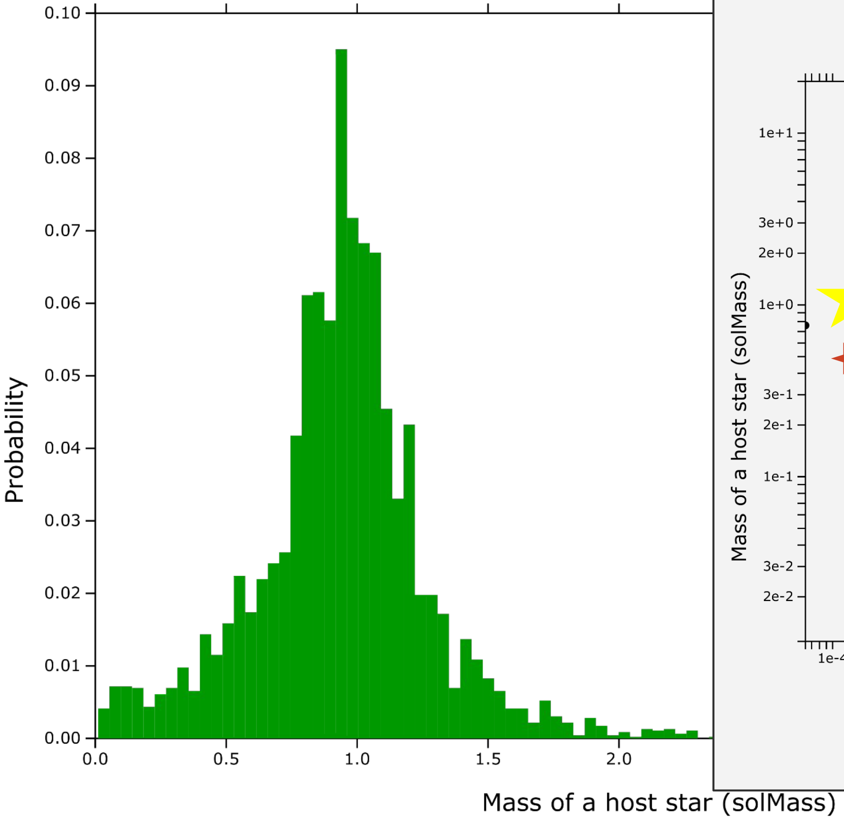
3. Mean magnetic field: type of dynamo could change over this stellar class.

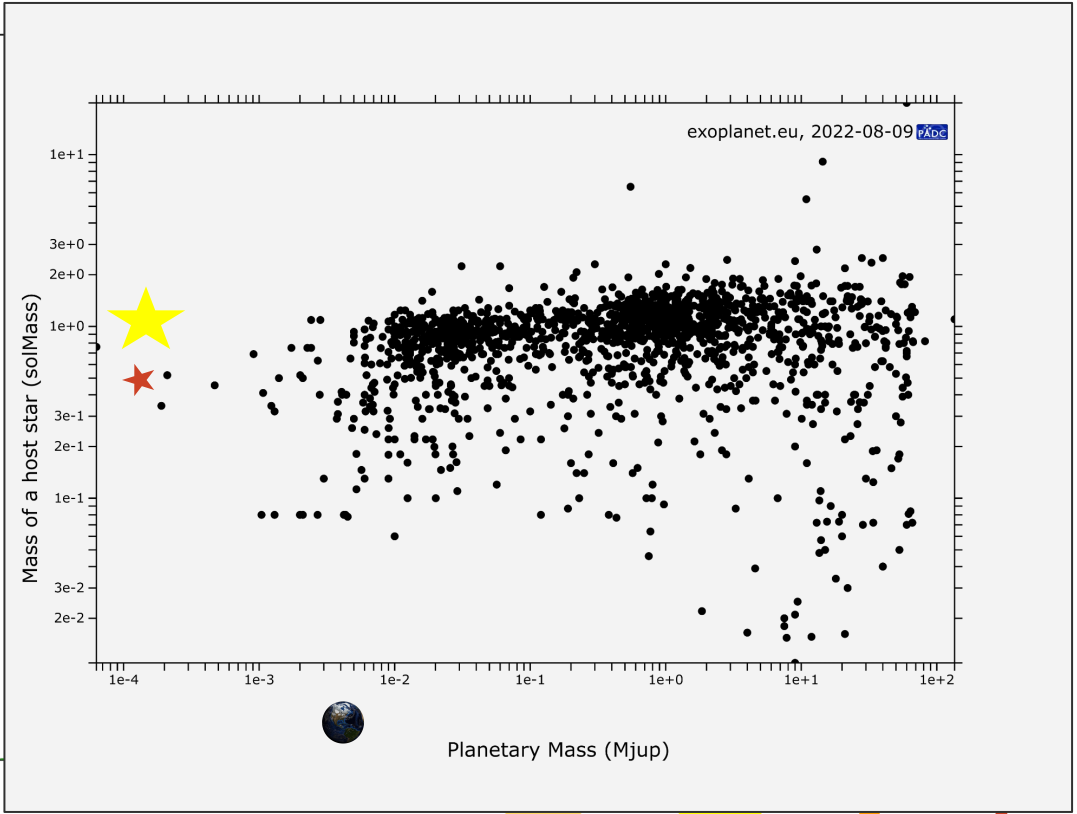
Planetas extrasolares

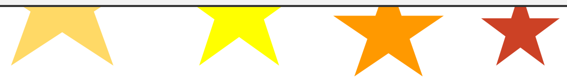




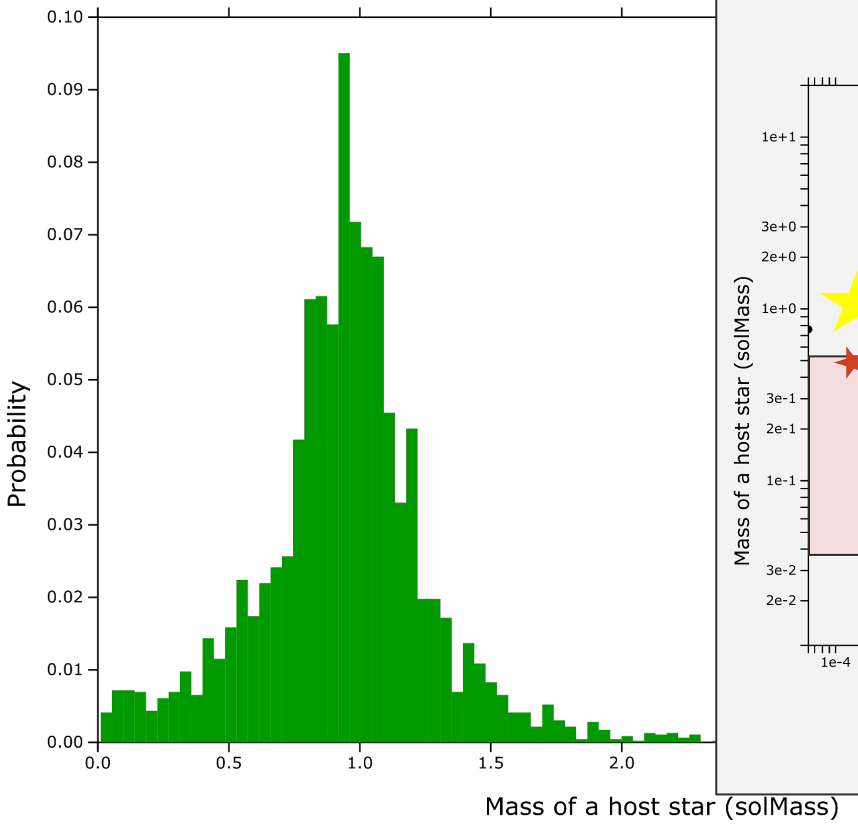
Planetas extrasolares

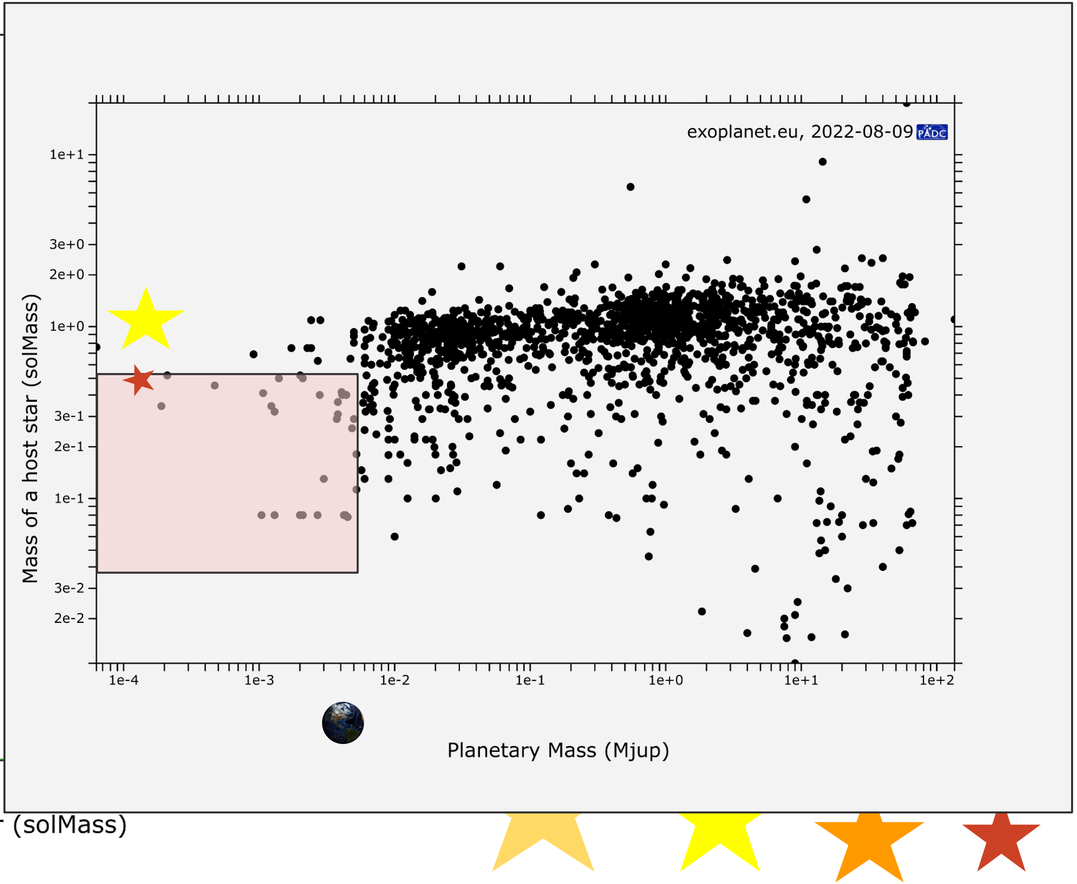






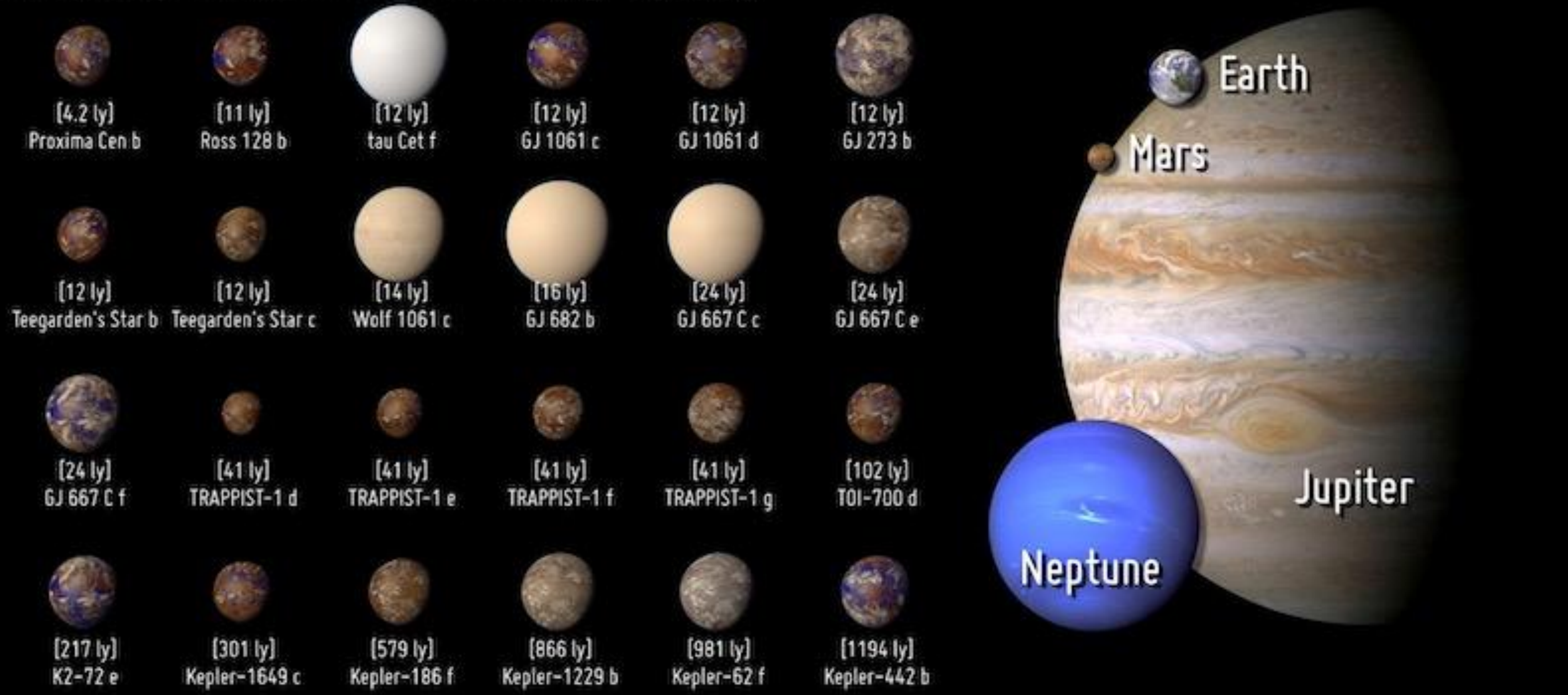
Planetas extrasolares





Potentially Habitable Exoplanets

Ranked by Distance from Earth (light years)

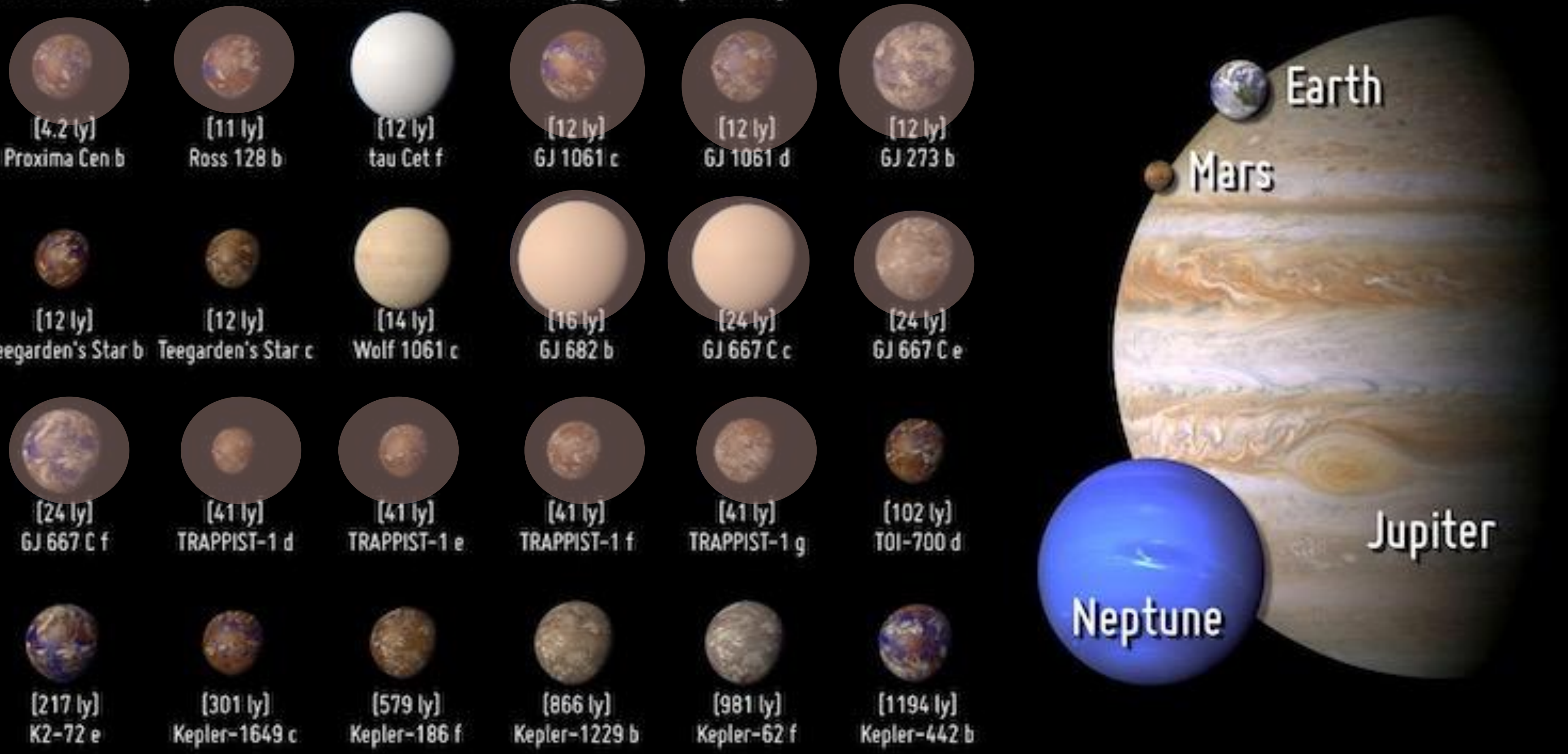


Artistic representations. Earth, Mars, Jupiter, and Neptune for scale. Distance from Earth is between brackets.

CREDIT: PHL @ UPR Arecibo (phl.upr.edu) Oct 5, 2020

Potentially Habitable Exoplanets

Ranked by Distance from Earth (light years)



Artistic representations. Earth, Mars, Jupiter, and Neptune for scale. Distance from Earth is between brackets.

CREDIT: PHL @ UPR Arecibo (phl.upr.edu) Oct 5, 2020

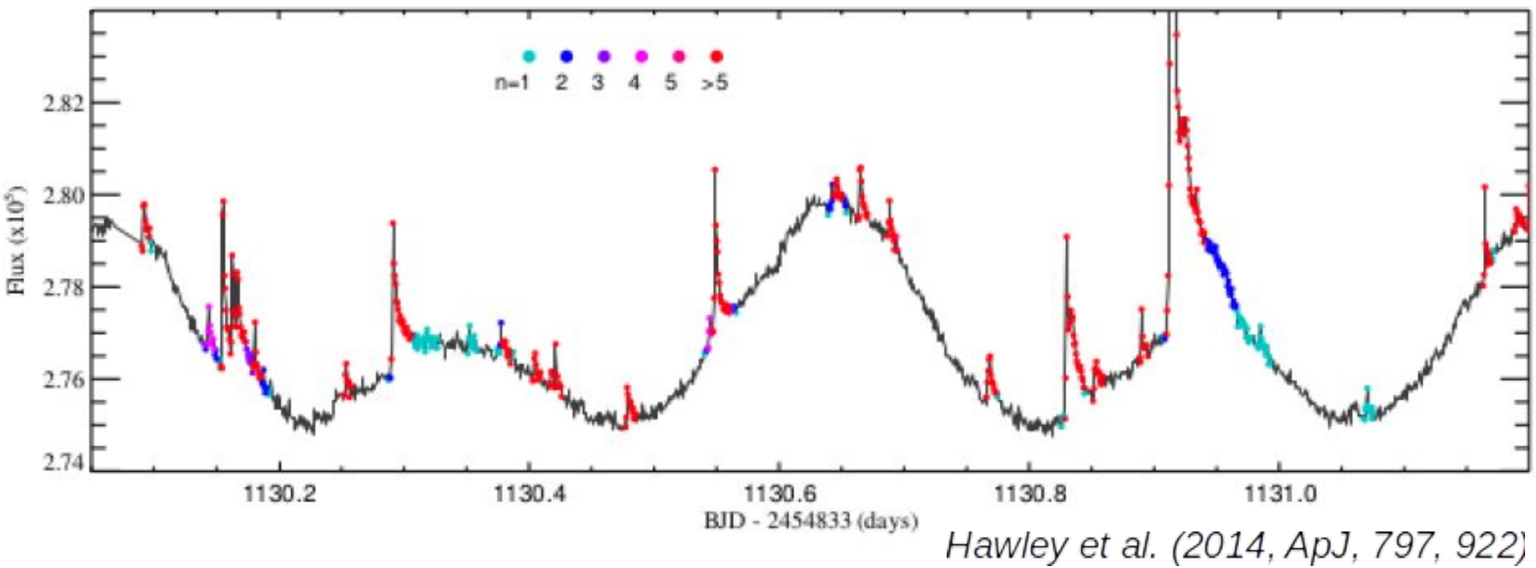
Beyond solar-type stars…

1. Easy to detect terrestrial habitable planets around them.

2. Remarkable short-term variations in stellar luminosity due to flares.

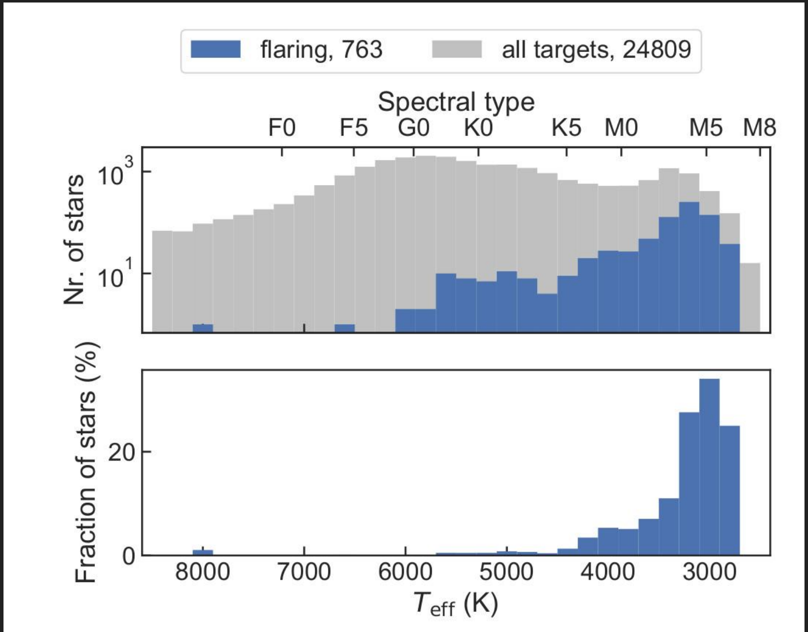
3. Mean magnetic field: type of dynamo could change over this stellar class.

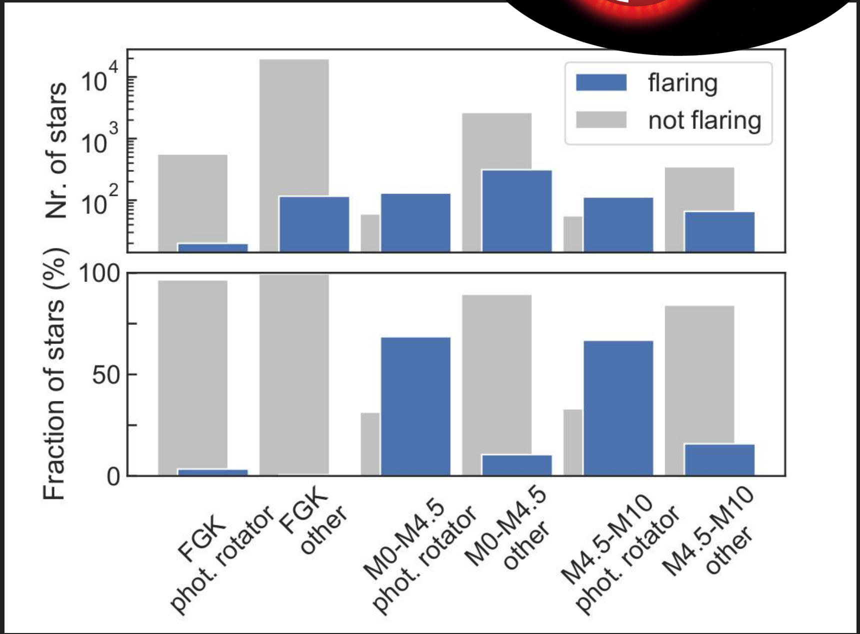
Flares in M dwarves



Light Curve of GJ 1243 (M4V). Over 6100 individual flare events, with energies ranging from 10^{29} to 10^{33} erg, are found in 11 months of 1 minute cadence data from Kepler (~18 flares per day).

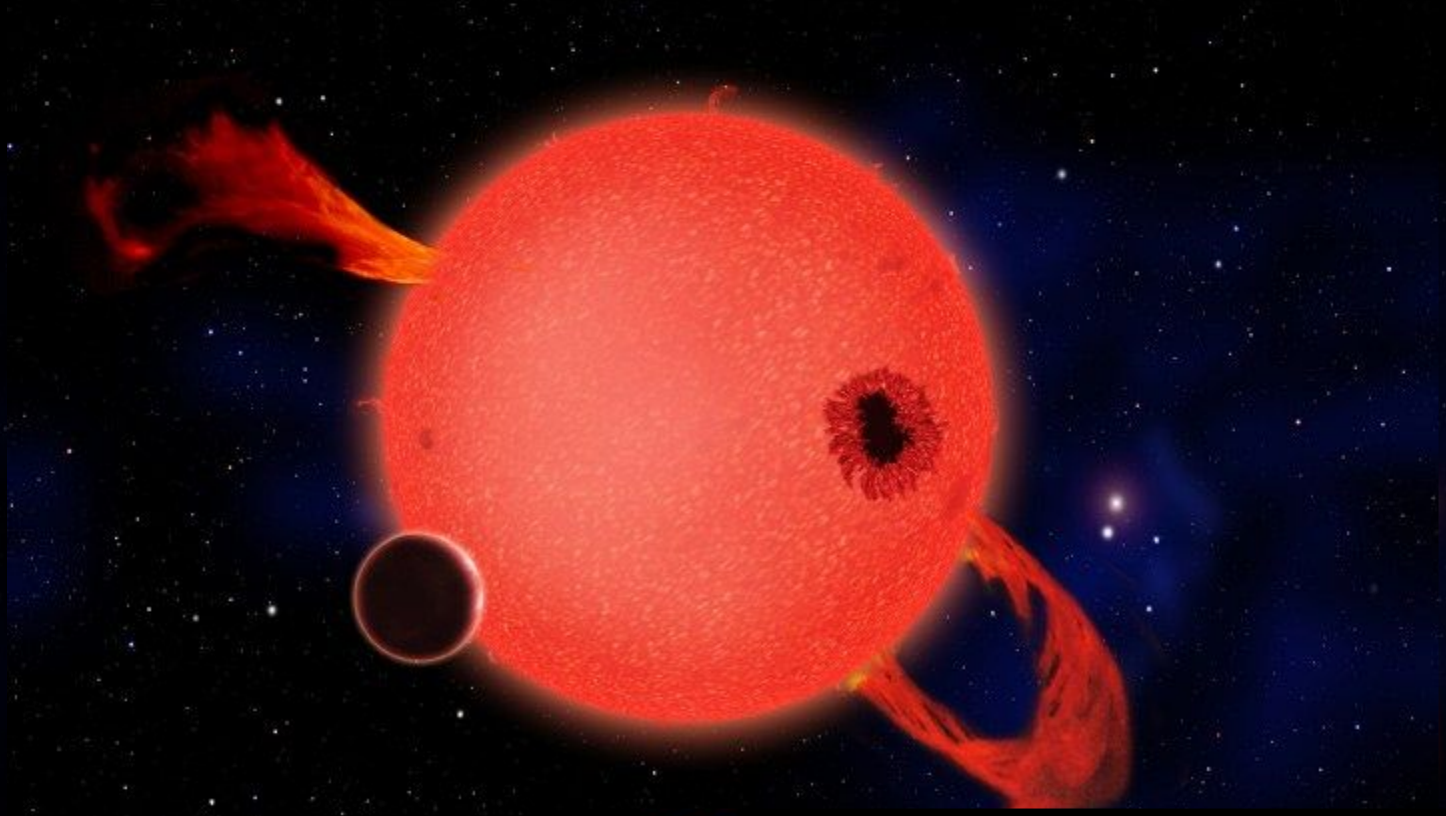
Flares with TESS photometry





Gunther et al. (2019, AJ, 60,21)

Actividad estelar y habitabilidad



HARVARD-SMITHSONIAN
CENTER FOR ASTROPHYSICS

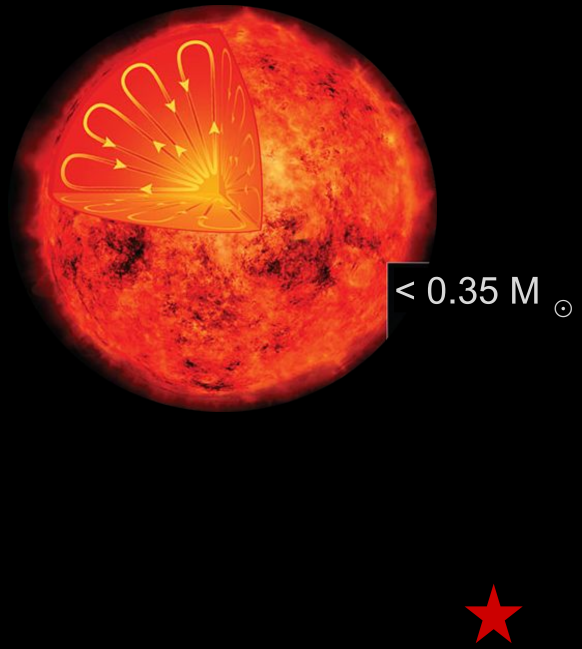
Beyond solar-type stars…

1. Easy to detect terrestrial habitable planets around them.

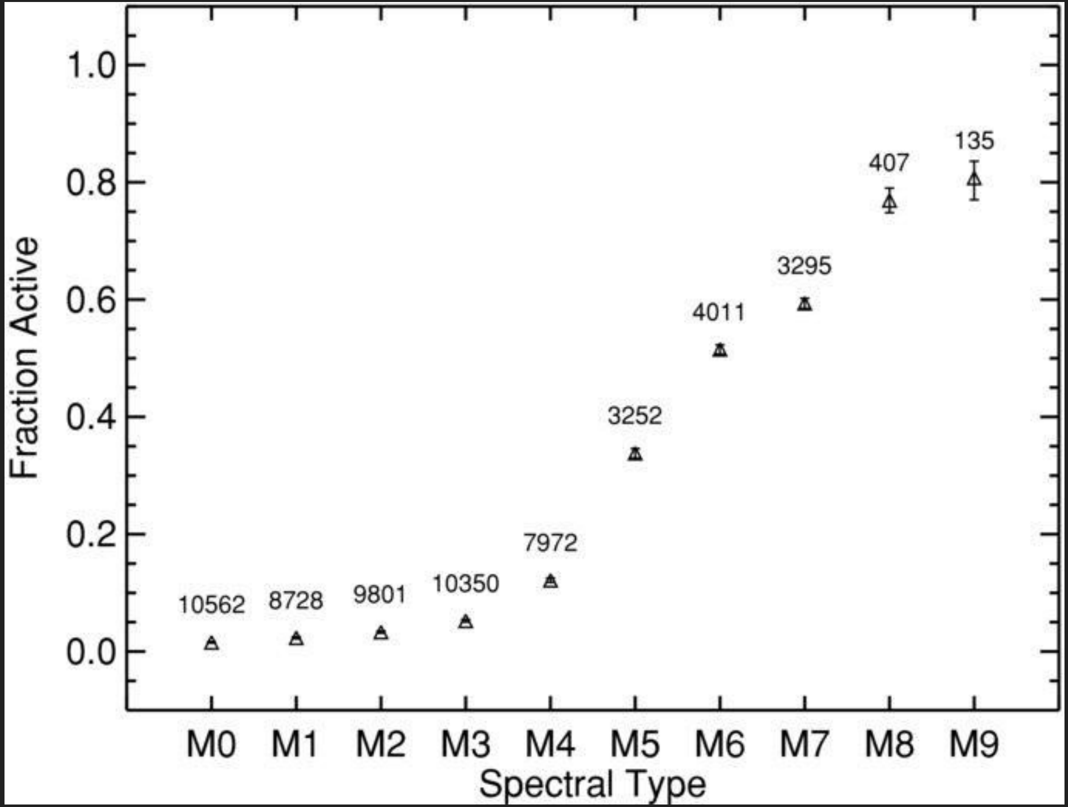
2. Remarkable short-term variations in stellar luminosity due to flares.

3. Mean magnetic field: type of dynamo could change over this stellar class.

Stellar interiors



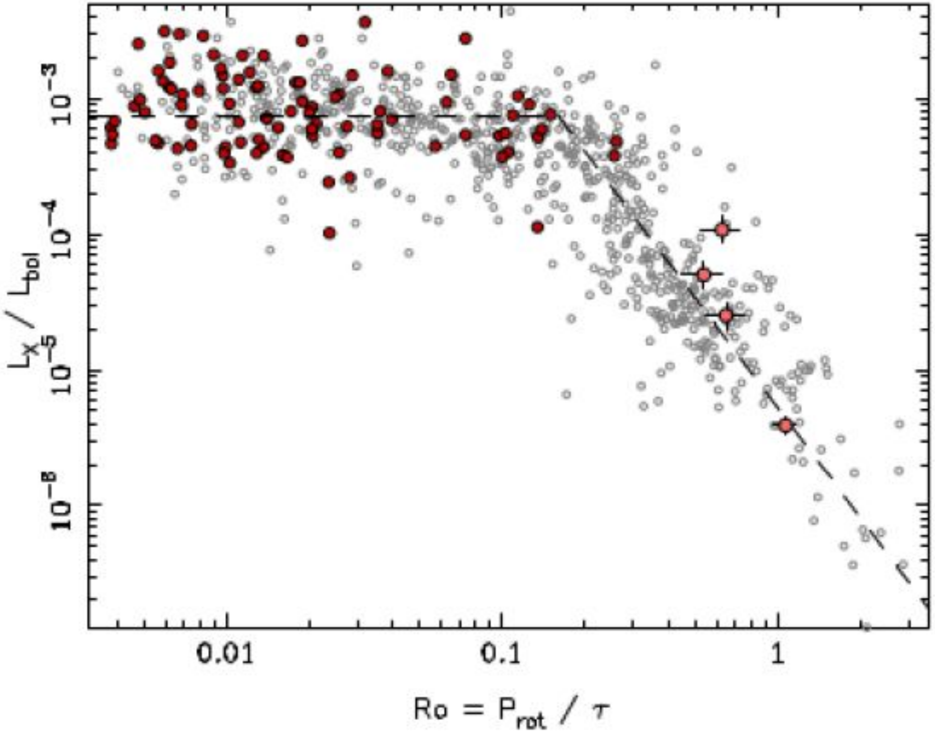
Actividad en estrellas parcial y puramente convectivas



West et al. (2011, AJ,141,97)

Magnetic activity without tachocline

“The lack of a tachocline in fully convective stars suggests that this is not a critical ingredient in the solar dynamo and supports models in which the dynamo originates throughout the convection zone.”



Wright and Drake (2016, Nature, 535, 526)

Beyond solar-type stars…

1. Easy to detect terrestrial habitable planets around them.

2. Remarkable short-term variations in stellar luminosity due to flares.

3. Mean magnetic field: type of dynamo could change over this stellar class.

Do solar type-stars always present activity cycles?

How do stellar parameters affect stellar activity cycles?

Do non solar type-stars present activity cycles?

Do solar type-stars always present activity cycles?

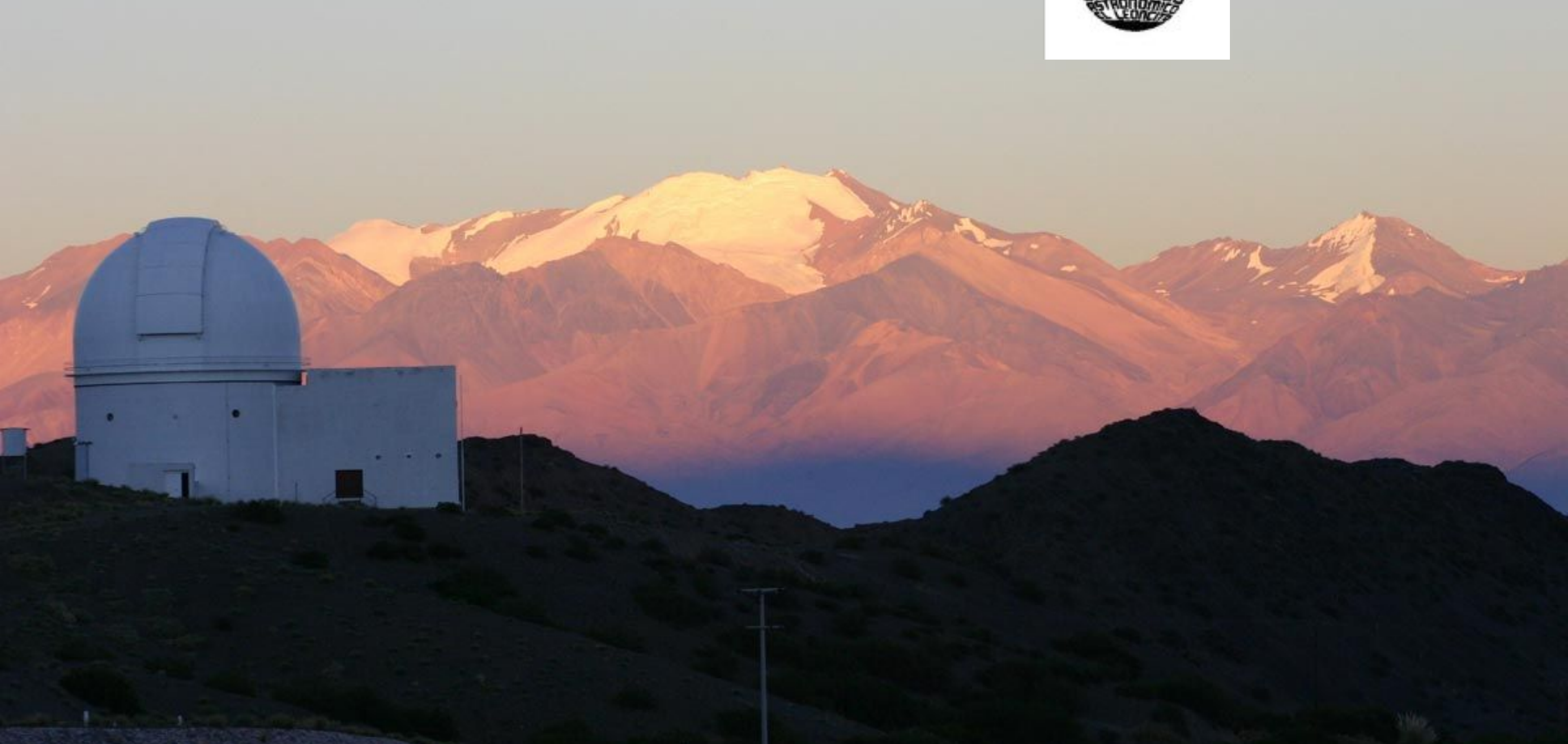
How do stellar parameters affect stellar activity cycles?

Do non solar type-stars present activity cycles?

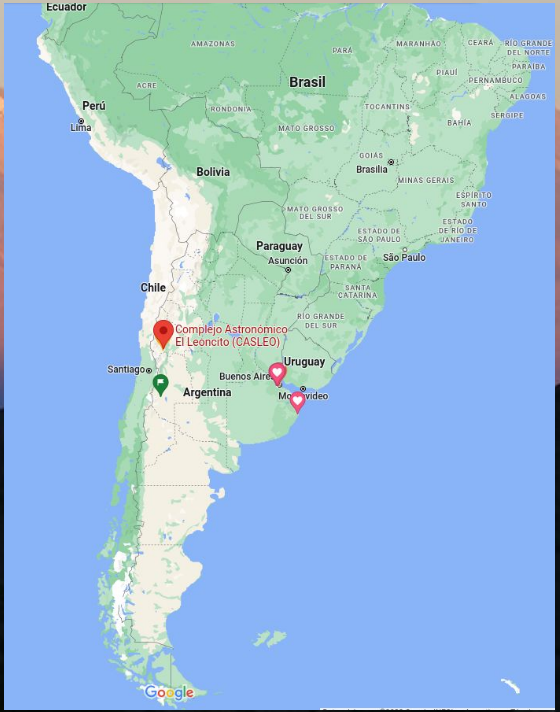
Do fully convective stars present activity cycles?

A long Time ago in a far away…

HKα Project



HKα Project



Complejo Astronómico El Leoncito
IAU Observatory Code: 829 (OC)
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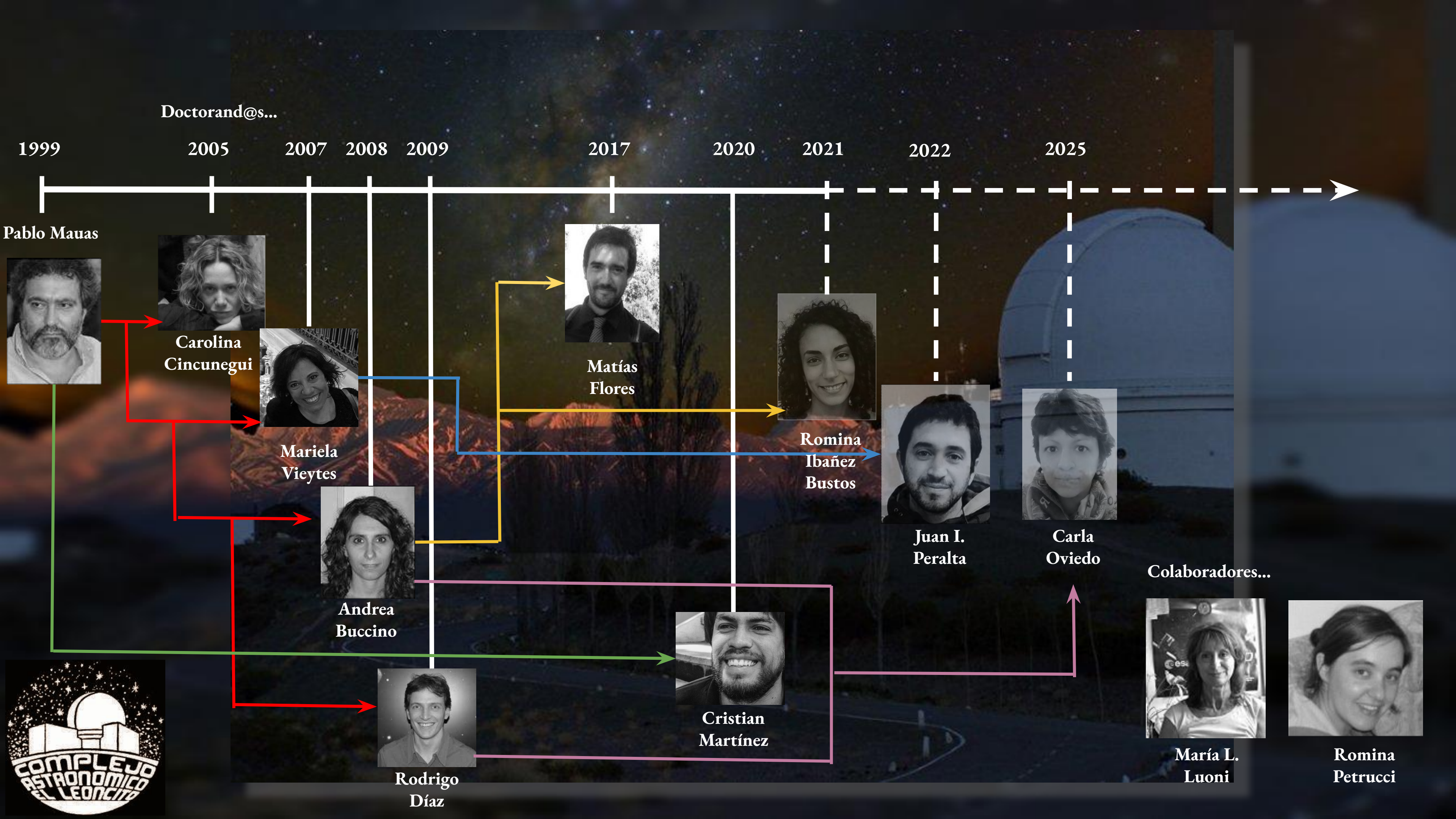
φ = -31°47’54”.7
h = 2552 msnm
UT-offset = -3 hs
url: casleo.conicet.gov.ar


Doctorand@s...
1999
2005
2007
2008
2009
2017
2020
2021
2022
2025
Pablo Mauas
Carolina Cincunegui
Mariela Vieytes
Andrea Buccino
Rodrigo Díaz
Matías Flores
Cristian Martínez
Romina Ibañez Bustos
Juan I. Peralta
Carla Oviedo
Colaboradores...
María L. Luoni
Romina Petrucci
COMPLEJO ASTRONOMICO EL LEONCITO

Main objectives
HKα Project

To build an atlas of flux calibrated reliable spectra of southern FGKM active stars to employ them in semiempirical atmospheric models.

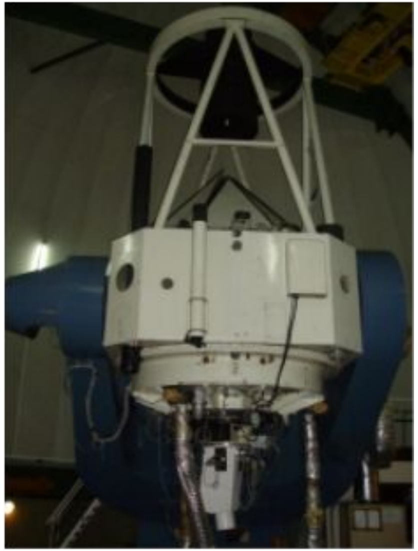
To explore long-term activity near the convective limit (~M3.5V).

Registry of simultaneous activity indicators of different stellar atmospheric depth (eg. Hα, Ca II).

HKα Project

Jorge Sahade telescope

Sistema óptico: Reflector Ritchey-Chrètien
Fabricante: Boller & Chivens
Montura: Tipo horquilla



Datos ópticos principales

Diámetro del espejo primario: 2153 mm
Razón focal Cassegrain: 8.485
Escala: 11.3 "/mm
Escala con Reductor: 33.9 "/mm
Diámetro del espejo secundario (Cassegrain): 660.3 mm
Diámetro del agujero del primario: 635 mm
Emergencia: 965 mm
Distancia focal primario: 5588 mm
Distancia focal secundario (Cassegrain): 2215 mm
Peso del espejo primario: 1315 kg
Peso del espejo secundario (Cassegrain): 71.7

REOSC Spectrograph

Características del CCD

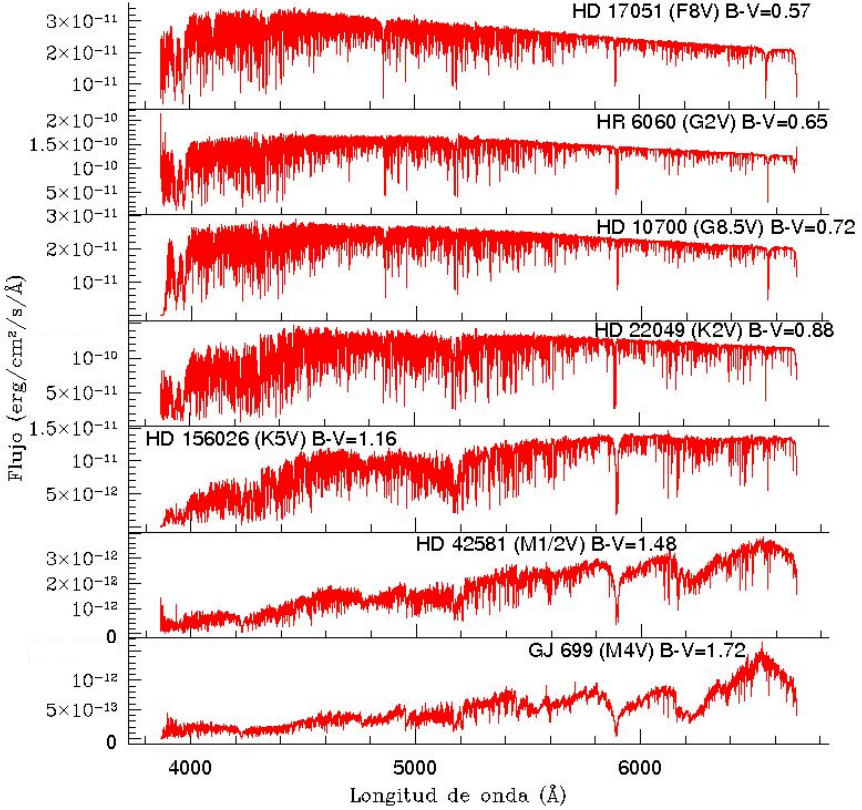
filas × columnas 1024 × 1024
tamaño del pixel 24 × 24 μm
dimensiones del chip 25 mm × 25 mm
ganancia 1 7.97 e-/ADU
ganancia 4 1.98 e-/ADU

ruido de lectura (gain 1) 0.4 e-
ruido de lectura (gain 4) 7.4 e-
corriente oscura 0.4 e-/hora/pixel
temperatura de trabajo -120 °C

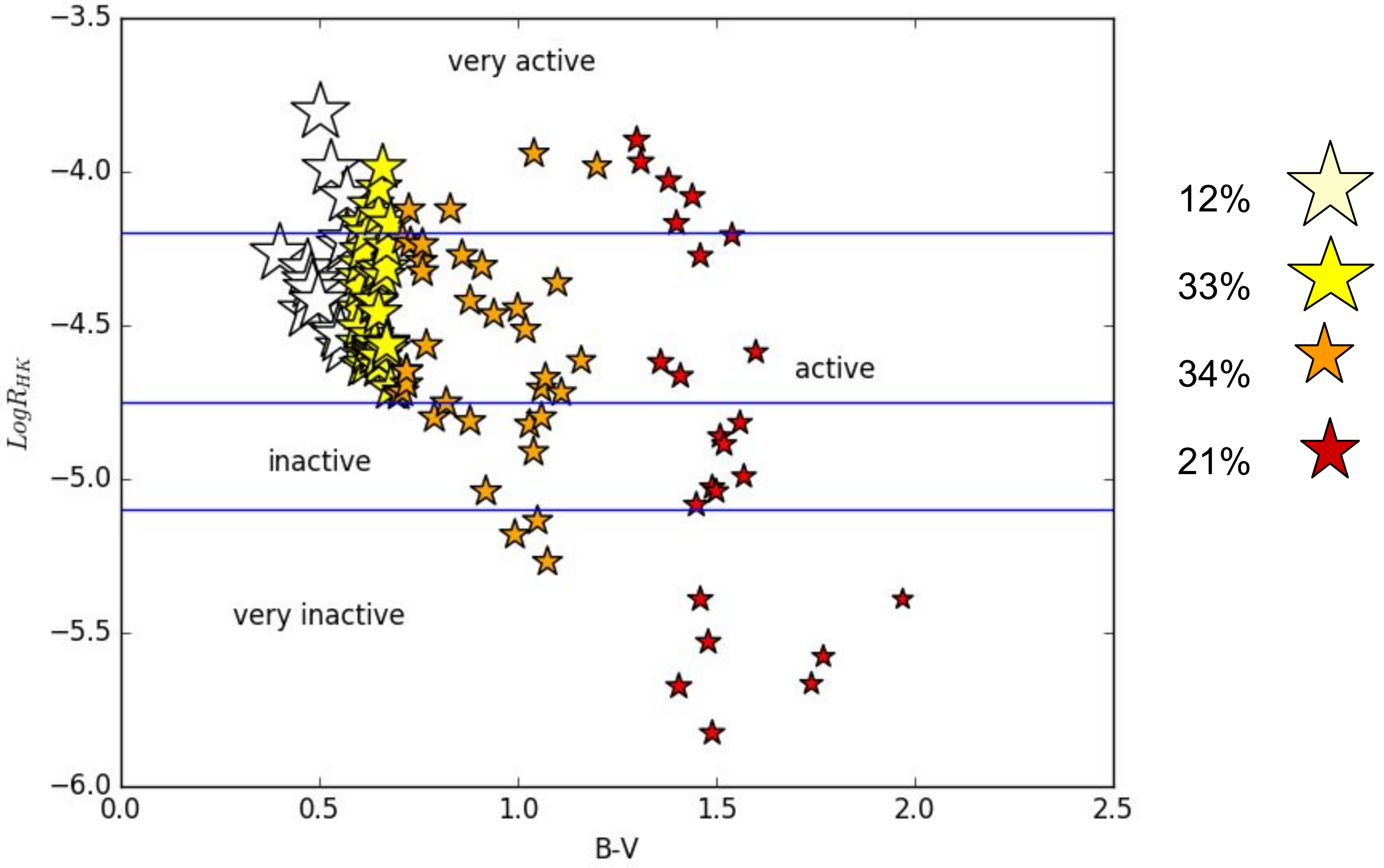
https://casleo.conicet.gov.ar/

HKα Project

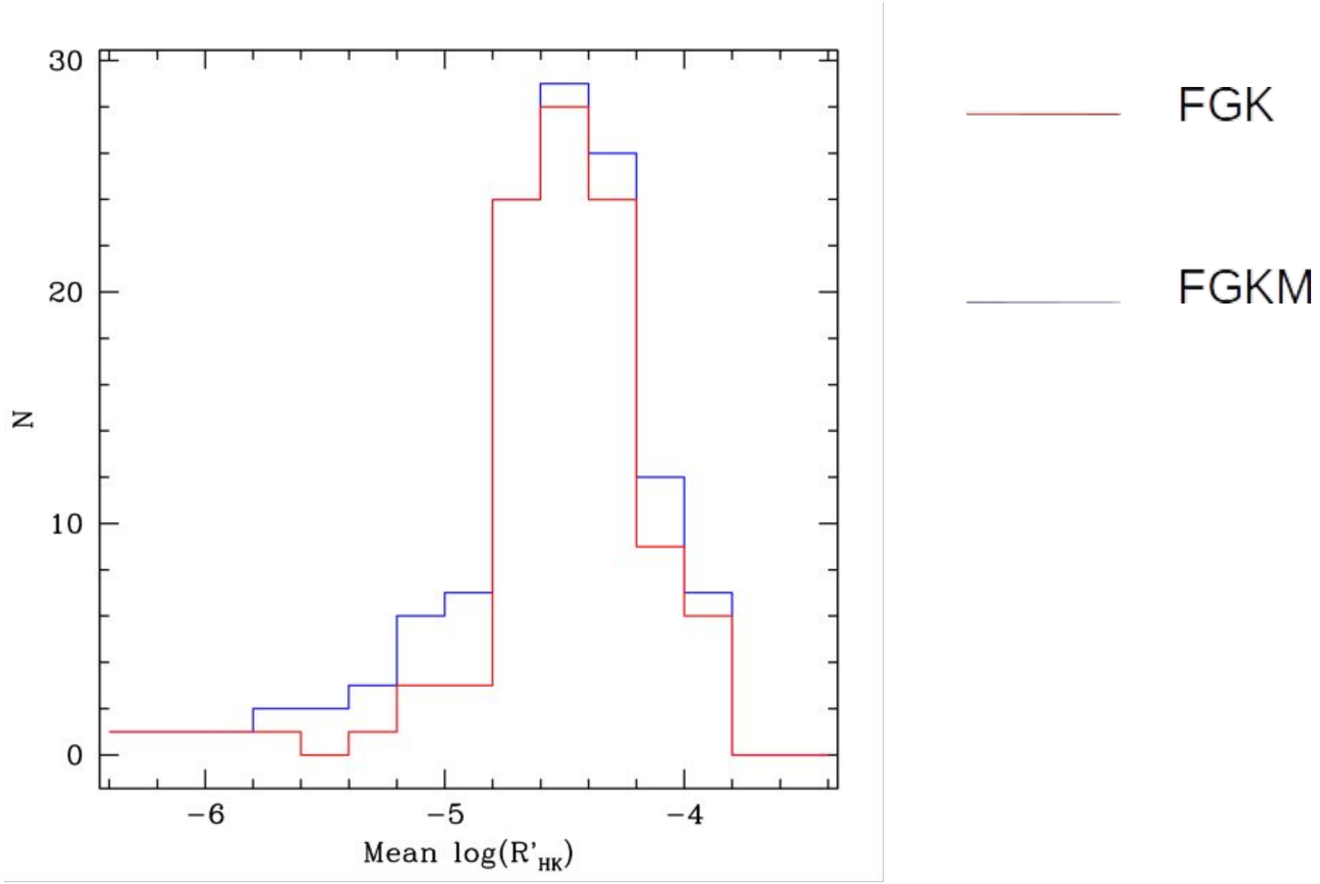
- 22 years of continuously observations since 1999, 4 observing runs a year.
- Near 5500 mid-res optical spectra (R=13000) calibrated in flux of near 150 F3V a M5.5V stars.
- Wavelength range from 3800 to 7000 A, which allows us to observe simultaneously different features formed at the high, mid and low chromosphere.
- One of the few program mainly dedicated to follow stellar activity of dwarf stars which lasted more than 16 years.



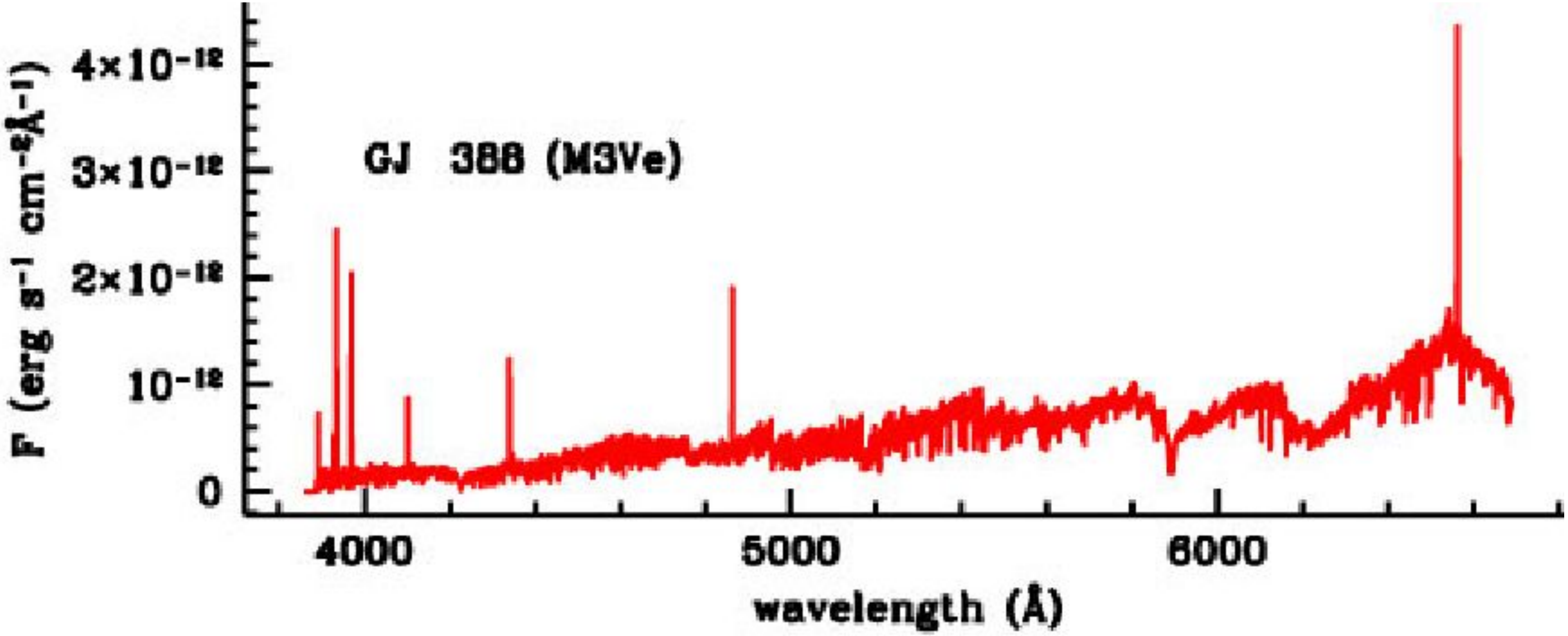
HKα Project sample



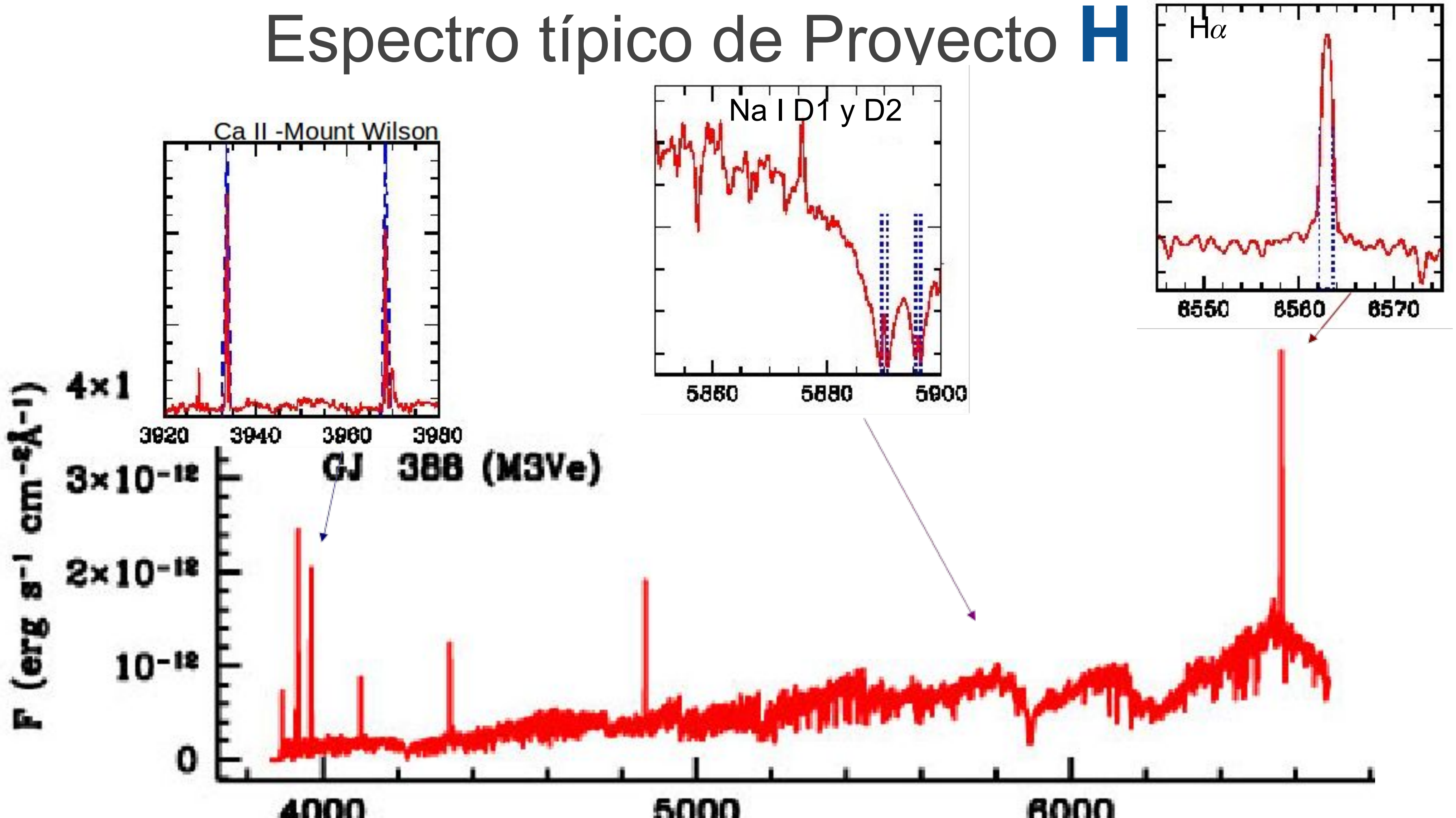
Muestra del Proyecto HKα



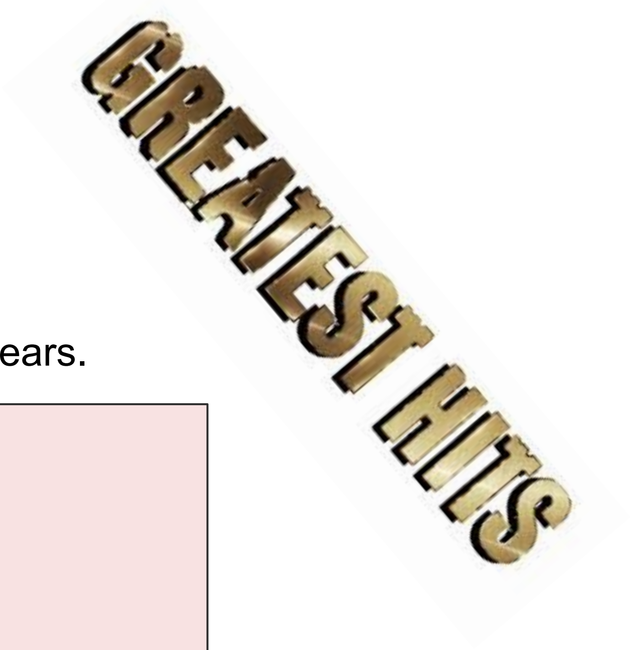
Espectro típico de Proyecto HKα



Espectro típico de Proyecto H



Proyecto HKα



1.*Cincunegui et al (2007, A&A, 469, 309)*
Hα - Ca II H+K is not unique for individual stars

2. *Metcalfe, Buccino, Brown et al. (2013, ApJL,763, 29)*
Two precise activity cycles for Eps Eridani (K2V) of 12 and 3 years.

3. *Cincunegui et al (2007, A&A, 414, 699)*
A 442-day activity cycle in M5.5Ve Proxima Centauri
First activity cycle in a dM star + purely convective star

4. *Buccino et al (2011, AJ,141, 34)*
Activity cycles in early dM stars GJ 229 A (4 years) y GJ 752 A (7 years)

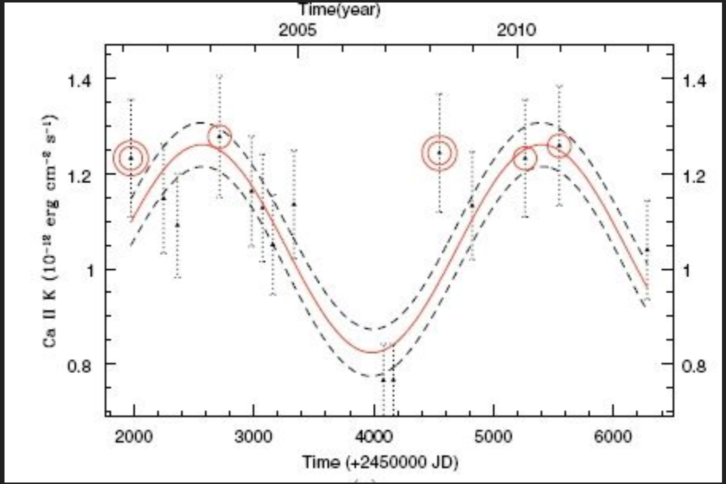
5. *Díaz et al (2007, A&A, 474, 345)*
800-day activity cycle of the two components of the binary system GJ 375 (M3.5V+M3.5V) Magnetic interaction?

Activity cycles in M stars by **HKα** Project

AD Leo-GL 388

Credit: National Astronomical Observatory of Japan.

2 simultaneous activity cycles of 2 and 8 years in a dM3.5 star in photometry and Ca II *(Buccino et al. 2014, ApJ, 781, L9)*



Activity cycles in M stars by HKα Project

AU Microscopii (Gl 803)

TSpec = M1Ve
$M = 0.5 M_{\odot}$
$R = 0.75 R_{\odot}$
V = 8.627
d = 9.9 pc
$P_{rot} = 4.85$ d

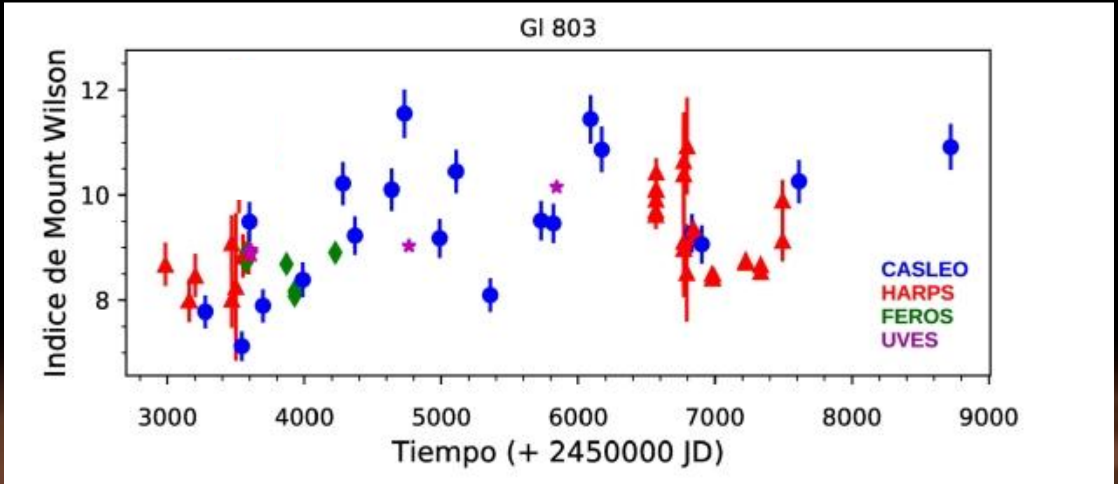
R. Ibañez Bustos

AU Microscopii (Gl 803-M1)

Long-term activity

$$S_{MW} = \alpha \frac{f_K + f_H}{f_R + f_V}$$

σ_S / <S> = 11%



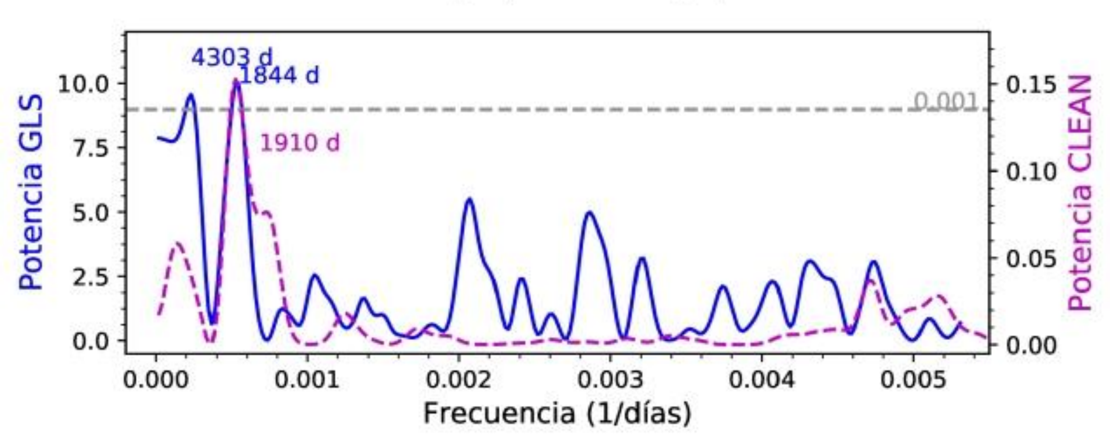
log R'_{HK} = - 3.849

P_{rot} = 4.85 d

(Ibañez Bustos et al. 2019, MNRAS, 483, 1159)

GLS (Zechmeister & Kürster 2009)

CLEAN (Roberts et al. 1987)



P_1 = (1844 ± 86) d -5 yr
P_2 = (4303 ± 562) d- 12 yr

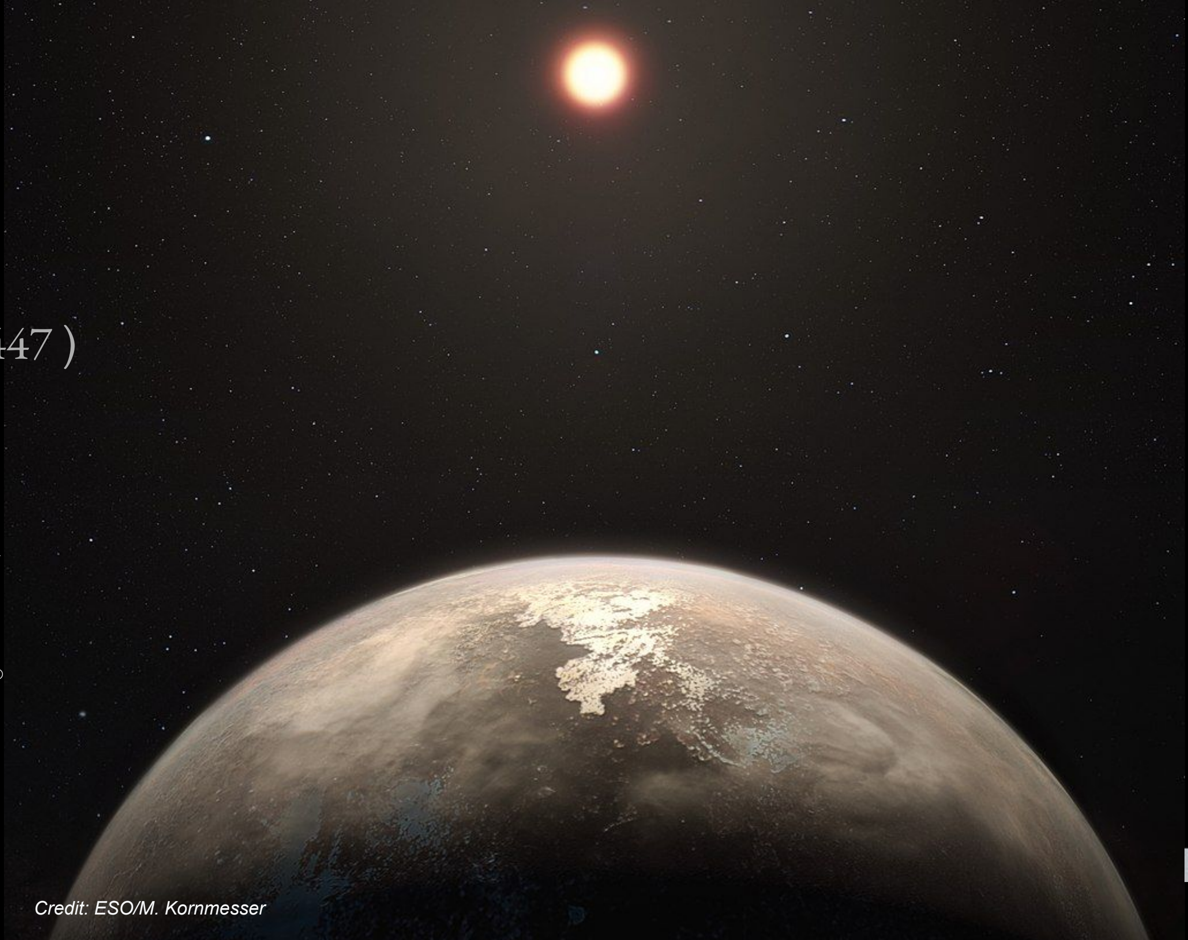
FAP_1 = 0.02 %
FAP_2 = 0.04 %

R. Ibañez Bustos

Activity cycles in M stars by HKα Project

Ross 128 (GJ 447)

TSpec = M4V
$M = 0.168\ M_\odot$
$R = 0.1967\ R_\odot$
V = 11.153
d = 3.49 pc
$P_{rot} = 121$ d



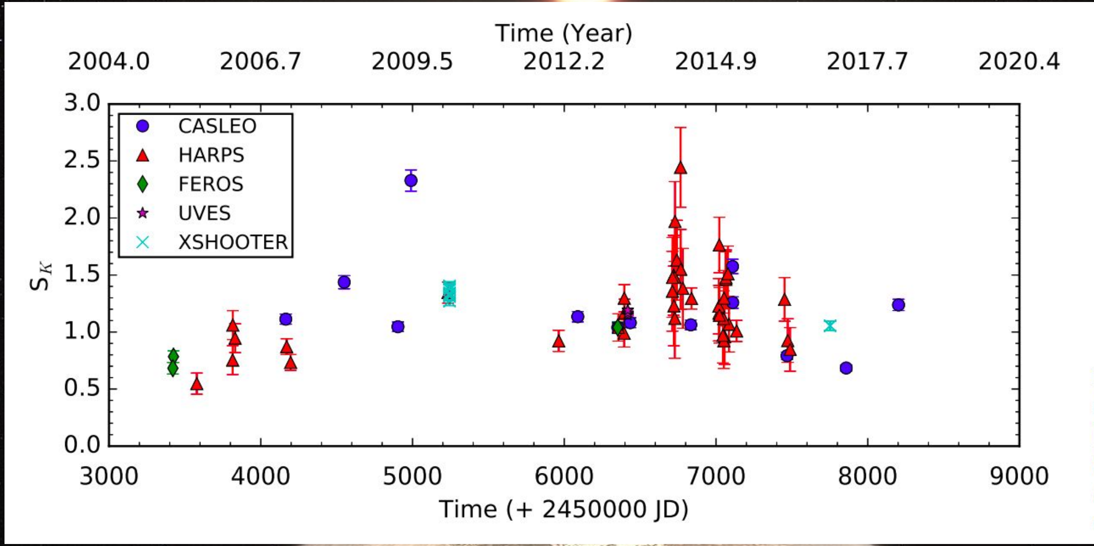
Credit: ESO/M. Kornmesser

R. Ibañez Bustos

Activity cycles in M stars by HKα Project

Ross 128 (GJ 447)

log R'_{HK}=-5.621



P_1 =1956 days -5 yr
FAP_1 = 0.02 %

TSpec = M4V
M = 0.168 $M_\odot$
R = 0.1967 $R_\odot$
V = 11.153
d = 3.49 pc
P_{rot} = 121 d

(Ibañez Bustos et al. 2019, A&A, 628, L1)

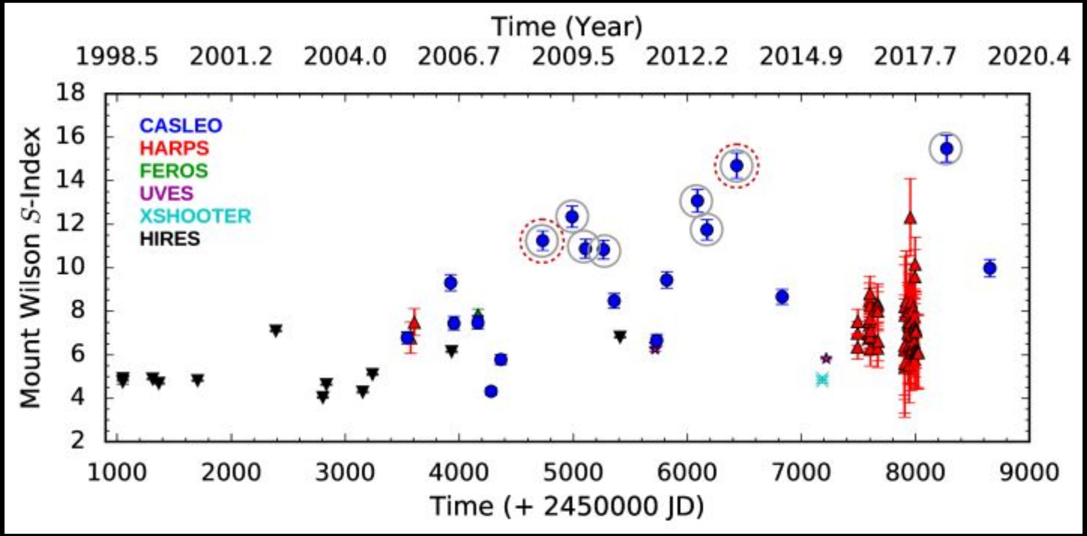
R. Ibañez Bustos

Credit: ESO/M. Kornmesser

Activity cycles in M stars by HKα Project

Long-term activity

GJ 729



TSpec = M4V
M = 0.14 $M_{\odot}$
R = 0.19 $R_{\odot}$
V = 10.43
d = 2.97 pc
P_{rot} = 2.869 d

(Ibañez Bustos et al. 2020, A&A, 644, A2)

$P_1 = (1521 \pm 20)$ d-4 yr
$P_2 = (297 \pm 2)$ d- 0.81 yr

FAP < 0.1 %

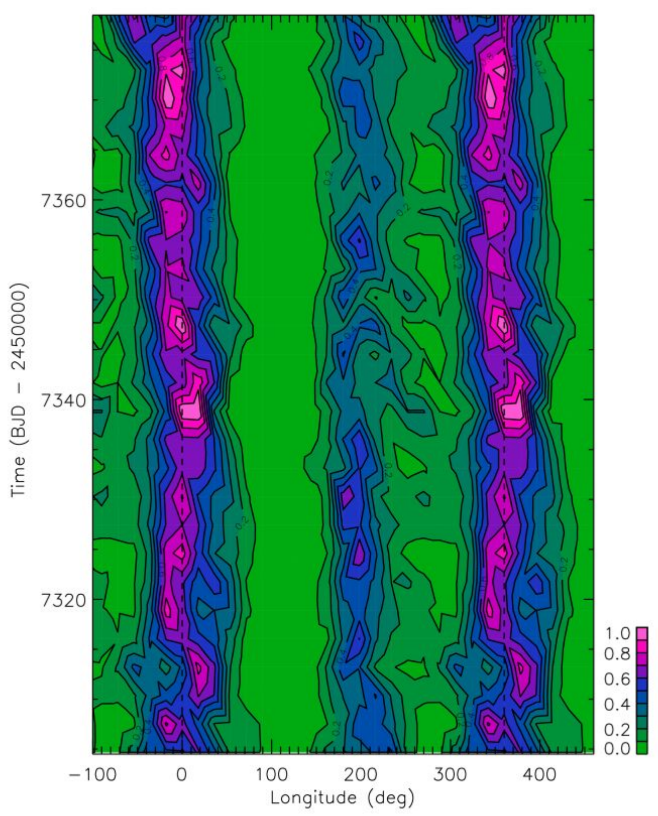
log R'_{HK} = -4.645

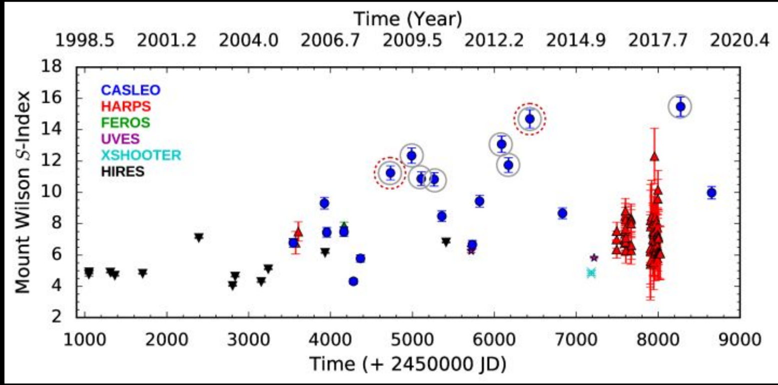
R. Ibañez Bustos

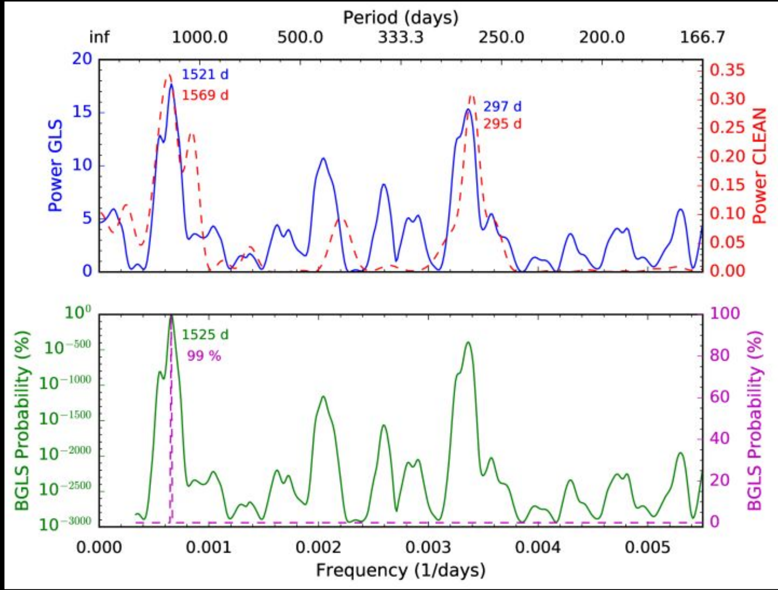
Long-term activity

Maximum-entropy spot model

S. Messina
A. F. Lanza





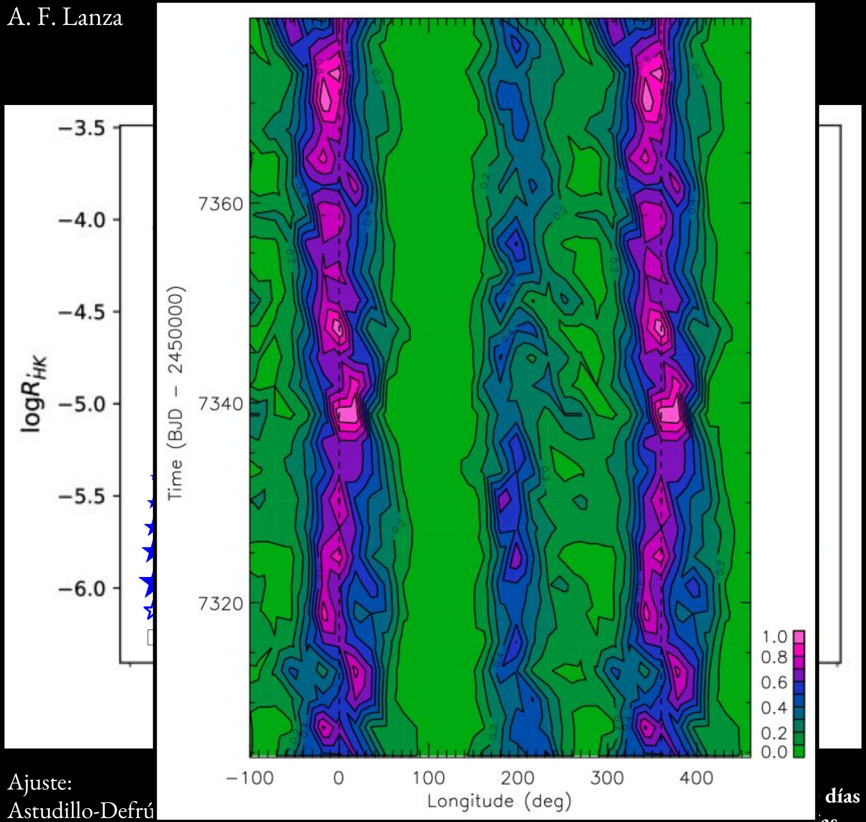


(Ibañez Bustos et al. 2020, A&A, 644, A2)

Long-term activity

Maximum-entropy spot model

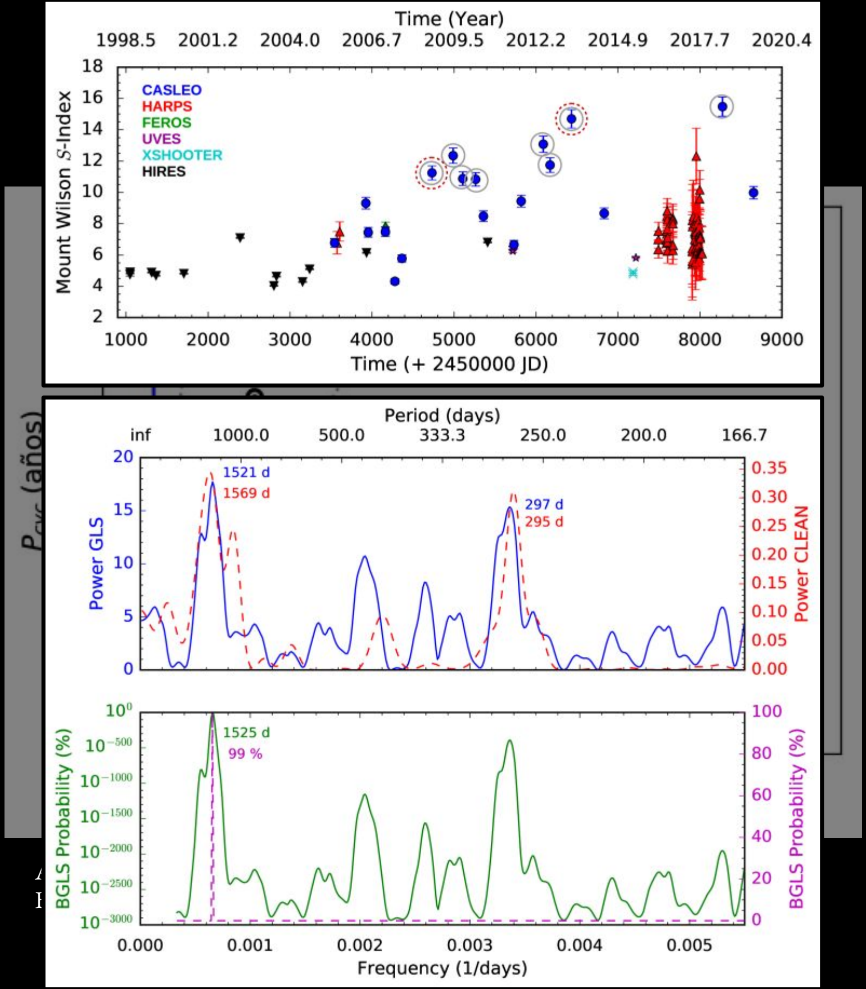
S. Messina
A. F. Lanza



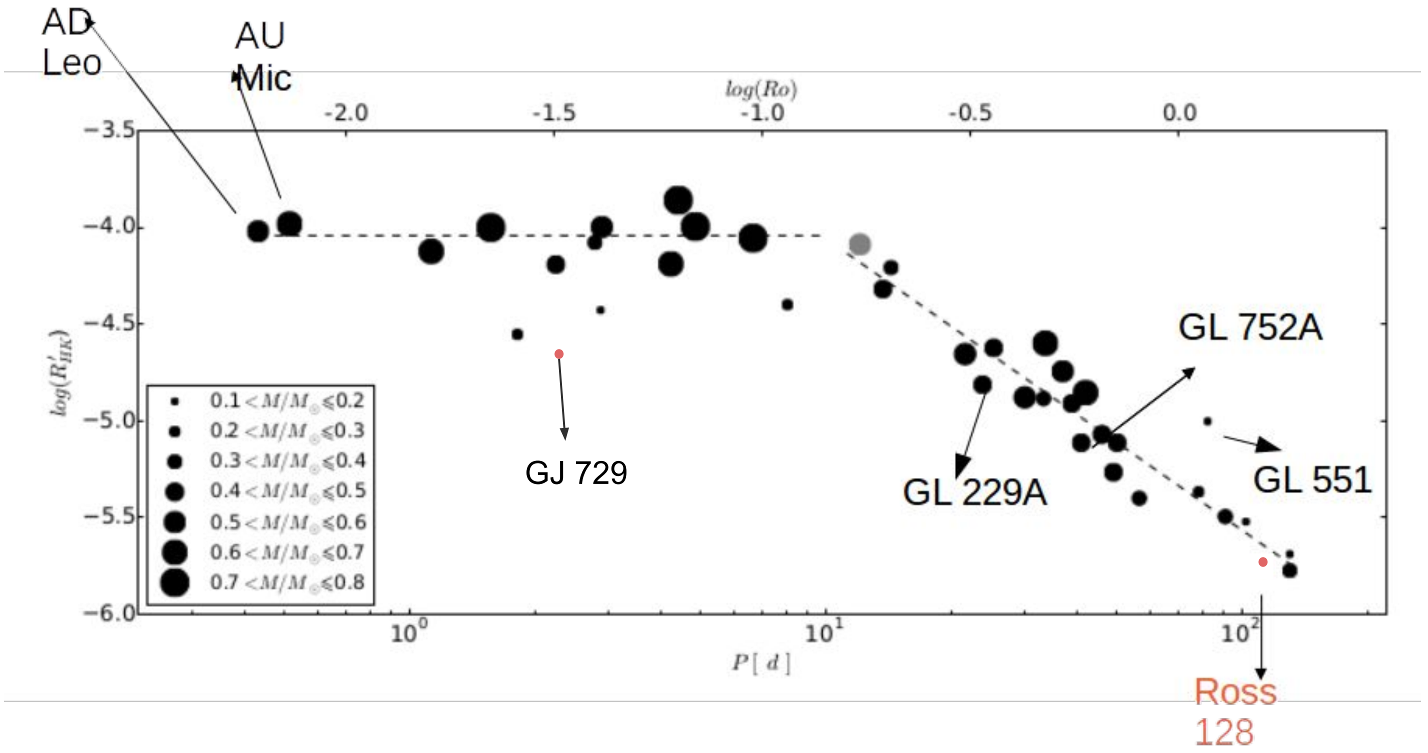
Ajuste:
Astudillo-Defrú

días
P_2 = (297 ± 2) días

FAP < 0.1 %



Magnetic activity vs. rotation period



Astudillo-Defru et a. (2017, A&A, 600, 13)

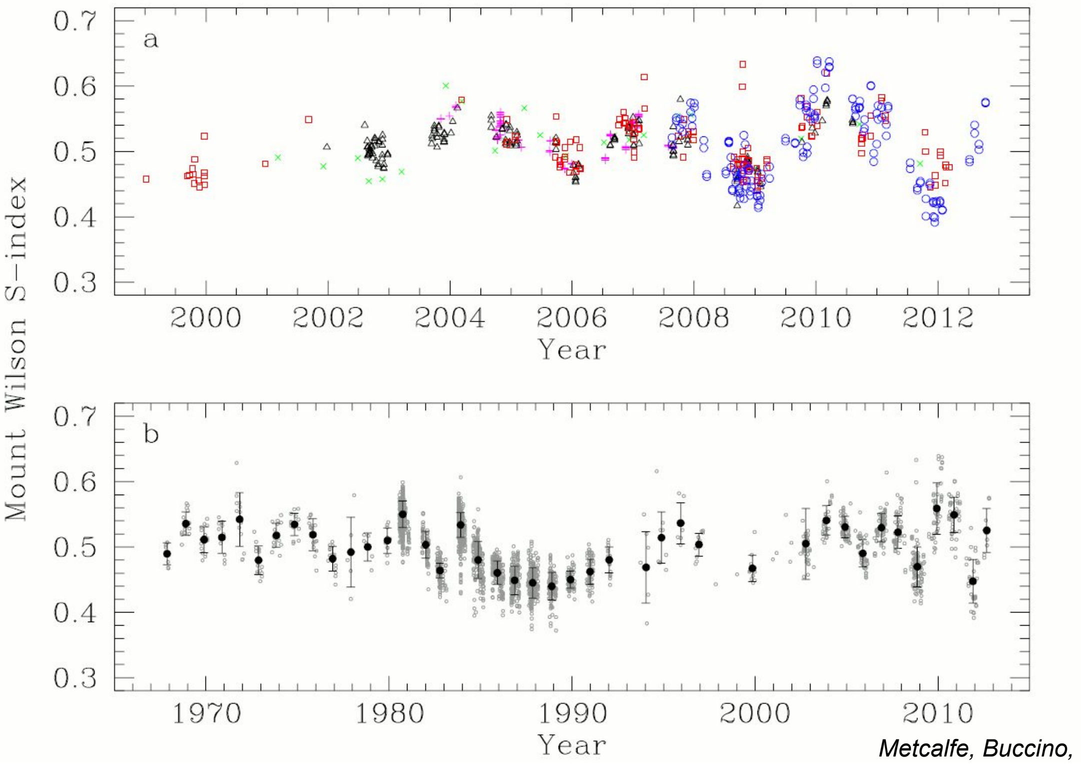
Ross 128 becomes one of the few slow-rotator stars of its class outside the saturation regime to present a stellar activity cycle.

First Conclusion

Early, fast rotators partially, slow-rotator and fully convective dM stars present stellar activity cycles similar to the solar-type stars. Similar dynamo?

We are working on expanding the sample and on building 2D non-linear dynamo models.

ε Eridani -HD 22049 (K2V)



Metcalfe, Buccino, Brown et al. (2013, ApJL,763, 29)

Figure 1. Chromospheric activity measurements of the K2V star ϵ Eri. **a:** Recent data from SMARTS (○), Lowell Observatory (□), and CASLEO (×), along with previously published measurements from CPS (△, Isaacson & Fischer 2010) and HARPS (+, Anglada-Escudé & Butler 2012). **b:** Archival data from Mount Wilson (1968-1992; Gray & Baliunas 1995) and the more recent observations (grey points) with seasonal means (●) and uncertainties reflecting the standard deviation within each season.

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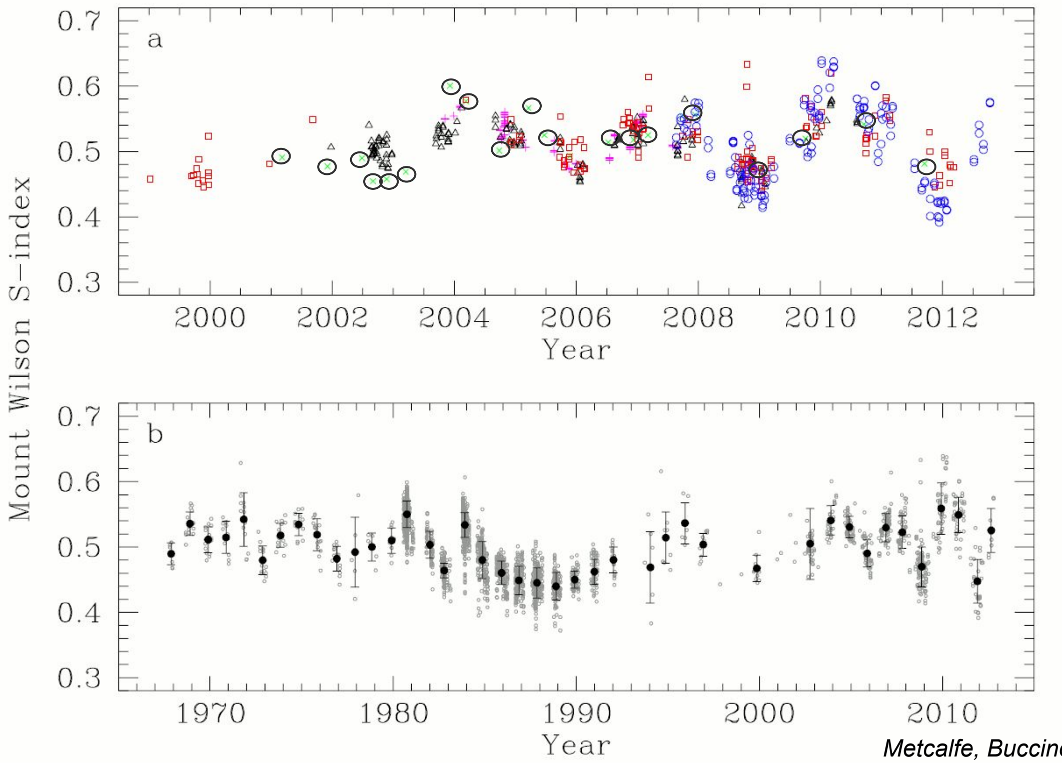

45 years span

Two simultaneous activity cycles of 3 and 13 years

Broad minimum between 1985 and 1992.

Metcalfe, Buccino, Brown et al. (2013, ApJL,763, 29)

Figure 1. Chromospheric activity measurements of the K2V star ϵ Eri. **a:** Recent data from SMARTS (○), Lowell Observatory (□), and CASLEO (×), along with previously published measurements from CPS (△, Isaacson & Fischer 2010) and HARPS (+, Anglada-Escudé & Butler 2012). **b:** Archival data from Mount Wilson (1968-1992; Gray & Baliunas 1995) and the more recent observations (grey points) with seasonal means (•) and uncertainties reflecting the standard deviation within each season.

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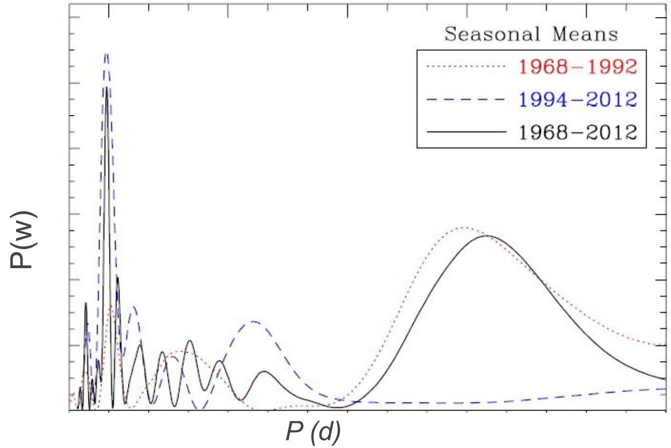

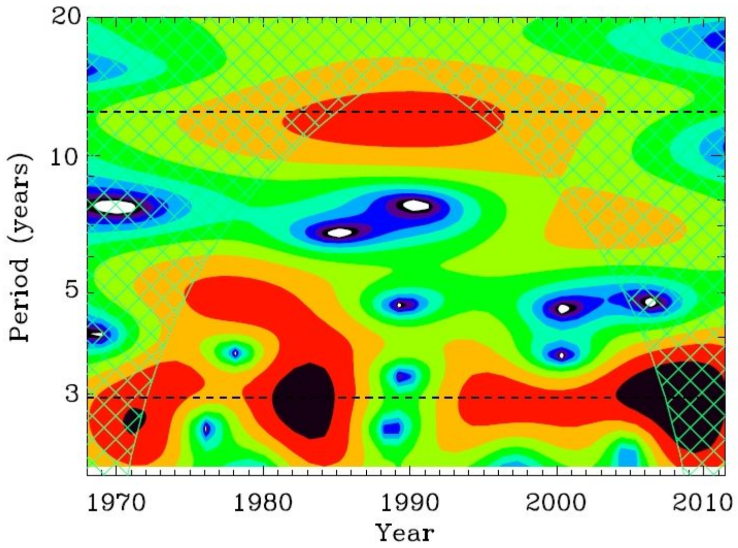

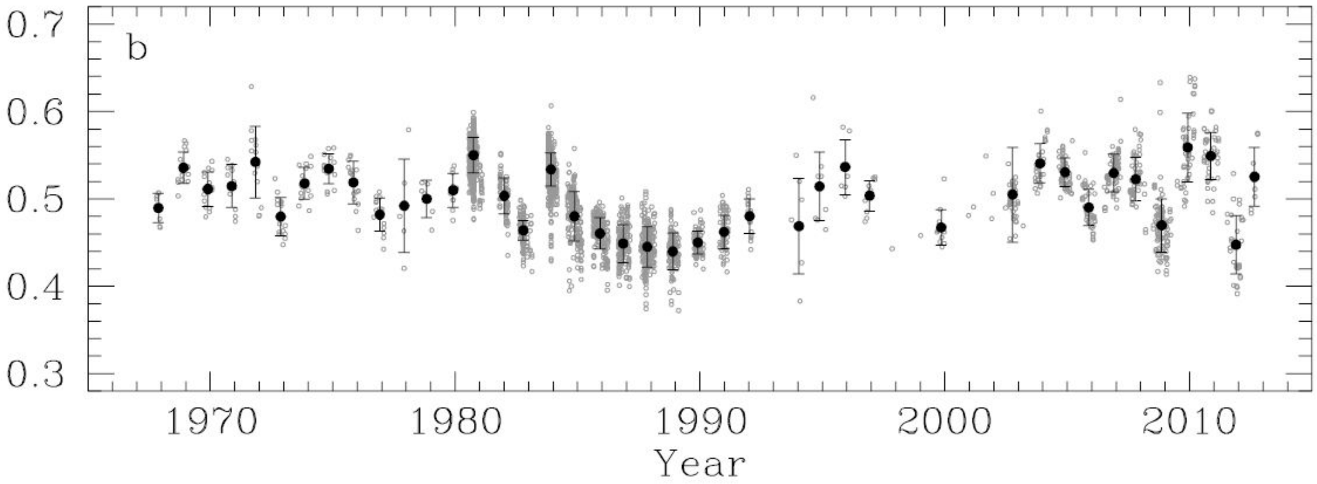

45 years span

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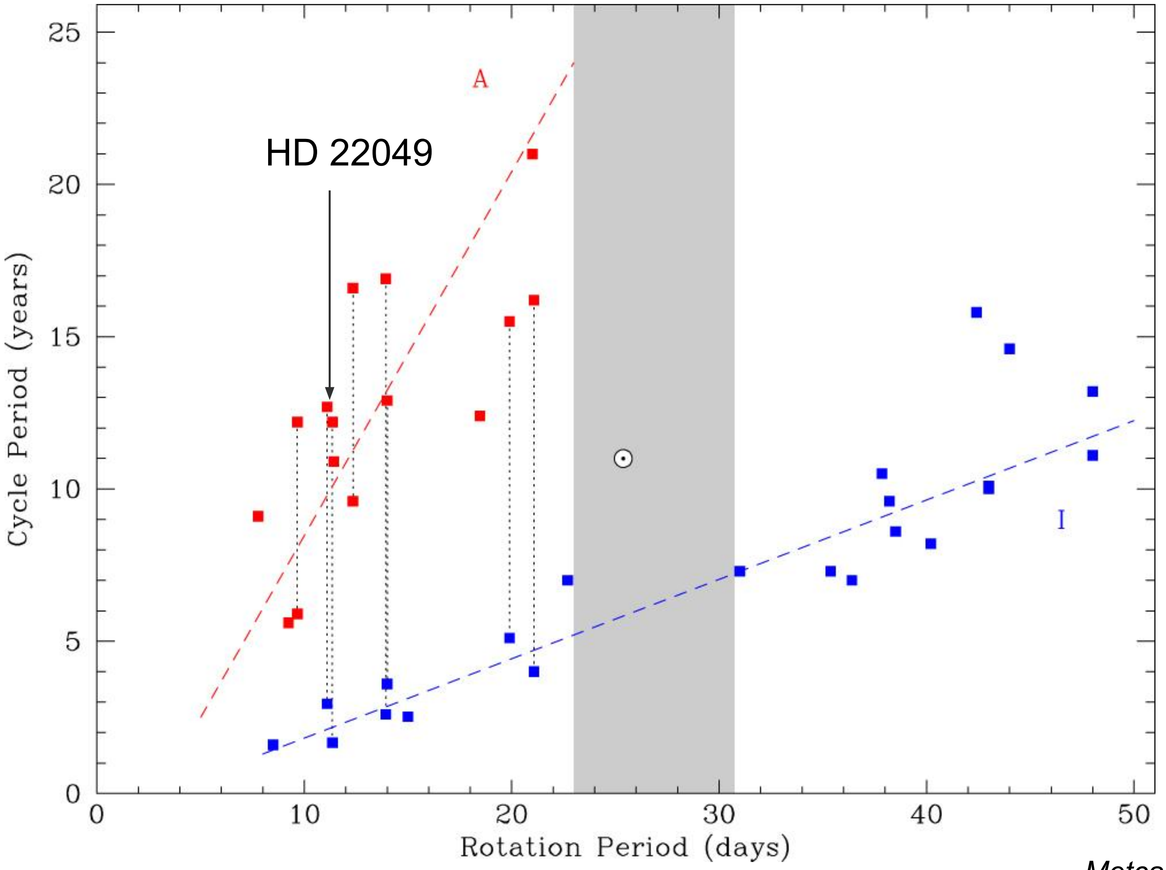
Solar dynamo in stellar context



P_{cyc}-P_{rot} distributed in two branches (active and inactive).

Coexisting activity cycles in stars with P_{rot}<20 d.

Solar cycle between both branches (middle age crisis?)

Non cyclic stars with 23 d< P_{rot}<31 d.

Metcalfe et al. (2016, ApJL,826, 5pp)

Un dínamo para Ɛ Eridani -HD 22049 (K2V)

Laura Sraibman y Fernando Minotti

$$\vec{B} = \vec{\nabla} \times (A\hat{e}_\phi) + B\hat{e}_\phi$$

$$\frac{\partial A}{\partial t} = U_r B_\theta - U_\theta B_r + \eta \left(\nabla^2 A - \frac{A}{r^2 sin^2\theta} \right) + S_\phi + \alpha B$$

$$\frac{\partial B}{\partial t} = [\vec{\nabla} \times (\vec{U} \times \vec{B} - \eta \vec{\nabla} \times \vec{B}) + \vec{\nabla} \times \vec{S}] \cdot \hat{e}_\phi$$

Sraibman y Minotti (2019, SoPhys, 294,14)

$$\alpha = \frac{\lambda^2 \chi}{24 s} \omega_s$$

$$\vec{S} = \langle \vec{\delta u} \times \vec{\delta b} \rangle_X$$

Axisymmetric non-linear model, where all parameters are constrained from observations and derived from exact relations.

A dynamo for Ɛ Eridani -HD 22049 (K2V)

Laura Sraibman y Fernando Minotti

Sraibman y Minotti (2019, SoPhys, 294,14)

Axisymmetric non-linear model, where all parameters are constrained from observations and derived from exact relations.

A dynamo for Ɛ Eridani -HD 22049 (K2V)

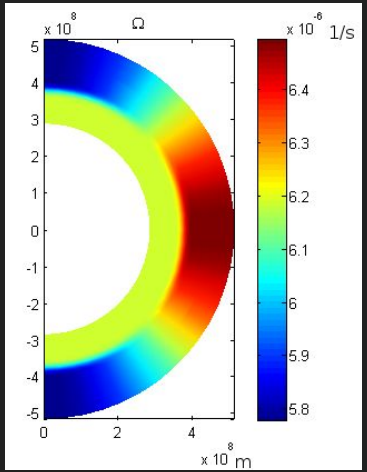
Laura Sraibman y Fernando Minotti

Sraibman y Minotti (2019, SoPhys, 294,14)

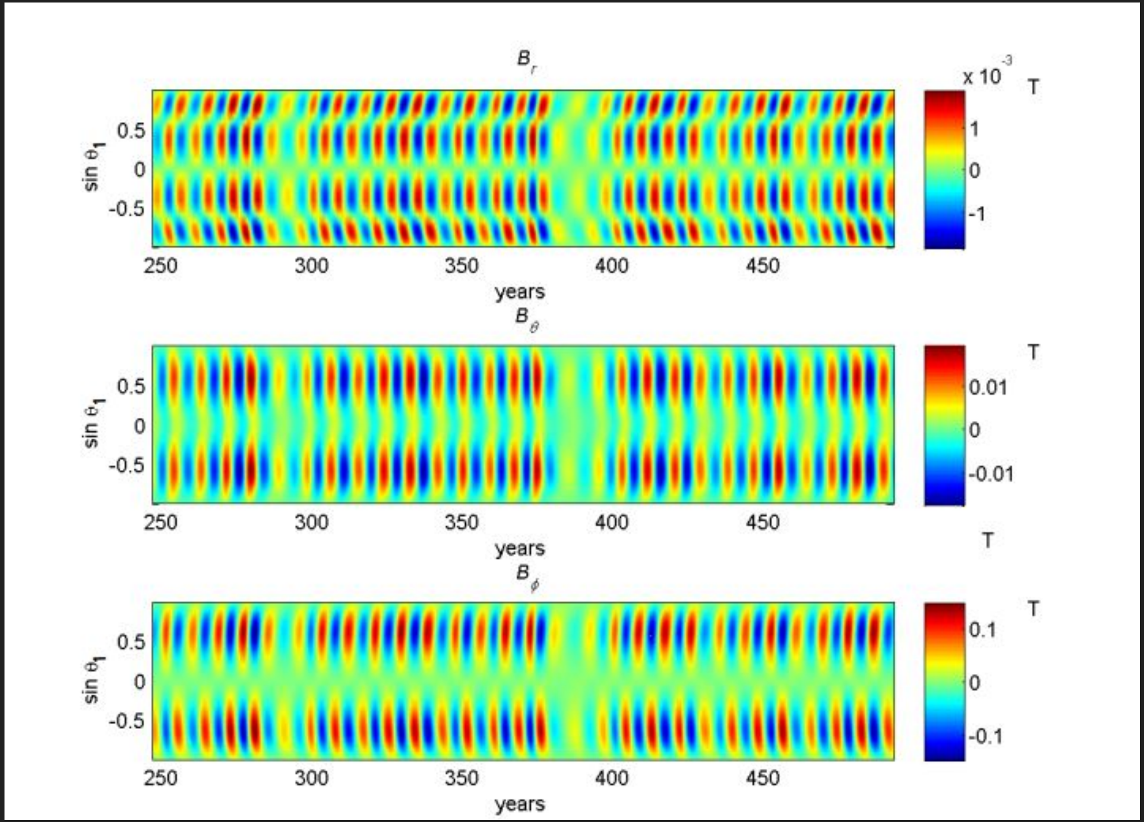
Axisymmetric non-linear model, where all parameters are constrained from observations and derived from exact relations.

Surface differential rotation

$$P_{\theta_1} = \frac{P_{EQ}}{1 - k.\sin^2\theta_1}$$

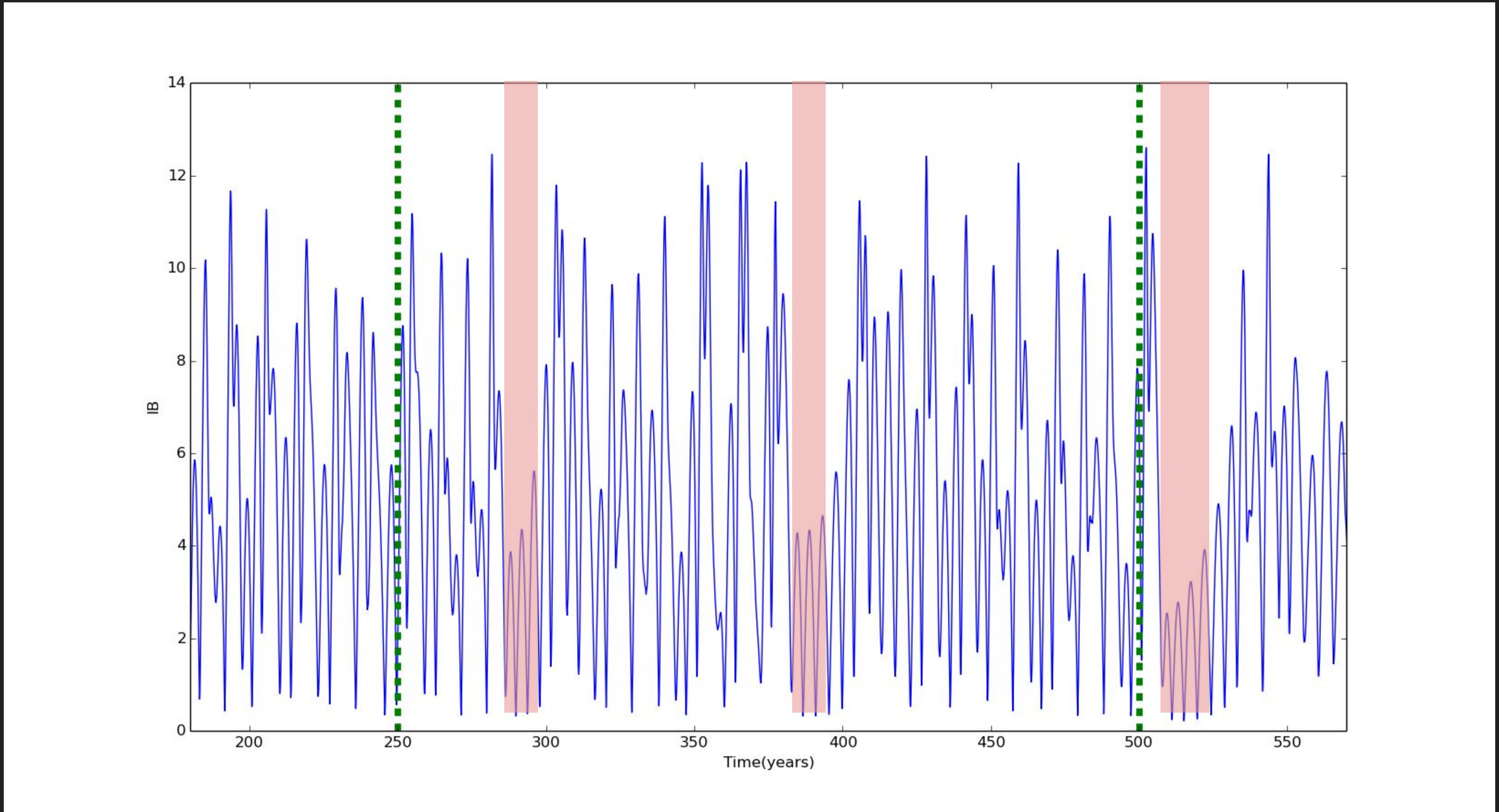


A dynamo for ε Eridani -HD 22049 (K2V)



Buccino, Sraibman et al. (2020, MNRAS, 497,3968)

Simulated activity series in Ɛ Eridani (250 yr)



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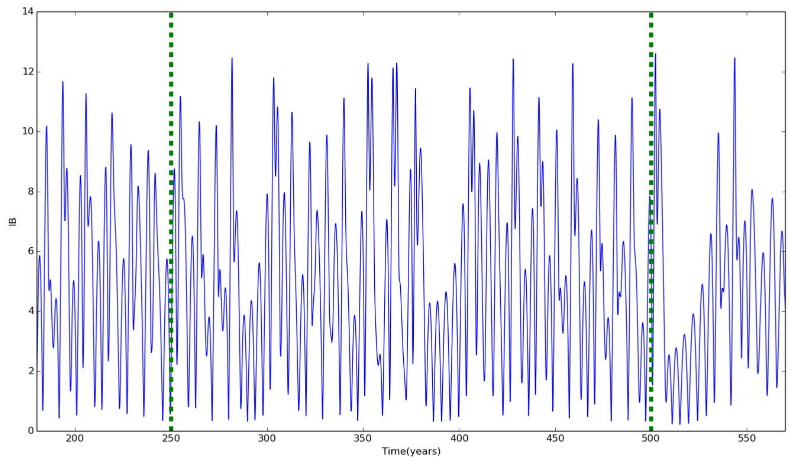
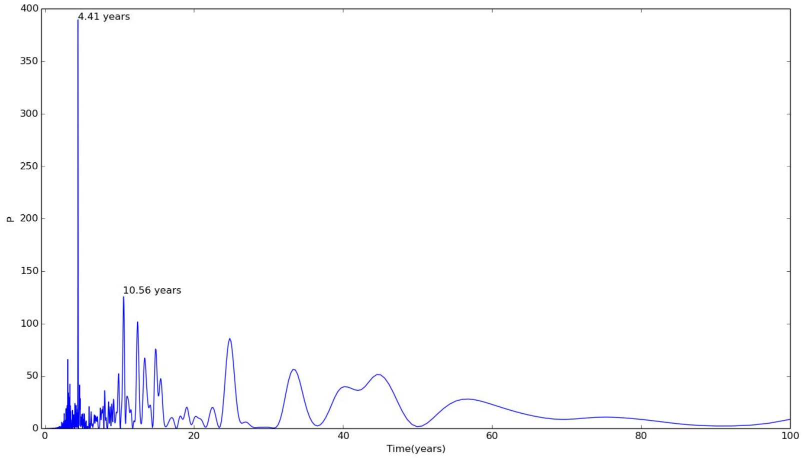
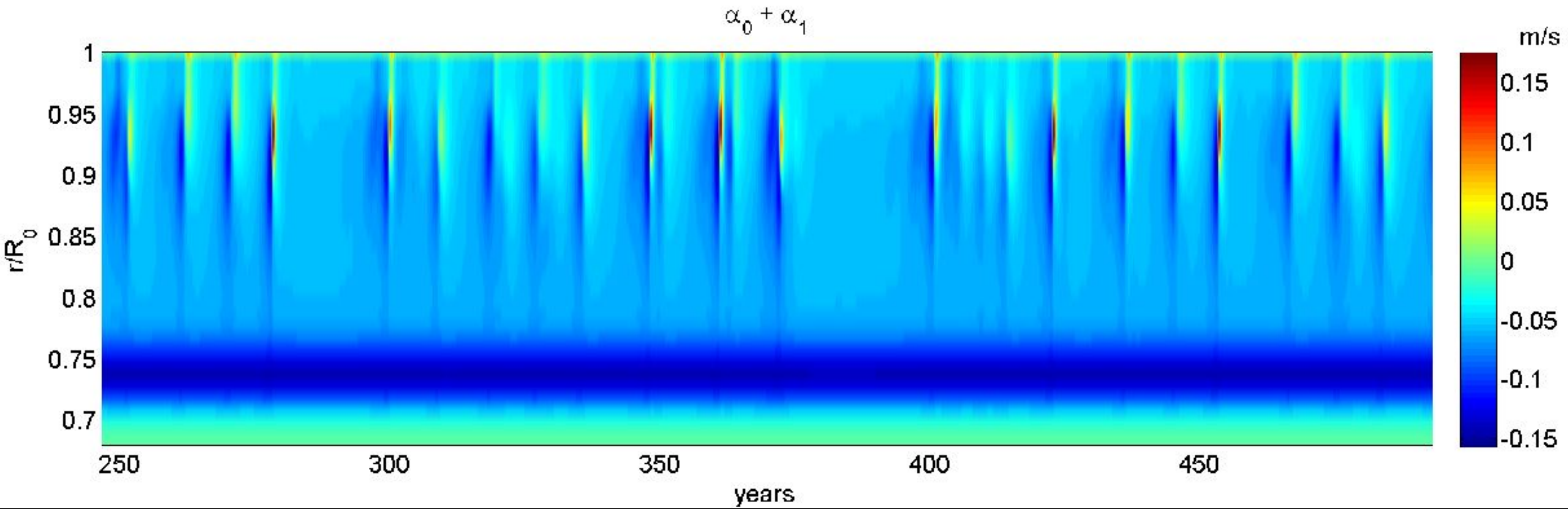




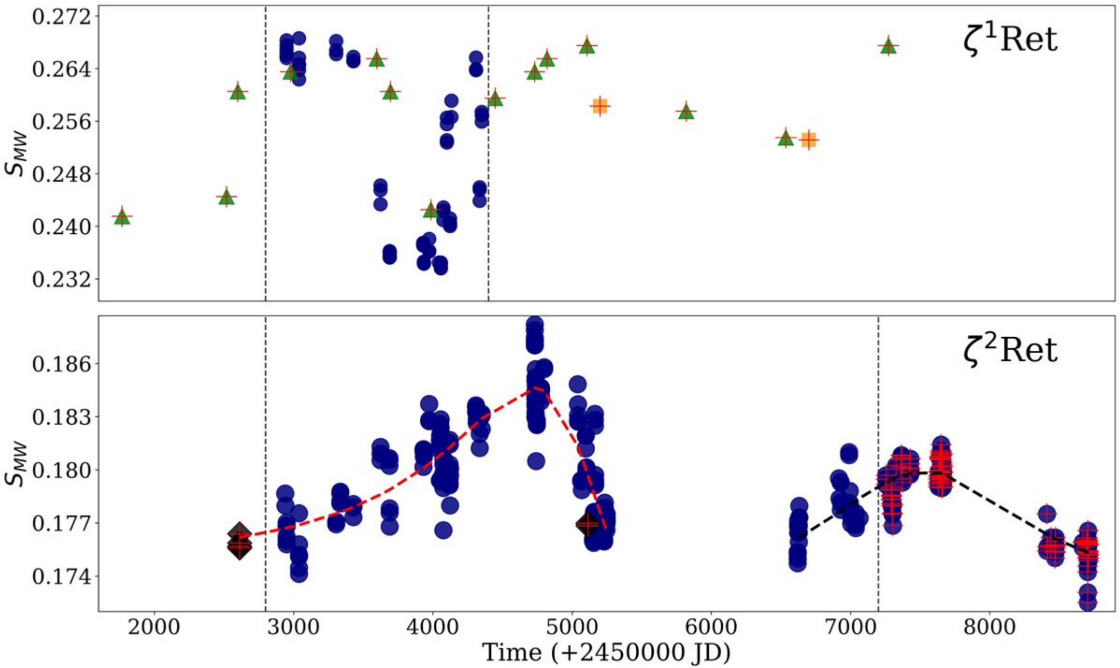
Buccino, Sraibman et al. (2020, MNRAS, 497,3968)

Alpha effect



Buccino, Sraibman et al. (2020, MNRAS, 497,3968)

ζ Ret - Binary system (G2V+G1V)



Matías Flores

17 years span

ζ^1 Ret 4.2 yr-cycle

ζ^2 Ret 7.9-yr cycle getting in a MM phase (Δlog R'$_{HK}$ ~0.24)

Upper panel: S index variation of ζ Ret. HARPS data are indicated with blue circles (for both panels), while REOSC and FEROS data are indicated with green triangles and orange squares, respectively. *Lower panel*: activity variation for ζ Ret. Here, UVES data are indicated with black diamonds. Both vertical dashed lines in each panel represent the time coverage of those series that were initially reported, while the new data are indicated with red crosses. Red and black dashed lines show the fitted activity maxima *f*(*t*) for both peaks.

Flores et al. (2021, A&A,645,L6)

Second Conclusion

Simultaneous activity cycles and broad minima in solar-type stars could be modeled by a typical $\alpha\Omega$ dynamo similar to the solar one. Broad minimum are usual and they not suppress short-activity cycle (tachocline cycle).

Main conclusion (invitation)

Let’s join our observations to get more reliable activity time series.


Thank you
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