X JORNADAS DE INTRODUCCIÓN A LA INVESTIGACIÓN

FACULTAD DE CIENCIAS FÍSICAS - 30 de mayo al 3 junio 2022

SESIONES INFORMATIVAS Y DE PUERTAS ABIERTAS

Departamento de Física de la Tierra y Astrofísica (FTA)

- Astrofísica estelar y exoplanetas

Nombre Apellido

X JORNADAS DE INTRODUCCIÓN A LA INVESTIGACIÓN

FACULTAD DE CIENCIAS FÍSICAS - 30 de mayo al 3 junio 2022

PROGRAMA DE CHARLAS:

El curriculum científico: hay vida más allá del expediente académico
Lucas Pérez García
Lunes 30 mayo. Aula 10 y online. 13:00

Posibilidades para iniciar la carrera investigadora
David Montes Gutiérrez
Vicedecano de Investigación y Doctorado de Físicas
Miércoles 1 junio. Aula 10 y online. 13:00

La biblioteca universitaria en la carrera del investigador
Beatriz García García (Biblioteca de la Facultad)
Viernes 3 junio. Online. 13:00

Online en: https://meet.google.com/cni-dkgh-wcj

SESIONES INFORMATIVAS Y DE PUERTAS ABIERTAS:

Los departamentos e institutos de la Facultad organizan **jornadas informativas** y de **puertas abiertas** durante la semana.

INVESTIGACIÓN EN LA FACULTAD:

En la planta baja y en la página web se podrán ver **pósters** con información sobre grupos y líneas de investigación en los departamentos e institutos de la Facultad:

- Estructura de la Materia, Física Térmica y Electrónica
- Física de la Tierra y Astrofísica
- Física de Materiales
- Física Teórica
- Óptica
- Sec. Dept. Arquitectura de Computadores y Automática

Ver programa en la página web:
https://fisicas.ucm.es/jornadas-intro-inv-2022

Astrofísica estelar y exoplanetas
(Grupo UCM: Sistemas Estelares, Espectrometría y Fotometría)

SESIONES INFORMATIVAS Y DE PUERTAS ABIERTAS

Departamento de Física de la Tierra y Astrofísica (FTA)

- Astrofísica estelar y exoplanetas

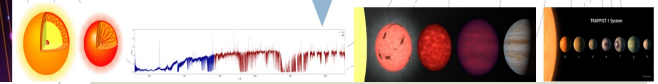
*** "De las estrellas frías a los exoplanetas: Gaia y CARMENES"**
David Montes (Prof. del Dpto)
*** "Códigos para la determinación de parámetros estelares"**
Hugo Tabernero (Postdoc coloborador del Dpto)
*** "Descifrando los parámetros atmosféricos estelares de estrellas M con CARMENES"**
Emilio Gómez Marfil (Postdoc coloborador del Dpto)
*** "La metalicidad de las estrellas M"**
Christian Duque Arribas (doctorando del Dpto)
*** "La relación Litio-edad"**
Marta Lúthien Gutiérrez Albarrán (postdoc del Dpto, online)
*** "Actividad cromosférica y relaciones flujo-flujo en las estrellas M de CARMENES"**
Fernando Labarga (doctorando del Dpto, online)

Fecha y hora: miércoles 1 junio 2022 a las 16:00
Lugar: Seminario Dpto. FTA de la planta 4
Online: https://meet.google.com/cni-dkgh-wcj

De las estrellas frías a los exoplanetas: Gaia y CARMENES

David Montes (FTA)

SEEF (Sistemas Estelares, Espectroscopía y Fotometría)



CÓDIGOS PARA LA DETERMINACIÓN DE PARÁMETROS ESTELARES

Dr. Hugo M. Tabernero
Postdoc en el Centro de Astrobiología
Colaborador del grupo de sistemas estelares, espectroscopía y fotometría

IX Jornadas de introducción a la investigación
Facultad de Ciencias Físicas · Universidad Complutense de Madrid
Contacto: htabernero@cab.inta-csic.es

Descifrando los parámetros atmosféricos estelares de estrellas M con CARMENES

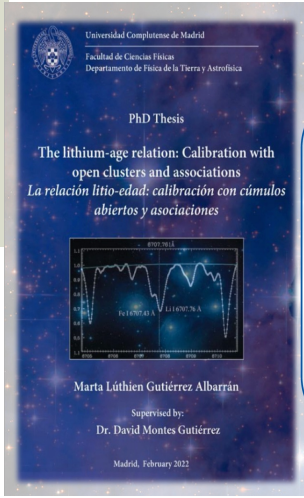
Dr. Emilio Gómez Marfil
X Jornadas de Introducción a la Investigación
30 mayo – 3 junio 2022

X Jornadas de Introducción a la Investigación 2022

LA METALICIDAD DE LAS ESTRELLAS DE TIPO M: CALIBRACIONES FOTOMÉTRICAS Y ESPECTROSCÓPICAS

Christian Duque-Arribas
Directores: Prof. Dr. David Montes y Dr. Hugo M. Tabernero

Sistemas estelares, espectroscopía y fotometría
Facultad de CC. Físicas - Universidad Complutense de Madrid



Facultad de CC. Físicas
Universidad Complutense de Madrid

La relación Li-edad

Marta Lúthien Gutiérrez Albarrán

X Jornadas de Introducción a la Investigación 2022

Actividad Cromosférica y Relaciones Flujo-Flujo de las estrellas M de CARMENES

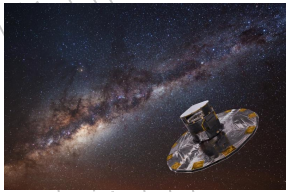
Fernando Labarga Ávalos. Estudiante de Doctorado
Prof. Dr. David Montes. Director de Tesis

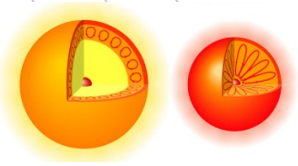
Facultad de Ciencias Físicas
Dpto. de Astrofísica y Ciencias de la Atmófera
Universidad Complutense de Madrid

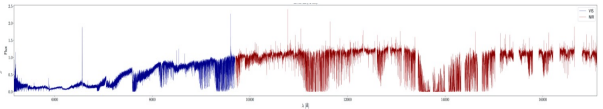
De las estrellas frías a los exoplanetas:
Gaia y CARMENES

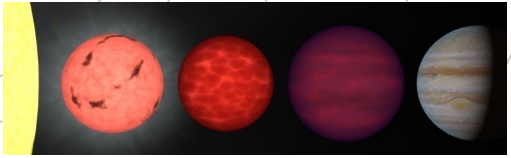
David Montes (FTA)

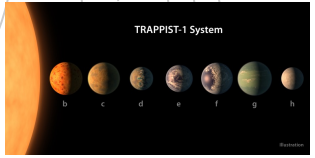
SEEF (Sistemas Estelares, Espectroscopía y Fotometría)





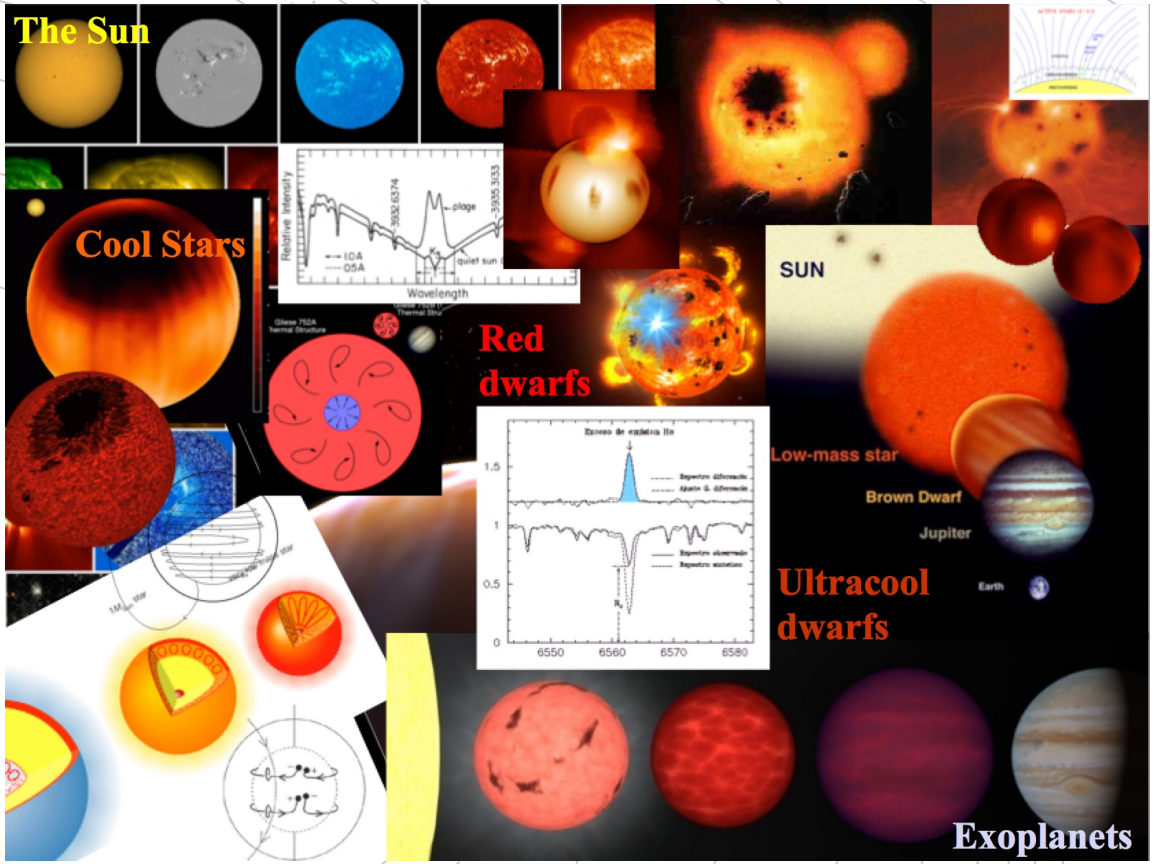






IPARCOS

Cool Stars,
Stellar Parameters,
Stellar Activity,
Exoplanetas
group:



IPARCOS

SEEF
(Stellar Systems, Spectroscopy and Photometry)

- **UCM** (Univ Complutense de Madrid)

  https://www.ucm.es

- Facultad. C.C. **Físicas**

  https://fisicas.ucm.es

- Dpto. de Física de la Tierra y **Astrofísica**

  https://www.ucm.es/fisica_de_la_tierra_y_astrofisica/

- **IPARCOS**-UCM (Instituto de Física de Partículas y del Cosmos de la UCM)

  https://www.ucm.es/iparcos/

- Grupo de investigación (**SEEF**)

  https://webs.ucm.es/info/Astrof/invest/actividad/actividad.html

IPARCOS

Grupos de Investigación

910491 SISTEMAS ESTELARES. ESPECTROSCOPIA Y FOTOMETRÍA

Centro:	F. CIENCIAS FISICAS www
Ámbito - Área AEI:	ÁREA DE EXPERIMENTALES - FÍSICA Y CIENCIAS DEL ESPACIO
Valoración :	BUENO
Acrónimo - E_Mail:	- dmontes@ucm.es
Director/es:	MONTES GUTIERREZ, DAVID
Miembros:	CABALLERO HERNANDEZ, JOSE ANTONIO; CASTRO RUBIO, ELISA DE ; DUQUE ARRIBAS, CHRISTIAN ; FERNANDEZ FIGUEROA, MARIA JOSE; GORGAS GARCIA, FRANCISCO JAVIER ; ROCA FABREGA, SANTI ; TABERNERO GUZMAN, HUGO MARTIN
Líneas de investigación:	Actividad cromosférica estelar, estrellas de los últimos tipos espectrales; Grupos cinemáticos y cúmulos estelares jóvenes.; Regiónes de transición y Coronas estelares, emisiones ultravioleta y rayos X; Caracterización espectroscópica de estrellas frías con posibles planetas o componetes subestelares; Espectrosopia de alta resolución, parámetros estelares
Palabras clave:	Actividad magnetica; cinematica; abundancias; fulguraciones; Cromosferas; Estrellas frías; Espectroscopia; Actividad estelar; Exoplanetas
Acceso a su web:	Acceder

SEEF
(Stellar Systems, Spectroscopy and Photometry)

IPARCOS

Cool Stars,
Stellar Parameters,
Stellar Activity,
Exoplanetas
group:

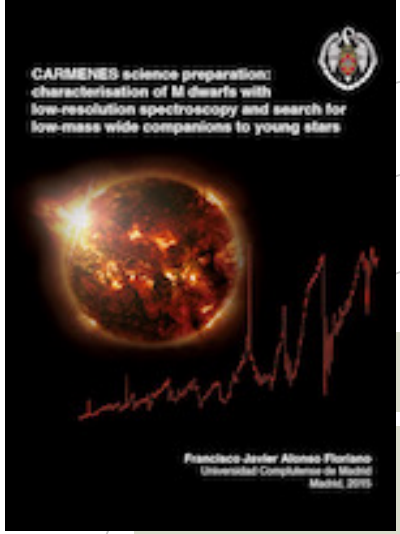
- **Profesores:**
  - Prof. David Montes
  - Profa. Elisa De Castro
  - Profa. Mª José Fernández-Figueroa
  - Prof. Manuel Cornide,
- **PostDocts:**
  - Dr. Hugo M., Tabernero (CAB)
  - Dra. Miriam Cortés Contreras (CAB)
  - Dr. Enrique Díez Alonso (Univ. Oviedo)
  - Dra. Marta L. Gutiérrez Albarran
  - Dr. Emilio Gómez Marfil (CAB)
  - Dr. F. Javier Alonso Floriano (Leiden Univ.)
  - Dr. Shinjirou Kouzuma (Chukyo Univ. Japan)
  - Dr. Javier López-Santiago
  - Dra. Mª.Cruz Gálvez

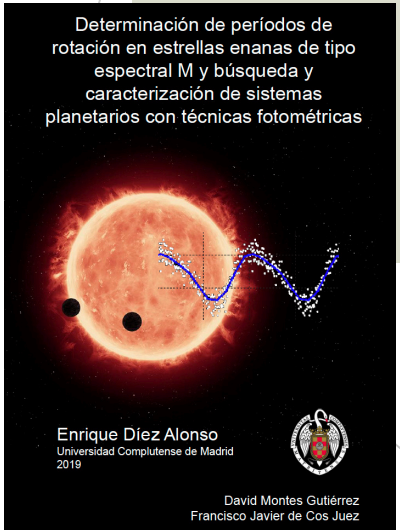
IPARCOS

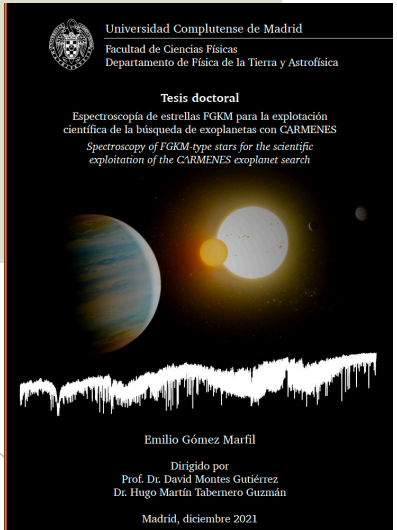
Cool Stars,
Stellar Parameters,
Stellar Activity,
Exoplanetas
group:

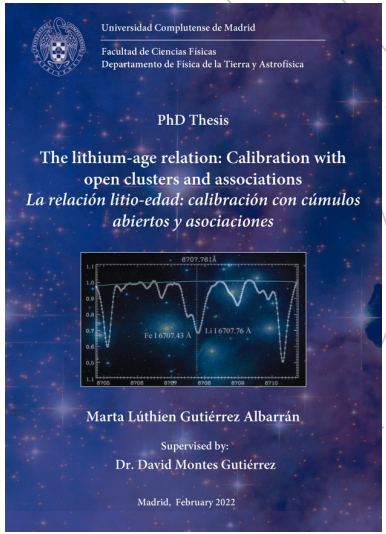
- **Estudiantes Doctorado:**
  - Fernando Labarga Ávalos
  - Christian Duque Arribas
  - Julián A. Rodríguez Baquerizo
  - Álvaro López Gallifa
  - Daniel Revilla Martínez de Albéniz
  - Dr. Miguel Ángel López García
  - Dr. Victor Pereira Blanco
  - Dra. Inés Crespo-Chacón
  - Dra. Magdalena Hernán Obispo
  - Dra. Raquel M. Martínez Arnáiz
- **Otros colaboradores:**
  - José Antonio Caballero (CAB)
  - Alexis Klutsch (IfA&A, *Tübingen, Germany*)
  - Jonay Isaí González Hernández (IAC)
  - David García Álvarez (GTC, IAC)

Últimas tesis doctorales defendidas









https://webs.ucm.es/info/Astrof/users/dmg/tesis_dirigidas_dmg.html

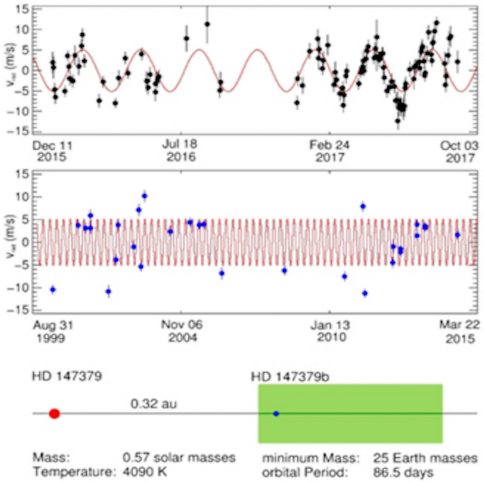
IPARCOS

Areas of research:

Cool Stars,
Stellar Parameters,
Stellar Activity,
Exoplanetas
group:

EXOPLANETAS

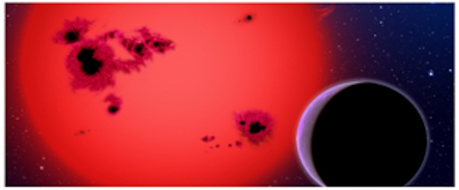
CARMENES es un espectrógrafo de alta resolución en el óptico e infrarrojo cercano para el telescopio de 3.5m del observatorio de Calar Alto.



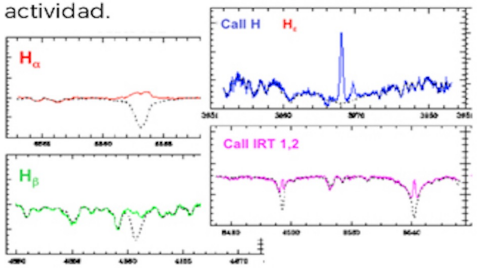
Está optimizado para la búsqueda de planetas alrededor de estrellas muy poco masivas (tipo espectral M). Es capaz de obtener velocidades radiales con una precisión de 1 m/s.

ACTIVIDAD ESTELAR

Fenómenos asociados a la actividad magnética en estrellas frías (tipos FGKM).



Espectroscopía de alta resolución para determinar sus principales parámetros atmosféricos, abundancias químicas y actividad.



La misión Gaia proporciona astrometría que permite estudiar la cinemática.

Exploraciones como GES (Gaia ESO survey) complementan desde Tierra estas observaciones.

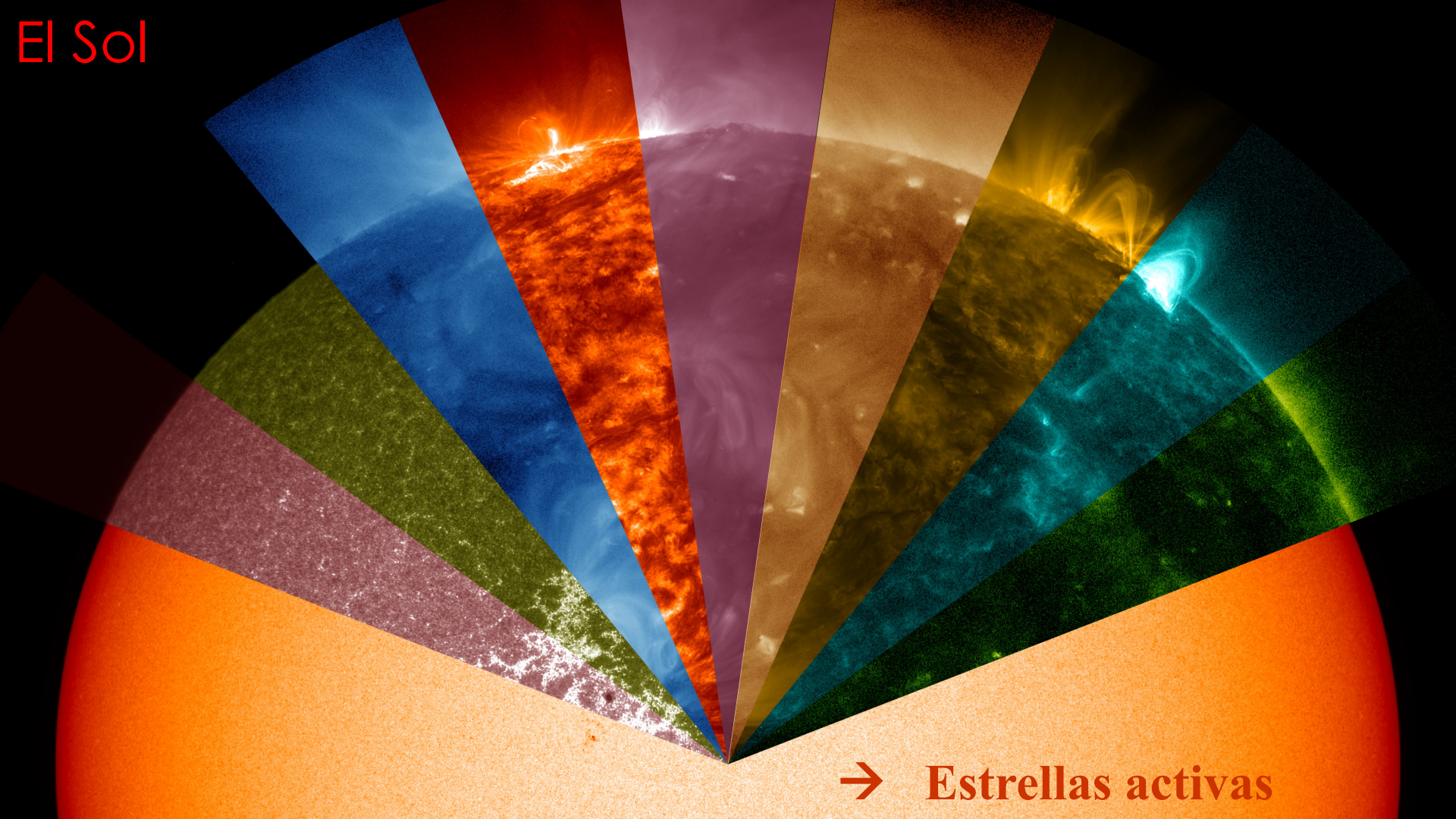
IPARCOS

Cool Stars,
Stellar Parameters,
Stellar Activity,
Exoplanetas
group:

Areas of research:

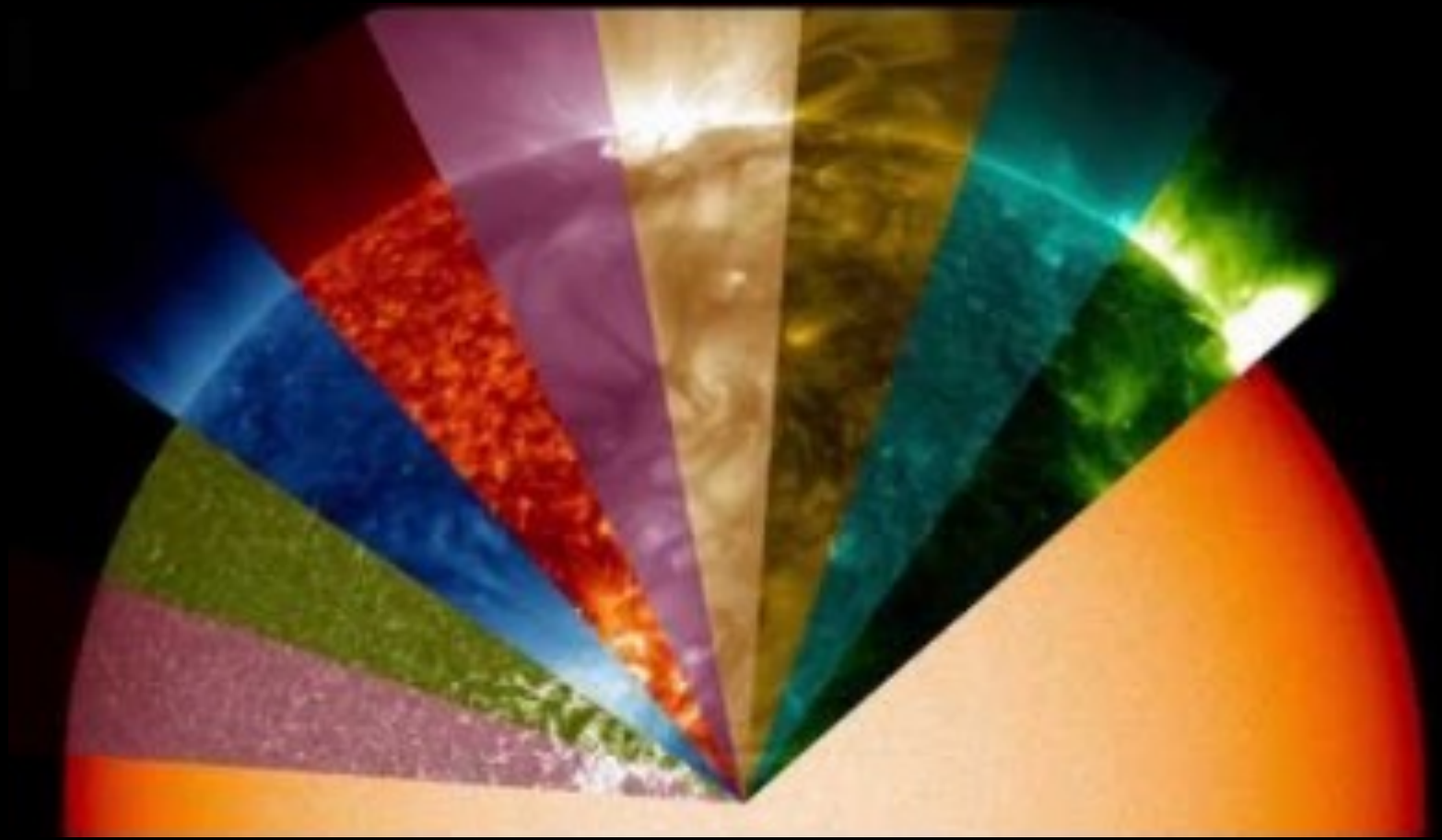
- Cool Stars (FGK)
- Stellar parameters ($T_{\rm eff}$, log$g$), [Fe/H])
- Abundances ([X/H], [X/Fe])
- Stellar activity (starspots, chromosphere, transition region, corona, flares, prominences, etc…)
- Rotation, age, kinematics
- Open clusters
- Stellar kinematic groups
- Nearby stars
- Red dwarfs stars (M)
- Exoplanets (detection and characterization)

El Sol



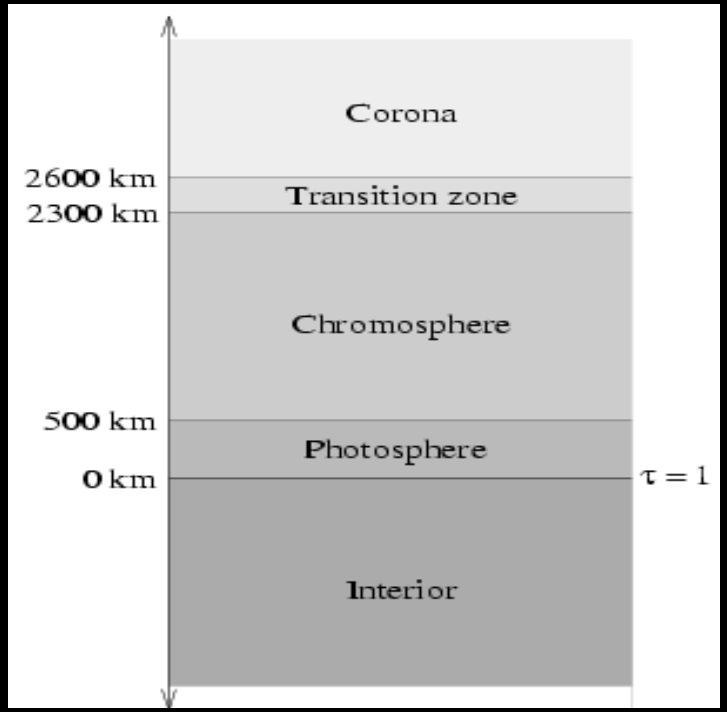
→ **Estrellas activas**

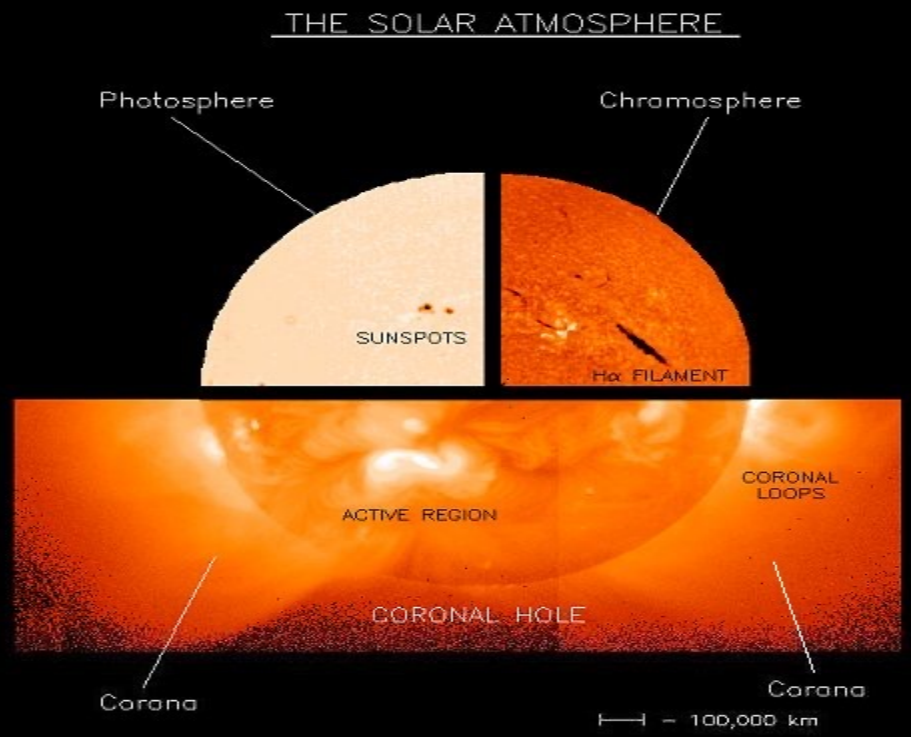
Jewel Box Sun

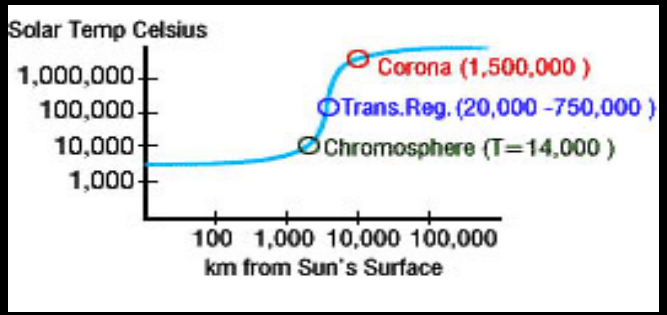


NASA movie of the sun based on data from NASA's Solar Dynamics Observatory, or SDO, shows the wide range of wavelengths - invisible to the naked eye - that the telescope can view. SDO converts the wavelengths into an image humans can see, and the light is colorized into a rainbow of colors.

Atmósfera del Sol:
Cromosfera,
Región de Transición
y Corona.





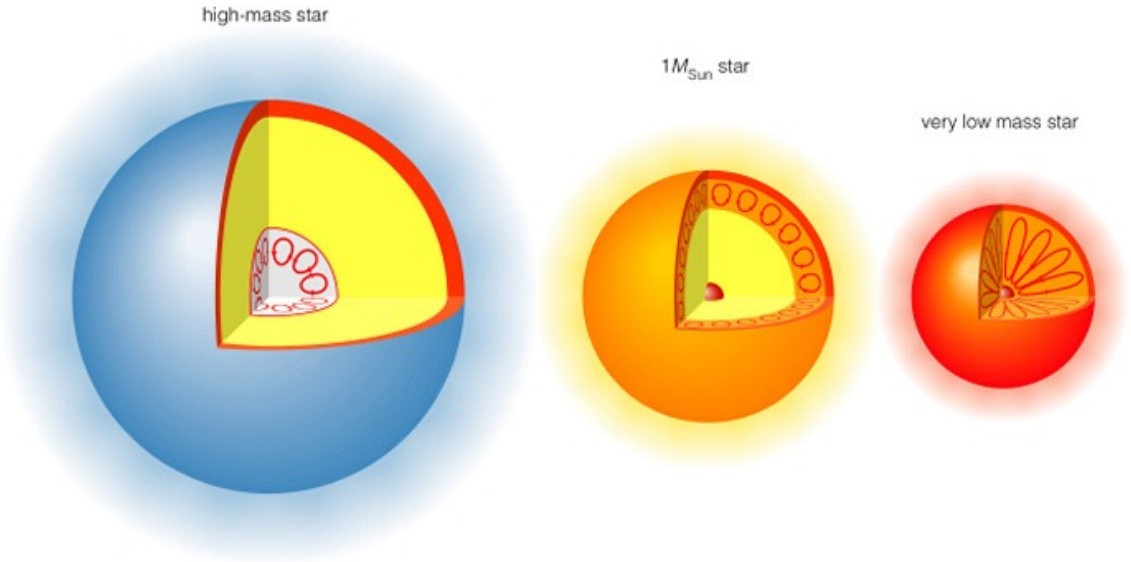


¿Que son las estrellas frías?

→ **Estrellas Frías**

Estrellas Frías (tipos F, G, K, M, L, T).

Cool Stars,
Stellar Parameters,
Stellar Activity,
Exoplanetas
group:

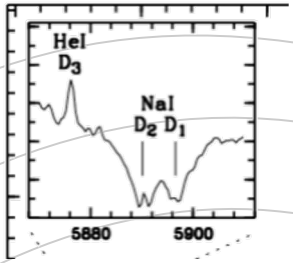


Estrella Caliente

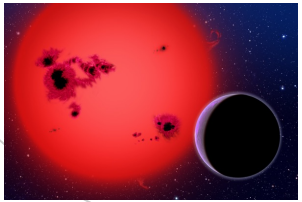
Estrellas Frías FGK
El Sol
Zona convectiva

Estrellas M completamente convectiva
> M3.5

IPARCOS

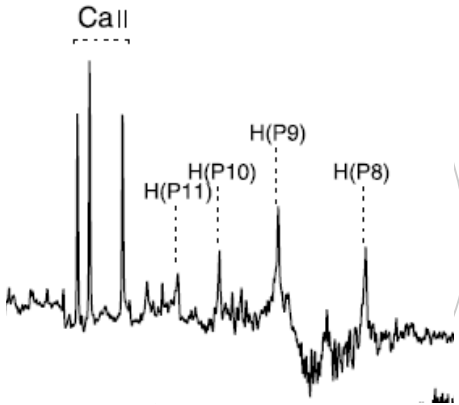


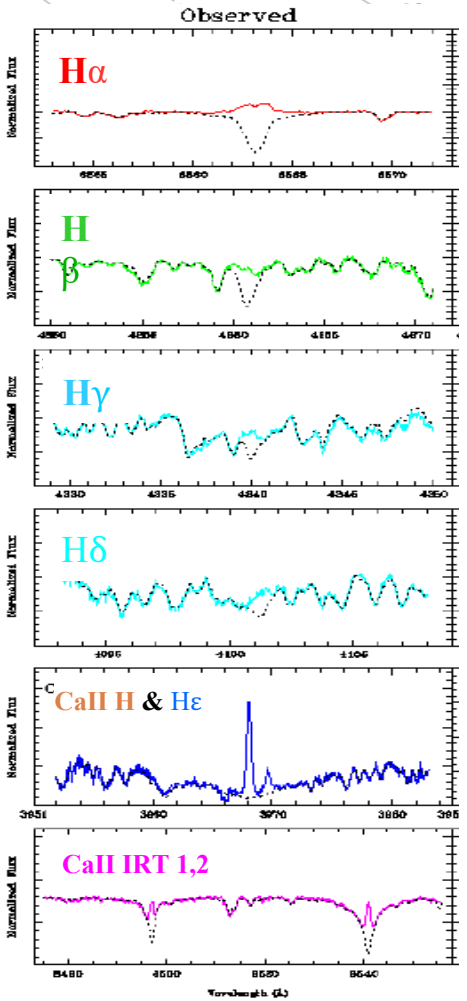
Cool Stars,
Stellar Parameters,
Stellar Activity,
Exoplanetas
group:



David Montes

- **Chromospheric activity indicators:**
  - Ca II H&K
  - Serie de Balmer:
    Hα, Hβ, Hγ, Hδ, Hε, …
  - Mg Ib
  - Na I D_1, D_2
  - He I D_3
  - Ca II IRT
  - He I 10830





International collaborations

Cool Stars,
Stellar Parameters,
Stellar Activity,
Exoplanetas
group:

- Ground based optical and infrared telescopes

- Space missions

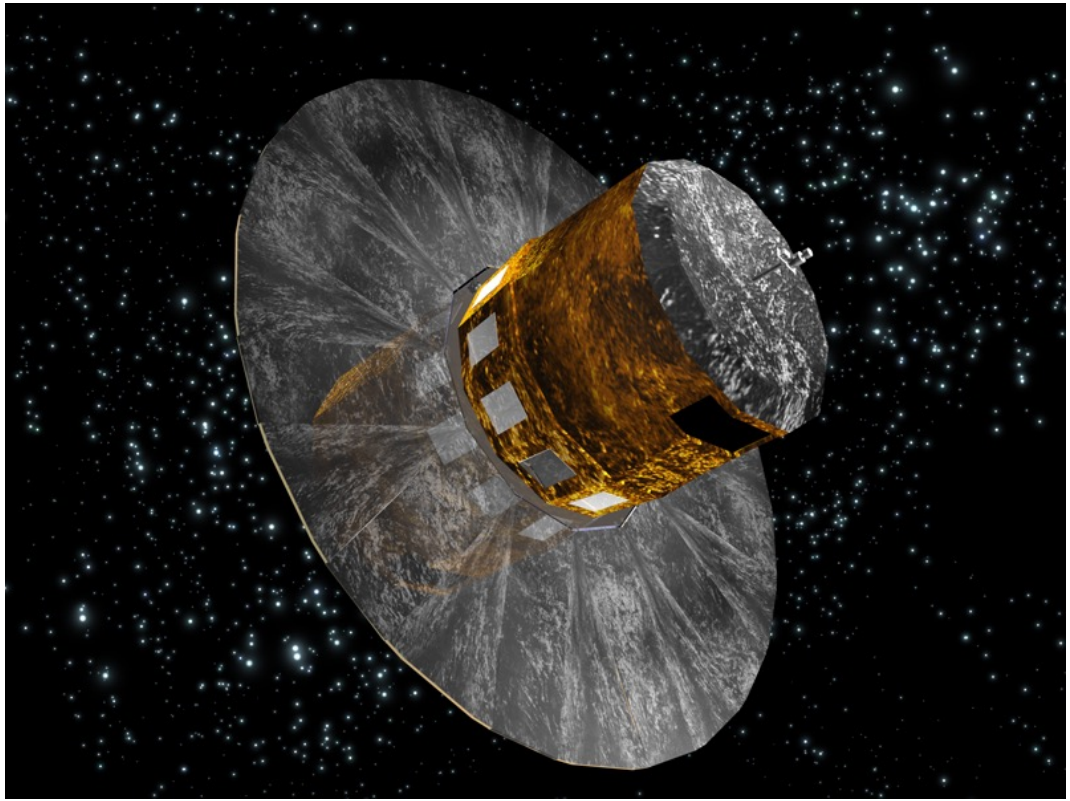
Paralaje trigonométrico (π)
Movimiento propio (μ)

Satélite Gaia
(2013-)

Precisión: microarcsecond

$$\Delta\pi = 0.000001\ ''$$

La estrella más cercana tiene una paralaje de solo 0,77 segundos de arco. Una estrella en el centro de la Galaxia tiene una paralaje de 0,0001 segundos de arco. Para medir ángulos tan pequeños hace falta un instrumento como Gaia.



http://www.esa.int/Our_Activities/Space_Science/Gaia

WHAT IS GAIA?

European mission

Structure

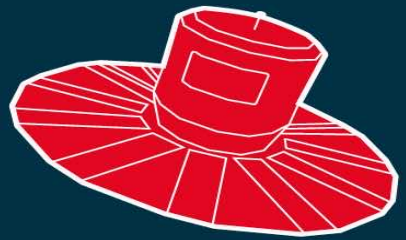
Origin

Evolution

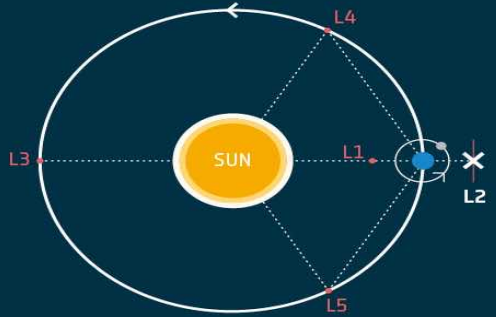
Most accurate
3D map of our galaxy

Almost
2 billion objects

Position,
velocity,
brightness,
temperature,
composition,
type



2 optical telescopes
3 instruments
1 billion pixel camera



In orbit around
Lagrange point 2

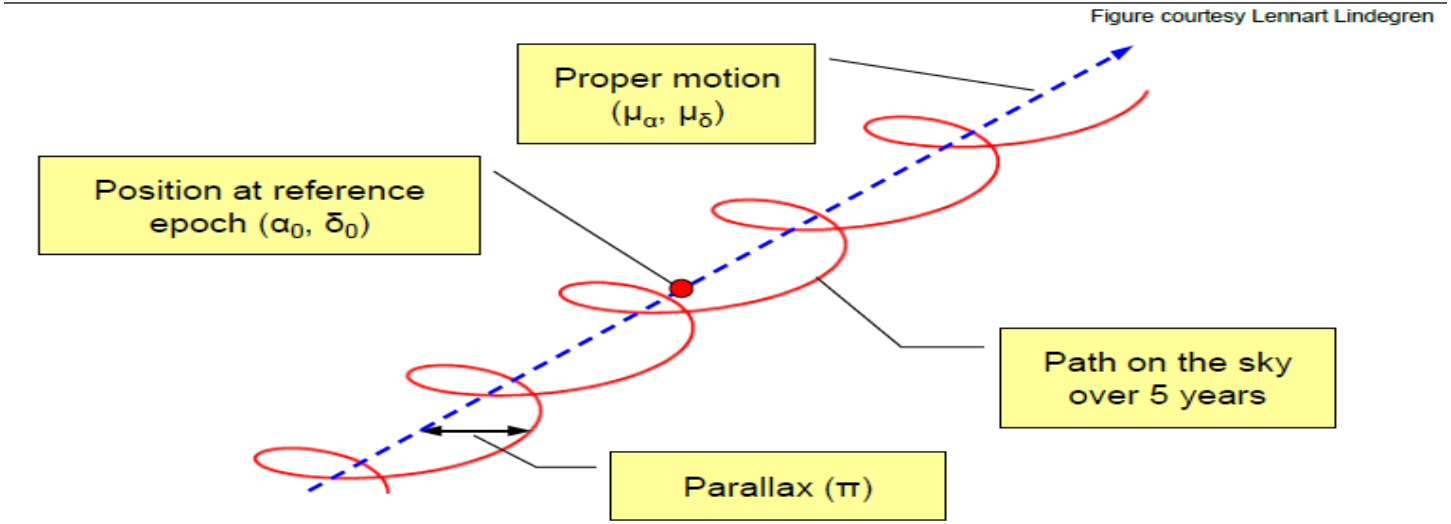
Inside our galaxy:

Stars, binary stars, exoplanets,
interstellar medium, Solar System objects

Outside our galaxy:

Quasars and other galaxies

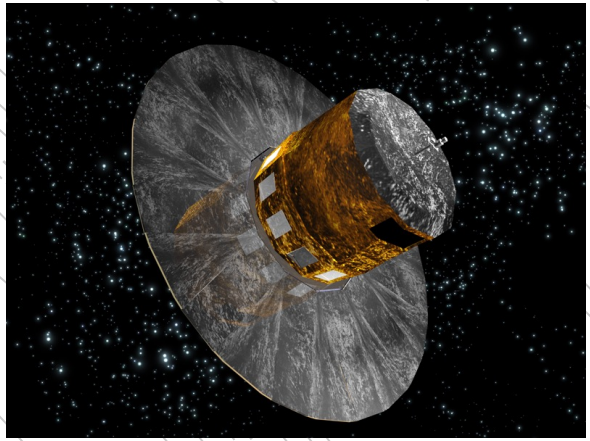
Paralaje (π) + Movimiento propio (μ):



Monitor this path for 10^9 stars during 5 years and fit, for each star, a five-parameter model to retrieve reference position, proper motion, and parallax (for a given instrument calibration and attitude)

IPARCOS

Gaia astrometric mission ESA



The SEEF group is involved in the scientific exploitation of the Gaia data and participate in the Spanish network of excellence REG (Red Española para la explotación científica de Gaia).

Gaia- **DR1.** (09 – 2016)
Gaia- **DR2** (04 – 2018)
Gaia- **EDR3** (12 - 2020)
Gaia- **DR3** (6 – 2022)

GAIA EARLY DATA RELEASE 3

esa

1 811 709 771
stellar positions

1 806 254 432
brightness
in white light

1 542 033 472
brightness
in blue light

1 540 770 489
colour

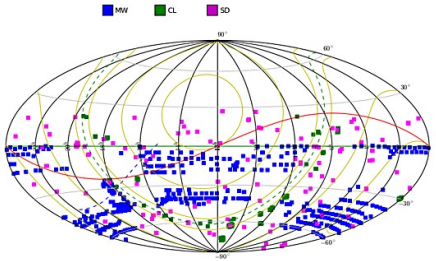
1 554 997 939
brightness
in red light

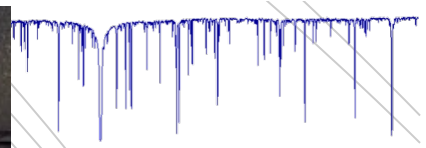
1 467 744 818
parallax and
proper motions

1 614 173
extragalactic
sources

#SpaceCare #ExploreFarther

IPARCOS





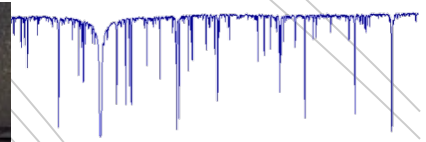
GES (Gaia-ESO spectroscopic Survey)

Public spectroscopic survey, targeting ≥ 10^5 stars, systematically covering all major components of the MilkyWay, from halo to star forming regions.

The SEEF group participate in the **WG 11** (UVES **FGK stars**) and **WG 12** (**pre-main sequence stars**) and has developed (Tabernero 2014, PhD. Thesis UCM) automatic tools to derive stellar atmospheric parameters: effective temperature ($T_{\rm eff}$), surface gravity (log*g*), metallicity ([Fe/H]), and the microturbulent velocity (ξ) as well as abundances (i.e., [X/H], [X/Fe]) for 20 different chemical elements (Na, Mg, Al, Si, Ca, Ti, V, Cr, Mn, Co, Fe, Ni, Cu, Zn, Y, Zr, Ba, Ce, and Nd) of FGK stars using the equivalent width (*EW*) method.

IPARCOS

GES (Gaia-ESO spectroscopic Survey)



The automatics codes ***StePar*** and ***SteAbu*** developed have been tested with well known stars (benchmarks stars) providing very accuracy results and used to apply the "*Chemical Tagging*" technique to test the common origin of two young stellar kinematic groups (Tabernero et al. 2012A&A...547A..13T; 2017A&A...597A..33T).

Recent Publications:

- "*The Gaia-ESO Survey: The analysis of high-resolution UVES spectra of FGK-type stars*", Smiljanic et al. 2014A&A...570A.122S

- "*Gaia-ESO Survey: Analysis of pre-main sequence stellar spectra*", Lanzafame et al., 2015A&A...576A..80L

The *Gaia*-ESO Survey: Calibrating the lithium-age relation with open clusters and associations

M.L. Gutiérrez Albarrán[1], D. Montes[1], M. Gómez Garrido[1,2], H. M. Tabernero[1,3], J.I. González Hernández[4,5], E. Marfil[1], and GES collaborators.

[1]Departamento de Física de la Tierra y Astrofísica and IPARCOS-UCM, Facultad de Ciencias Físicas, Universidad Complutense de Madrid, E-28040, Madrid, Spain; [2] Observatorio Astronómico Nacional (OAN-IGN), Alcalá de Henares; [3] Instituto de Astrofísica e Ciências do Espaço, Universidade do Porto; [4] Instituto de Astrofísica de Canarias (IAC); [5] Universidad de la Laguna, Tenerife.

Abstract

Li depletion is strongly **age-dependent** but currently available data have shown a complex pattern of Li depletion on the pre- and main-sequence stars that is not yet understood. The lithium abundance observed in late-type stars depends not only of the age and the temperature but also on metallicity, mixing mechanisms, convection structure, rotation and magnetic activity. The large number of stars observed within the Gaia-ESO survey (**GES**) for many open clusters and associations can be used to calibrate the **lithium-age relation** and its dependence with other parameters that can be derived from the UVES and GIRAFFE spectroscopic observations. We performed a thorough analysis of **membership and Li abundance of 20 clusters** observed in **GES (iDR4)**, ranging in age from **young clusters and associations**, to **intermediate-age and old open clusters**, in order to conduct a comparative study. All this allowed us to characterize the properties of the members of these clusters, as well as identify a series of **field contaminant stars, both lithium-rich giants and non-giant outliers**.

Gutiérrez Albarrán, M. L.; Montes, D.; et al. 2020A&A...643A..71G

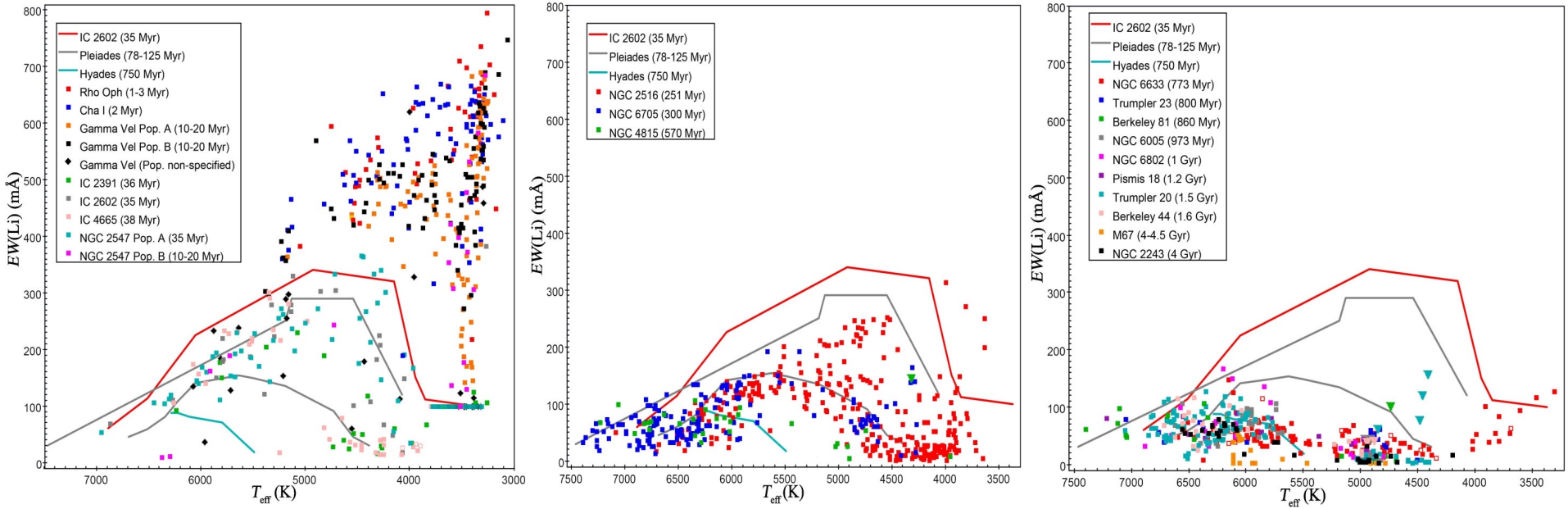
IPARCOS

GaiaESO

Young clusters (1-50 Myr)

Intermediate –age clusters (50-700 Myr)

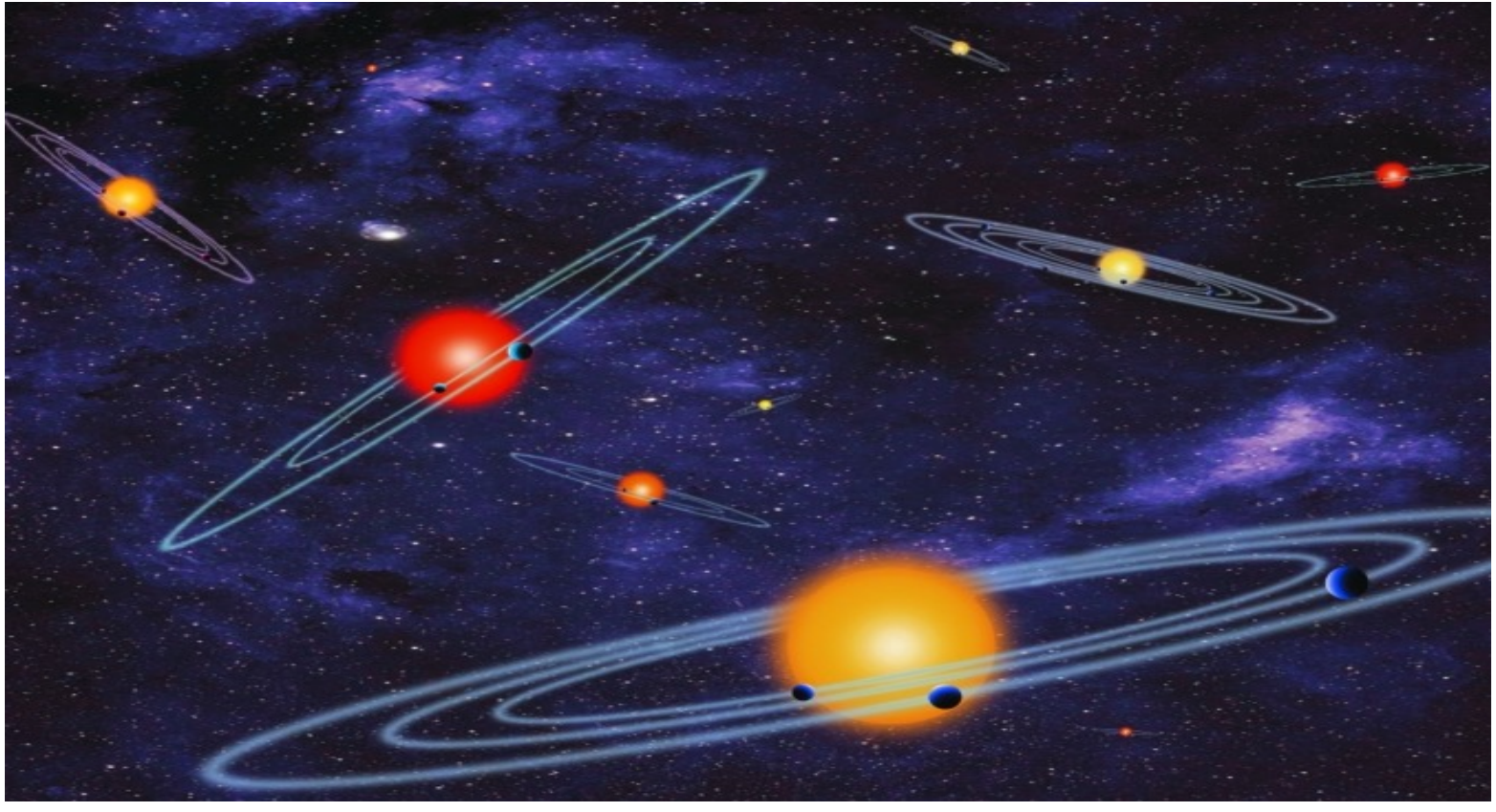
Old clusters (>700 Myr)



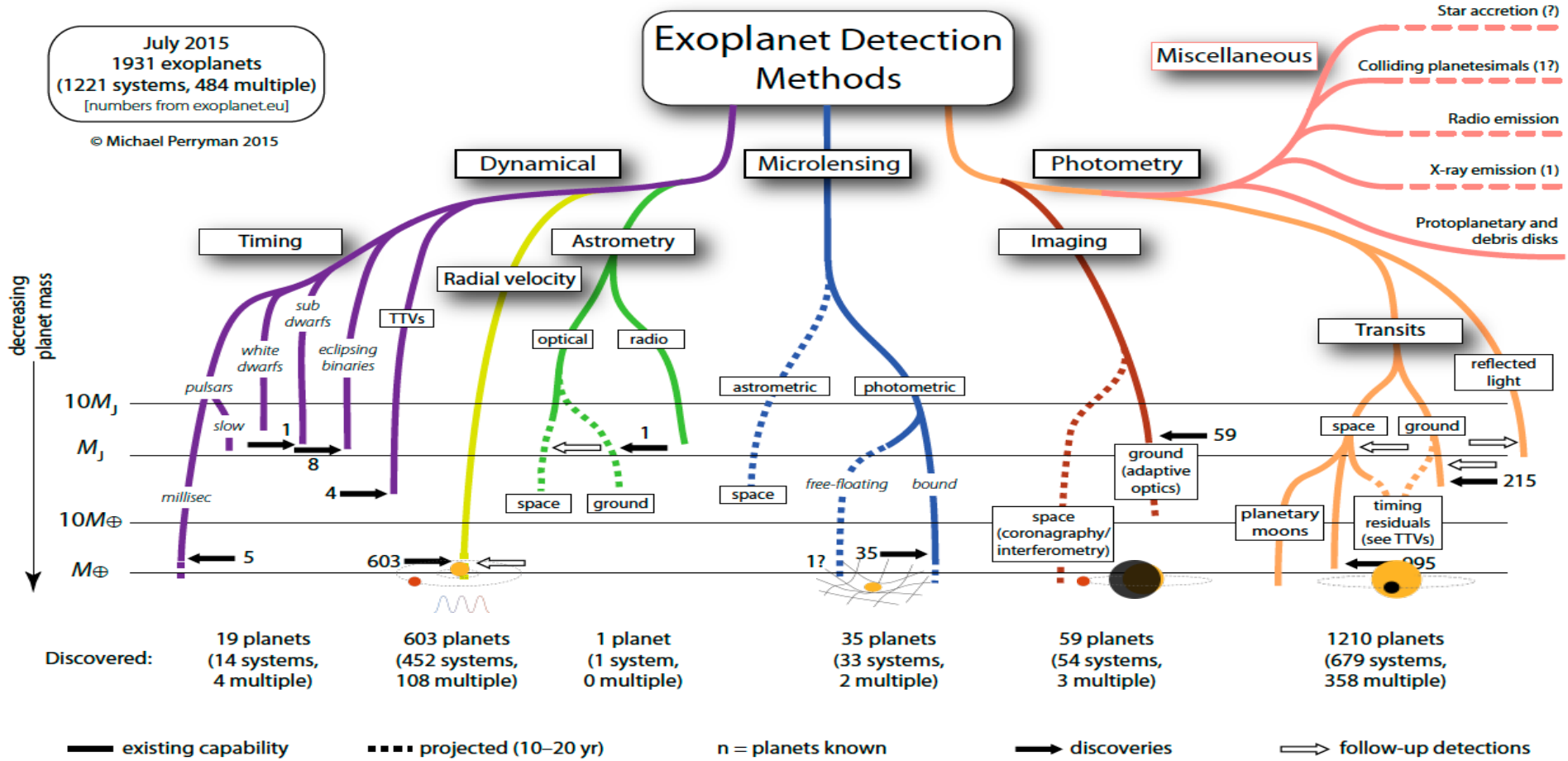
***EW*(Li) vs T_{eff} diagrams for the candidate members** of the **young clusters** (1-50 Myr, left panel), as well as the i**ntermediate-age** (50-700 Myr, middle panel) and **old clusters** (>700 Myr, right panel). We also show the **lithium envelopes** of **IC 2602** (35 Myr, red), the **Pleiades** (78-125 Myr, grey), and the **Hyades** (750 Myr, turquoise). **Open squares** indicate possible members only, while **inverted triangles** refer to Li-rich members**.**

Exoplanets: planets in other stars

Exoplanets

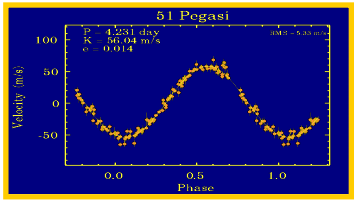


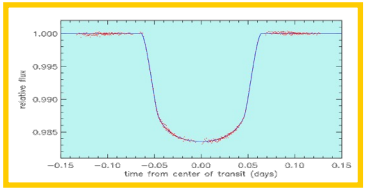
Métodos de detección

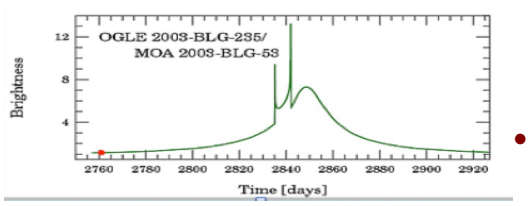


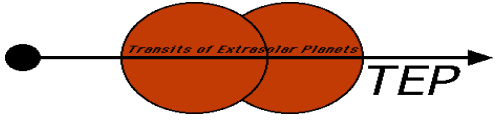
Métodos de detección

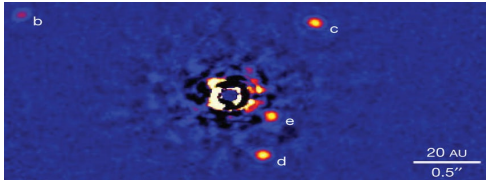
- Velocidad radial (efecto Doppler).
- Tránsitos fotométricos.
- Microlentes gravitatorias.
- Timing (eclipses, pulsaciones).
- Imagen directa.
- Astrometría.









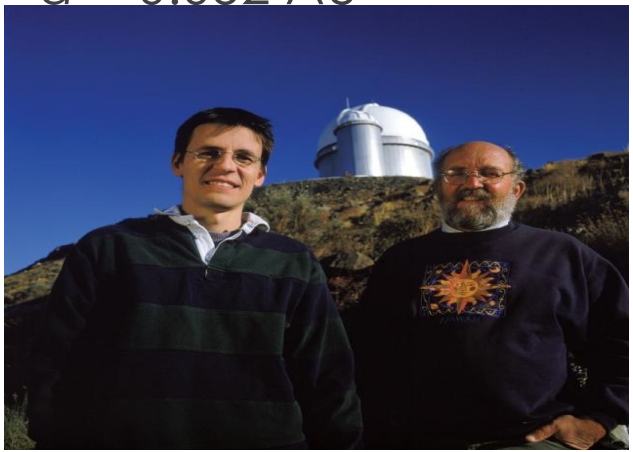


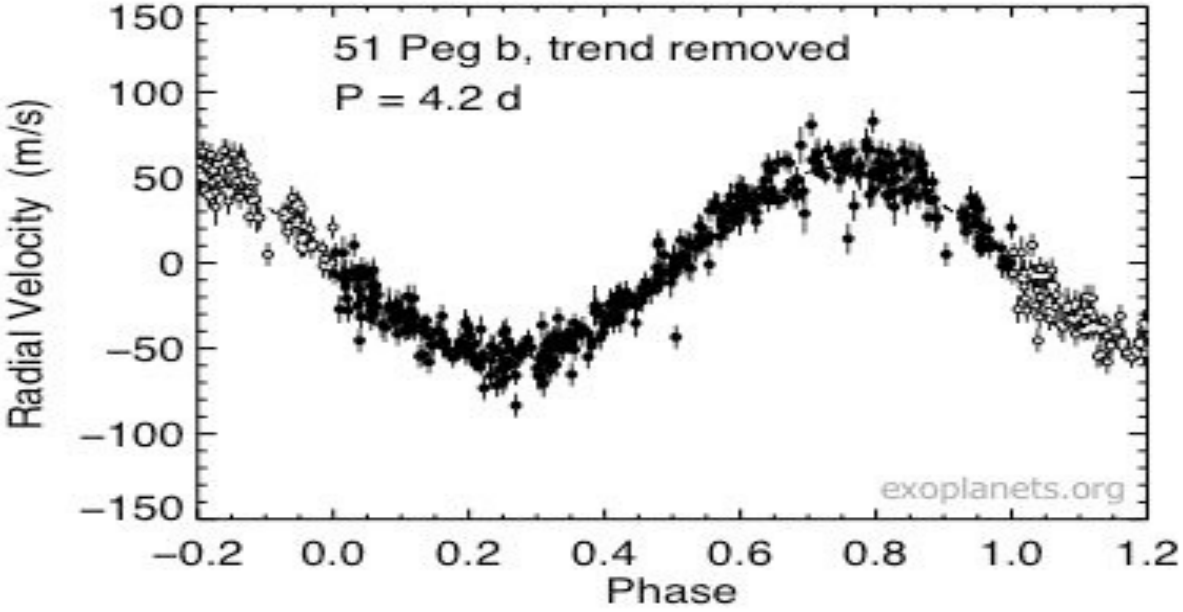
- WATCHING FOR WOBBLE
  Radial Velocity
- SEARCHING FOR SHADOWS
  Transits
- LIGHT IN A GRAVITY LENS
  Gravitational Microlensing
- Timing
  (eclipses, pulsation)
- TAKING PICTURES
  Direct Imaging
- MINISCULE MOVEMENTS
  Astrometry

1995: the first exoplanet (really)

51 Peg b (Mayor & Queloz 1995)

Primary: G2V
$M_2 \, sen \, i = 0.468 \, M_{Jup}$
$P = 4.23077$ d
$a = 0.052$ AU

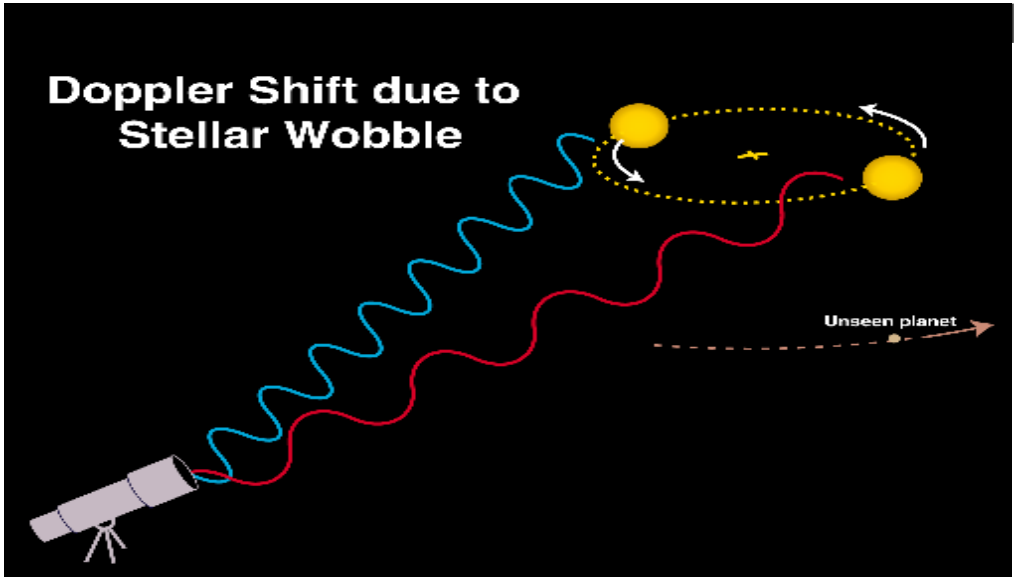


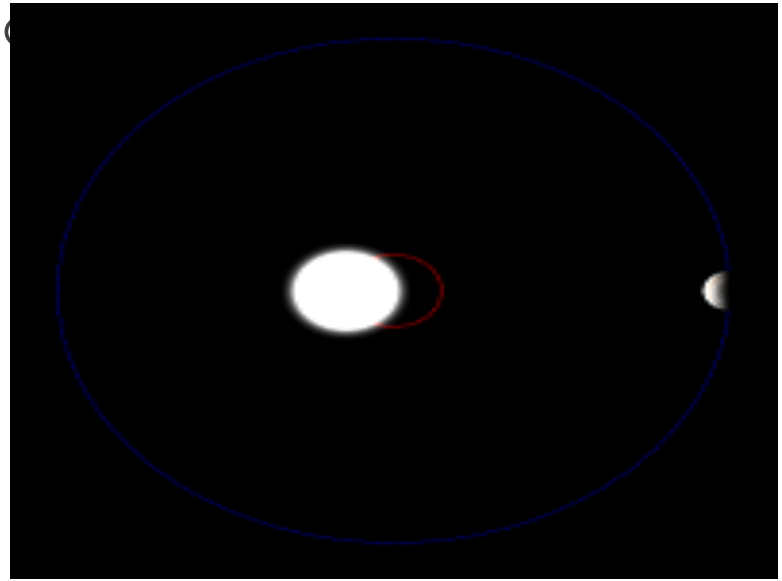


Exoplanets: radial velocity

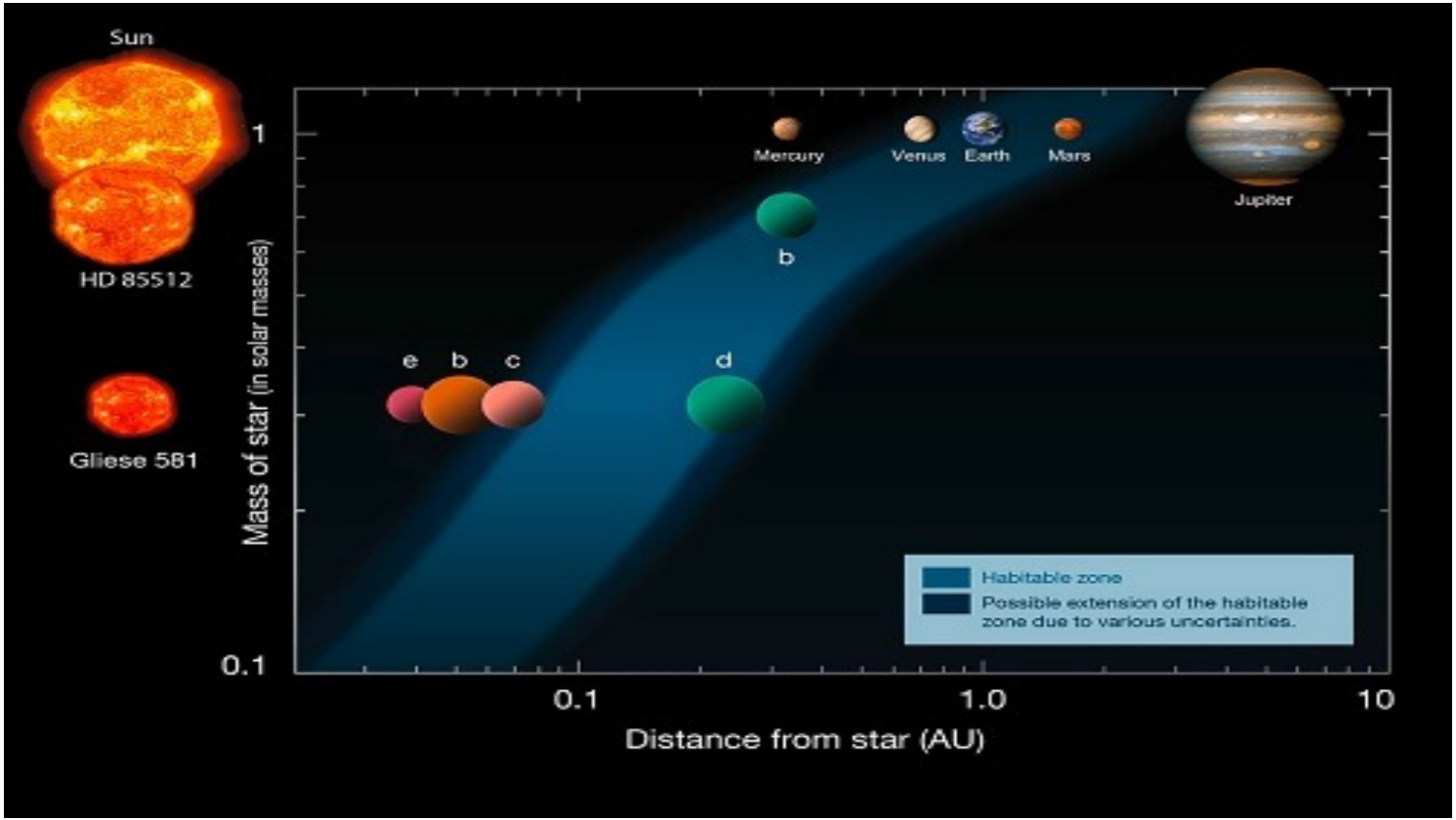
Desplazamiento del **baricentro** del sistema estrella-planeta → efecto **Doppler**

Estrella se **aleja**: espectro desplazado al **rojo**

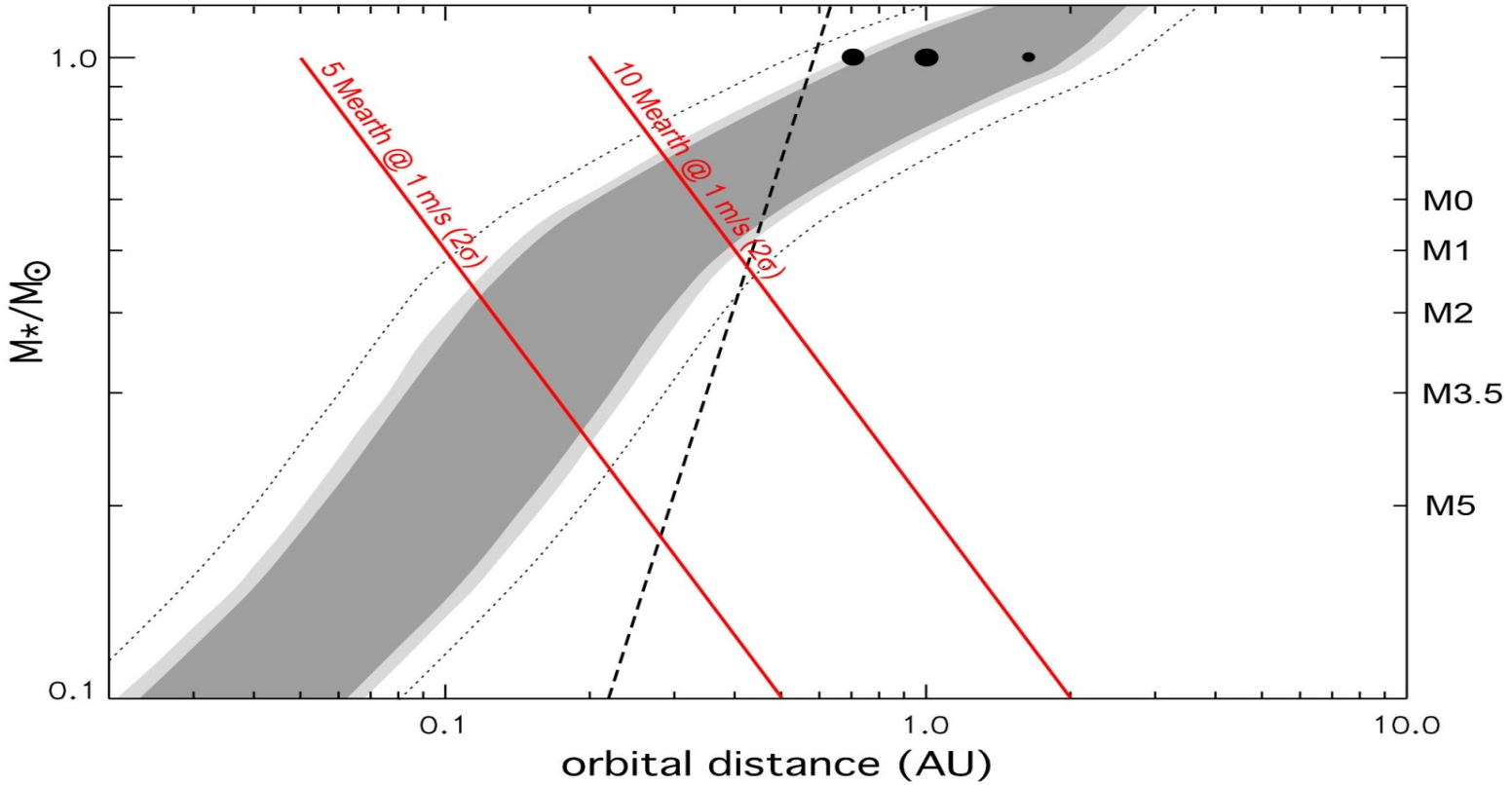




(the smaller, the better)



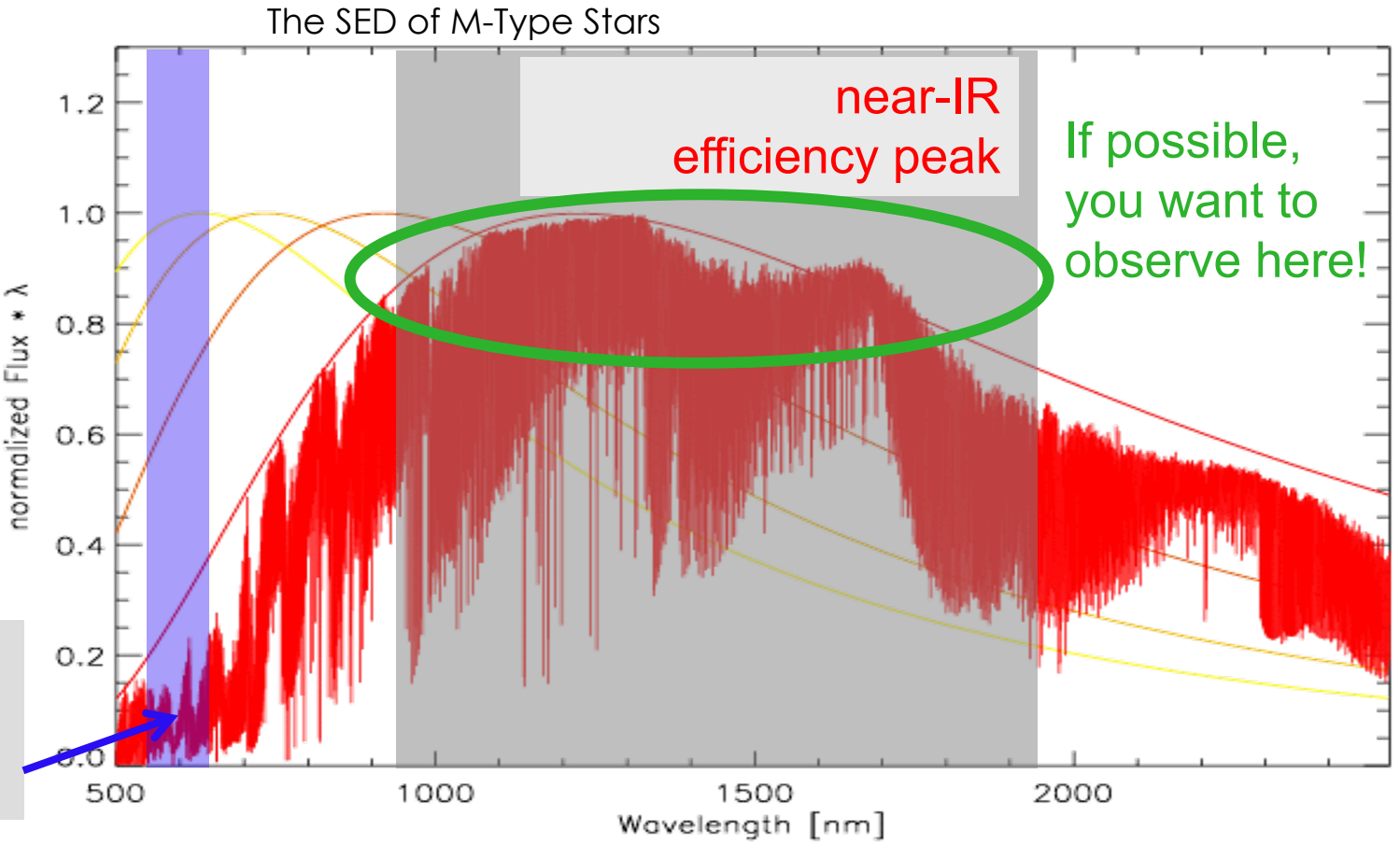
(the smaller, the better)



(the redder, the better)

HARPS Δλ = 533-691 nm

But M dwarfs are faint (and active) in the optical!

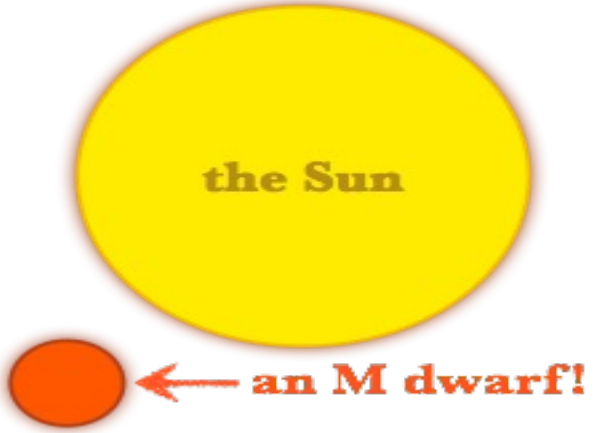


"classical" *visible light* RV instruments

Why M stars?

- **Bigger Doppler signal**

→ the **lower masses** of the stars means the gravitational tug of an Earth-mass planet will result in a **larger stellar motion**, resulting in a **bigger Doppler signal** than observed for Sunlike stars.

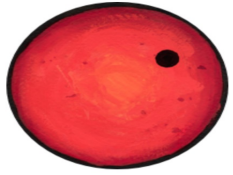


- **HZ is much closer**

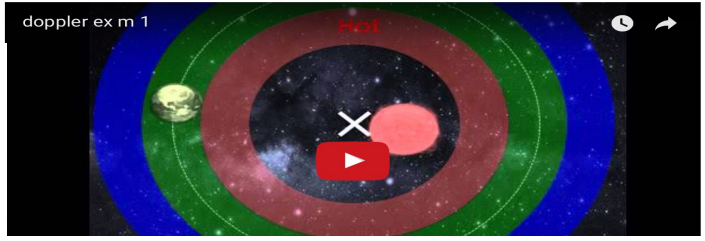
→ are also **cooler**, the HZ is much **closer** to the star. The **shorter orbital radii** results in **shorter orbital periods**, allowing us to discover them using less telescope time.

- **Large fracction block**

→ increases the probability the planets will **transit** → opportunity to characterize their atmospheres, and percentage of light blocked by a transiting planet is larger.



And here is the motion induced by the same planet around an M dwarf:



http://hpf.psu.edu/the-purpose-of-hpf/

carmenes

El cazador de exoplanetas de Calar Alto

CARMENES. ¿Qué?: un nuevo espectrógrafo óptico-infrarrojo. ¿Dónde?: en Calar Alto, Almería. ¿Cuándo?: su primera luz en 2015. ¿Cómo?: con el método de velocidad radial. ¿Para qué?: para descubrir planetas como el nuestro alrededor de las estrellas más cercanas al Sol.

MAX-PLANCK-GESELLSCHAFT CSIC ICE INSTITUT FÜR ASTROPHYSIK GÖTTINGEN TLS DFG DLR Unión Europea Fondo Europeo de Desarrollo Regional "Una manera de hacer Europa" Calar Alto

IPARCOS

carmenes

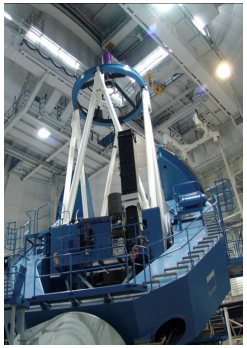
CARMENES

carmenes

Calar
Alto high-
Resolution search for
M dwarfs with
Exoearths with
Near-infrared and visible
Echelle
Spectrographs

Calar Alto

MPIA (Heidelberg) • **IAA** (Granada) • **LSW** (Heidelberg) • **ICE** (Barcelona) • **IAG** (Göttingen) • **IAC** (Tenerife) • **TLS** (Tautenburg) • **UCM** (Madrid) • **HS** (Hamburg) • **CAB** (Madrid) • **CAHA** (50% MPG + 50% CSIC)



Unión Europea
Fondo Europeo de Desarrollo Regional
"Una manera de hacer Europa"

MAX-PLANCK-GESELLSCHAFT

CSIC

Calar Alto

DFG

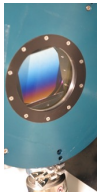
http://carmenes.caha.es/

IPARCOS

carmenes

CARMENES

<u>At UCM</u>: CCD detector characterization (Art. 83 with Fractal SLNE) @ LICA

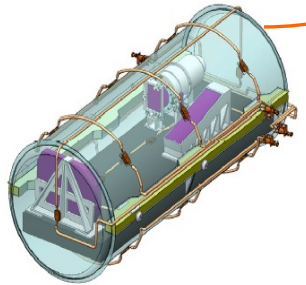


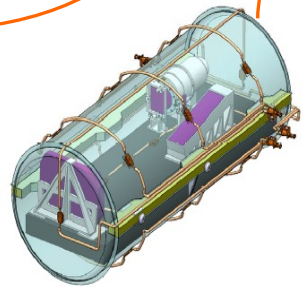
David Montes

CARMENES, the instrument

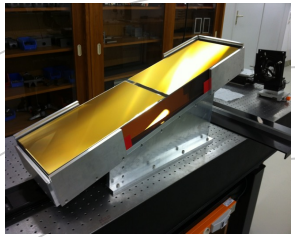
carmenes

Two fibre-fed stabilised échelle spectrographs (R=82,000) inside the coudé room of the 3.5 m CA telescope (NIR and VIS)





IPARCOS



CARMENES

David Montes

CARMENES, the instrument

Precision ~1 m/s (SNR=150, J=9, 15 min)

carmenes

Basic parameters	NIR channel	VIS channel
Δλ [μm]	0.96 - 1.71 (28 orders)	0.52 - 0.96 (61 orders)
R	80 400 2.8 Pix sampling	96 500 2.5 Pix sampling
Cross disperser	Grism, infrasil	Grism, LF5 glass
Working *T* [K]	In vacuum, Stabilized at ~138	In vacuum, stabilized at ambient T ~295
Detector(s)	2 x 2kx2k Hawaii 2-RG (2.5 μm)	1 x 4kx4k e2v CCD231-84
Calibration λ	U-Ne [F-P etalon]	U-Ne, Th-Ne, U-Ar [F-P etalon]

IPARCOS

carmenes

CARMENES

CARMENES radial velocity instrument

carmenes

→ Search for **Earth-like habitable planets** around low-mass stars (**M-stars**)

– Number and formation mechanisms

– Properties and habitability

• Survey of **300 M dwarf** stars simultaneously in visible light and near-infrared

• GermanSpanish instrument for 3.5-m Calar Alto

• 600 - 750 "useful" nights guaranteed

• Survey on-going **since Jan 1, 2016**

- "***CARMENES instrument overview***"
  (Quirrenbach et al. 2014SPIE.9147E..1FQ)
- "***CARMENES: an overview six months after first light***"
  (Quirrenbach et al. 2016SPIE.9908E..12Q)
- "***CARMENES: high-resolution spectra and precise radial velocities in the red and infrared***"
  (Quirrenbach et al. 2018SPIE10702E..0WQ)
- "***The CARMENES M-dwarf planet survey***"
  (Quirrenbach et al. 2020SPIE11447E..3CQ)

CARMENES input catalogue

→ CARMENES **input catalogue** of
~2200 nearby bright **M dwarfs** (δ > −23 deg)

→ **~300 GTO (G**uaranteed **T**ime **O**bservations**) targets**

→ **CARMENCITA**:
CARMENES **C**ool dwarf **I**nformation and da**T**a **A**rchive

→ **Science preparation** (Low-res & High-res spectra)
- "***CARMENES: data flow***"
(Caballero et al. 2016SPIE.9910E..0EC)

IPARCOS

carmenes

CARMENES science preparation

CARMENES input catalogue of M dwarfs.

IPARCOS

carmenes

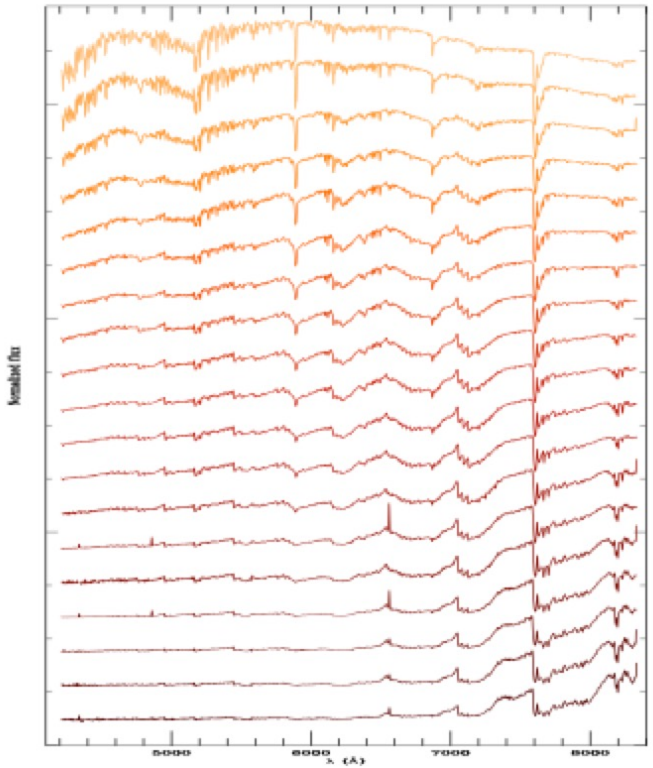
CARMENES science preparation

CARMENES input catalogue of M dwarfs.

David Montes

- I. Low-resolution spectroscopy with CAFOS

(Alonso-Floriano, et al., 2015A&A...577A.128A)



Spectral types for all 753 stars, of which 305 are new and 448 are revised.

IPARCOS

carmenes

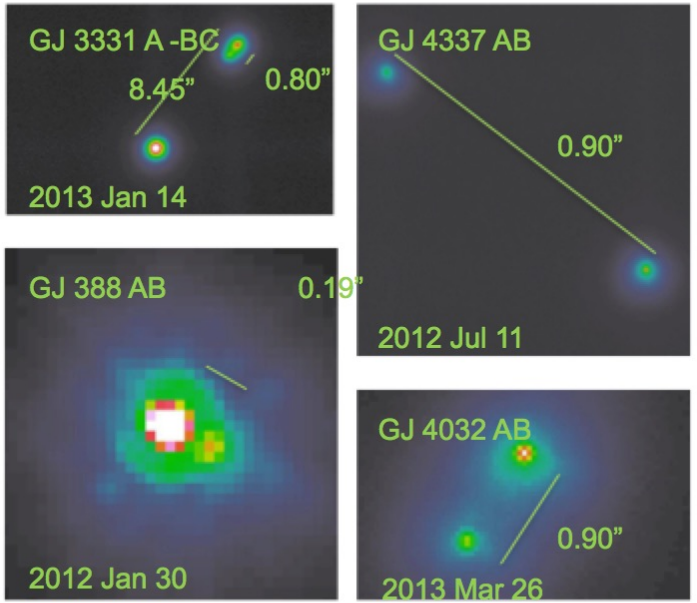
CARMENES science preparation

CARMENES input catalogue of M dwarfs.

David Montes

- II. High-resolution imaging with FastCam

(Cortés-Contreras, et al., 2017A&A...597A..47C)



From the 490 observed stars, we detected 80 companions in 76 systems, of which 30 are new discoveries. Another six companion candidates require additional astrometry to confirm physical binding. The multiplicity fraction in our observed sample is 16.7 ± 2.0%.

IPARCOS

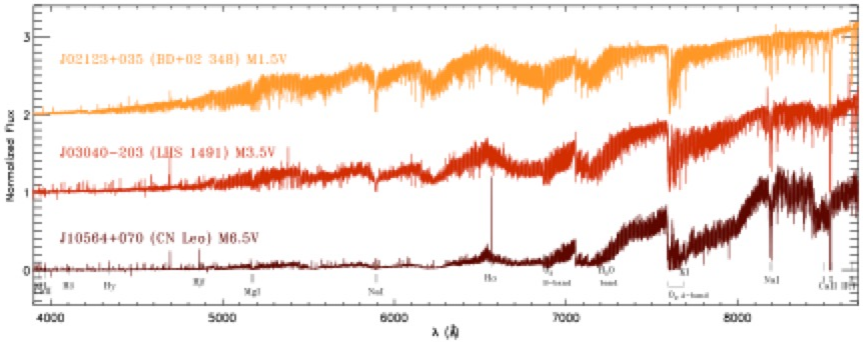
carmenes

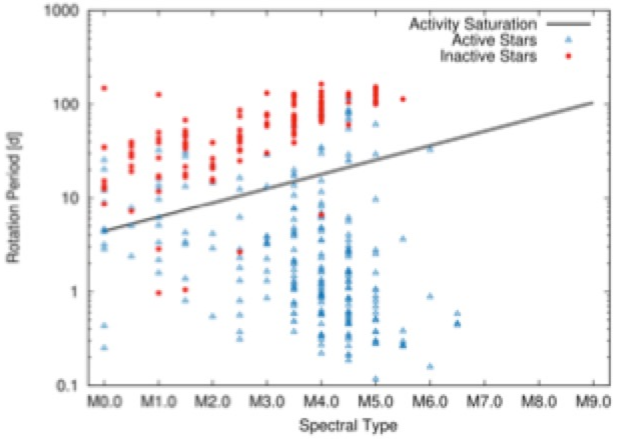
CARMENES science preparation

CARMENES input catalogue of M dwarfs.

David Montes

- III. Rotation and activity from high-resolution spectroscopic observations
(Jeffers, et al., 2018A&A...614A..76J)





IPARCOS

carmenes

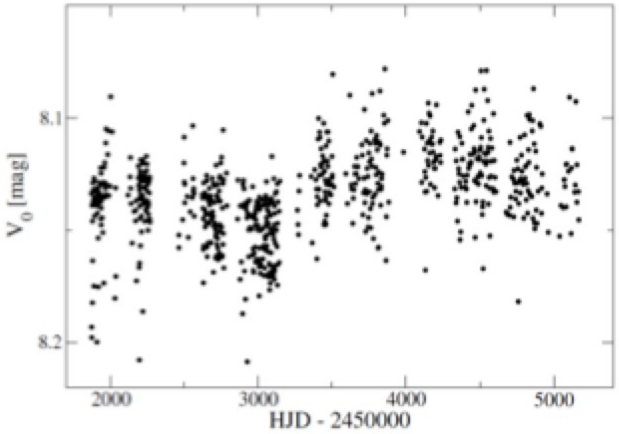
CARMENES science preparation

CARMENES input catalogue of M dwarfs.

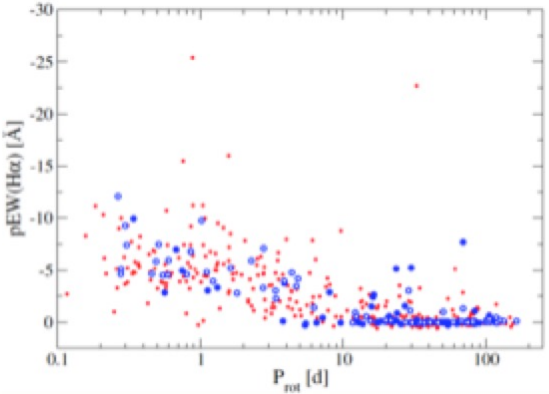
David Montes

- IV. New rotation periods from photometric time series

(Díez Alonso, et al. 2018, A&A, arXiv:1810.03338)



Rotational periods from long-term photometric monitoring surveys (MEarth, ASAS, SuperWASP, NSVS, Catalina, ASASSN, K2, and HATNet).



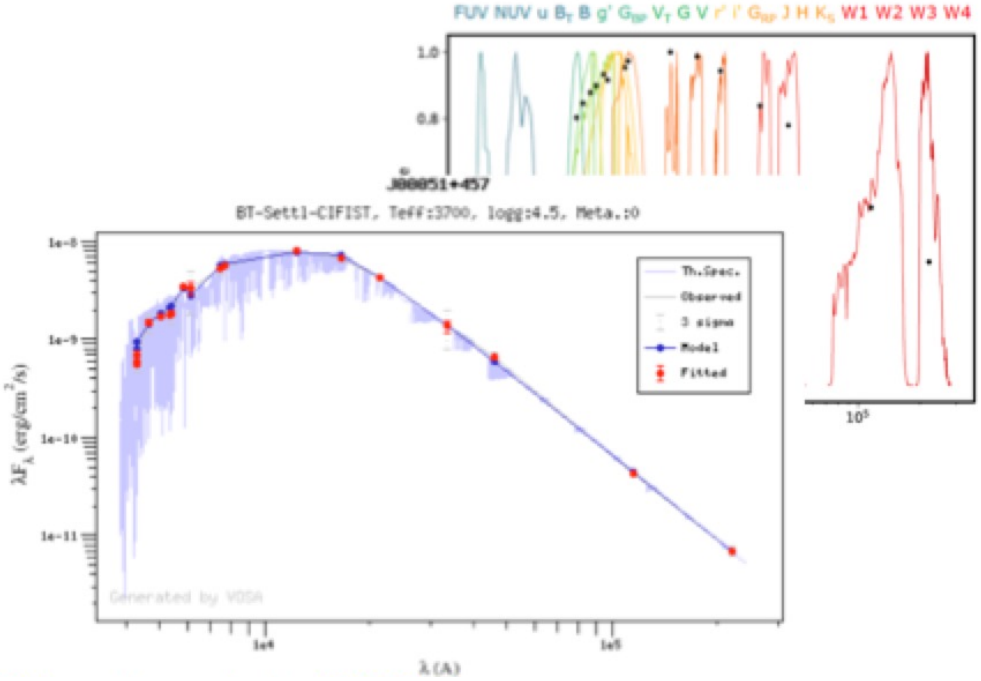
IPARCOS

carmenes

CARMENES science preparation

CARMENES input catalogue of M dwarfs.

Spectral energy distributions and luminosities of M dwarfs



Cifuentes et al. [2020A&A...642A.115C]

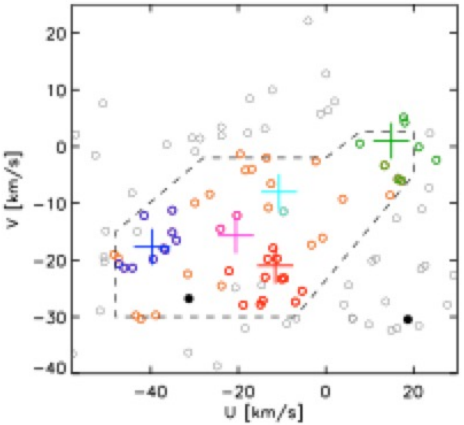
IPARCOS

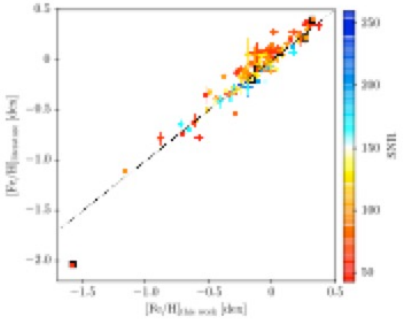
carmenes

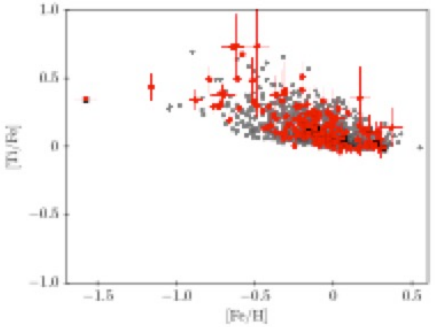
CARMENES science preparation

CARMENES input catalogue of M dwarfs.

Calibrating the metallicity of M-dwarfs with wide visual binaries (FGK+M)







(Montes et. al., 2018MNRAS.479.1332M).

IPARCOS

carmenes

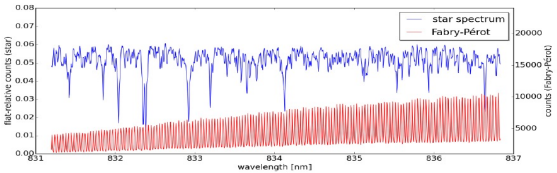
CARMENES science exploitation

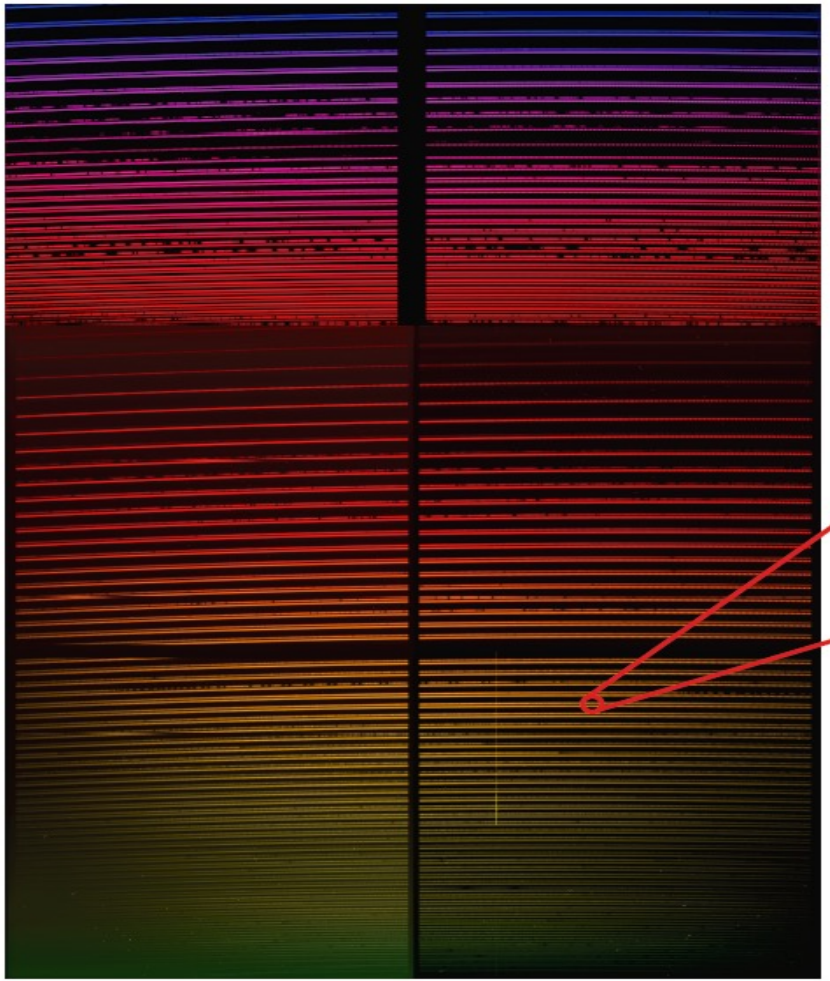
The CARMENES search for exoplanets around M dwarfs.

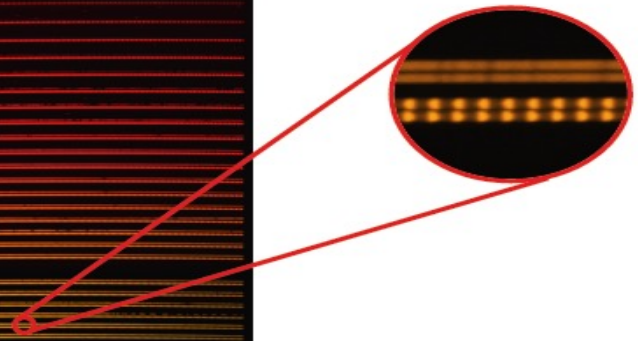
CARMENES spectra

NIR: 0.96-1.71 µm,
28 orders
2 2kx2k Hawaii-2RG,
R = 80 400

VIS: 0.52-0.96 µm,
61 orders
4kx4k e2v CCD231-84,
R = 96 500

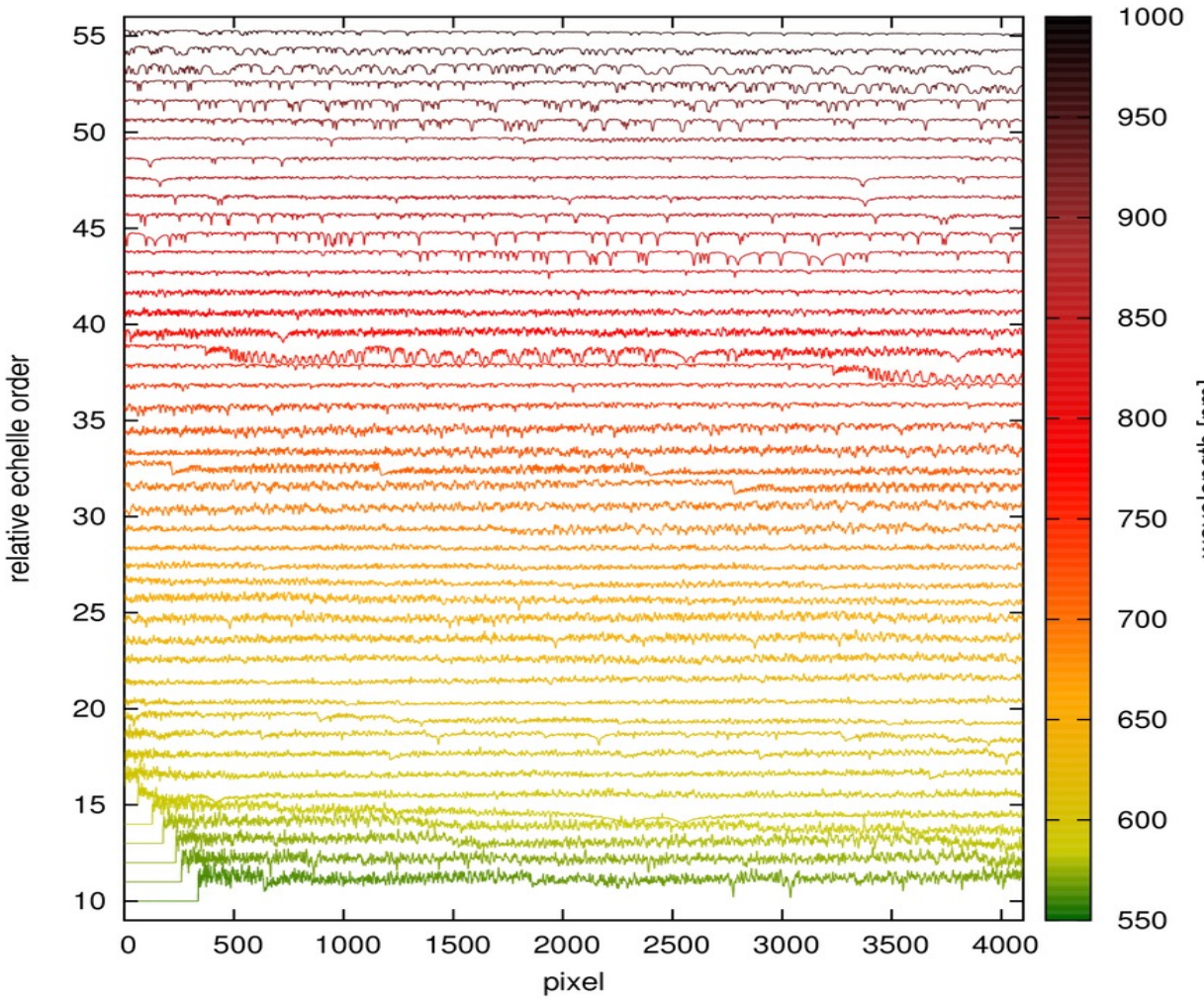






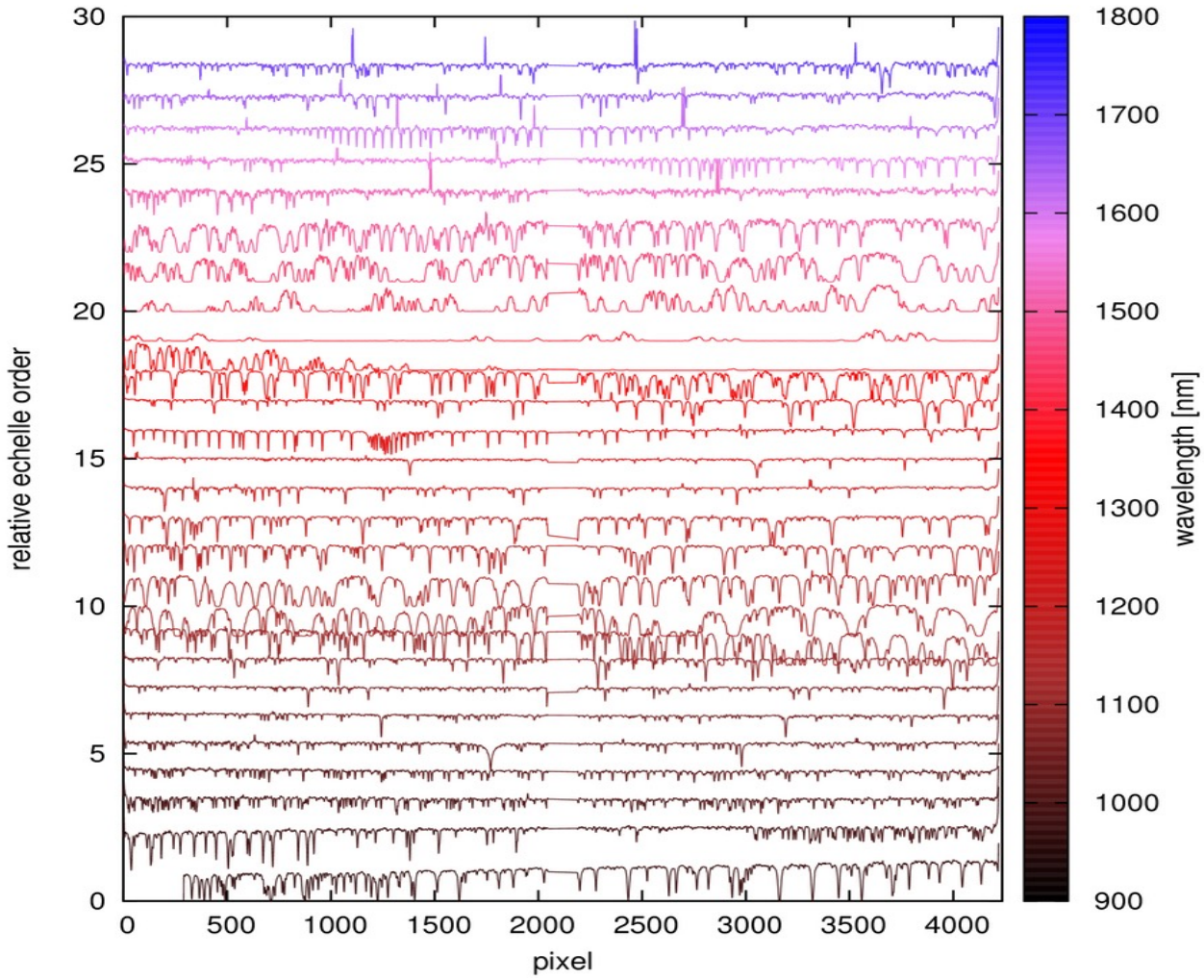
CARMENES spectra

VIS: 0.52-0.96 µm,
61 orders
4kx4k e2v CCD231-84,
R = 96 500



CARMENES spectra

NIR: 0.96-1.71 µm,
28 orders
2 2kx2k Hawaii-2RG,
R = 80 400

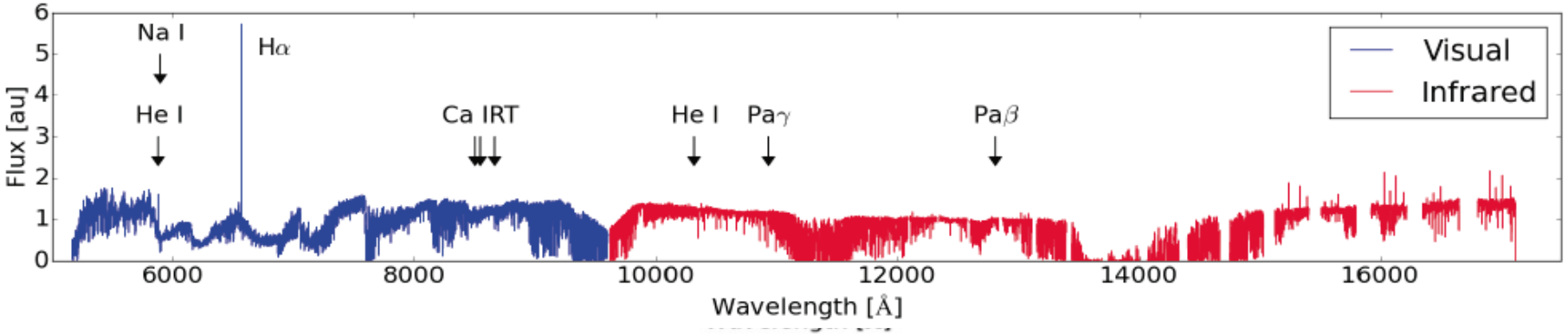


carmenes

CARMENES spectra

VIS + NIR Observations:

VIS: 0.52-0.96 μm, 4kx4k e2v CCD231-84, *R* = 96 500
NIR: 0.96-1.71 μm, 2 2kx2k Hawaii-2RG, *R* = 80 400



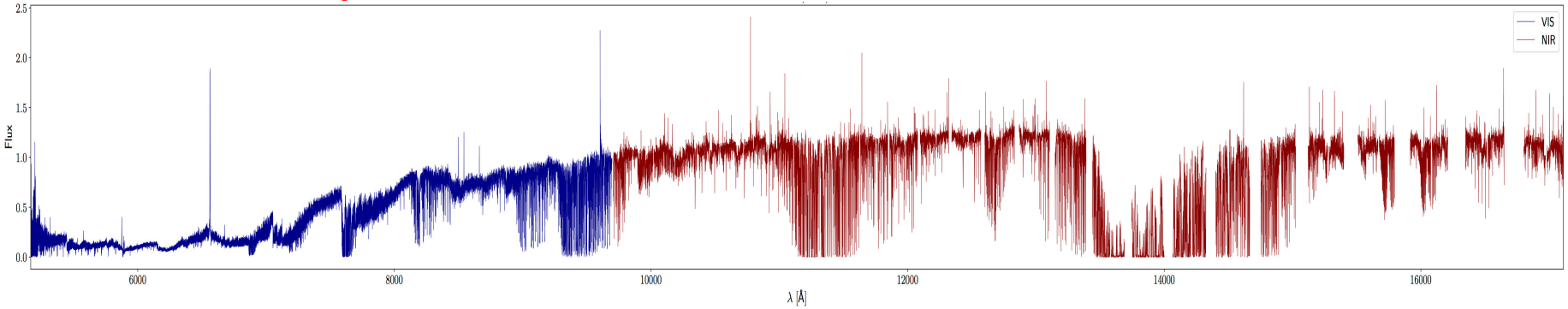
(YZ CMi, M4.5Ve)
Poster #191, Czesla et al.

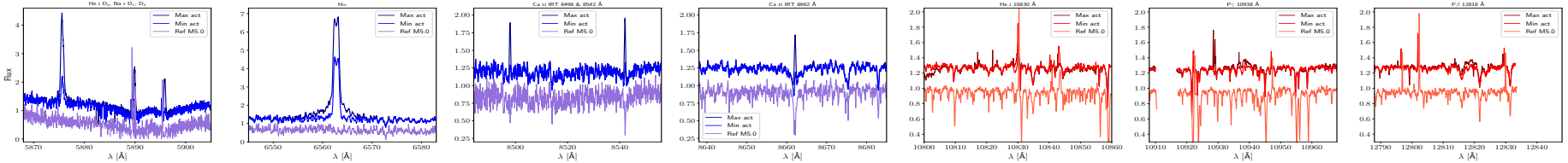
CARMENES spectra

VIS + NIR Observations:

VIS: 0.52-0.96 μm, 4kx4k e2v CCD231-84, *R* = 96 500
NIR: 0.96-1.71 μm, 2 2kx2k Hawaii-2RG, *R* = 80 400

Estrella M5.5V





IPARCOS

carmenes

CARMENES science exploitation

The CARMENES search for exploitation around M dwarfs.

David Montes

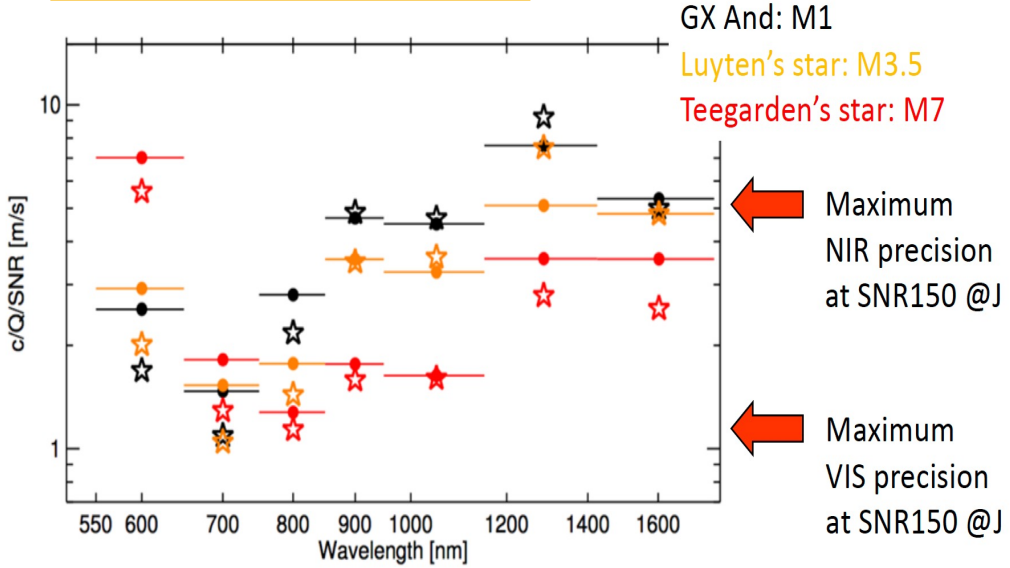
The CARMENES search for exoplanets around M dwarfs

carmenes

High-resolution optical and near-infrared spectroscopy of 324 survey stars

A. Reiners[1,*], M. Zechmeister[1], J. A. Caballero[2,3], I. Ribas[4], J. C. Morales[4], S. V. Jeffers[1], P. Schöfer[1], L. Tal-Or[1], A. Quirrenbach[3], P. J. Amado[5], A. Kaminski[3], W. Seifert[3], M. Abril[5], J. Aceituno[6], F. J. Alonso-Floriano[8,12], ...

2018A&A...612A..49R



IPARCOS

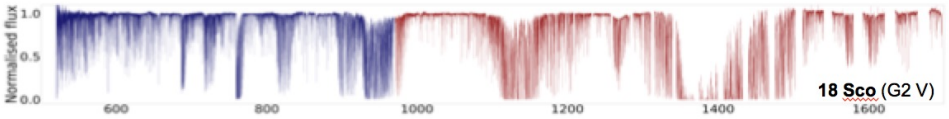
carmenes

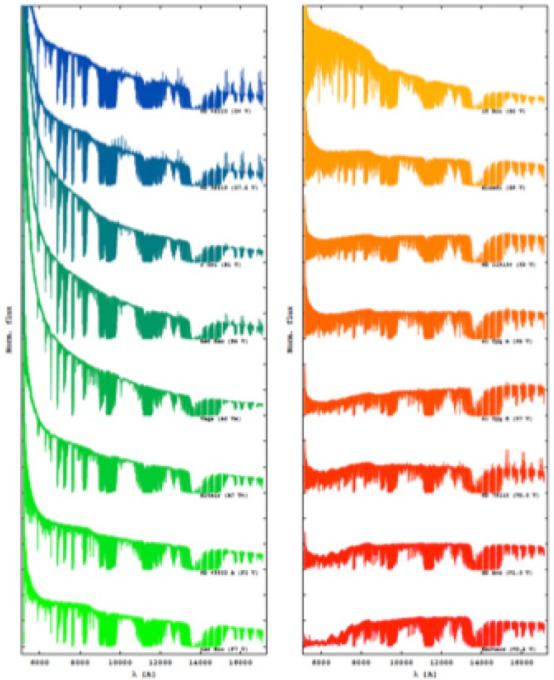
CARMENES science exploitation

The CARMENES search for exoplanets around M dwarfs.

David Montes

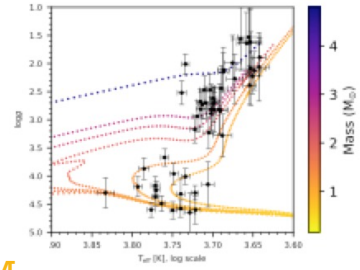
CARMENES OBAFGKM spectral library





Full wavelength-coverage spectra (**VIS**: 0.52-0.96 μm **+ NIR**: 0.96-1.71 μm) of 16 representative main-sequence stars with spectral types from **O4V** to **F** (left) and **G** to **M3.5V** (right).

Stellar atmospheric parameters of **FGK**-type stars from high-resolution VIS and NIR CARMENES spectra using the EW method and *StePar*.



Caballero et al. 2019, in prep.

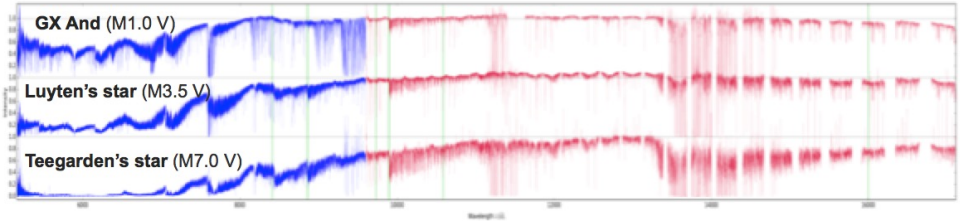
Marfil et al. 2020MNRAS.492.5470M

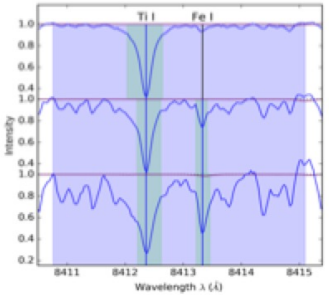
CARMENES science exploitation

The CARMENES search for exoplanets around M dwarfs.

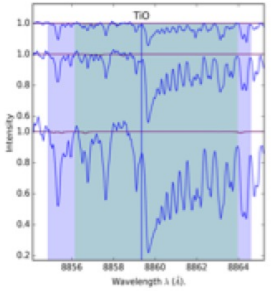
David Montes

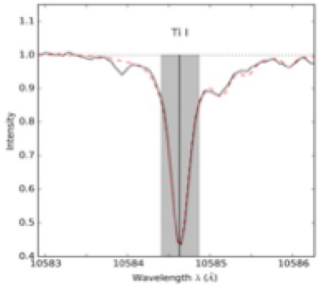
Spectral synthesis of CARMENES M-type stars: stellar parameters

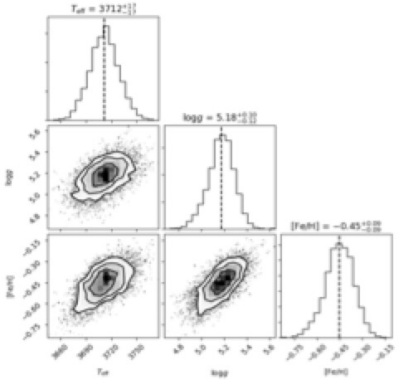




We used the *Turbospectrum* code along with PHOENIX model atmospheres to generate the We calculated the probability distribution of the stellar parameters (T_{eff}, **log** ***g*** and **[Fe/H]**) using the *SteParSyn* code (Tabernero et al. 2018), which implements a MCMC algorithm.







Marfil et al. 2021 in prep

IPARCOS

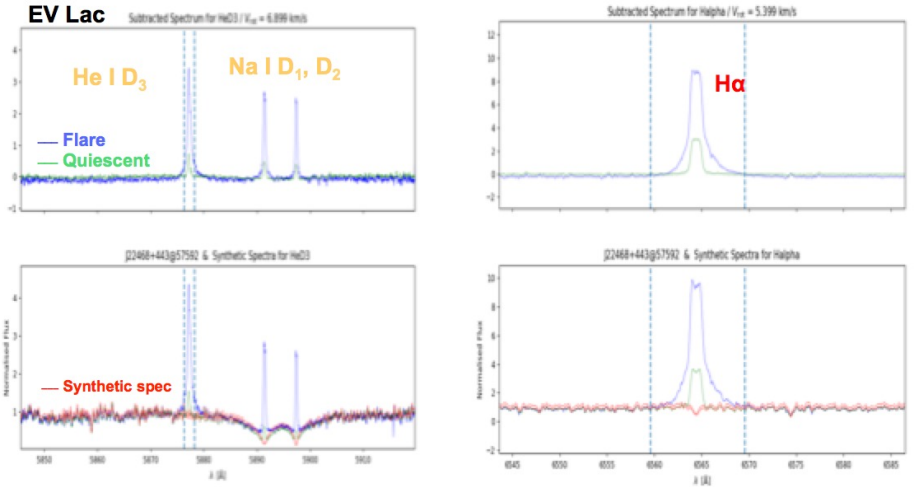
carmenes

CARMENES science exploitation

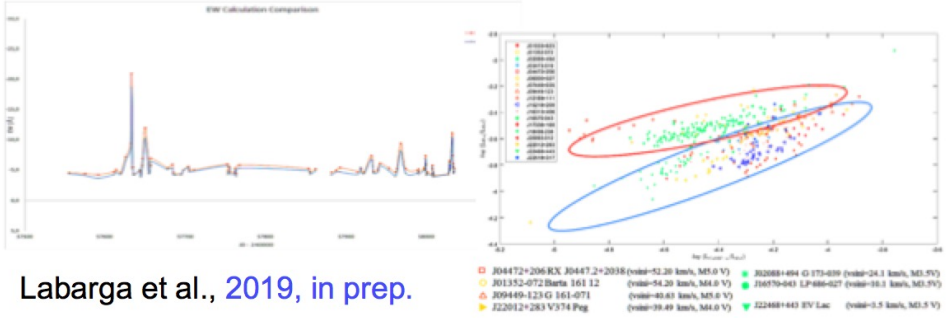
The CARMENES search for exoplanets around M dwarfs.

David Montes

The chromospheric activity of CARMENES M dwarfs



The spectral subtraction have been performed by means of the *Python* code ***iSTARMOD***, based on a former code *STARMOD* (Barden 1985; Montes et al. 2000).



Labarga et al., 2019, in prep.

CARMENES science exploitation

The CARMENES search for exoplanets around M dwarfs.

David Montes

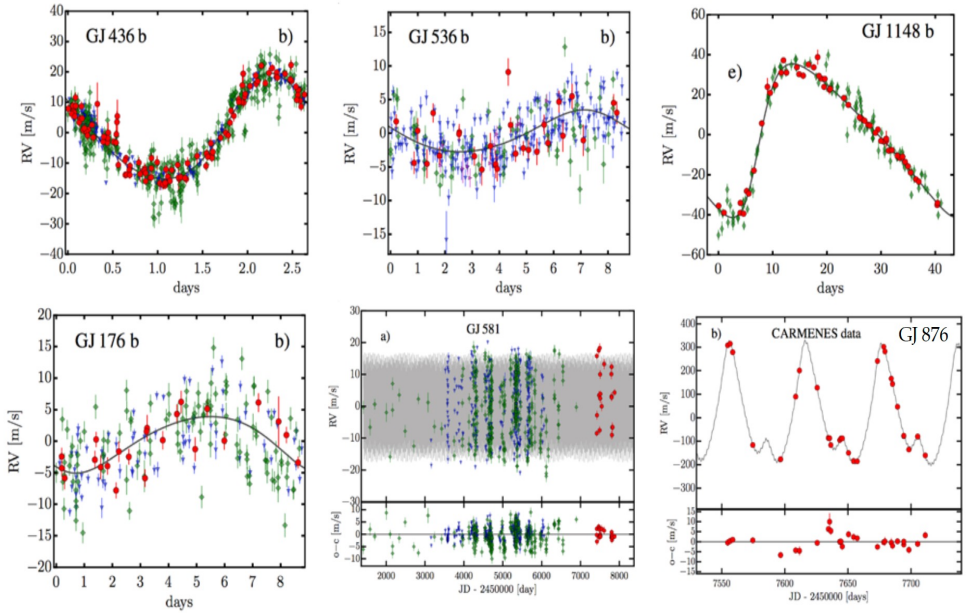
Confirmation of exoplanets

The CARMENES search for exoplanets around M dwarfs

First visual-channel radial-velocity measurements and orbital parameter updates of seven M-dwarf planetary systems★

T. Trifonov[1], M. Kürster[1], M. Zechmeister[2], L. Tal-Or[2], J.A. Caballero[3,5], A. Quirrenbach[5], I. Ribas[7], A

2018A&A...609A.117T



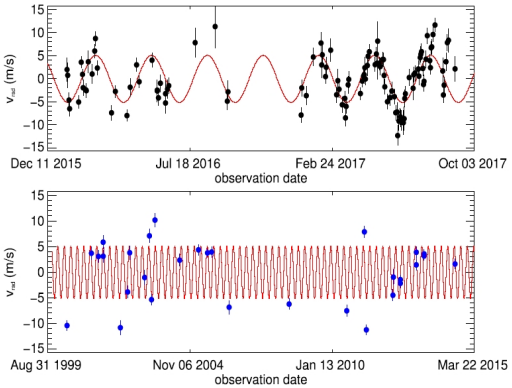
CARMENES science exploitation

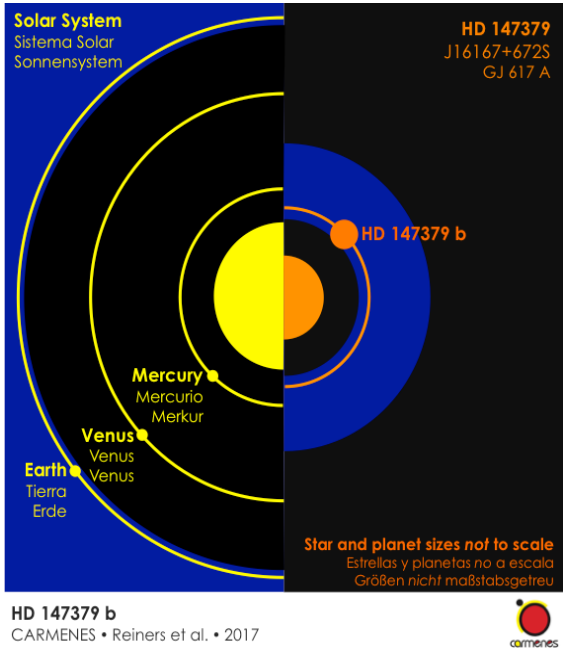
The CARMENES search for exoplanets around M dwarfs.

David Montes

First CARMENES exoplanets

"The CARMENES search for exoplanets around M dwarfs. ***HD147379 b****: A nearby Neptune in an early-M dwarf's temperate zone".*
Reiners, et al. 2018 Astronomy & Astrophysics Letters, A&A 609, L5

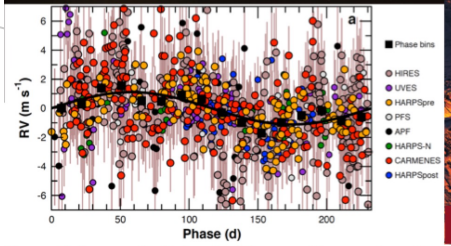


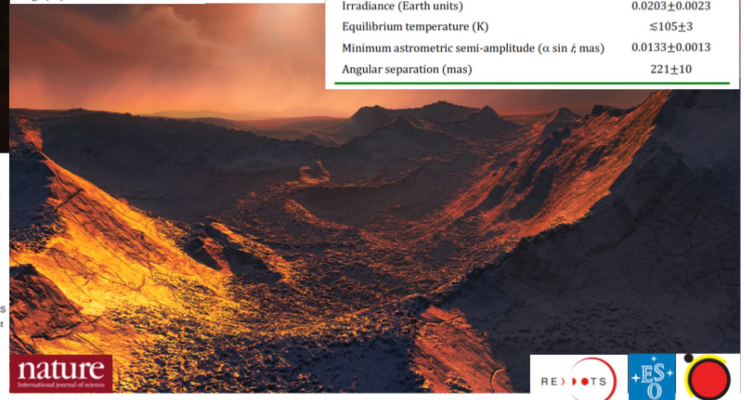


Supertierra fría orbitando la estrella de Barnard

Star parameter	Value
Spectral type	M3.5 V
Mass ($M_\odot$)	0.163±0.022
Radius ($R_\odot$)	0.178±0.011
Luminosity ($L_\odot$)	0.00329±0.00019
Effective temperature (K)	3278±51
Rotation period (d)	140±10
Age (Ga)	7–10

Planet parameter	Value
	Barnard's star b
Orbital period (d)	$232.80^{+0.38}_{-0.41}$
Radial velocity semi-amplitude (m s^{-1})	1.20±0.12
Eccentricity	$0.32^{+0.10}_{-0.15}$
Argument of periastron (deg)	107^{+19}_{-22}
Mean longitude at BJD2455000.0 (deg)	203±7
Minimum mass ($M \sin i$, $M_\oplus$)	3.23±0.44
Orbital semi-major axis (au)	0.404±0.018
Irradiance (Earth units)	0.0203±0.0023
Equilibrium temperature (K)	≤105±3
Minimum astrometric semi-amplitude ($\alpha \sin i$, mas)	0.0133±0.0013
Angular separation (mas)	221±10





"A candidate super-Earth planet orbiting near the snow line of Barnard's star", I. Ribas, M. Tuomi, A. Reiners, et al., Nature 563, 365–368 (2018)

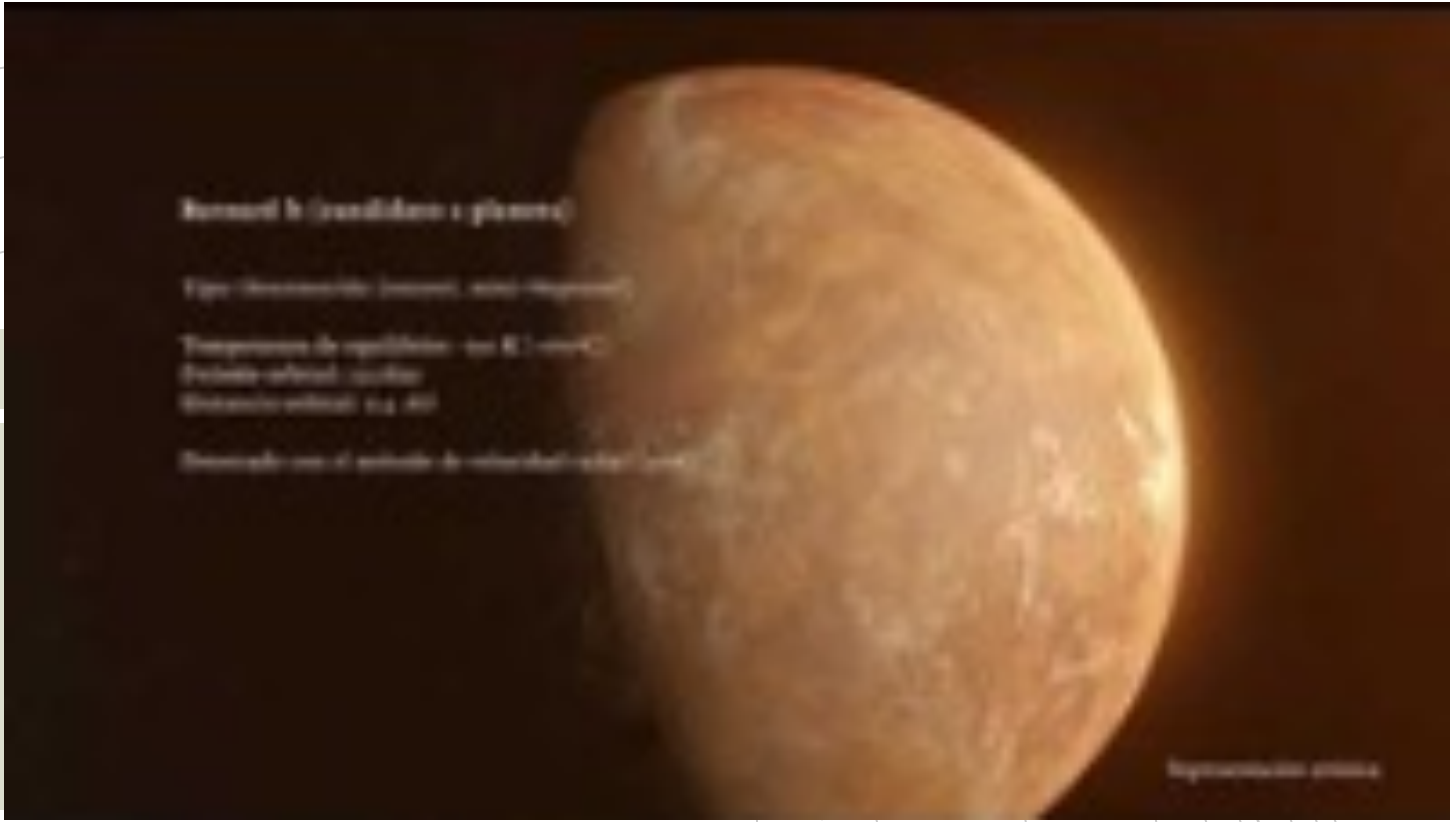
CARMENES science exploitation

The CARMENES search for exoplanets around M dwarfs.

Publication en Nature:

- ***A candidate super-Earth planet orbiting near the snow line of Barnard's star***
I. Ribas, M. Tuomi, A. Reiners, et al.
Nature 15 nov 2018
Nature 563, 365–368 (2018)

Planeta órbitando alrededor de la estrella de Barnard.

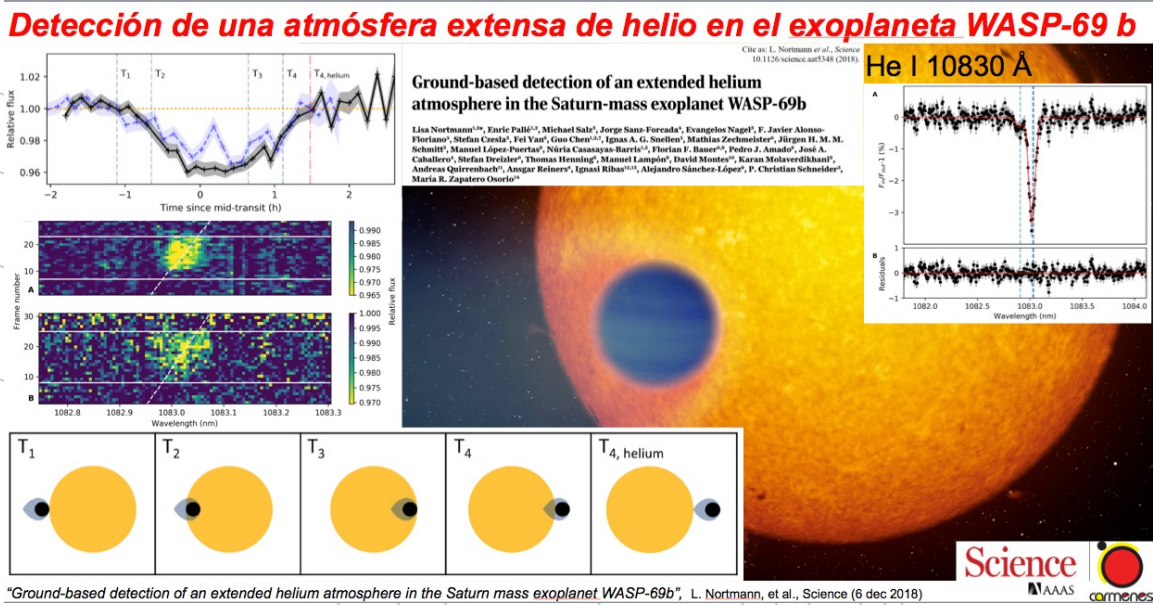


https://youtu.be/pvQ1I1Q0RJs

CARMENES science exploitation

CARMENES exoplanet atmospheres characterization

David Montes

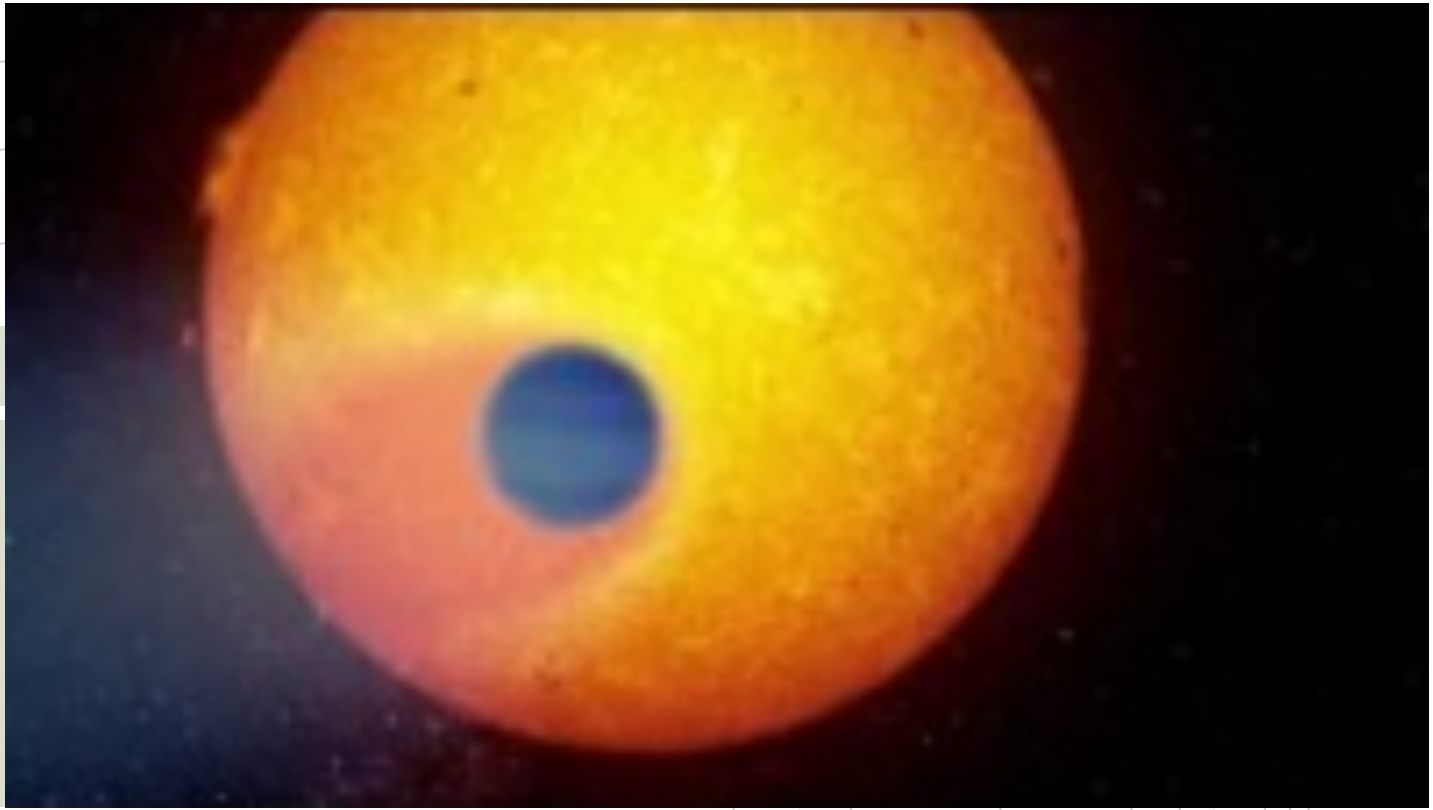


Publications:

1: "***Ground-based detection of an extended helium atmosphere in the Saturn mass exoplanet WASP-69 b***",
Nortmann, L., et al. Science 21 Dec 2018: Vol. 362, Issue 6421, pp. 1388-1391

2: "**Detection of He I 10830 Å absorption on HD 189733 b with CARMENES high-resolution transmission spectroscopy**",
Salz, M., et al. A&A 620, A97 (2018)

3: "**Multiple water band detections in the CARMENES near-infrared transmission spectrum of HD 189733 b**",
Alonso-Floriano, F. J., et al., 2019A&A...621A..74A



Simulación del exoplaneta gigante **WASP-69** b que pierde su atmósfera en forma de cola

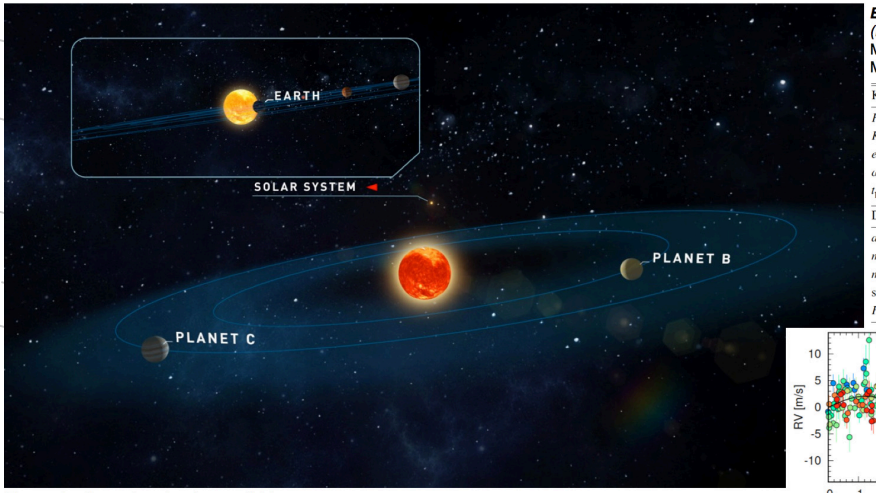
https://youtu.be/auOFiackQpg

CARMENES science exploitation

The CARMENES search for exoplanets around M dwarfs.

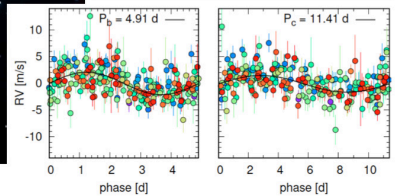
David Montes

Dos planetas templados de masas ≈ a la Tierra en la Estrella de Teegarden



Estrella deTeegarden
(Karmn J02530+168)
M7.0 V, d = 3.831 pc = 12.5 ly
$M = 0.089\ M_\odot$, $R = 0.107\ R_\odot$

Keplerian parameters	Planet b	Planet c
P [d]	$4.9100^{+0.0014}_{-0.0014}$	$11.409^{+0.009}_{-0.009}$
K [m/s]	$2.02^{+0.19}_{-0.20}$	$1.61^{+0.19}_{-0.19}$
e [a]	$0.00^{+0.16}$	$0.00^{+0.16}$
ω [deg]	77^{+52}_{-79}	286^{+101}_{-74}
$t_p - 2\,458\,000$ [d]	$52.3^{+0.7}_{-1.1}$	$53.2^{+3.2}_{-2.3}$
Derived parameters		
a [au]	$0.0252^{+0.0008}_{-0.0009}$	$0.0443^{+0.0014}_{-0.0015}$
$m \sin i\ [M_\oplus]$	$1.05^{+0.13}_{-0.12}$	$1.11^{+0.16}_{-0.15}$
$m\ [M_\oplus]$ [b]	$1.25^{+0.68}_{-0.22}$	$1.33^{+0.71}_{-0.25}$
$\sin i$ [b]	$0.87^{+0.12}_{-0.31}$	
$F\ [S_\oplus]$ [c]	$1.15^{+0.08}_{-0.08}$	$0.37^{+0.03}_{-0.03}$



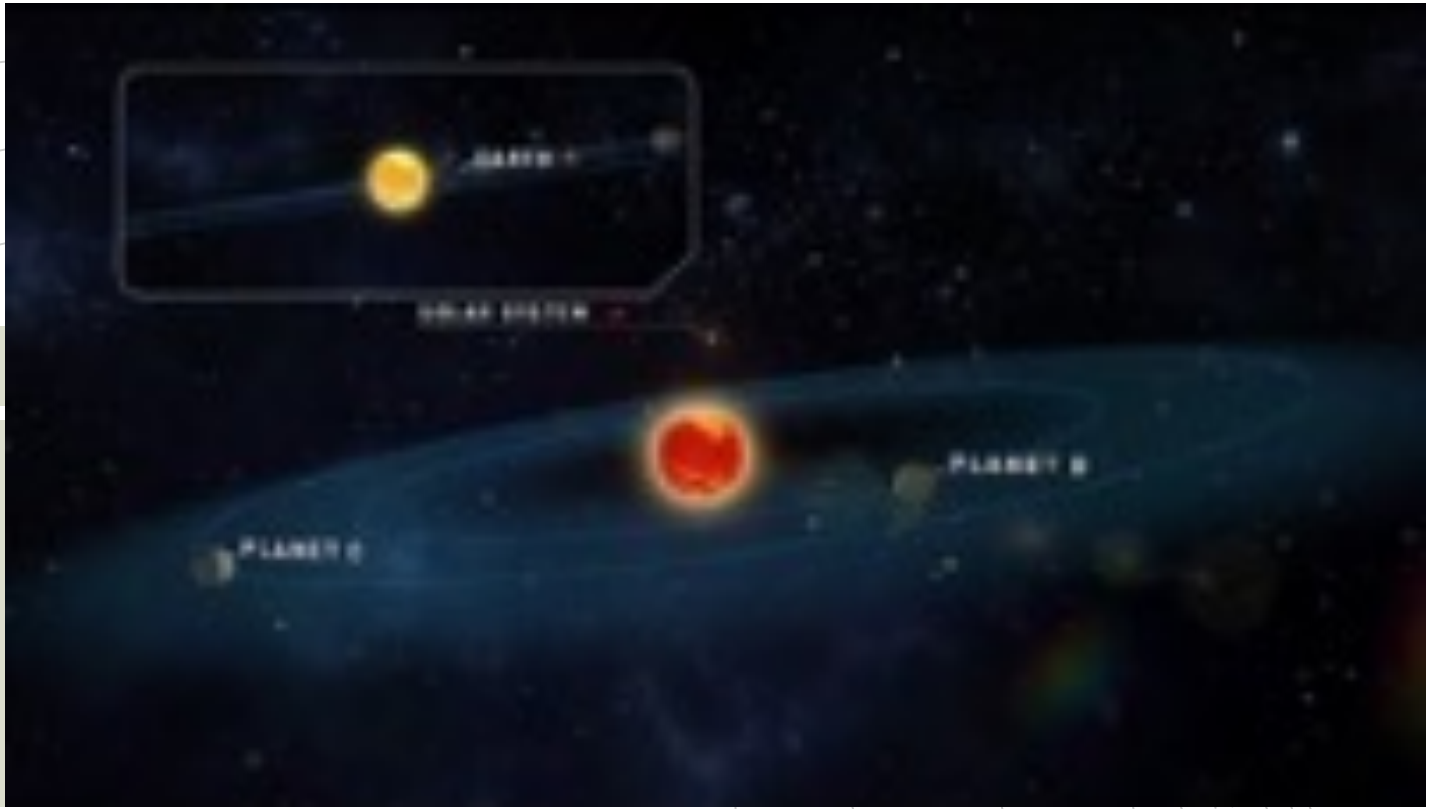
Teegarden b y c, dos planetas candidatos:
➔ cada uno con una masa mínima de 1.1 $M_\oplus$, orbitando con periodos de 4.91 y 11.4 d sin evidencia de tránsitos.
➔ la cuarta estrella mas cercana con planetas potencialmente habitables, después de Proxima Cen, Tau Ceti, y Luyten's Star.
➔ la estrella más pequeña en la que hasta ahora se ha podido determinar la masa de los planetas directamente.

The CARMENES search for exoplanets around M dwarfs
Two temperate Earth-mass planet candidates around Teegarden's Star,
Zechmeister et al. 2019, A&A, DOI: 10.1051/0004-6361/201935460

Publicación en A&A:

- "***The CARMENES search for exoplanets around M dwarfs. Two temperate Earth-mass planet candidates around Teegarden's Star***", de M. Zechmeister et al., que aparece en la revista Astronomy & Astrophysics el 18 de junio de 2019, 2019A&A...627A..49Z, - DOI https://doi.org/10.1051/0004-6361/201935460

Publicaciones adicionales:
- "***On the Habitability of Teegarden's Star planets***", Amri Wandel, Lev Tal-Or, 2019ApJ...880L..21W



Teegarden's Star"

Viaje desde nuestro sistema solar al sistema planetario de la Estrella de Teegarden. Simulación y representación artística

https://youtu.be/wlPfI5zUYyE

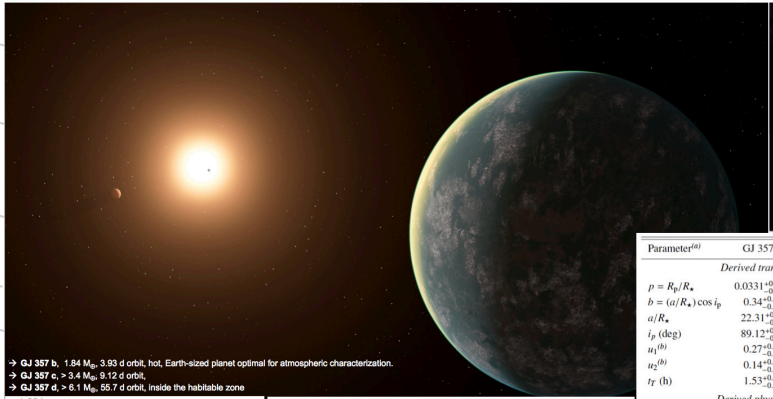
David Montes

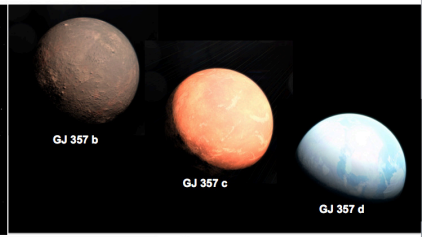
CARMENES science exploitation

The CARMENES search for exoplanets around M dwarfs + TESS.

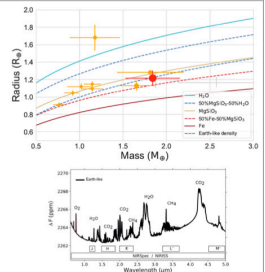
David Montes

Planetary system around the nearby M dwarf GJ 357 – TESS + CARMENES + ...





Parameter[a]	GJ 357 b	GJ 357 c	GJ 357 d
Derived transit parameters			
$p = R_p/R_\star$	$0.0331^{+0.0009}_{-0.0009}$	...	...
$b = (a/R_\star)\cos i_p$	$0.34^{+0.10}_{-0.14}$	...	...
$a/R_\star$	$22.31^{+0.76}_{-0.90}$	...	...
i_p (deg)	$89.12^{+0.37}_{-0.31}$	...	...
u_1[b]	$0.27^{+0.24}_{-0.17}$	...	...
u_2[b]	$0.14^{+0.29}_{-0.24}$	...	...
t_T (h)	$1.53^{+0.12}_{-0.11}$	...	...
Derived physical parameters			
M_p ($M_\oplus$)[c]	$1.84^{+0.31}_{-0.31}$	$> 3.40^{+0.46}_{-0.46}$	$> 6.1^{+1.0}_{-1.0}$
R_p ($R_\oplus$)	$1.217^{+0.084}_{-0.083}$	...	...
ρ_p (g cm^{-3})	$5.6^{+1.7}_{-1.3}$	...	...
g_p (m s^{-2})	$12.1^{+2.9}_{-2.5}$	...	...
a_p (au)	$0.035^{+0.002}_{-0.002}$	$0.061^{+0.004}_{-0.004}$	$0.204^{+0.015}_{-0.015}$
T_{eq} (K)[d]	525^{+11}_{-9}	$401.2^{+10.8}_{-10.7}$	$219.6^{+5.9}_{-5.9}$
S ($S_\oplus$)	$12.6^{+1.1}_{-0.8}$	$4.45^{+0.14}_{-0.14}$	$0.38^{+0.01}_{-0.01}$



- Planetary system around the nearby M dwarf GJ 357 including a transiting, hot, Earth-sized planet optimal for atmospheric characterization,
Luque, et al. 2019, A&A, DOI: https://doi.org/10.1051/0004-6361/201935801 - TESS Science Conference I - @TessSciCon1 #TESScon

Publicación en A&A:

- **Planetary system around the nearby M dwarf GJ 357 including a transiting, hot, Earth-sized planet optimal for atmospheric characterization,**
R. Luque, E. Pallé, D. Kossakowski, et al., 2019, A&A, 628, A39, 2019A&A...628A..39L, DOI: https://doi.org/10.1051/0004-6361/201935801

GJ357bcd

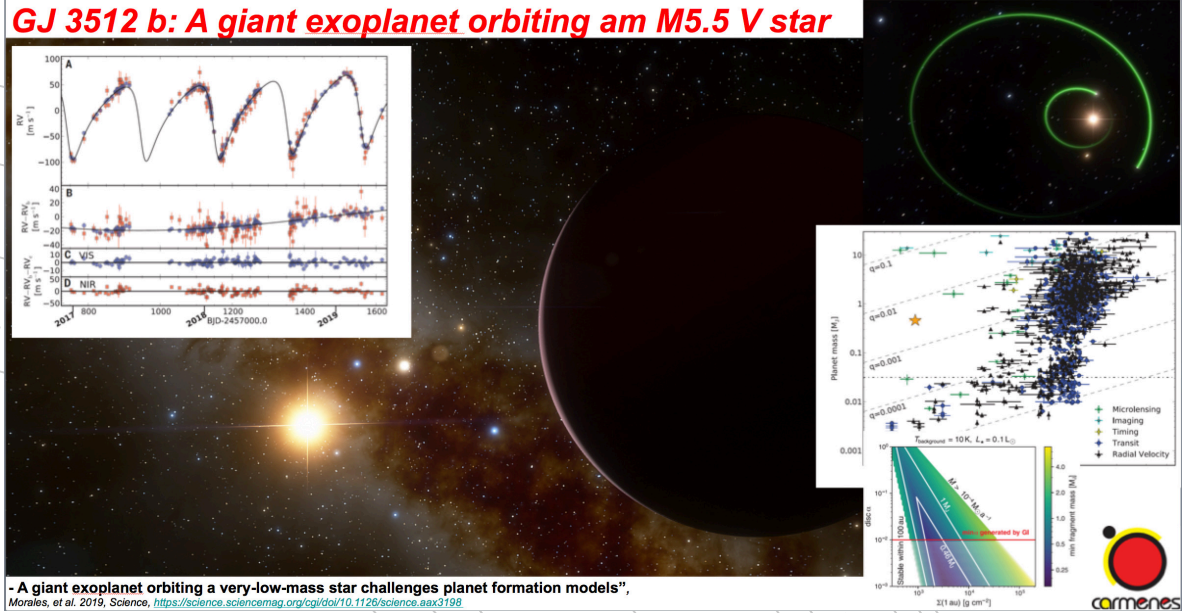
TESS ayuda a descubrir múltiples planetas, incluyendo un mundo prometedor

https://youtu.be/7ei38_rwbgs

CARMENES science exploitation

The CARMENES search for exoplanets around M dwarfs.

David Montes



Publicación en la revista Science:

- "***A giant exoplanet orbiting a very-low-mass star challenges planet formation models***",
Morales et al., Science 27 Sep 2019, Vol. 365, Issue 6460, pp. 1441-1445 - DOI: 10.1126/science.aax3198 - arXiv:1909.12174

- *Oddball solar system throws planet formation theories into question*
By Sid Perkins, Science Share, Sep. 26, 2019 , 2:00 PM

- *The world that came in from the cold*
By Greg Laughlin, Science 27 Sep 2019, Vol. 365, Issue 6460, pp. 1382-1383

IPARCOS

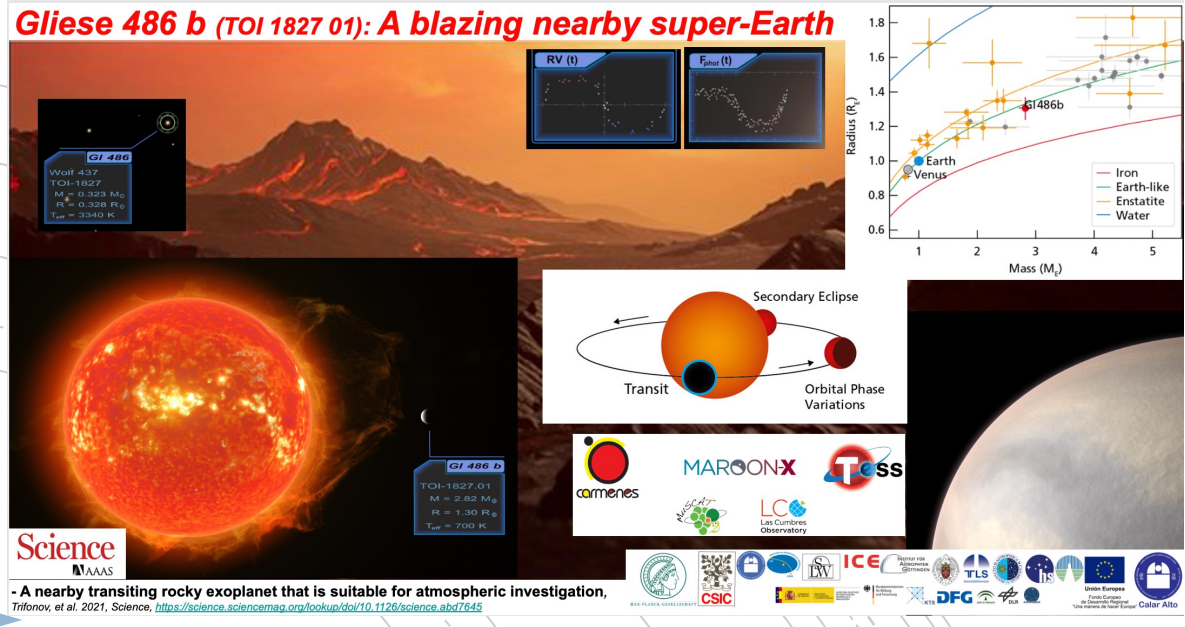
carmenes

GJ 3512 b

Massive Exoplanet Discovered Orbiting Small Red Dwarf Star

https://youtu.be/3rHKSsTaOdM

CARMENES science exploitation



The CARMENES search for exoplanets around M dwarfs + TESS

David Montes

Publicación en la revista Science:

- "***A nearby transiting rocky exoplanet that is suitable for atmospheric investigation***"
Trifonov et al., Science 5 Mar 2021 Vol. 371, Issue 6533, pp. 1038-1041,
DOI: 10.1126/science.abd7645

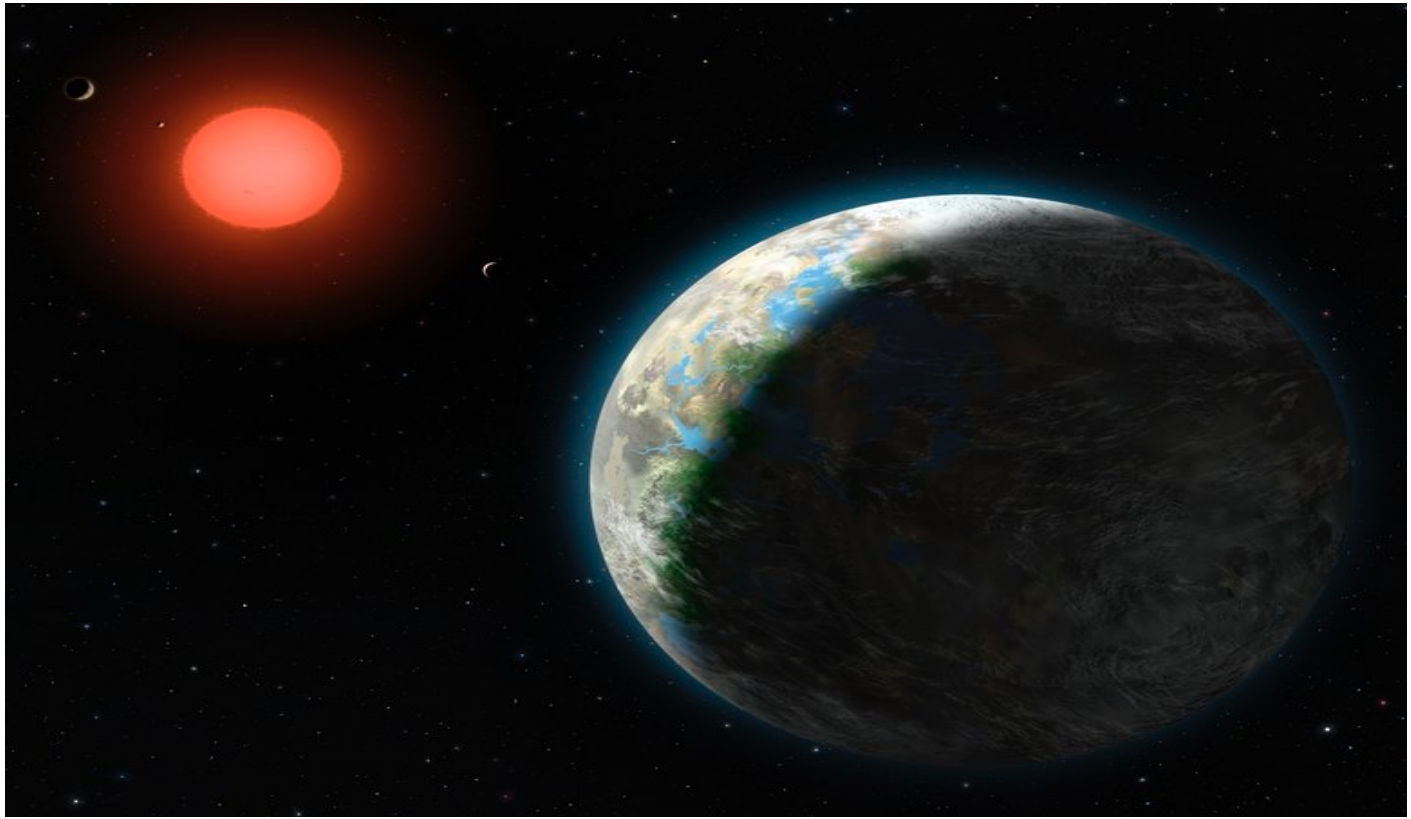
Gliese 486 b

Descubierta una súper-Tierra que servirá para probar los modelos atmosféricos planetarios

https://youtu.be/3URkH7lsUc8

Is there anybody out there?

(How many planets will we find in our 300-M-star sample?)



Summary

- CARMENES regular operations since Jan 1, 2016 for a 5-year survey (750 n., 2016-2020)
- Both channels are online and acquiring data
- Currently:
  - VIS ➔ 2-4 m s^{-1} rms (uncertainty + activity jitter) over timescale of years
  - NIR ➔ few m s^{-1} over timescale of several nights & ~10 m s^{-1} rms over timescales of years
- The CARMENES survey is revealing a treasure trove of extremely interesting planets
- Will discover a statistically-significant sample

Summary of advantages

- Simultaneous near-infrared and visible observations
- Both high resolution and wide spectral coverage
- Dedication to stable high-precision radial-velocity survey of exoplanets around M dwarfs
- Long guaranteed time for the completion of the project
- Early first light with respect to “competitors”
- Plenty of planets for astro-statistics!

Final remarks

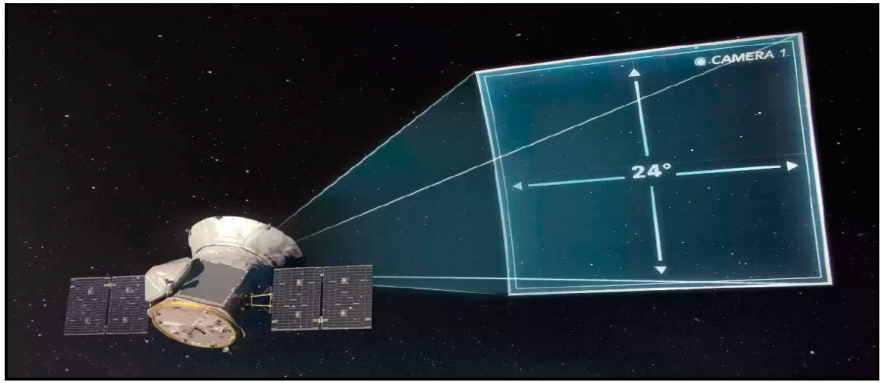
- You can do **your** science (whatever you like *except* exoplanets around M dwarfs) with CARMENES in open time

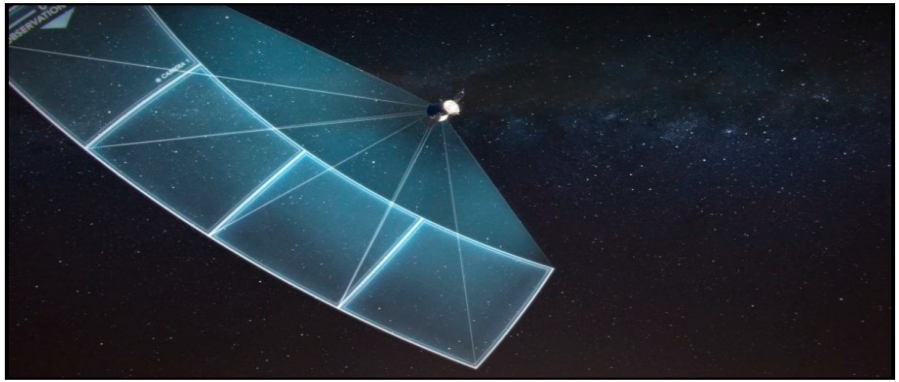
- Complementarity with current and near-future instruments (HARPS N&S, ESPRESSO, HPF…)

- Synergies with space missions: *Gaia, TESS, JWST* and *Plato*

CARMENES beyond 2020

- CARMENES II presented at the "New Instrumentation and Legacy Projects for Calar Alto" workshop in Oct 2016
- LoI submitted to the call for new instrumentation
- CARMENES II Phase A to be started at the end 2018/start 2019
- Main drivers:
  - CARMENES technical upgrade
  - Competitive science case:
    - Extension of the current survey
    - Survey of exoplanet atmosphers
    - TESS follow-up





http://carmenes.caha.es/


carmenes

CARMENES unitedsoundsofcosmos

https://www.youtube.com/watch?v=sgV8yIZ-E9c

Antonio Arias - Carmenes

https://www.youtube.com/watch?v=YT36FUHXq8c

http://www.rtve.es/alacarta/videos/los-conciertos-de-radio-3/conciertos-radio-3-antonio-arias/2338867/