



carmenes

carmenes

The Calar Alto exoplanet hunter



José A. Caballero
Centro de Astrobiología
Madrid

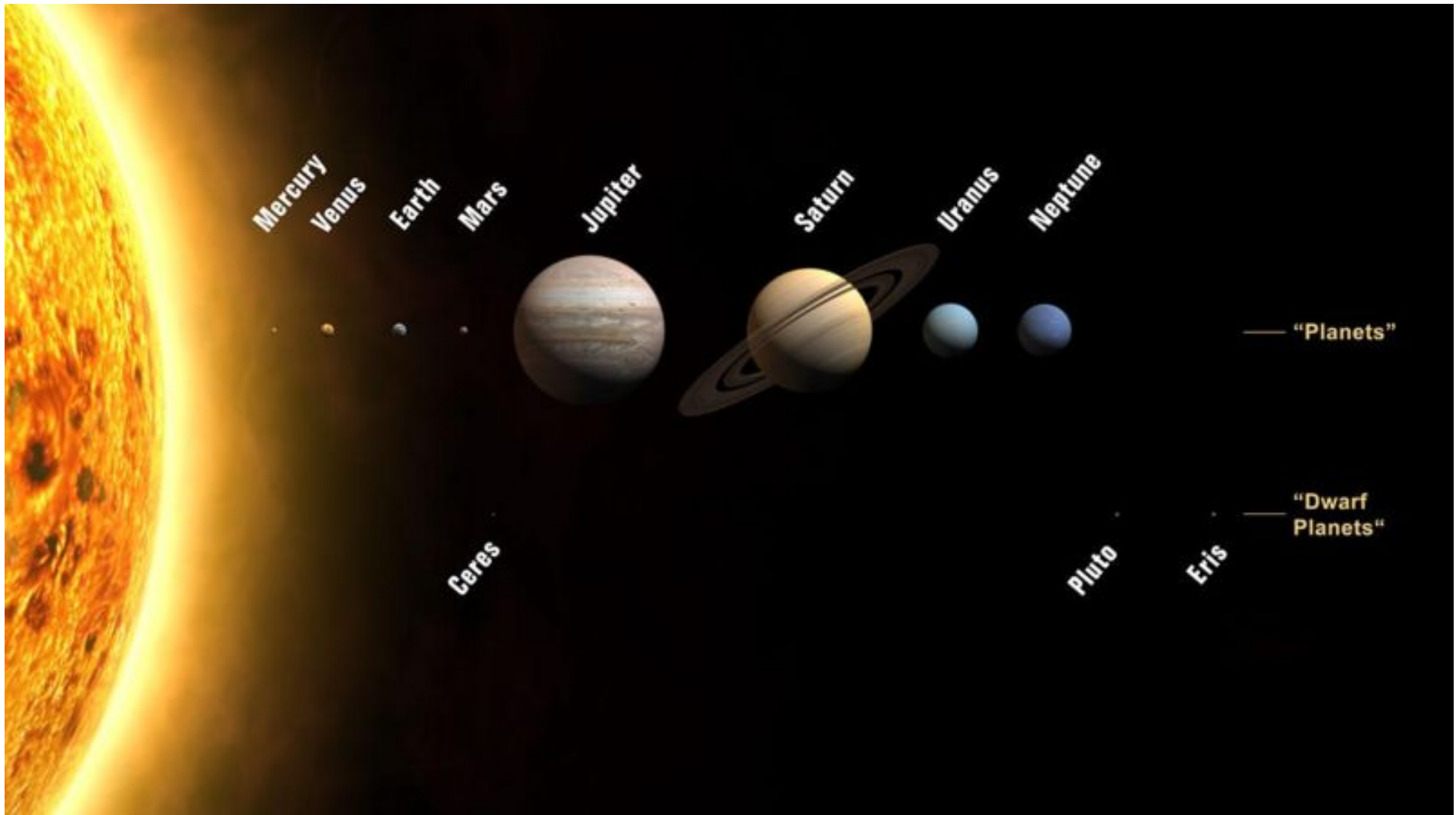
The East of the Orion Belt (Anitak, σ Orionis, The Horsehead, The Flame...)



Raúl Alcaraz Gómez, Astronomía & Caballero et al.

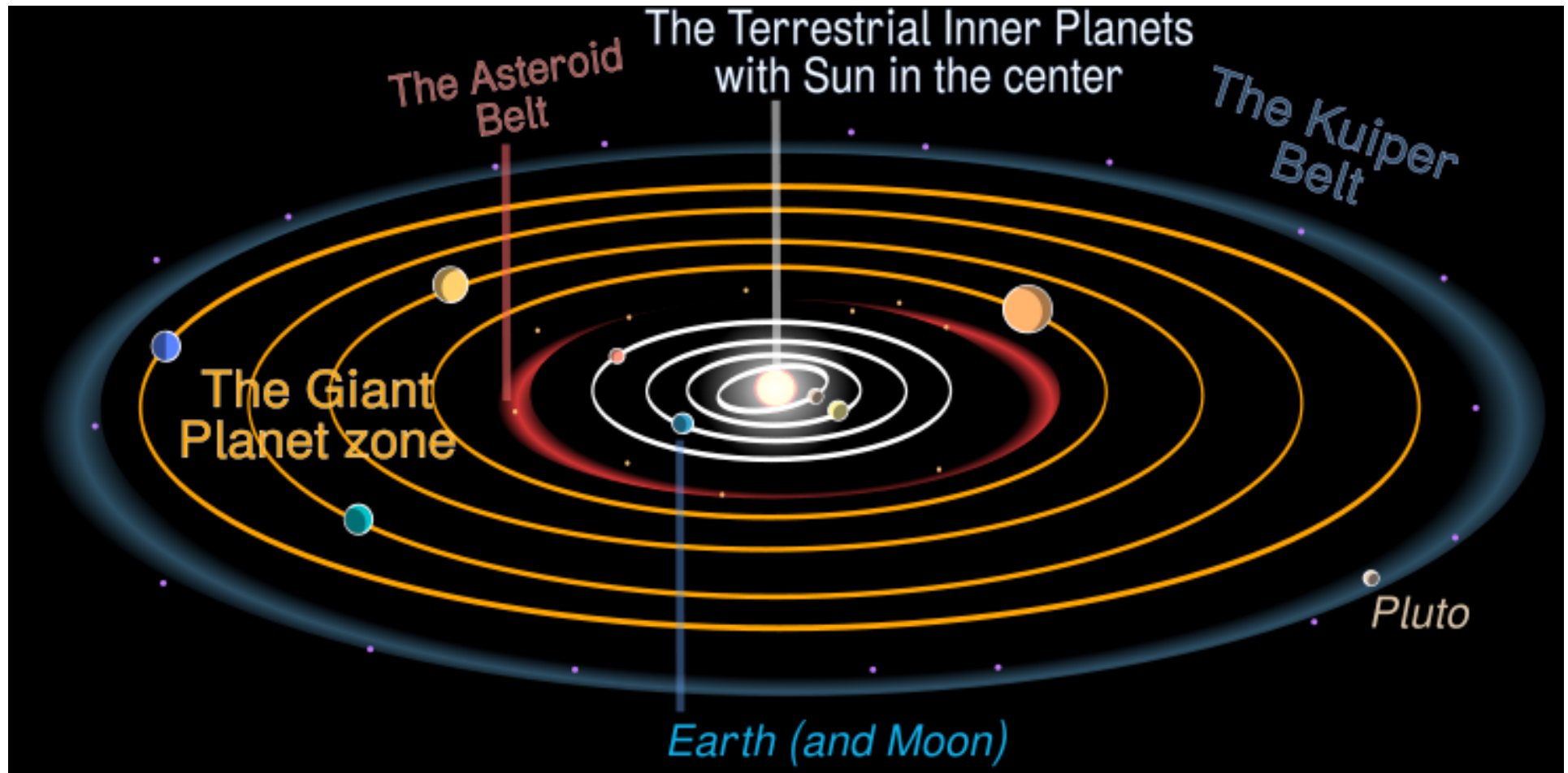
Planets: our Solar System

8 planets (+ 5 dwarf planets)

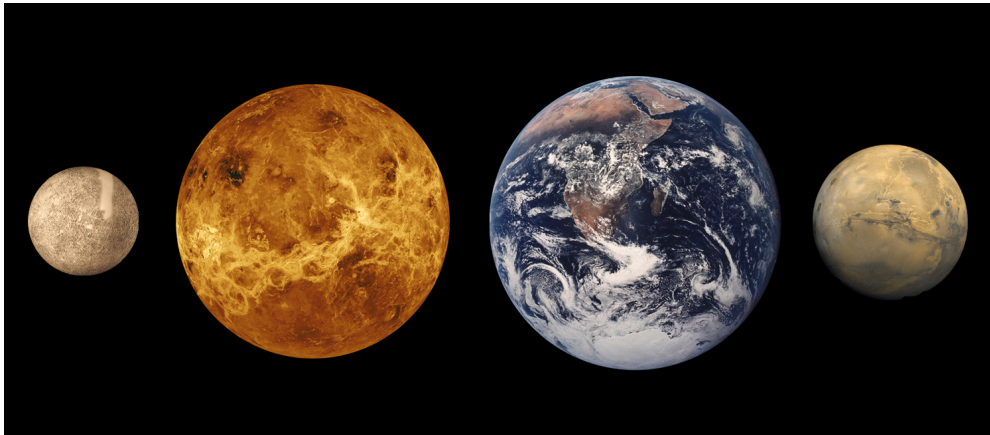


Planets: our Solar System

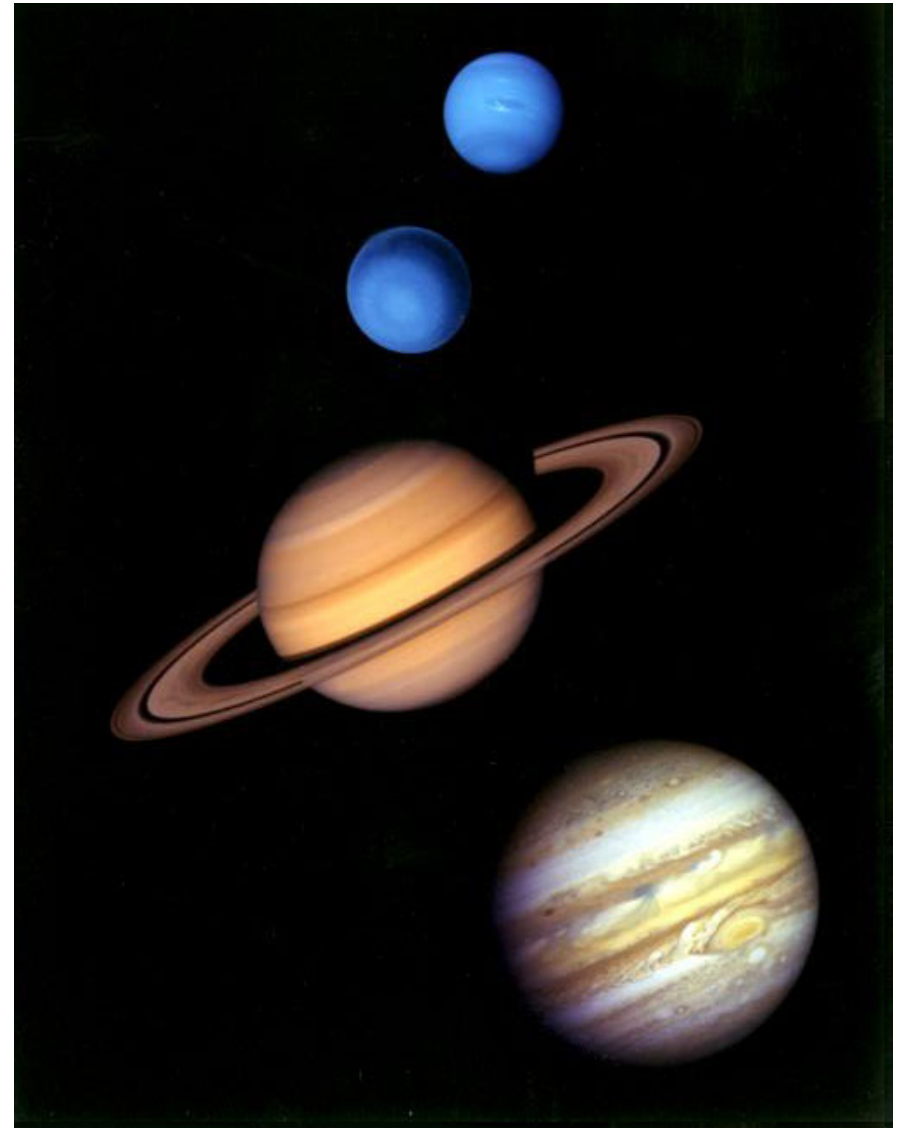
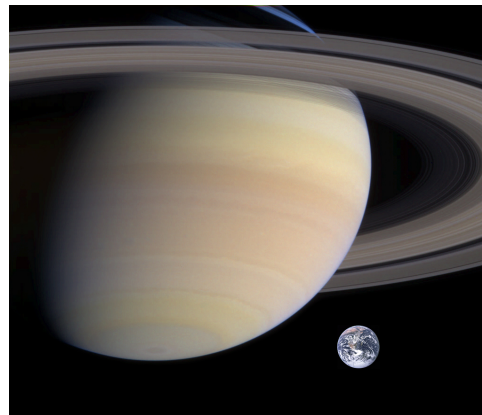
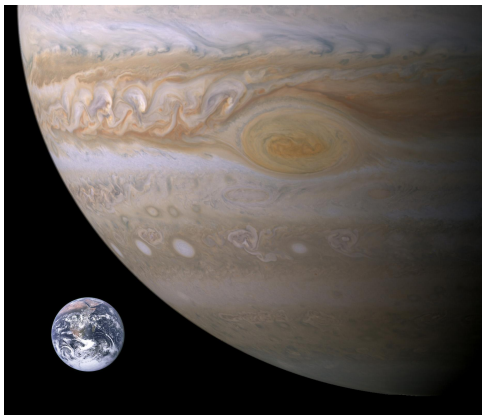
$a = 0.39, 0.72, 1.00, 1.52, 5.20, 9.54, 19.22, 30.06$ AU



Planets: our Solar System



Gaseous, giant or Jovian planets
vs. Terrestrial, Earth-like, telluric
planets



La pluralité des mondes habités



G. Bruno (†1600)

Mártir de la Ciencia:

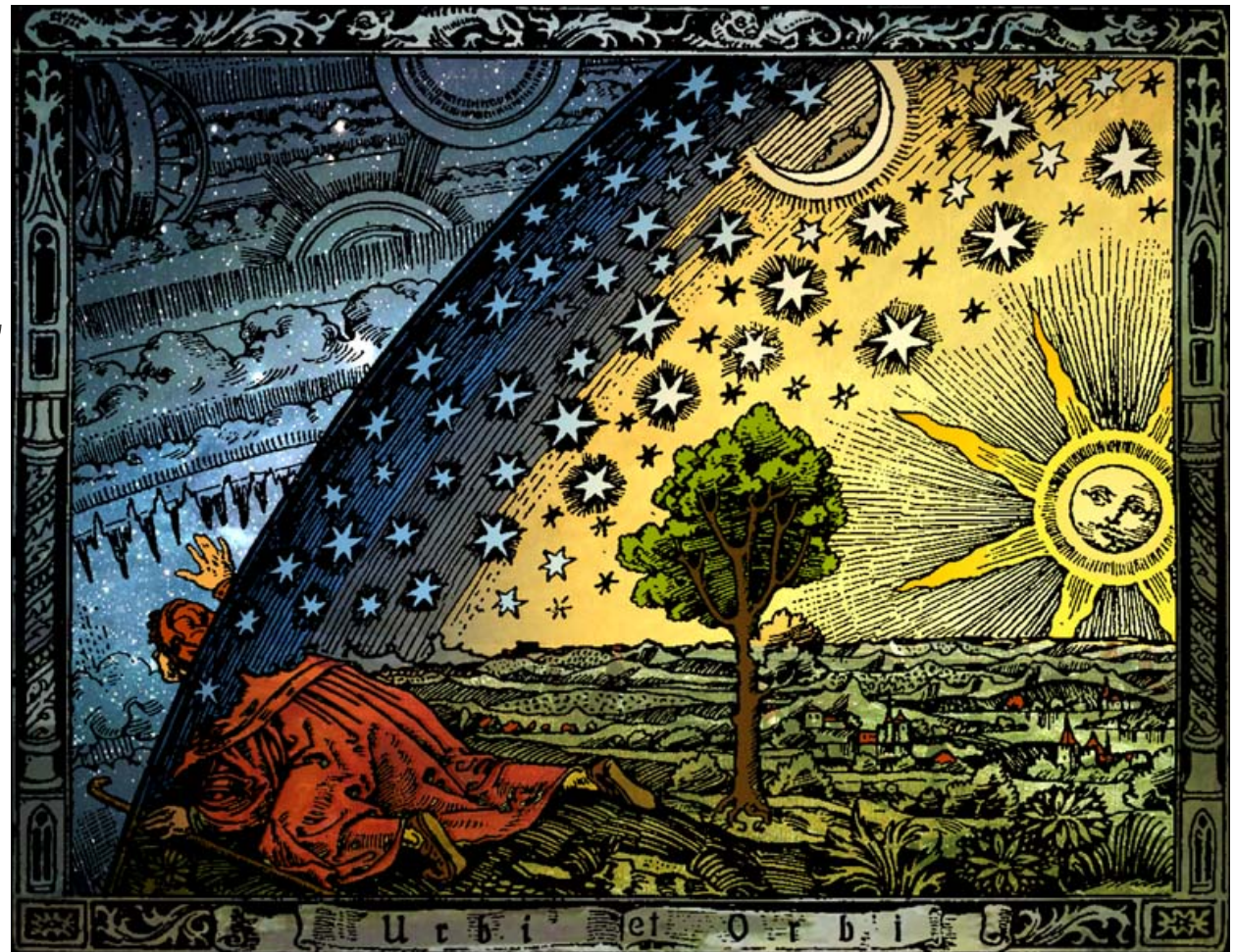
“Manifestar la existencia de una pluralidad (infinitud) de mundos y su eternidad”
(+ otros 7 cargos)

I. Newton (1713)

C. Flammarion (1862)

S. H. Dole (1968)

Habitable Worlds



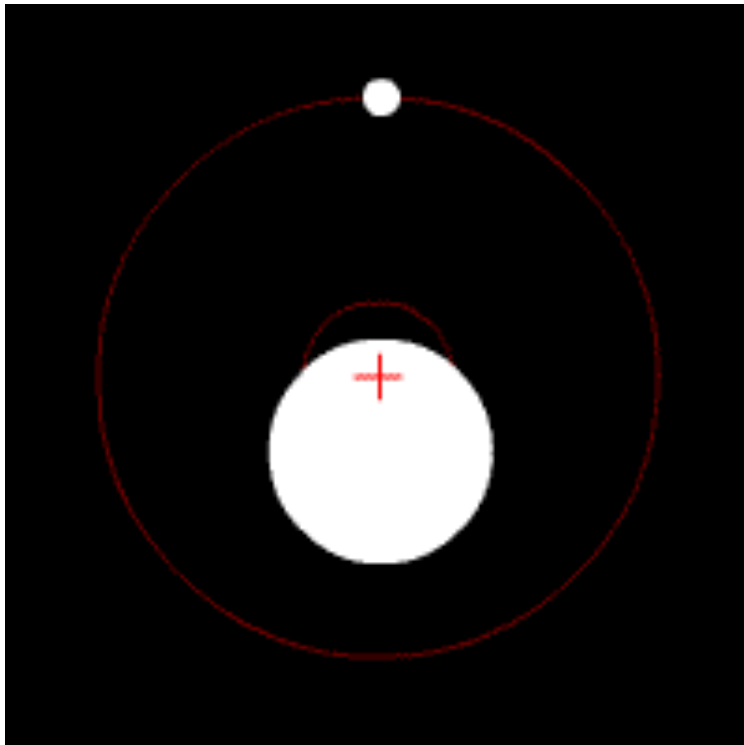
The first exoplanets?



70 Oph (Jacob 1855)

Barnard's Star (van de Kamp 1963)

PSR 1829-10 (Lyne et al. 1991)



The first exoplanets?



γ **Cep** (Campbell et al.
1988)

Confirmed in 2003

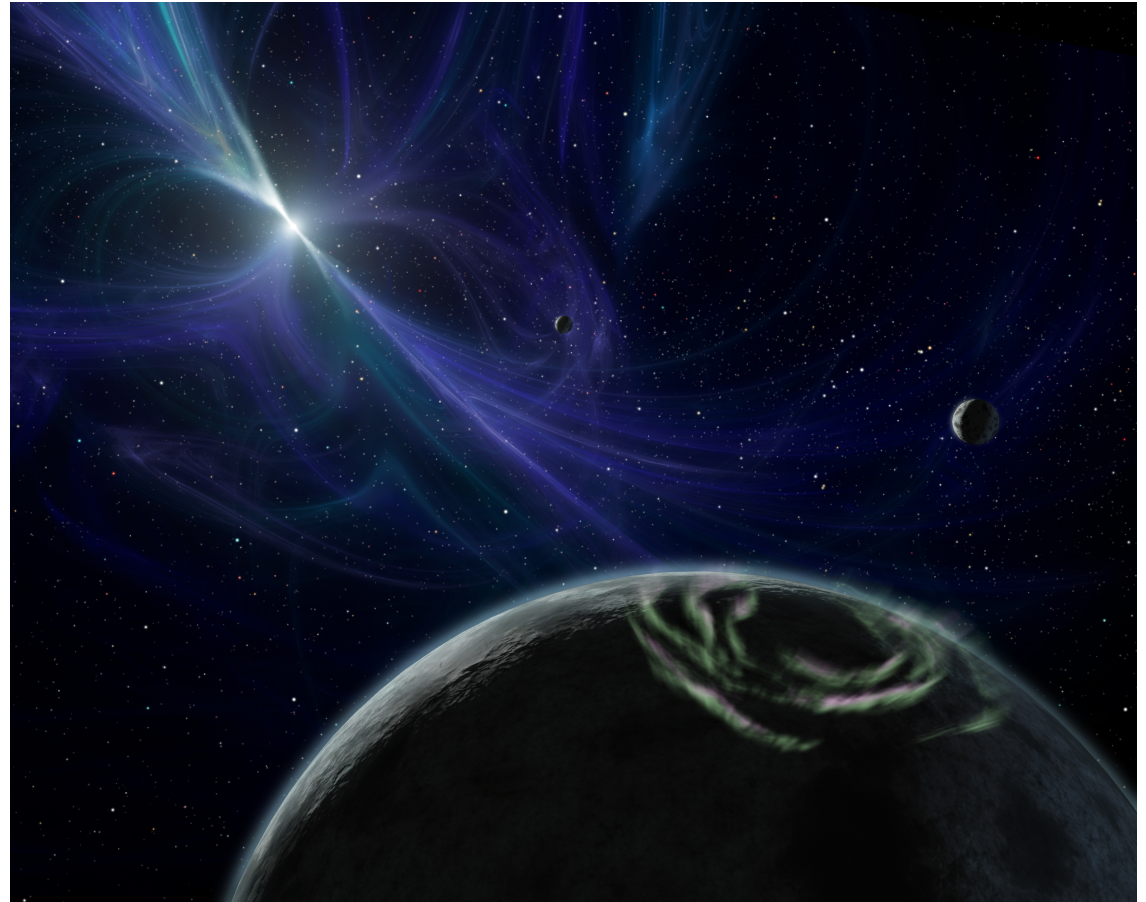
HD 114762 (Latham et al.
1989)

Likely a brown dwarf

PSR 1257+12 (Wolszczan &
Frail 1992)

Two terrestrial planets around a
pulsar

Plus: Aldebarán, Proxima
Centauri, CM Dra, β Pic...



1995: the first exoplanet (really)



51 Peg b (Mayor & Queloz 1995)

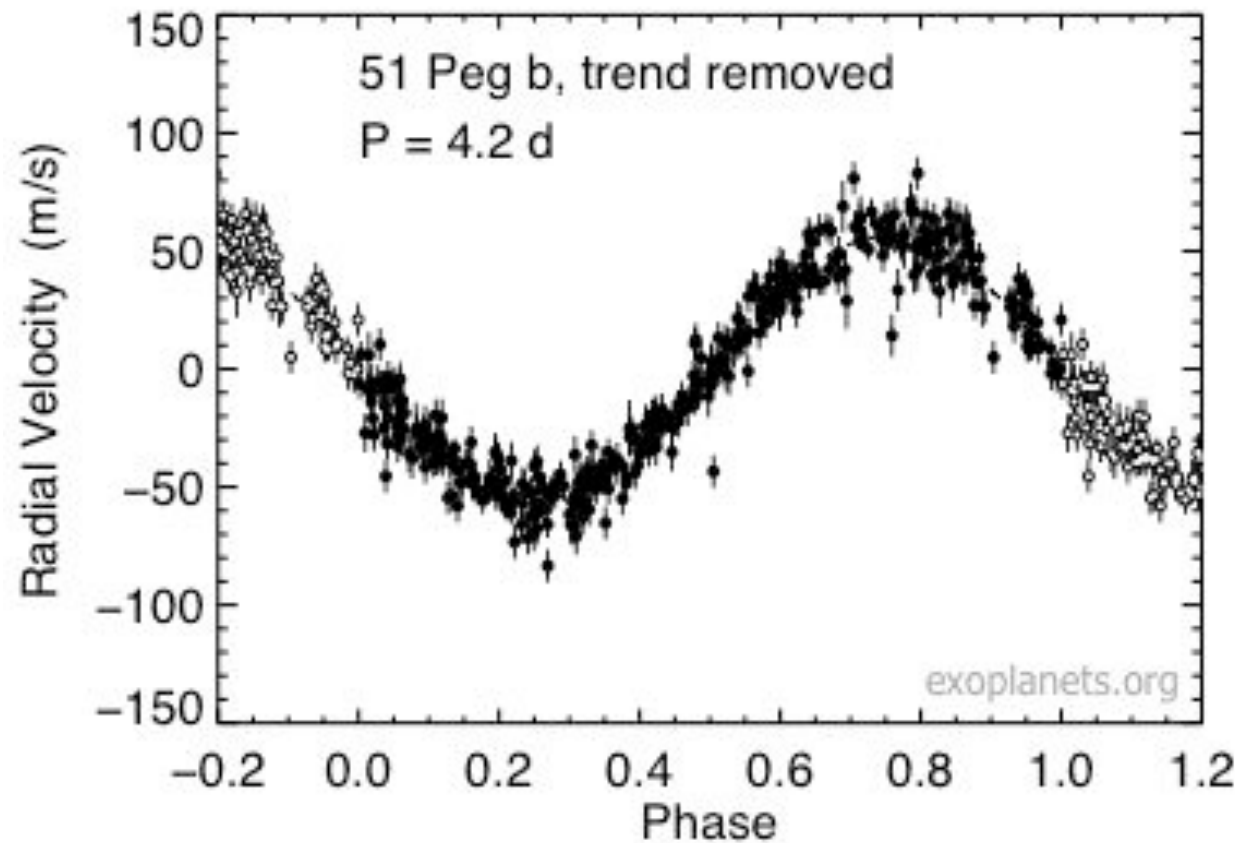
Primary: G2V

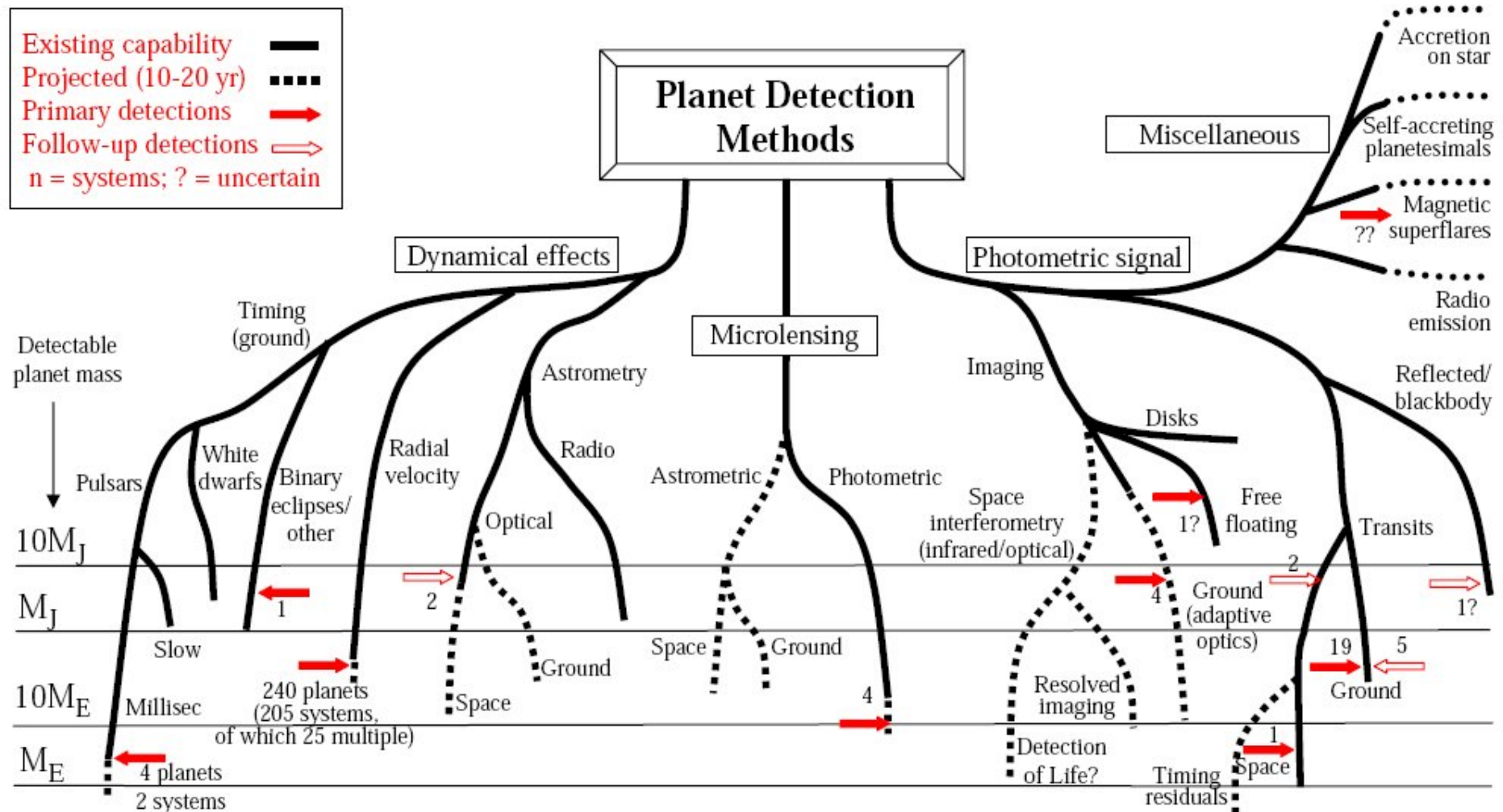
$M_2 \sin i = 0.468 M_{Jup}$

$P = 4.23077$ d

$a = 0.052$ AU

$e = 0.00$



The Carmenes logo features a stylized circular emblem composed of a red circle, a black ring, and a yellow arc, with a small black dot above it. Below the emblem, the word "carmenes" is written in a lowercase, sans-serif font, with a yellow dot above the 'a' and a red dot above the 'e'.

Exoplanetas: velocidad radial



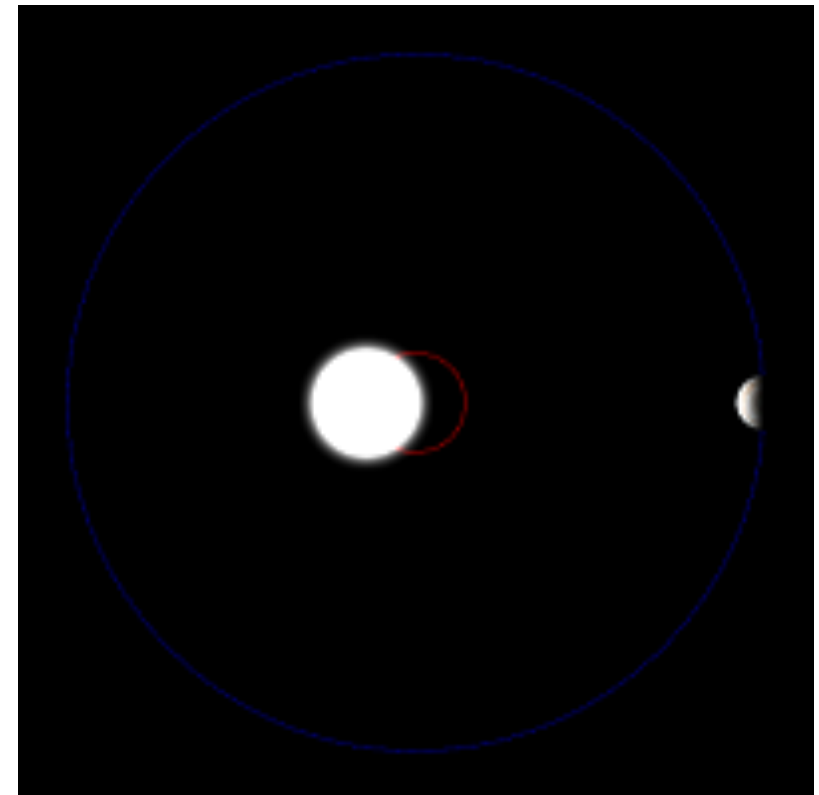
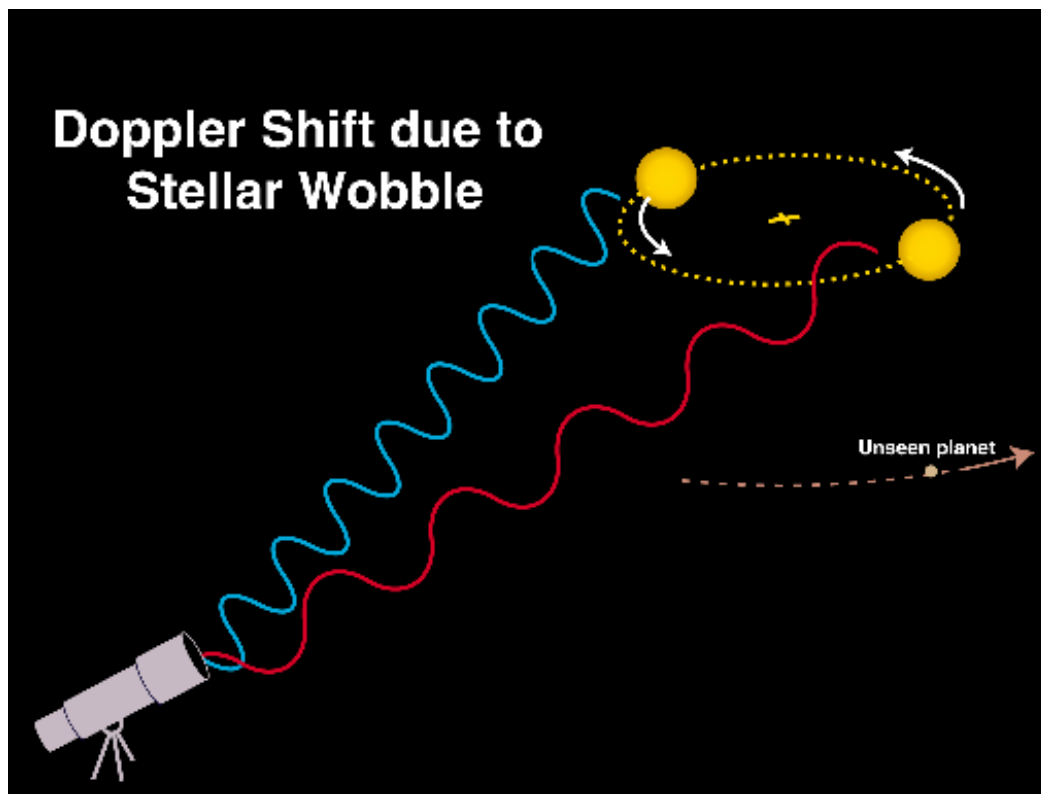
Exoplanetas: velocidad radial



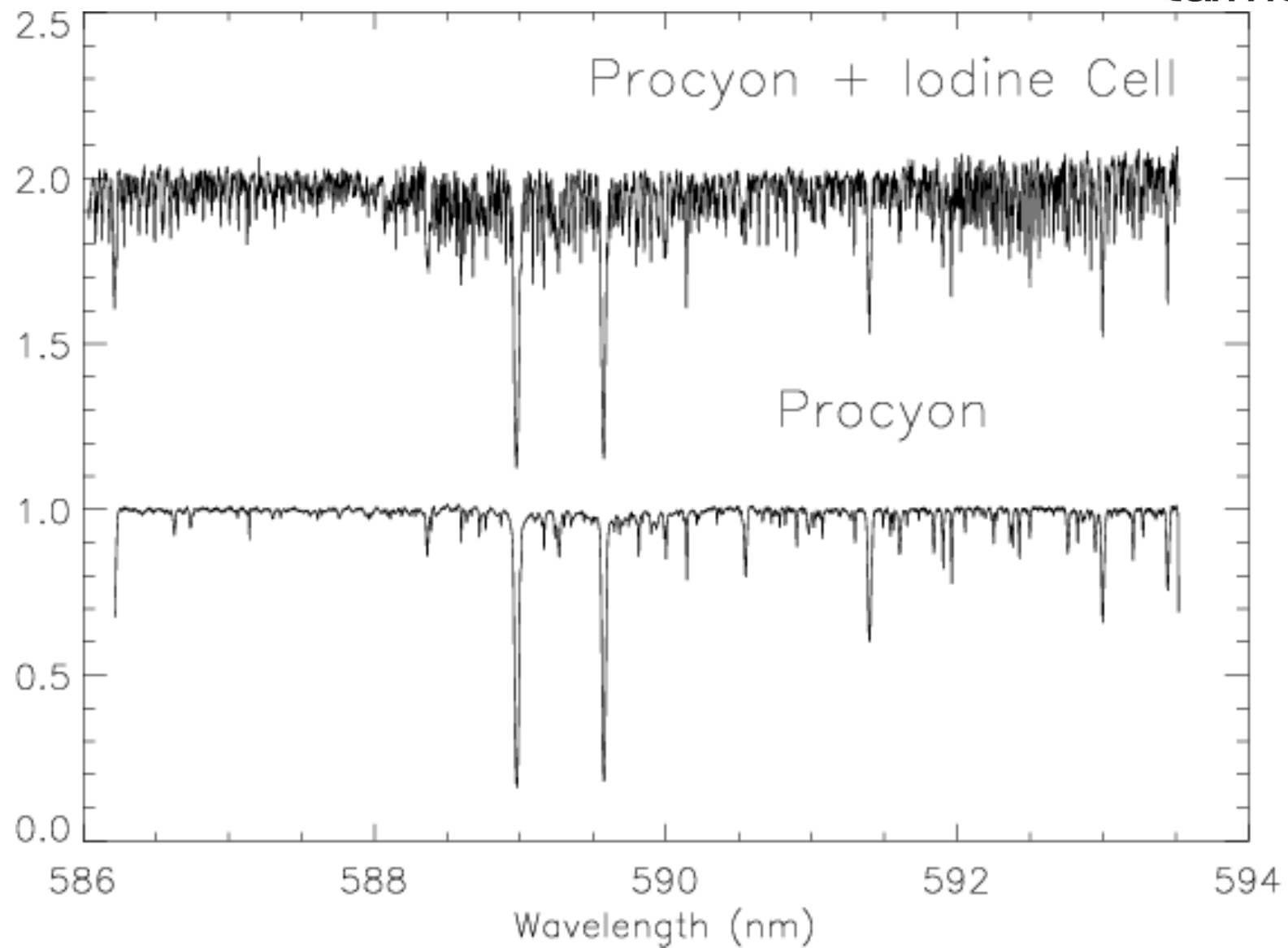
Desplazamiento del **baricentro** del sistema estrella-planeta → efecto **Doppler**

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

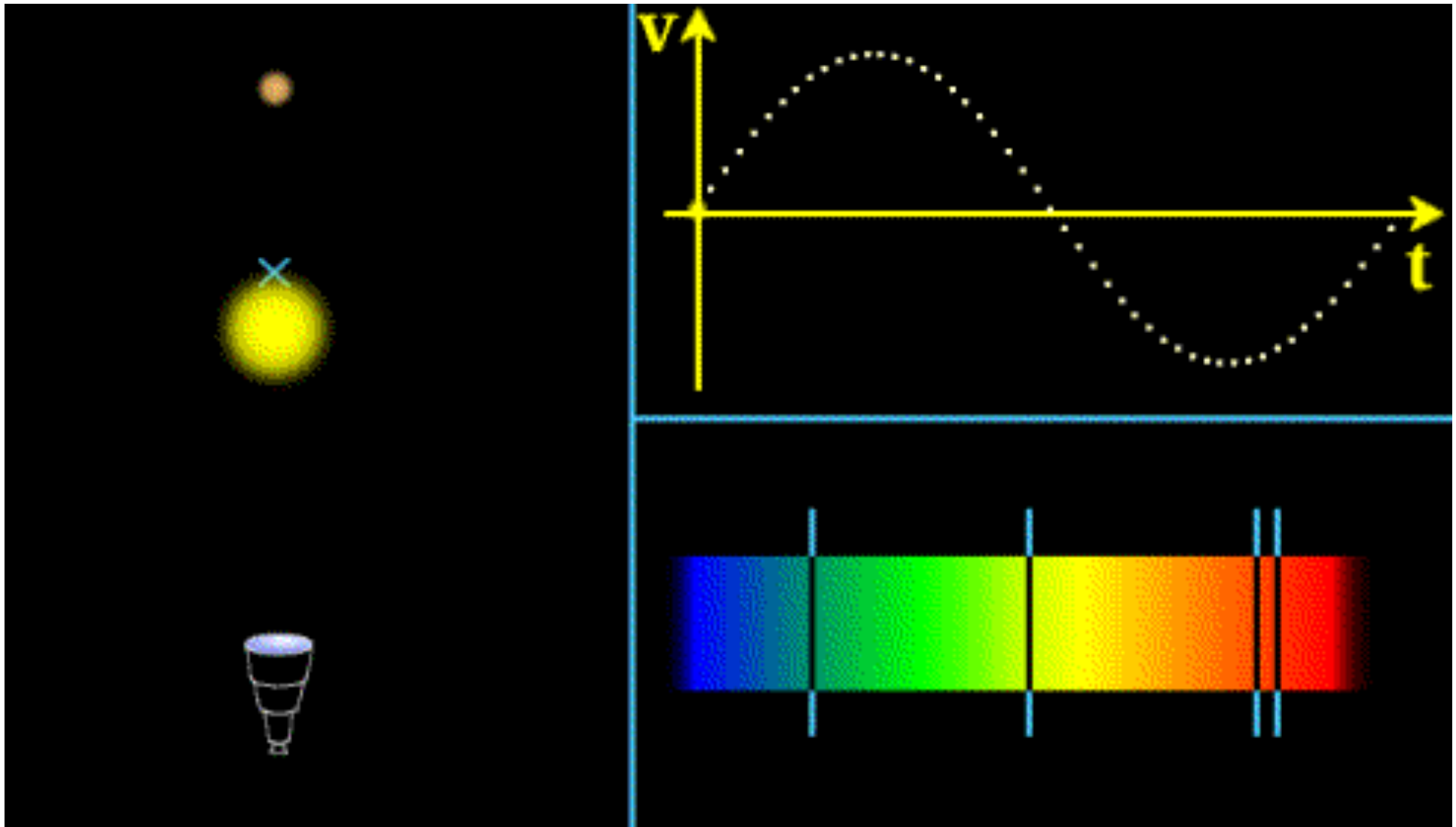
Estrella se **acerca**: espectro desplazado al **azul**



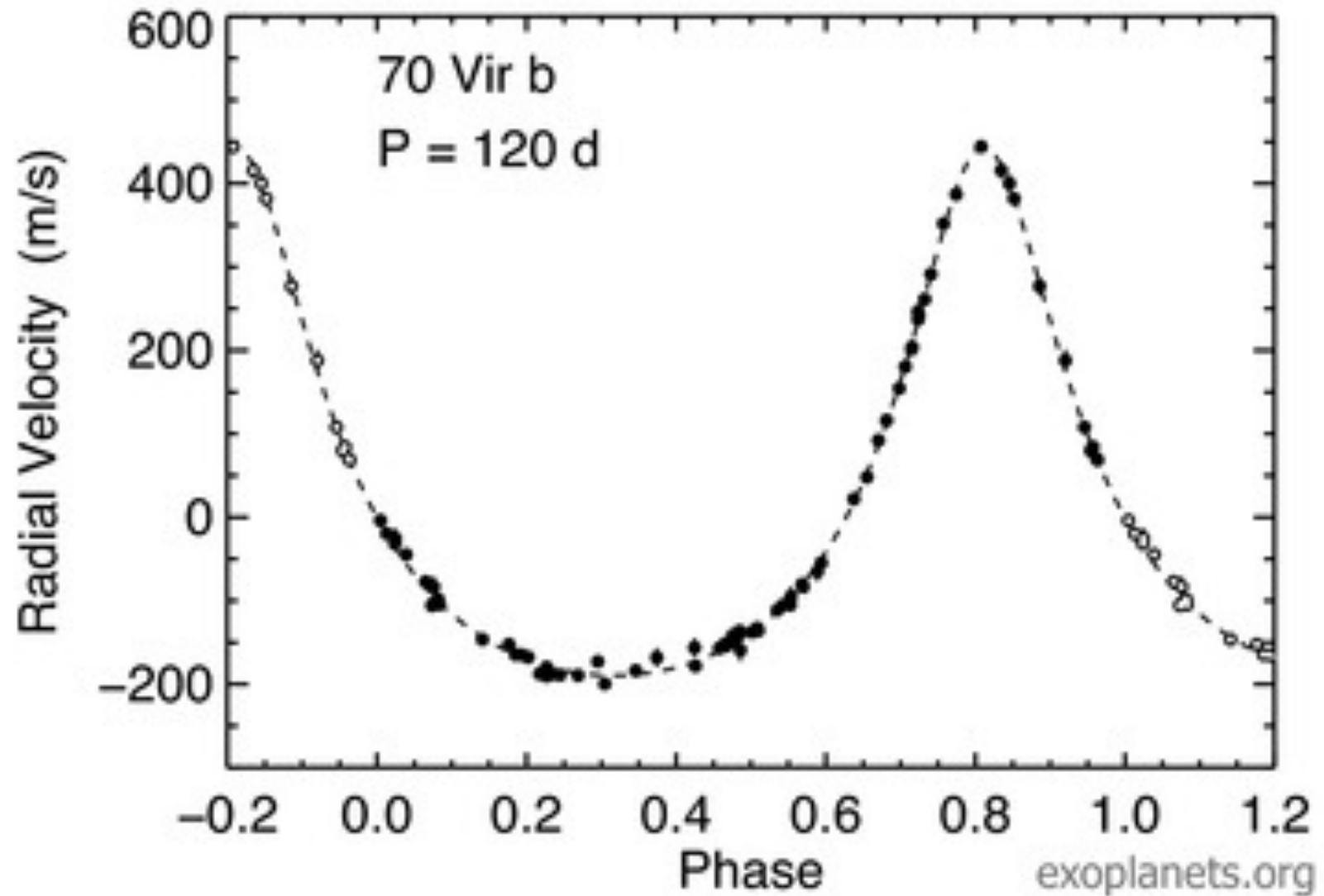
Exoplanetas: velocidad radial



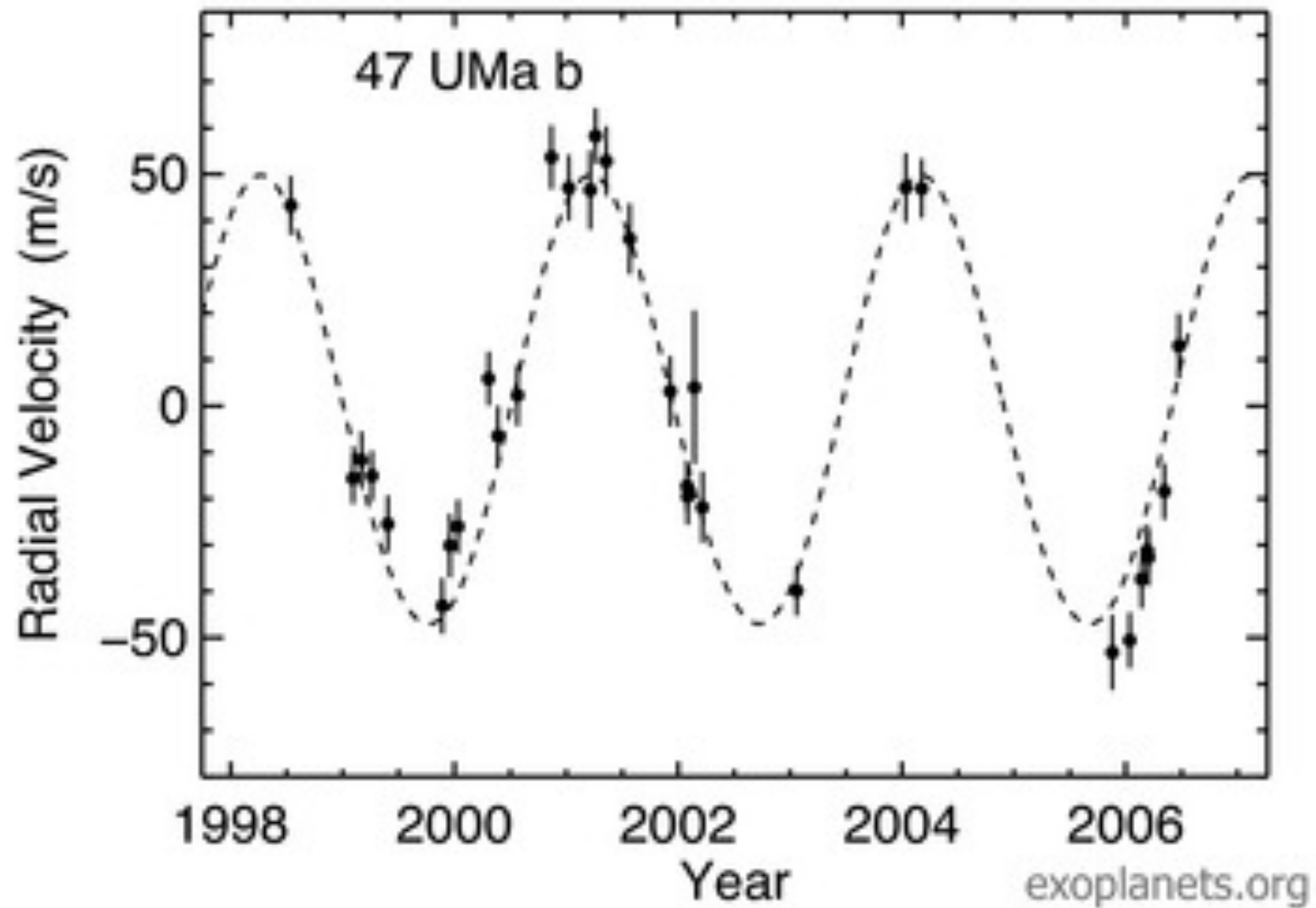
Exoplanetas: velocidad radial



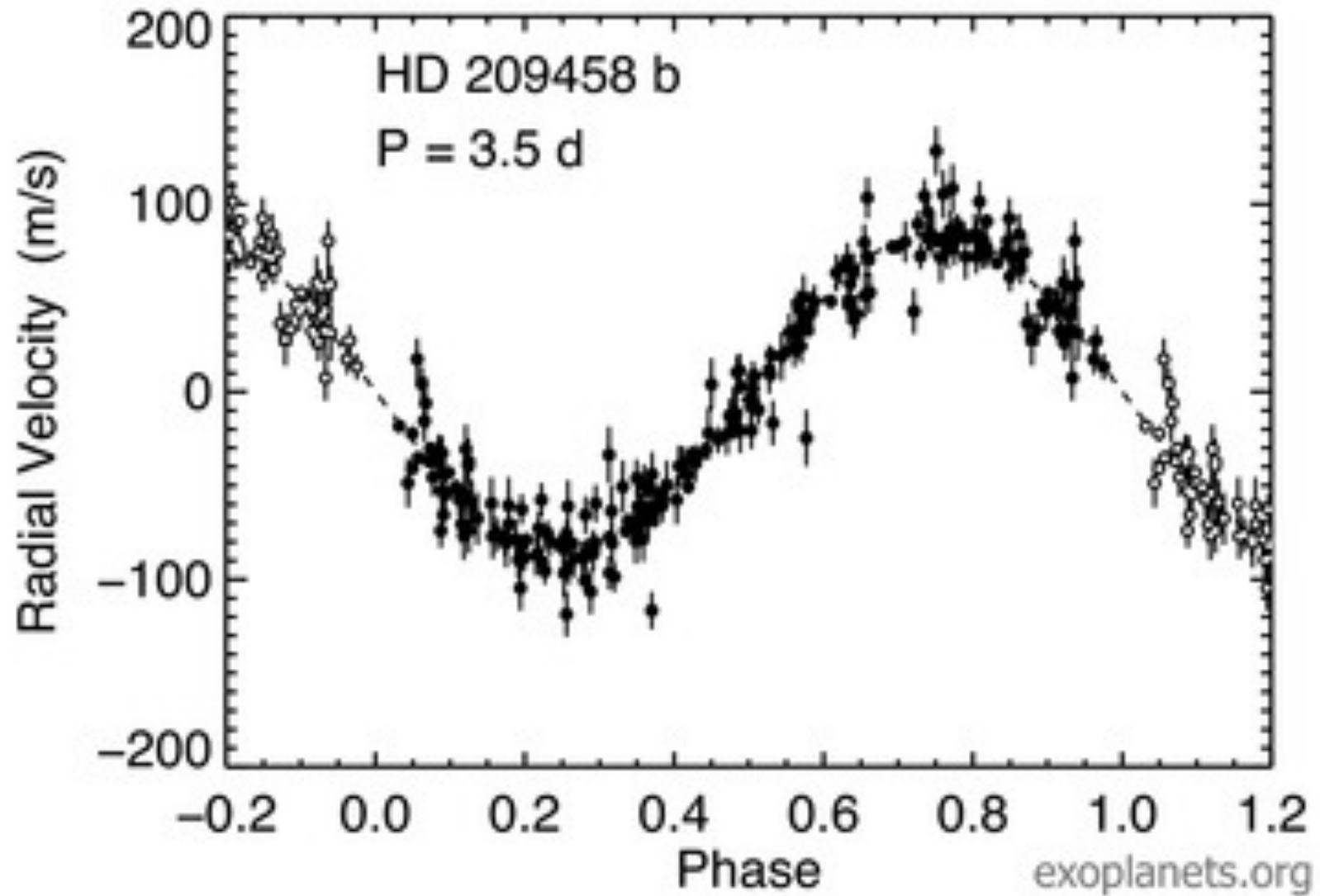
Exoplanetas: velocidad radial



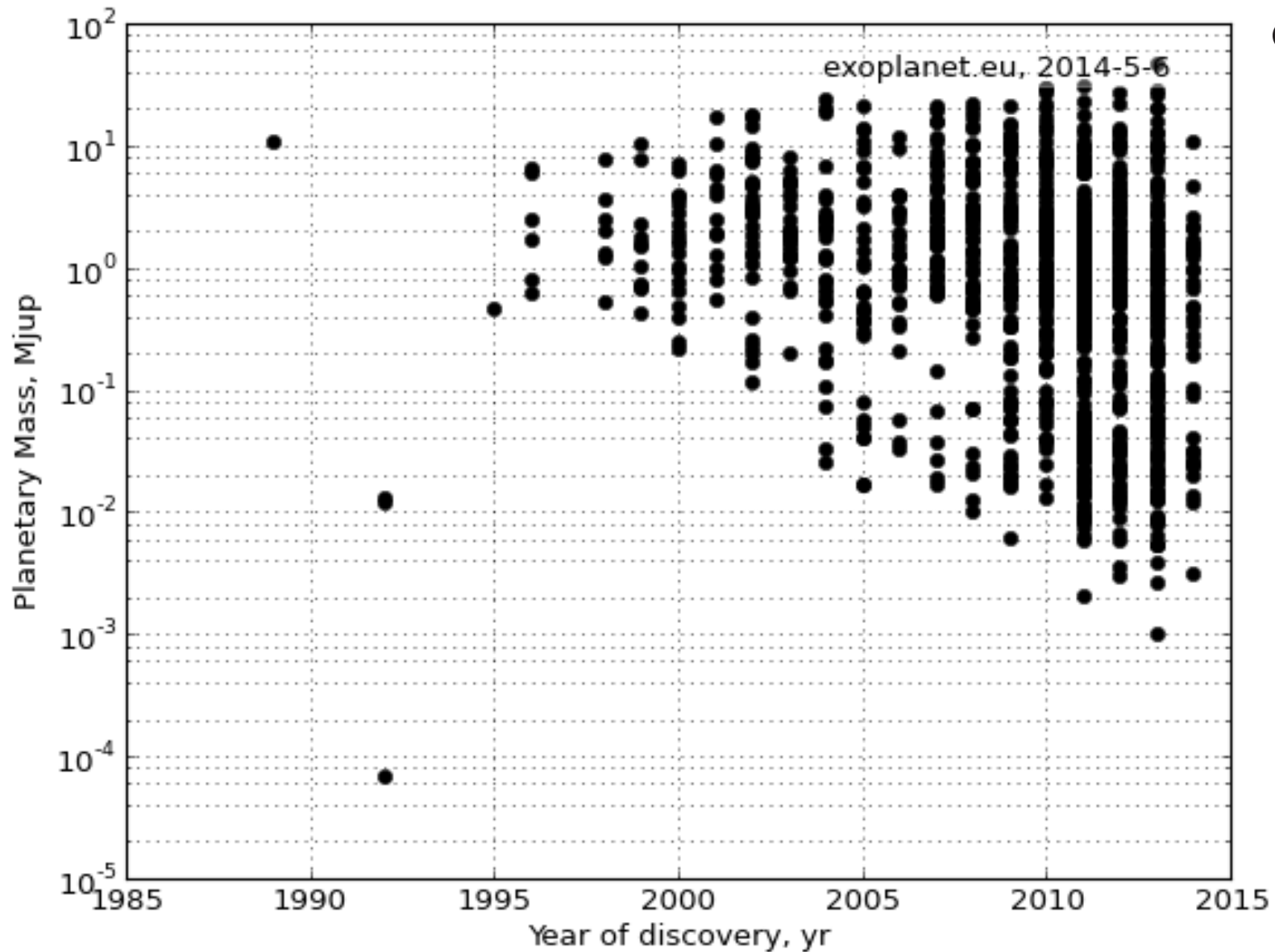
Exoplanetas: velocidad radial



Exoplanetas: velocidad radial



Exoplanetas: velocidad radial





carmenes

What is CARMENES?

/kár-men-es/



- a) An instrument
- b) A consortium
- c) A science project
- d) All of the above

What is CARMENES?



- a) An instrument (for the 3.5 m telescope on Calar Alto)
- b) A consortium (of over 100 people in 11 centres in Spain and Germany)
- c) A science project (to be carried out during guaranteed time – 600+ nights)
- d) All of the above

What does CARMENES mean?



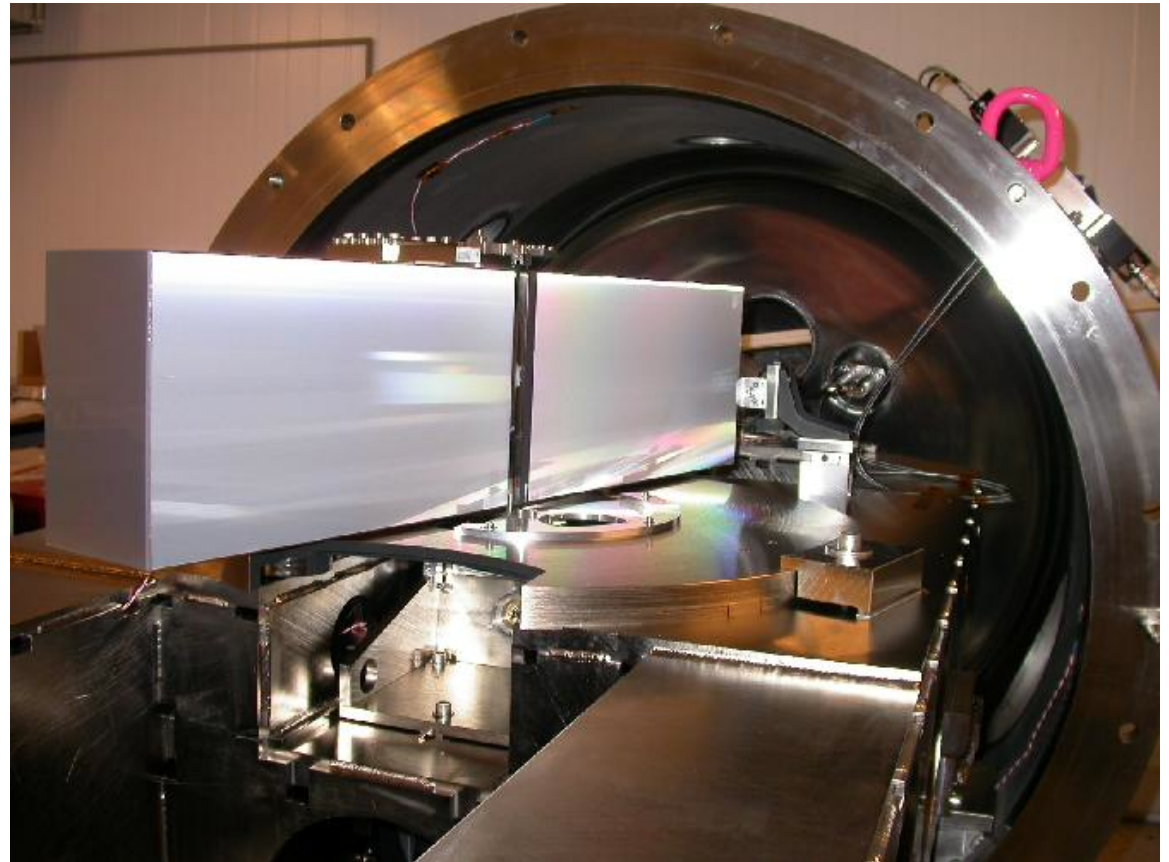
Calar **A**lto high **R**esolution
search for **M** dwarfs with
Exoearths with **N**ear-
infrared and optical
Echelle **S**pectrographs

A bit of history: Feb 2003

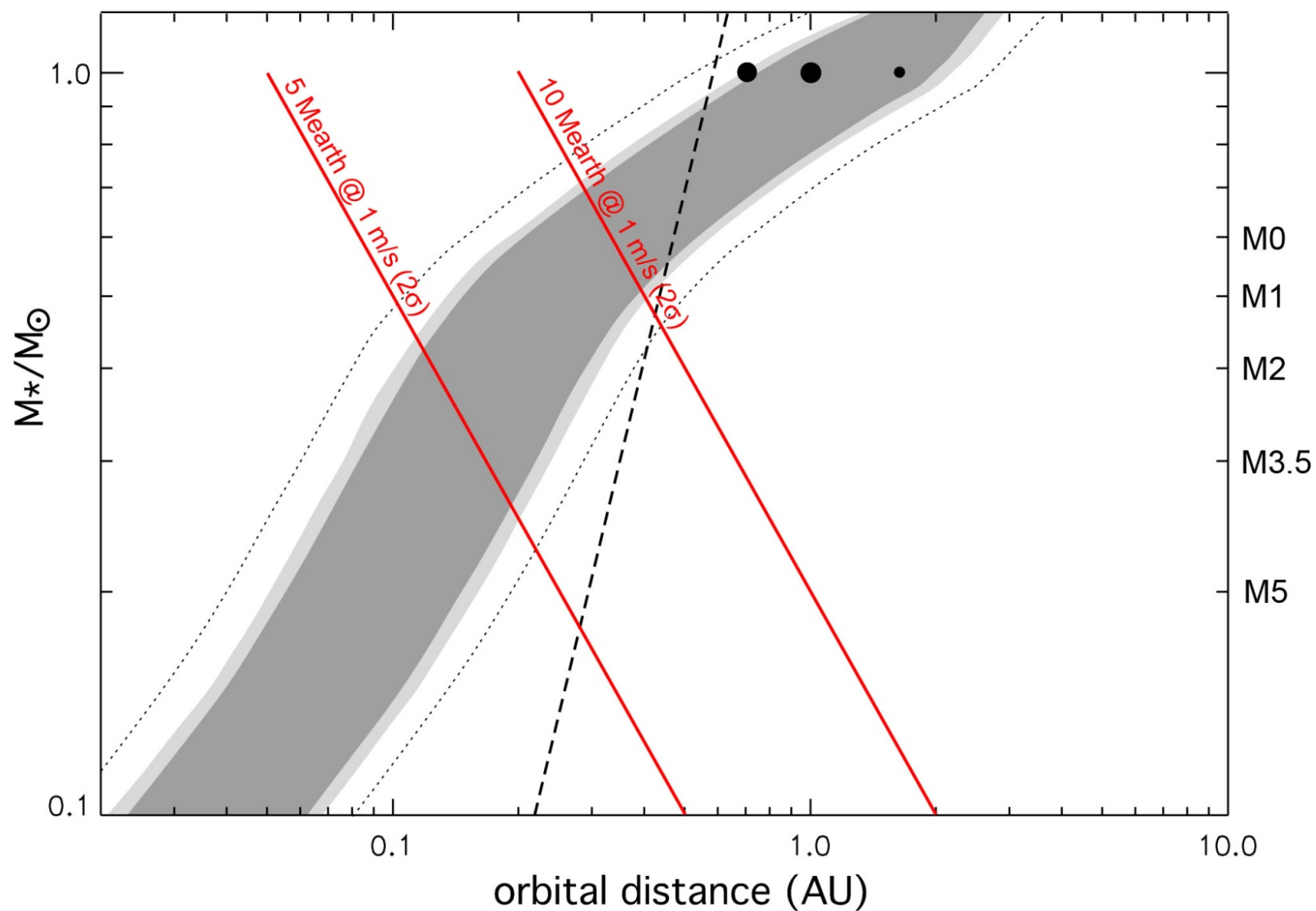


First light of
HARPS at the
ESO 3.6 m
telescope, the
“exoplanet
hunter”

(aka HARPS-
South...)



(the smaller, the better)

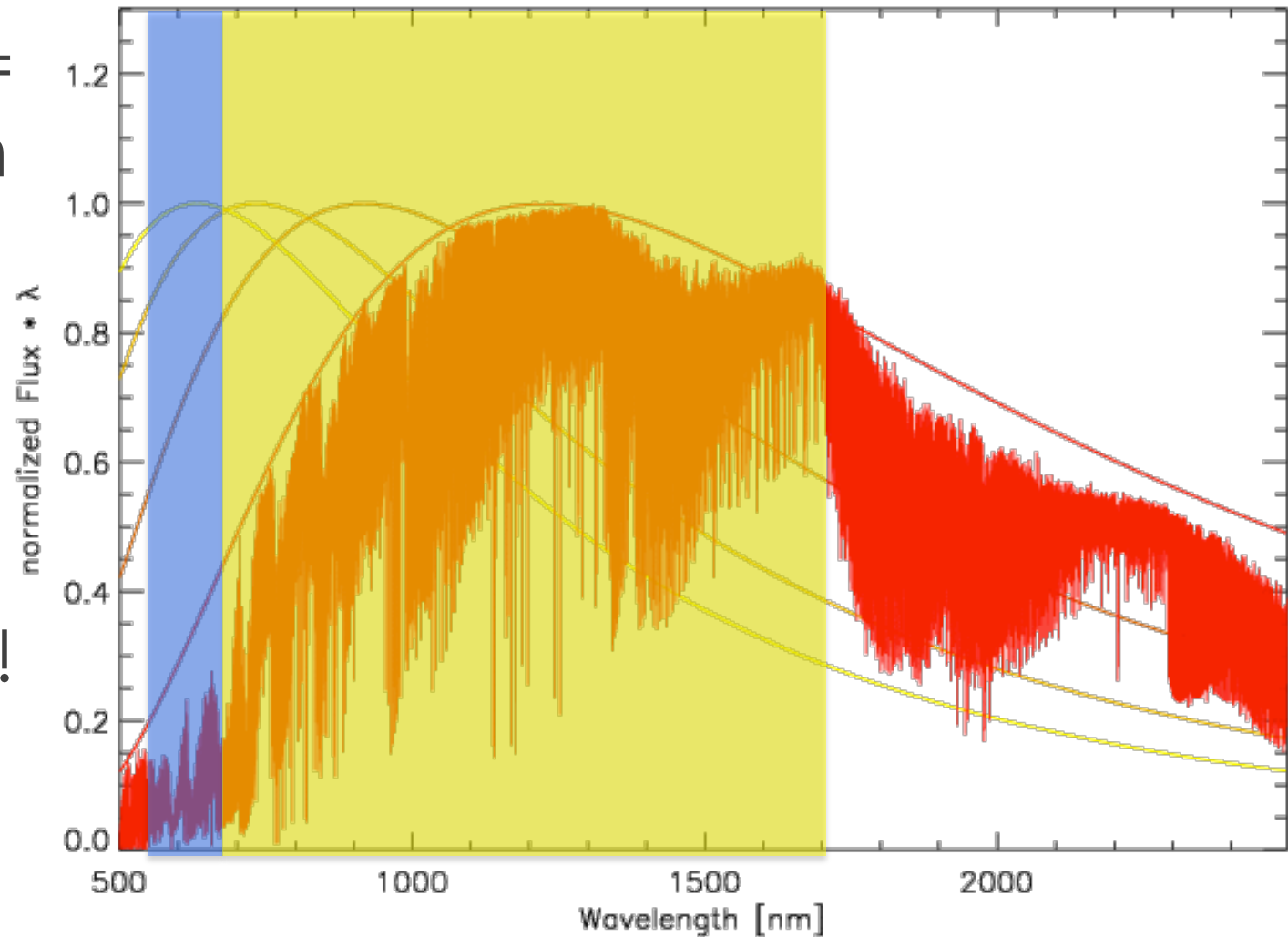


(the redder, the better)



HARPS $\Delta\lambda =$
533-691 nm

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



A bit of history: Jun 2004

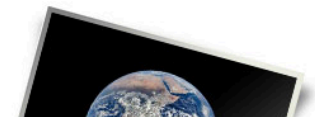


NAHUAL

A high-resolution near-infrared echelle spectrograph for large telescopes



UPF - Searching for Earth-mass Planets



A bit of history: Mar 2008



Calar Alto Instrumentation Workshop

IAA-Granada, June 11-13, 2008



SOC: J. Alves, M. Casali, M. Colless, R. García-López, T. Henning, J. Masegosa, S. Pedraz,
F. Prada, D. Reimers, H-W. Rix, M. Roth, S. Sánchez, U. Thiele, S. Warren

LOC: J. Alves, J. Masegosa, S. Pedraz, S. Sánchez, U. Thiele

www.caha.es



Workshop de la Red de Infraestructuras de Astronomía (RIA)

A bit of history: Mar 2008





A bit of history: Jun 2008

A high resolution multi-object spectrograph for Calar Alto

Eike Guenther, Thueringer Landessternwarte

Up to now, most infrared high resolution spectrographs have only limited spectral ranges. However, the large detector arrays that are now available allows us to built cross-

A high-resolution near-infrared spectrograph for the CAHA 3.5-m telescope

Pedro J. Amado González , IAA

In this talk, we present a proposal for a new instrument for the 3.5m telescope at Calar Alto, Almería, Spain. This instrument will be a high-resolution near-infrared spectrograph

Multi-Object High-Resolution Spectrograph

Andreas Quirrenbach, Landessternwarte Heidelberg

Scientific drivers, technical approaches, and potential consortium arrangements for the construction of a (massively?) multiplexed high-resolution spectrograph will be discussed.

XMS - Extreme Multiplex Spectrograph for CAHA 3.5m

Tom Shanks, Durham University

I shall describe the science case for XMS, a prime focus spectrograph for the Calar Alto 3.5-m that can deliver 4000 MOS slits over a 1 degree field. This extreme multiplex capa-

A bit of history: Jan-Feb 2009



Calar Alto design studies decision: XMS and...

Guenther+Amado+Quirrenbach's proposals merged into one: **HRS** ("High Resolution near-infrared and optical Spectrograph")

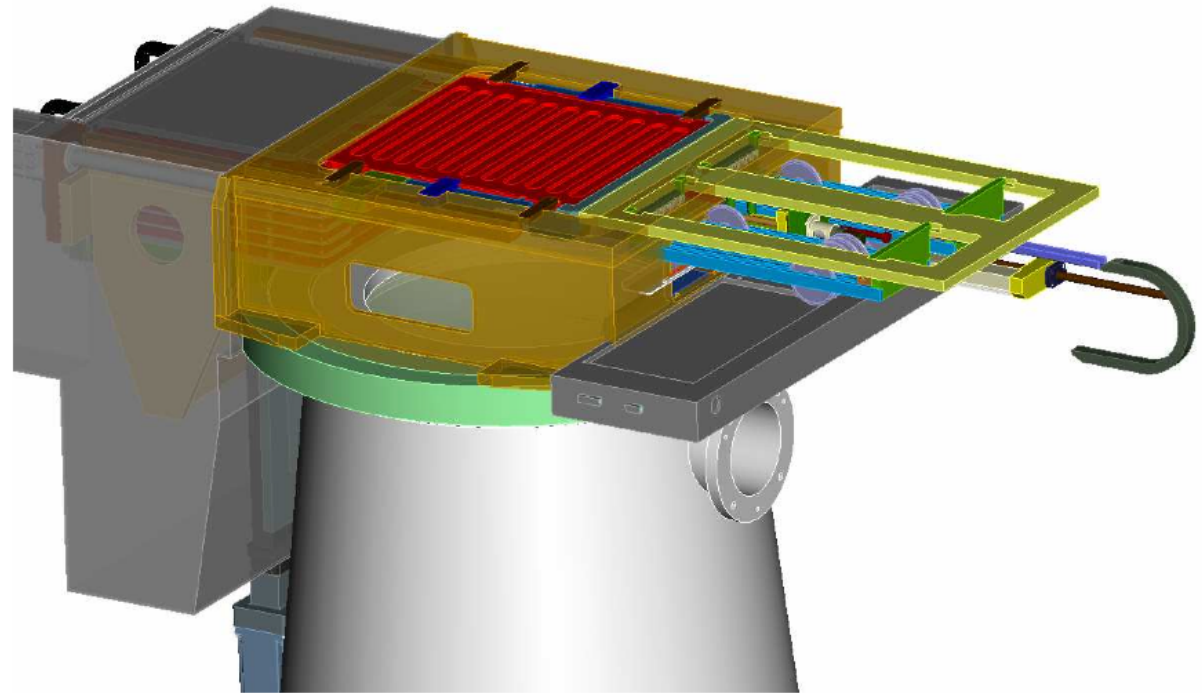
Kick-off meeting in Heidelberg – **Project start**

A bit of history: Oct 2009



Conceptual
Design Review:
*"do one thing,
and do it well"*

HRS becomes
CARMENES
and XMS pulls
out



A bit of history: Mar 2010



Report by the ETSRC on Europe's 2-4m OIR telescopes over the next decade

3.2.4 Near-IR, highly-stable high-resolution echelle spectrograph ($R \sim 70000$)

Science

Highly-stable, high-resolution spectrographs in the near-IR, capable of delivering RV with precision better than 1m/s are needed to conduct RV surveys of M dwarfs to find Earth-size planets in the habitable zone. Because of their low masses, radii and resultant low effective temperatures, M-type stars are more viable for RV detection of Earth-like planets at near-IR wavelengths.

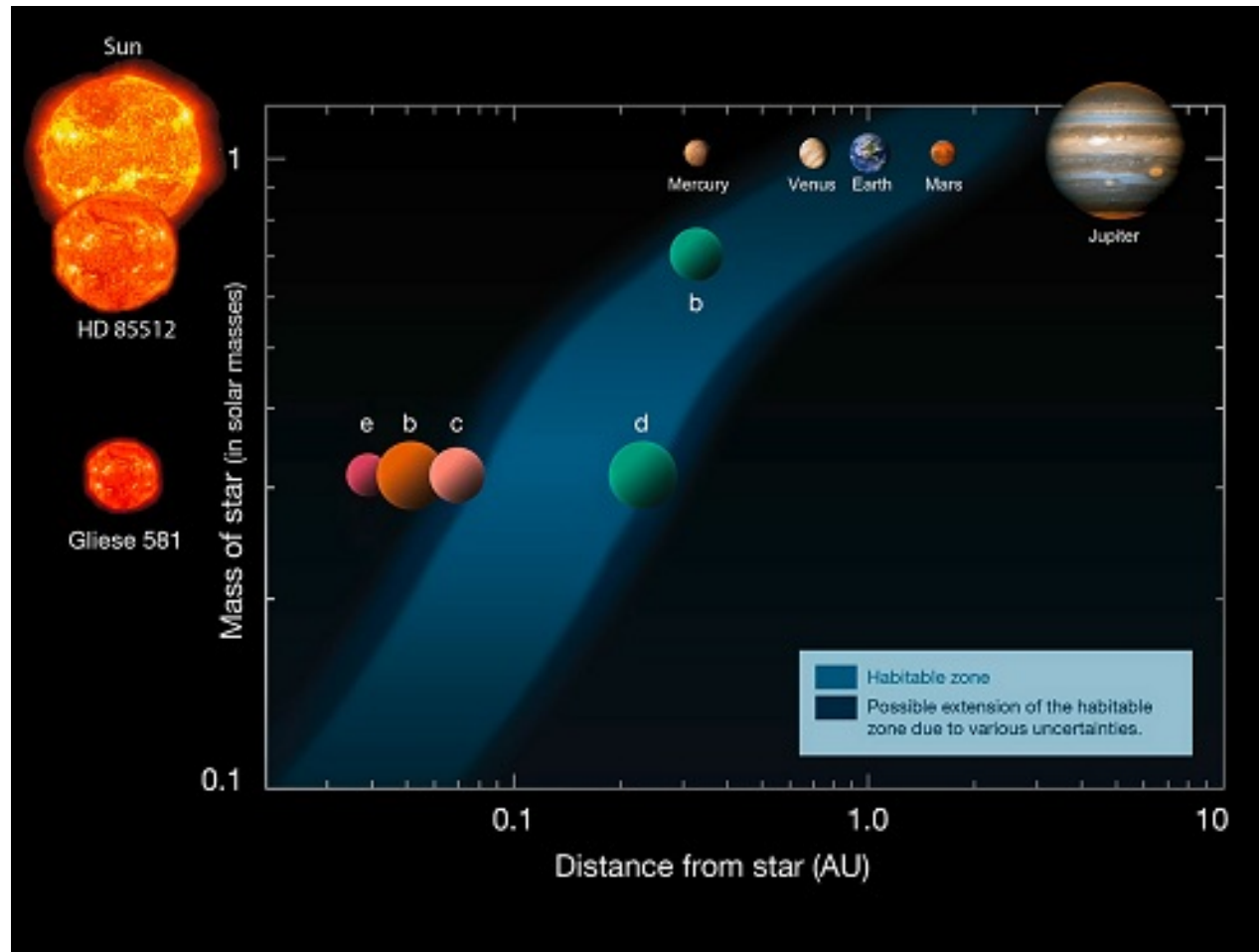
A bit of history: Mar 2010



Report by the ETSRC on Europe's 2-4m OIR telescopes over the next decade

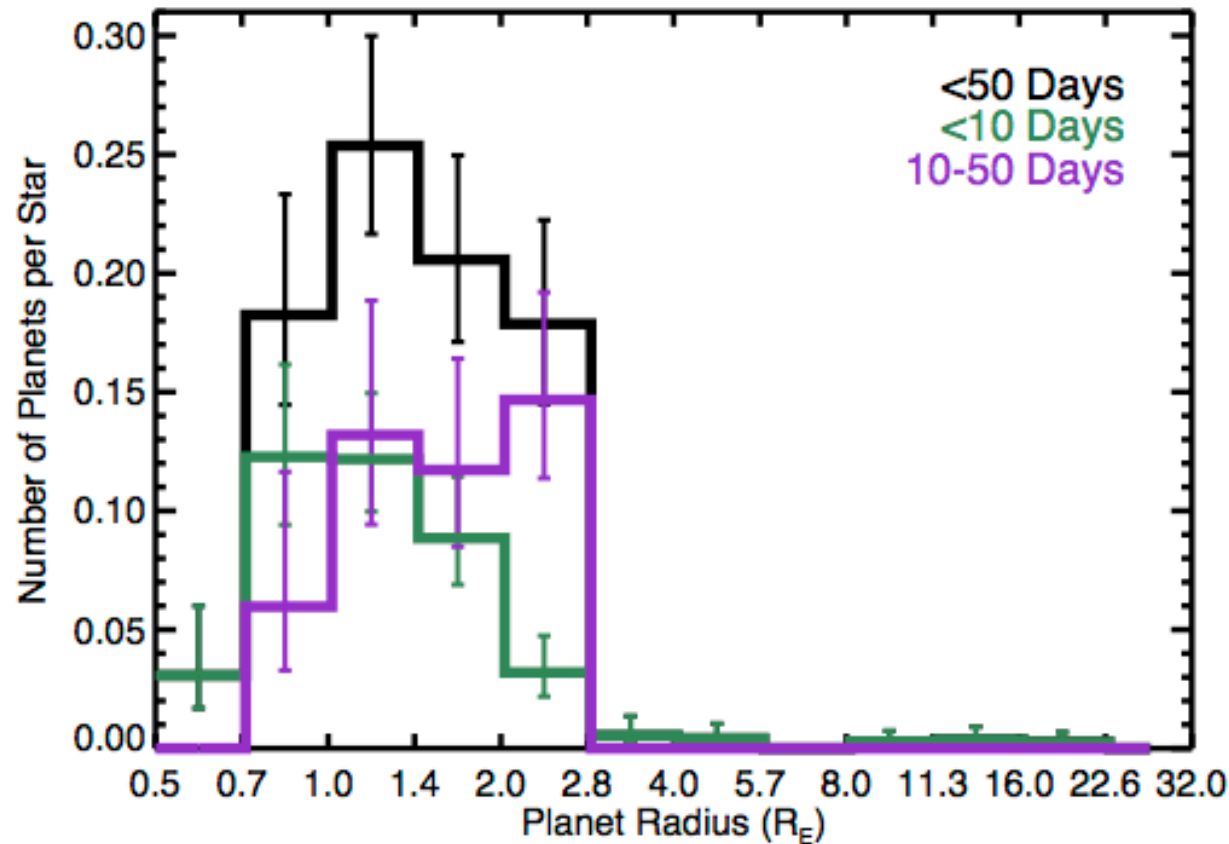
Capability		Explanation	
ID & hemisphere/aperture		problem	timescale/remedy
1-1: $R \sim 5000$ optical wide-field spectrograph	N/4m	WHT/WYFFOS multiplex + unvignetted field inadequate	~ 2015 on a 4-m
	S/4m	none available	new VISTA sp'graph after nir surveys
1-2: $R > 20000$ optical wide-field spectrograph	N/4m	not available – needs 2-deg corrector	gain early S experience (below); combine with 1-1 capability
	S/4m	(as north)	AAT/HERMES buy-in and/or VLT/FLAMES use preparatory to new build
2-1: highly stable $R \sim 10^5$ optical echelle sp'graph	N/4m	HARPS-NEF private and temporary	alternative from end of MOU (CFHT pref.)
2-3: $R \sim 70000$ nir echelle (with spectropolarimetry)	either/4m	closest matches SPIRou, CARMENES not confirmed	~ 2015 : support SPIRou or CARMENES
3-1: $500 < R < 5000$ opt+nir spectroscopy	S/4m	ageing EFOSC2, SOFI: prospect of no 2-4m sp'graph of the class in the south	upgrade needed by 2015

A bit of history: Sep 2010



HARPS GJ 581's planet in habitable zone and...
We get money! (Calar Alto 2013-2018)

A bit of history: Feb 2013

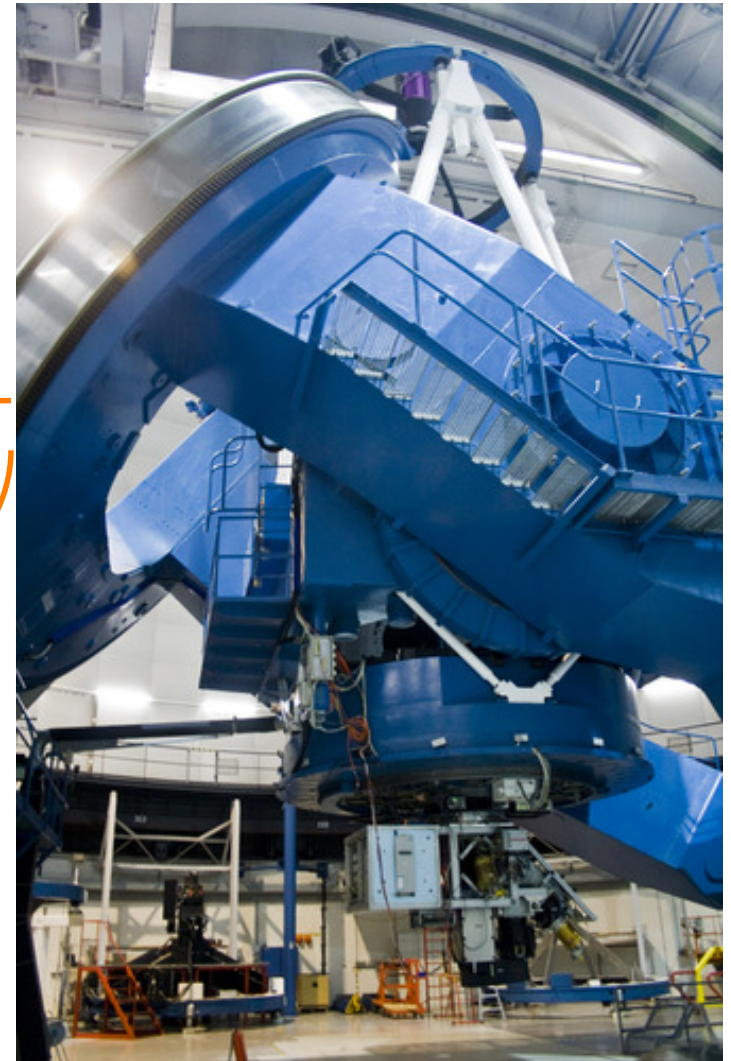
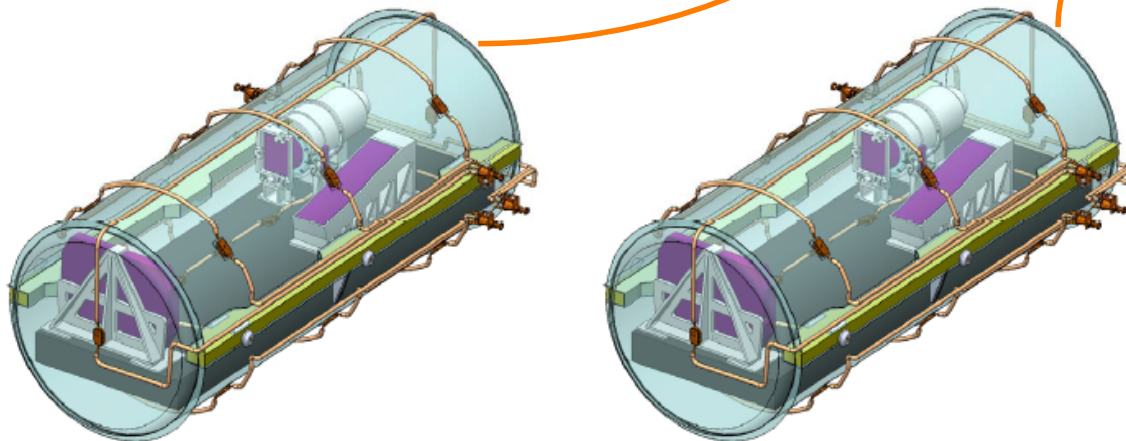


The frequency of (habitable?) planets around M dwarfs from *Kepler* (~50%!) and...
CARMENES passed the FDR!

CARMENES, the instrument



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



CARMENES, the instrument



<i>Basic engineering parameters</i>	NIR channel	VIS channel
$\Delta\lambda$ [μm]	0-95-1.70 (29 orders)	0.55-1.05 (53 orders)
Cross disperser	Grism, infrasil	Grism, LF5 glass
Working T [K]	~140	~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]	Th-Ne [F-P etalon]
Optical parameters	Fixed R=82,000*, 2.8-pix sampling (>2.3 pix), 7-pix inter-fibre spacing	

The Carmenes logo features a stylized circular emblem composed of a red circle, a black ring, and a yellow arc, with a small black dot above it. Below the emblem, the word "carmenes" is written in a lowercase, sans-serif font, with the "c" and "e" highlighted in yellow.

Germany + Spain ≥ 5.0 MEUR (hardware)



Project supervisory board
MPIA director, IAA director,
CAHA director, Pls

**Core
Management
Team**

Principal investigators
A. Quirrenbach (LSW)
P. J. Amado (IAA)

**Institution
representatives**
R. Mundt (MPIA)
P. J. Amado (IAA)
A. Quirrenbach (LSW)
I. Ribas (ICE)
A. Reiners (IAG)
V. J. S. Béjar (IAC)
E. W. Guenther (TLS)
D. Montes (UCM)
J. H. H. M. Schmidt (HS)
E. L. Martín (CAB)
D. Barrado (CAHA)

System engineers
W. Seifert (LSW)
M. A. Sánchez Carrasco (IAA)

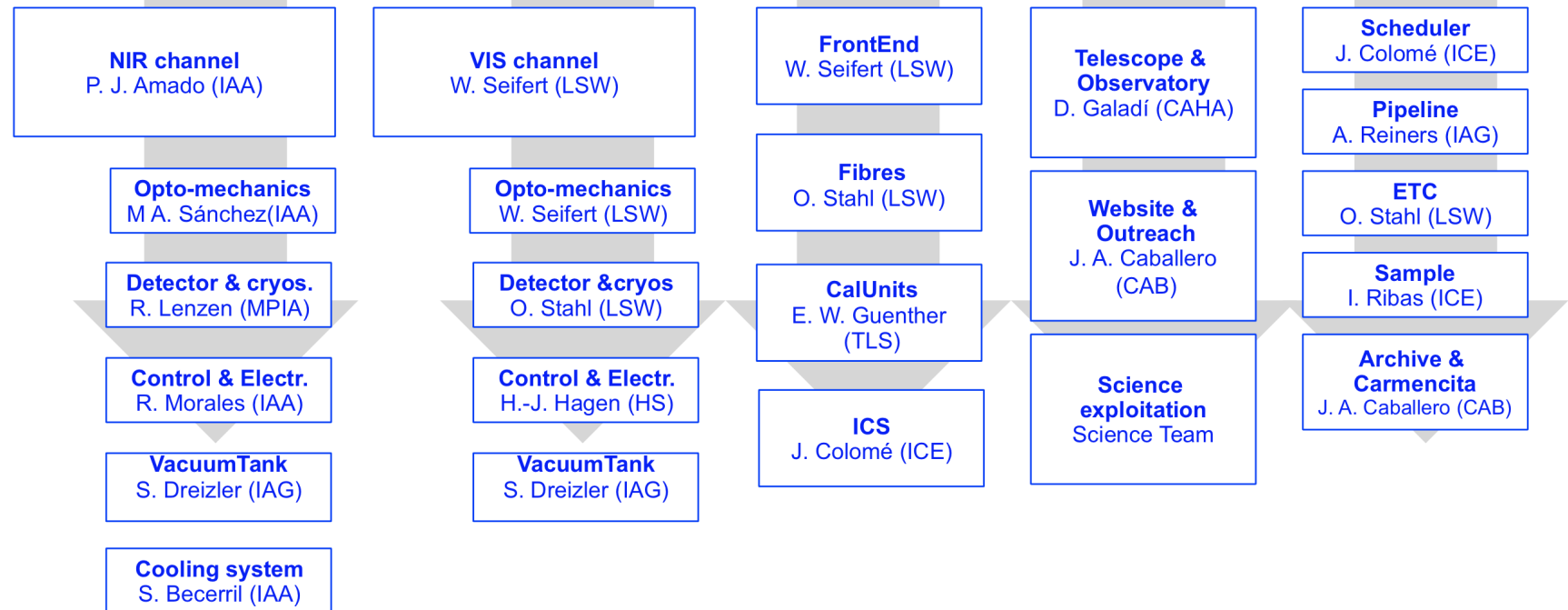
Project managers
M. L. Garcia-Vargas (*Fractal*)
J. A. Caballero (CAB)

Project scientists
I. Ribas (ICE)
A. Reiners (IAG)

MPIA liaison
R. Mundt (MPIA)

Associate project managers
M. Azzaro (CAHA)
H. Mandel (LSW)

CAHA liaison
D. Galadí (CAHA)



CARMENES. I: Instrument and Survey Overview

A. Quirrenbach^a, P. J. Amado^b, W. Seifert^a, M. A. Sánchez Carrasco^b, H. Mandel^a,
J. A. Caballero^c, R. Mundt^d, I. Ribas^e, A. Reiners^f,
M. Abril^b, J. Aceituno^g, F. J. Alonso-Floriano^h, M. Ammler-von Eiffⁱ, G. Anglada-Escudé^f,
R. Antona Jiménez^b, H. Anwand-Heerwart^f, D. Barrado y Navascués^g, S. Becerril^b,
V. J. S. Béjar^j, D. Benítez^g, M. C. Cárdenas^b, A. Claret^b, J. Colomé^e, M. Cortés-Contreras^h,
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D. Galadí^g, R. Garrido^b, J. I. González Hernández^j, J. Guàrdia^e, E. W. Guentherⁱ,
E. de Guindos^g, J. Gutiérrez-Soto^b, H.-J. Hagen^k, A. P. Hatzesⁱ, P. H. Hauschildt^k,
J. Helmling^g, T. Henning^d, E. Herrero^e, A. Huber^d, K. F. Huber^k, S. Jeffers^f, V. Joergens^d,
E. de Juan^g, M. Kehrⁱ, A. Klutsch^h, M. Kürster^d, S. Lalitha^k, W. Laun^d, U. Lemke^f,
R. Lenzen^d, J. L. Lizon^m, M. López del Fresno^c, M. López-Morales^e, J. López-Santiago^h,
U. Mall^d, E. L. Martín^c, S. Martín-Ruiz^b, E. Mirabet^b, D. Montes^h, J. C. Morales^e,
R. Morales Muñoz^b, A. Moya^c, V. Naranjo^d, R. Oreiro^b, D. Pérez Medialdea^b, M. Plutoⁱ,
O. Rabaza^b, A. Ramón^b, R. Rebolo^j, S. Reffert^a, P. Rhode^f, H.-W. Rix^d, F. Rodler^e,
E. Rodríguez^b, C. Rodríguez-López^b, E. Rodríguez-Pérez^b, A. Rodríguez Trinidad^b,
R.-R. Rohloff^d, E. Sánchez-Blanco^b, J. Sanz-Forcada^c, S. Schäfer^f, J. Schillerⁱ, C. Schmidt^f,
J. H. M. M. Schmitt^k, E. Solano^c, O. Stahl^a, C. Storz^d, J. Stürmer^a, J. C. Suárez^b, U. Thiele^g,
R.-G. Ulbrich^f, M. Vidal-Dasilva^c, K. Wagner^a, J. Winklerⁱ, W. Xuⁿ, M. R. Zapatero Osorio^c,
and M. Zechmeister^f

Project schedule



- **Pre-selection:** *Jan 2009*
- **CDR** (Conceptual Design Review): *Oct 2009*
- **pCDR** (post-CDR): *July 2010*
- **Green light:** *Nov 2010*
- **PDR** (Preliminary Design Review): *July 2011*
- **oFDR** (optics Final Design Review): *Apr 2012*
- **FDR** (Final Design Review): *Feb 2013*
- **AIV:** *now...*
- **First light, commissioning:** Jan 2015 (Front-End), Summer 2015 (VIS), Autumn 2015 (NIR)
- **Start survey:** Winter 2015-2016



carmenes

Public

Project

Private

Referees

Project

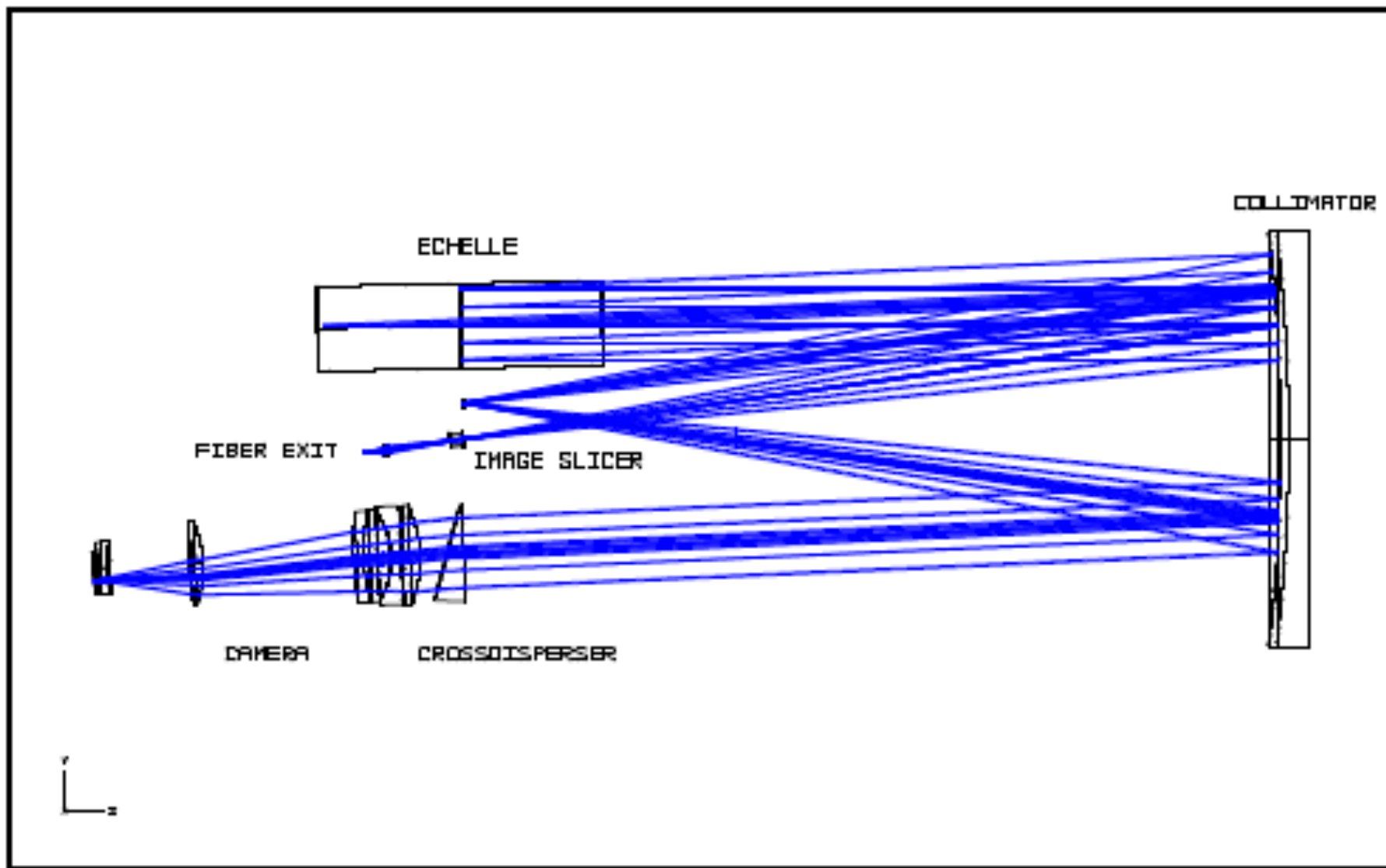
Reviewers

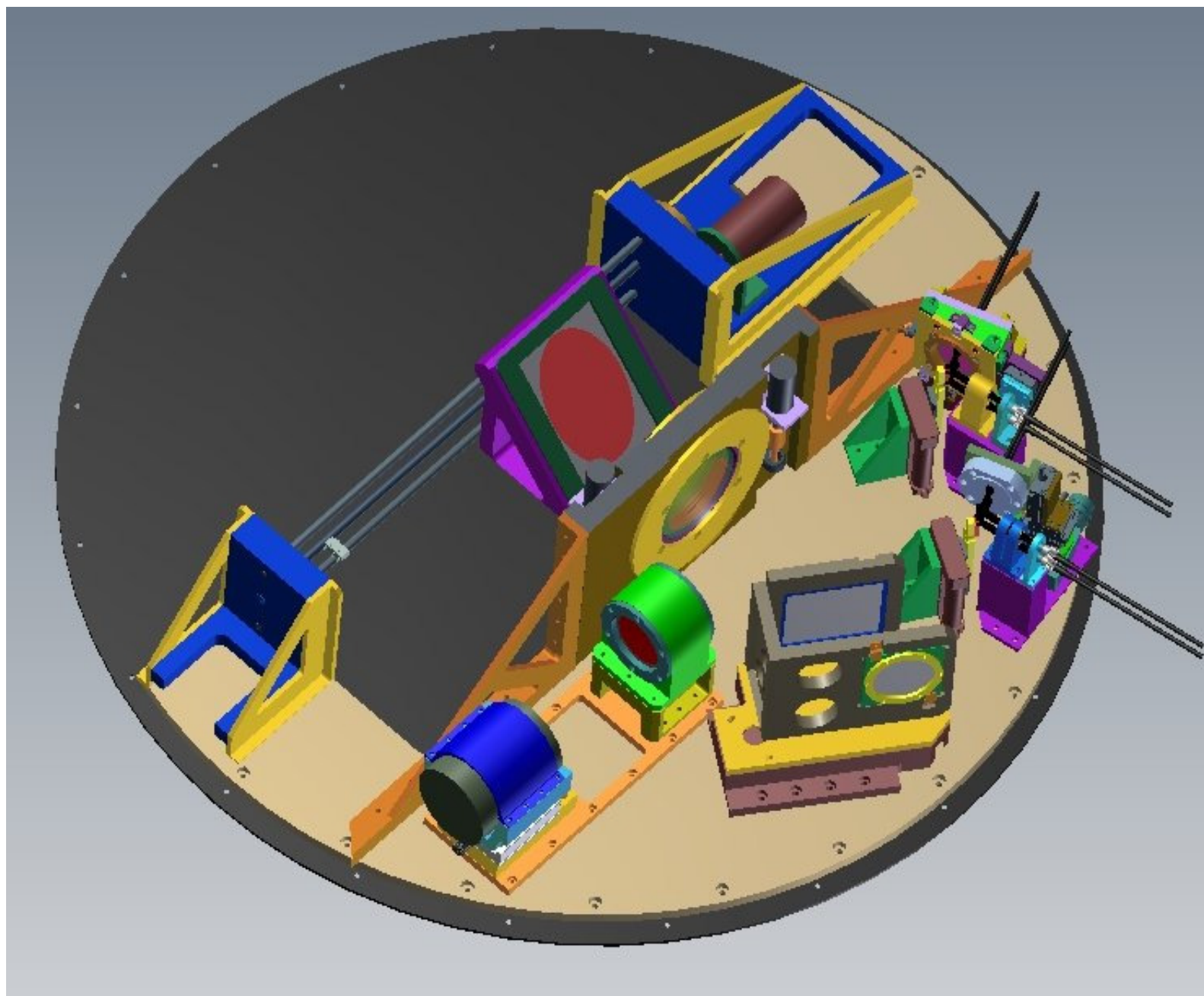
Final Design Review (Feb 2013):

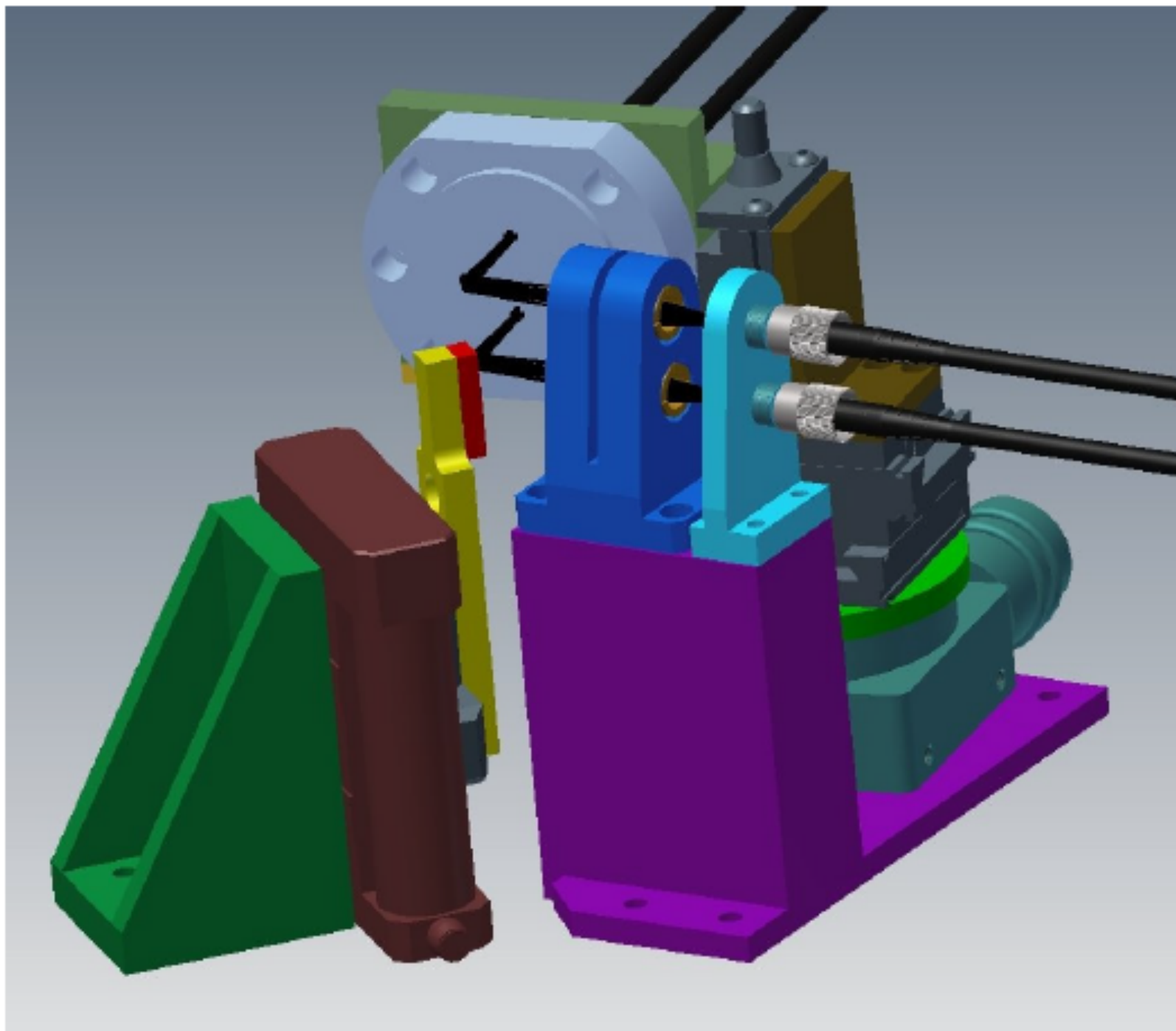
- Lawrance W. **Ramsey** (Penn State, USA) [chair]
- Jesús **Aceituno** (CAHA)
- Carlos **Díaz Cano** (CAB)
- Eva **Díaz Catalá** (CAB)
- Hugh R. A. **Jones** (University of Hertfordshire, UK)
- Bernard **Lefort** (Conseil Européen pour la Recherche Nucléaire, Switzerland)
- Miguel **Mas** (CAB)
- Andoni G. **Moral** (Instituto Nacional de Técnica Aeroespacial, Spain)
- Luca **Pasquini** (European Southern Observatory, Garching, Germany)
- Gert **Raskin** (Leuven-Mercator, Belgium-Spain)
- David **Terrett** (Rutherford Appleton Laboratory, UK)

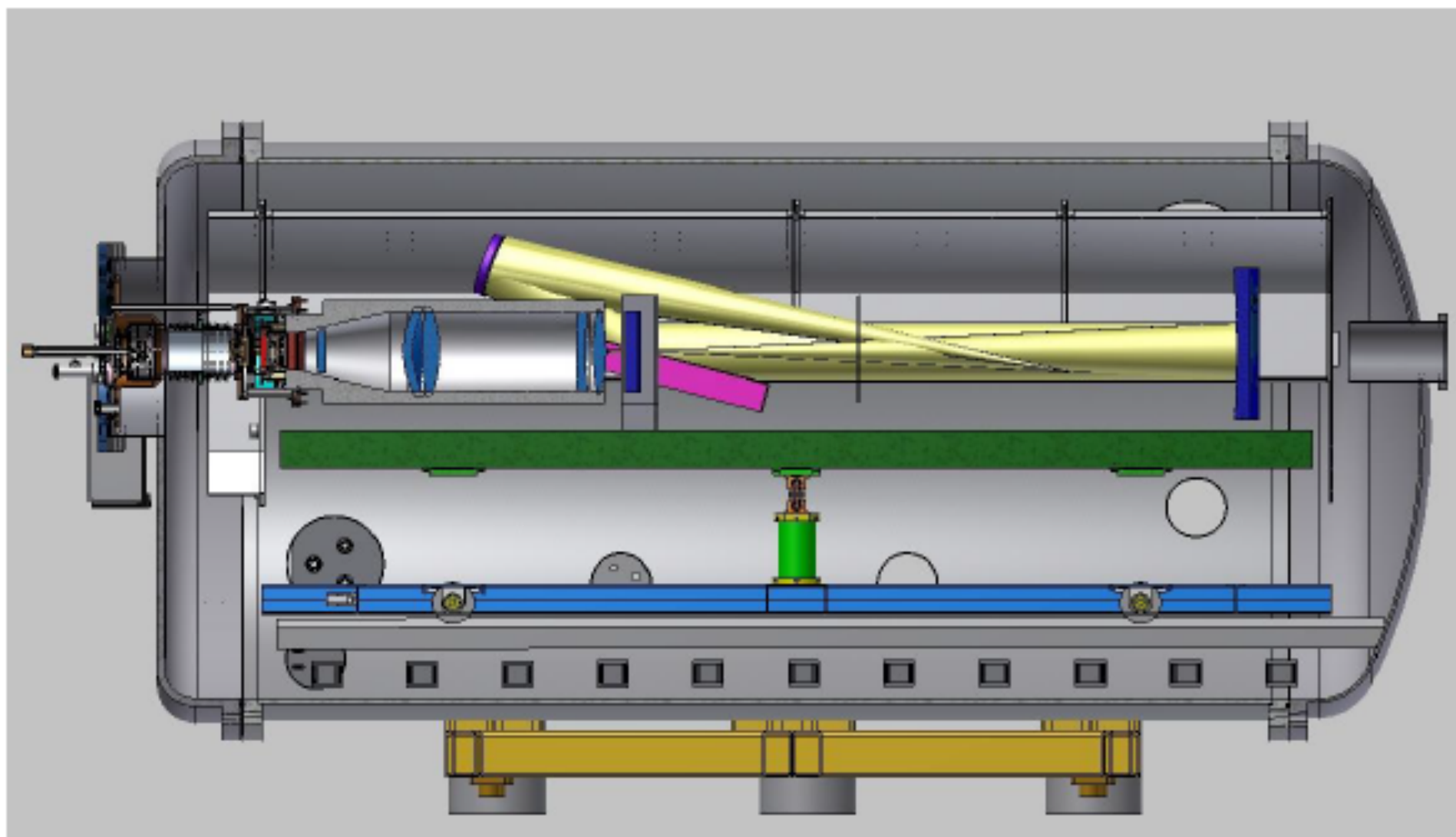
Observers of the *Deutsche Forschungsgemeinschaft*, *Plan Nacional de Astronomía y Astrofísica* and *Red de Infraestructuras de Astronomía*:

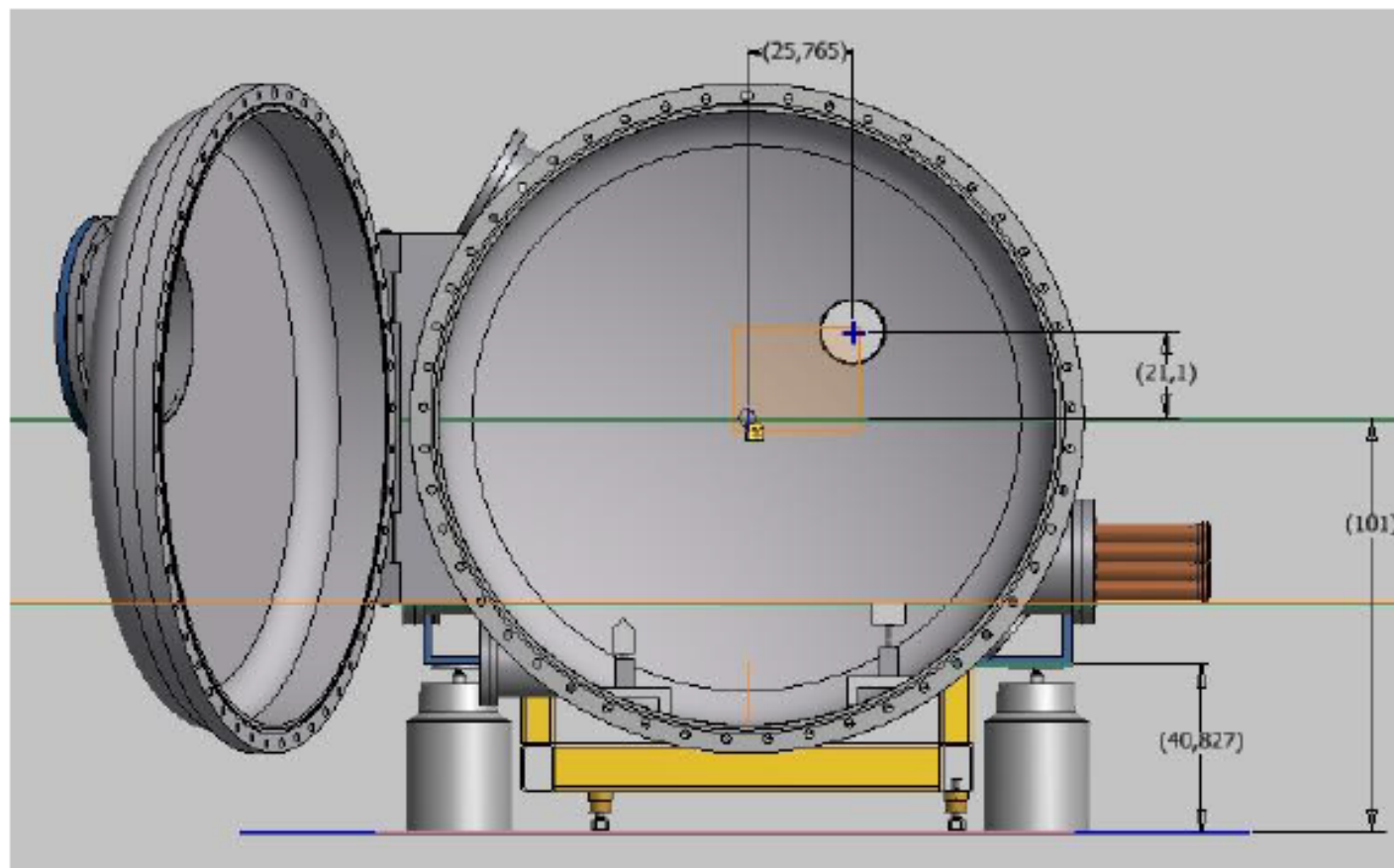
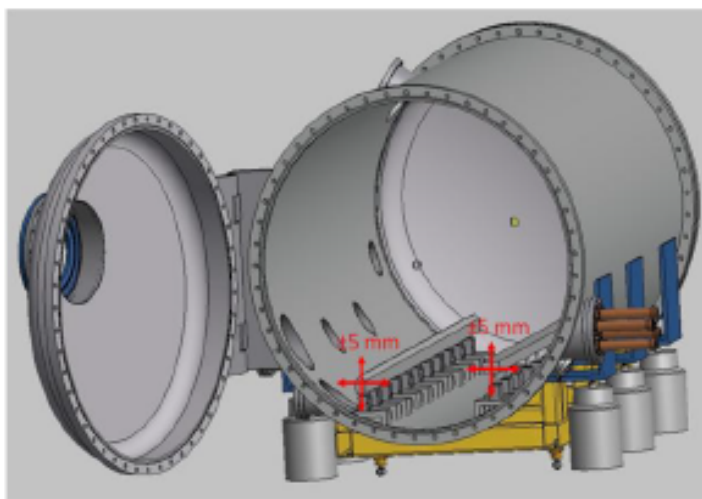
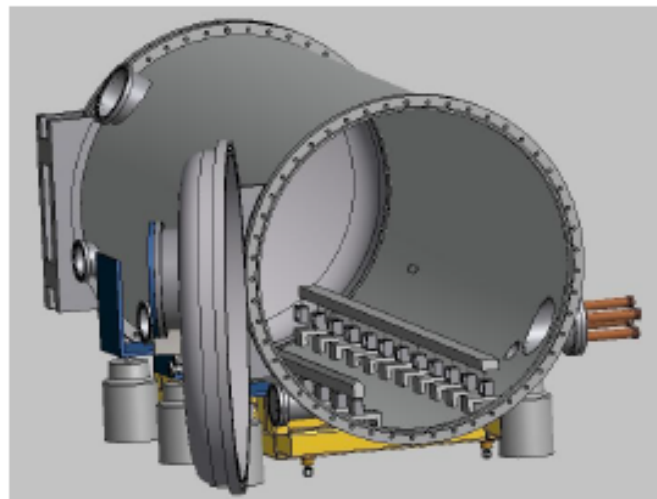
- Rafael **Bachiller** (Observatorio Astronómico Nacional, Madrid, Spain)
- Achim **Tieftrunk** (DFG, Germany)

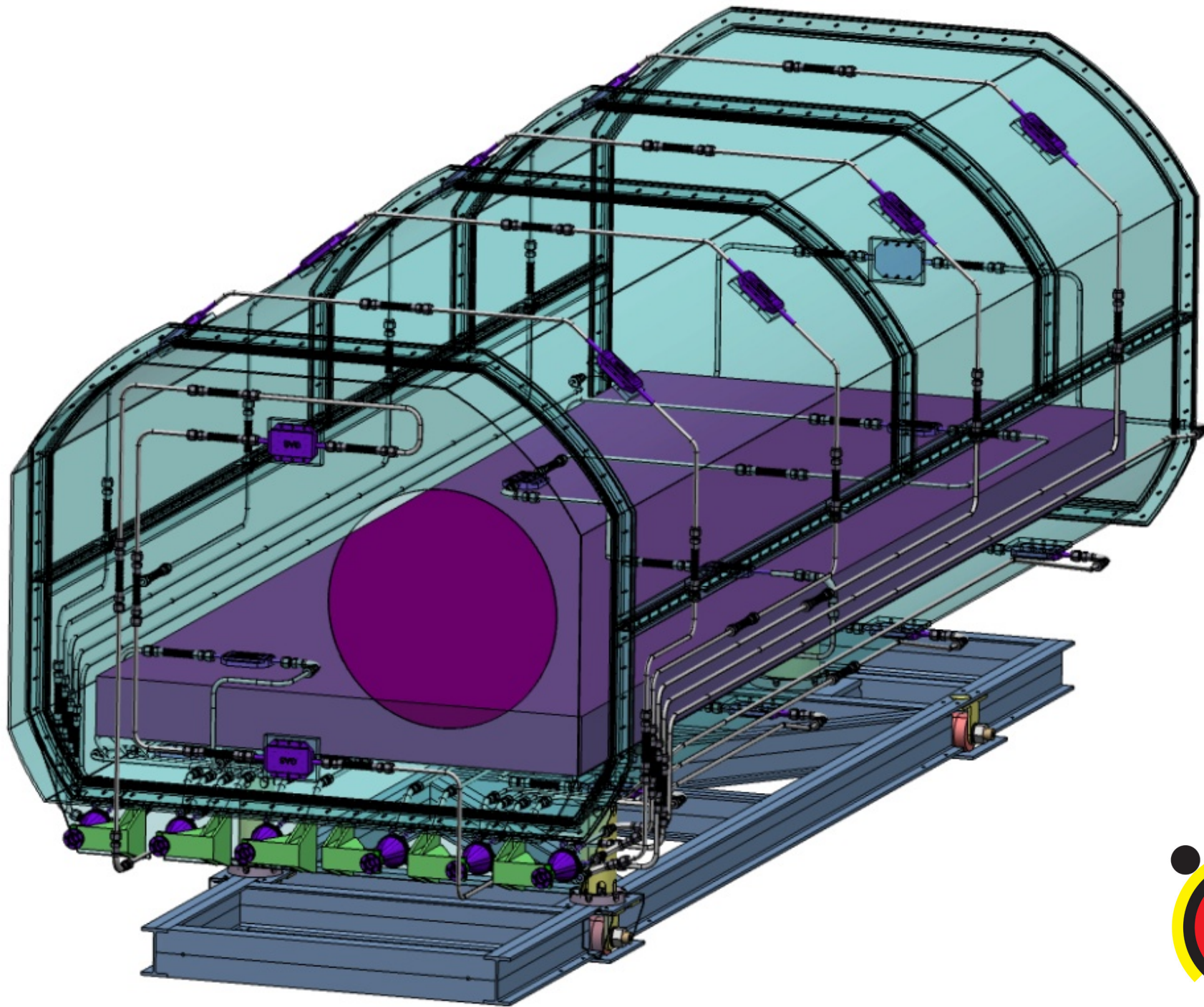


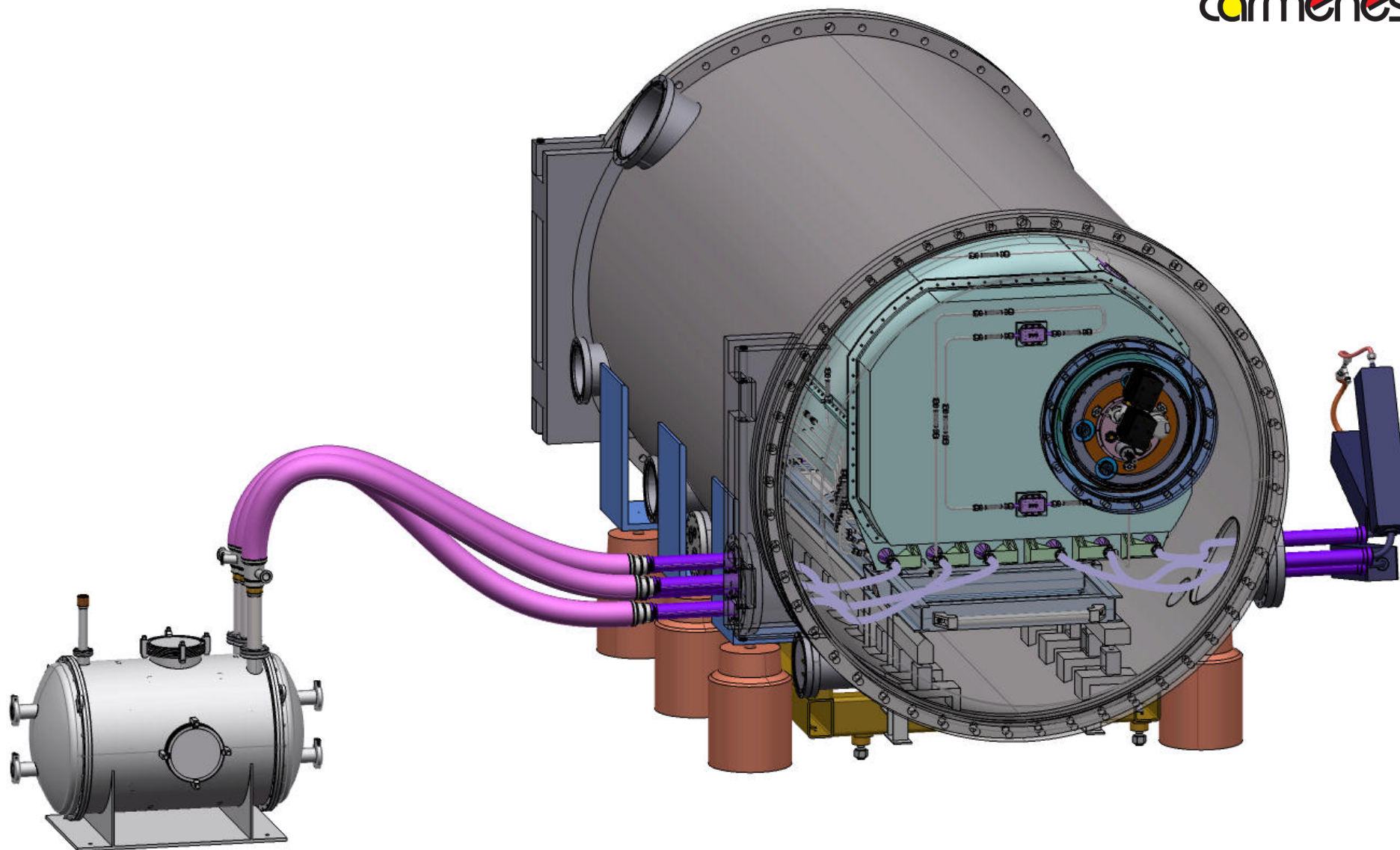


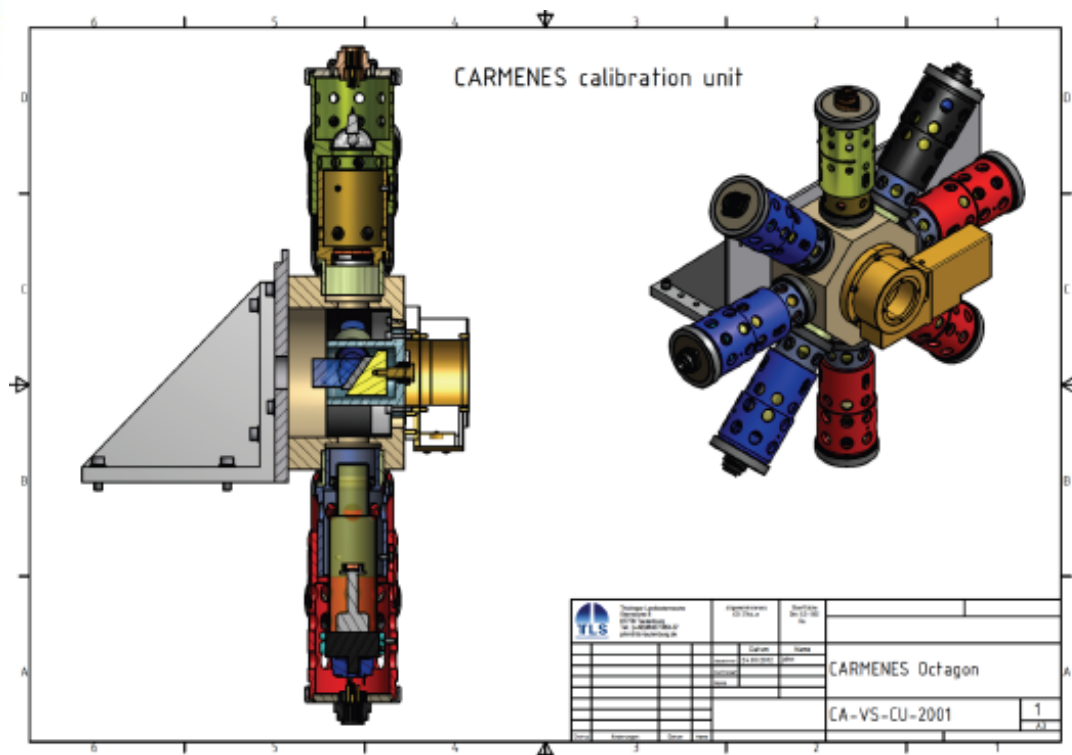
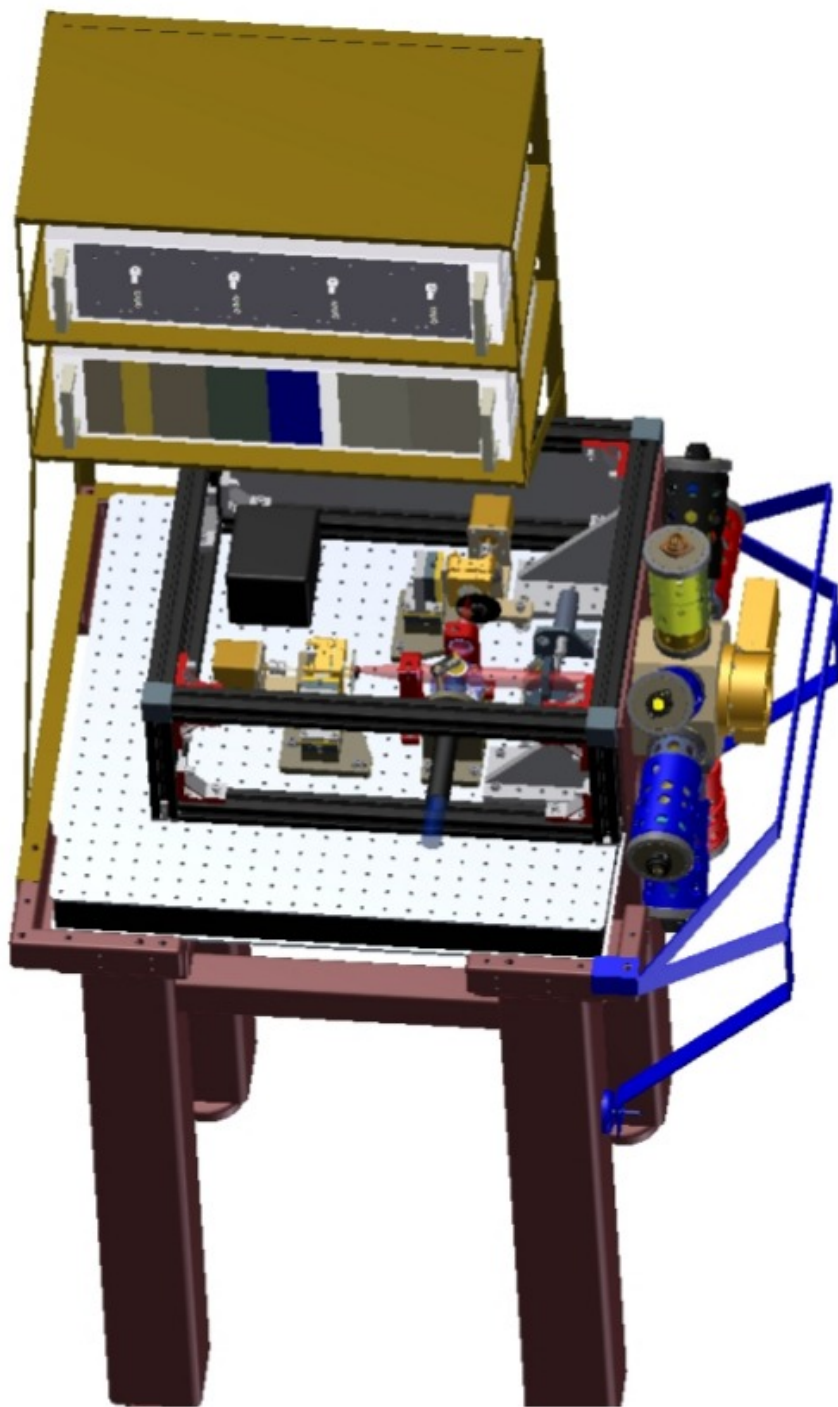


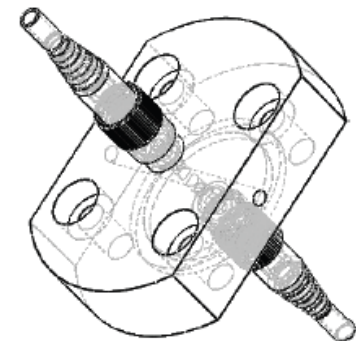
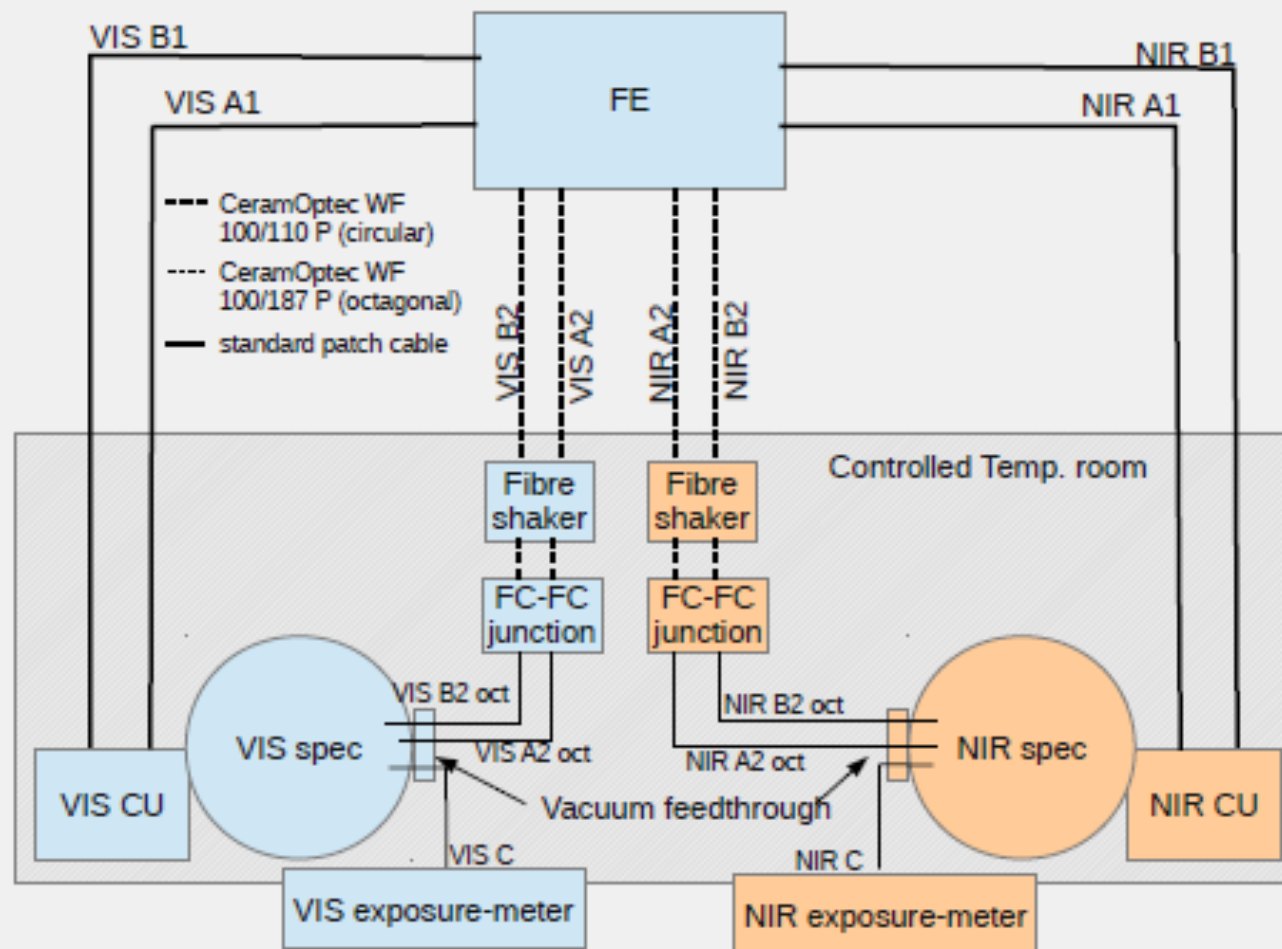


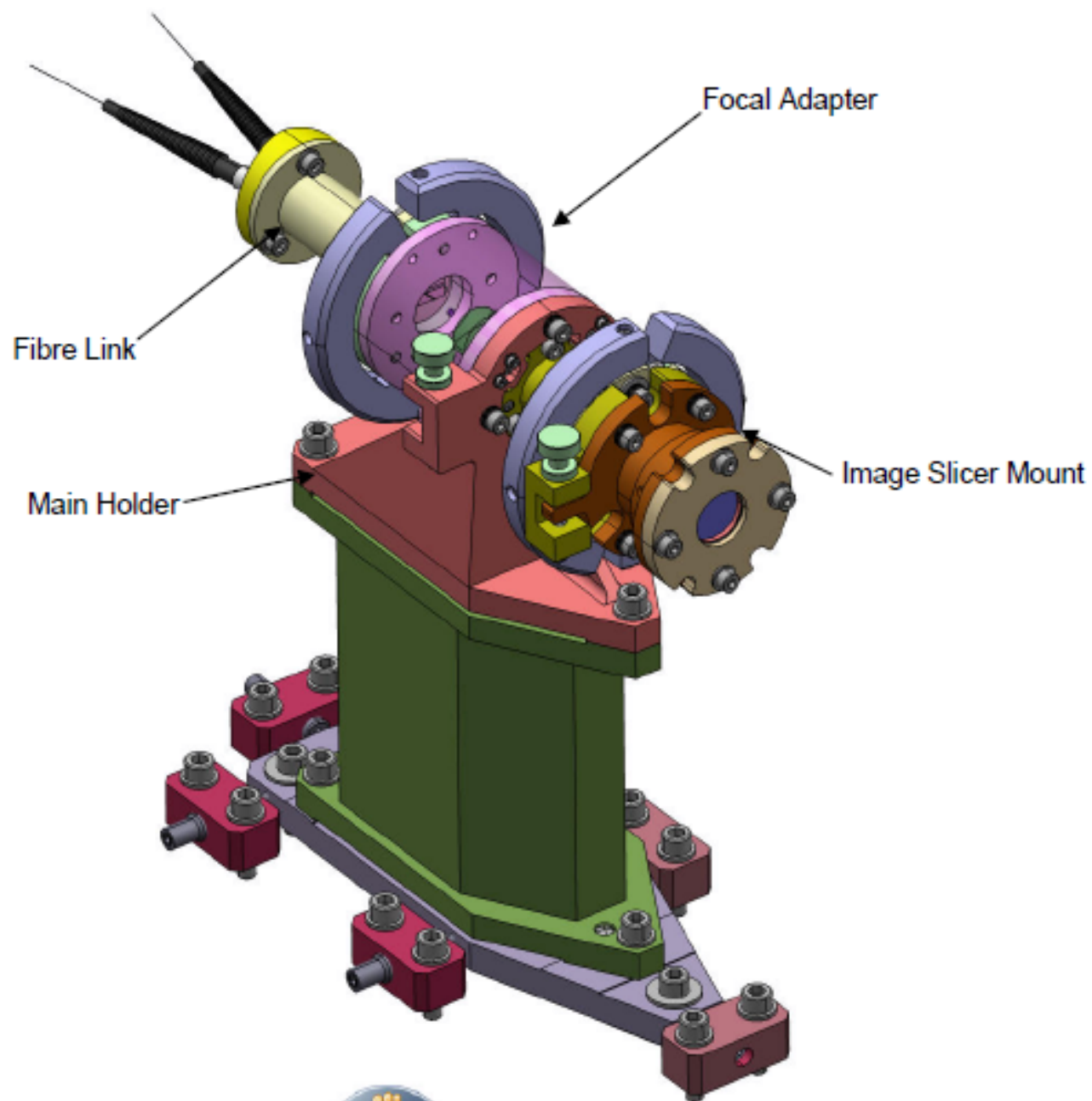


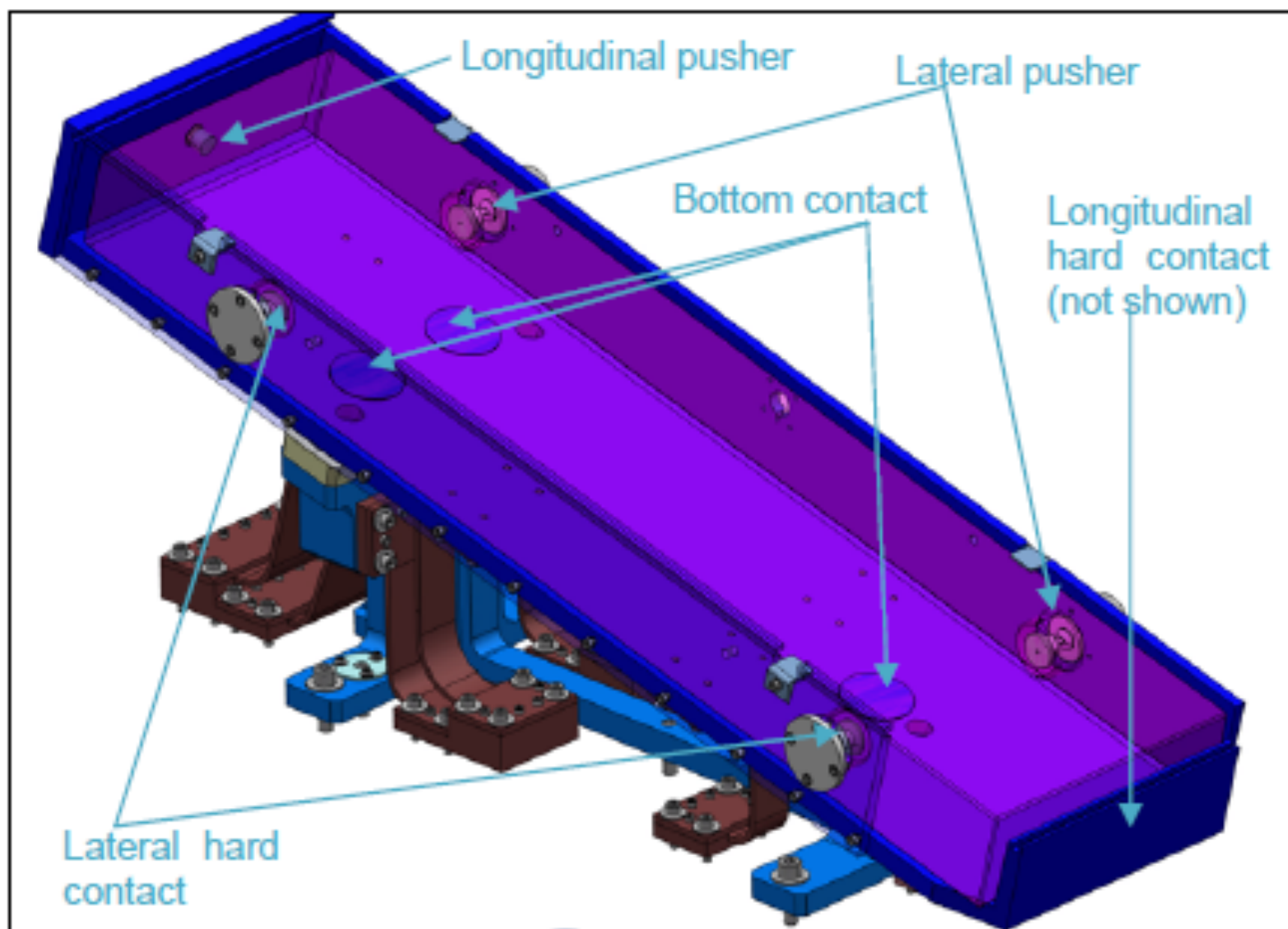


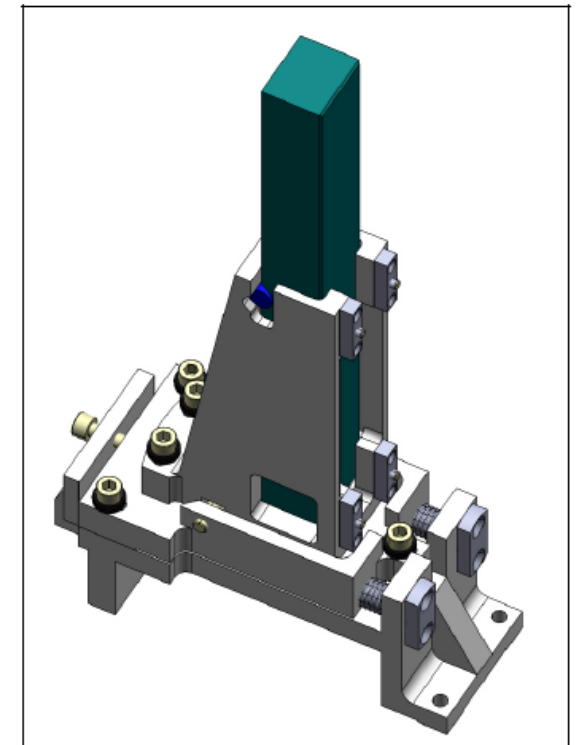
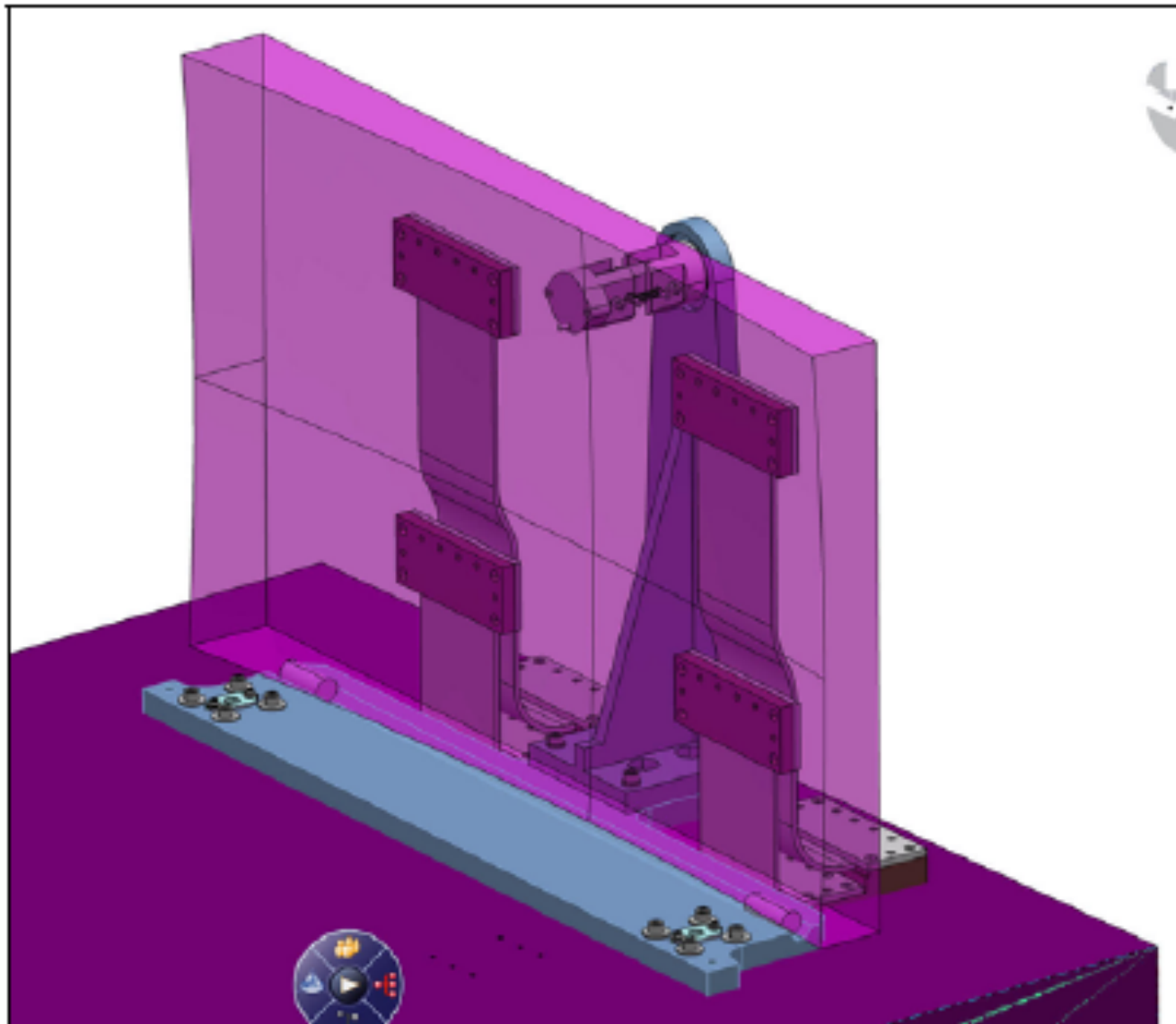


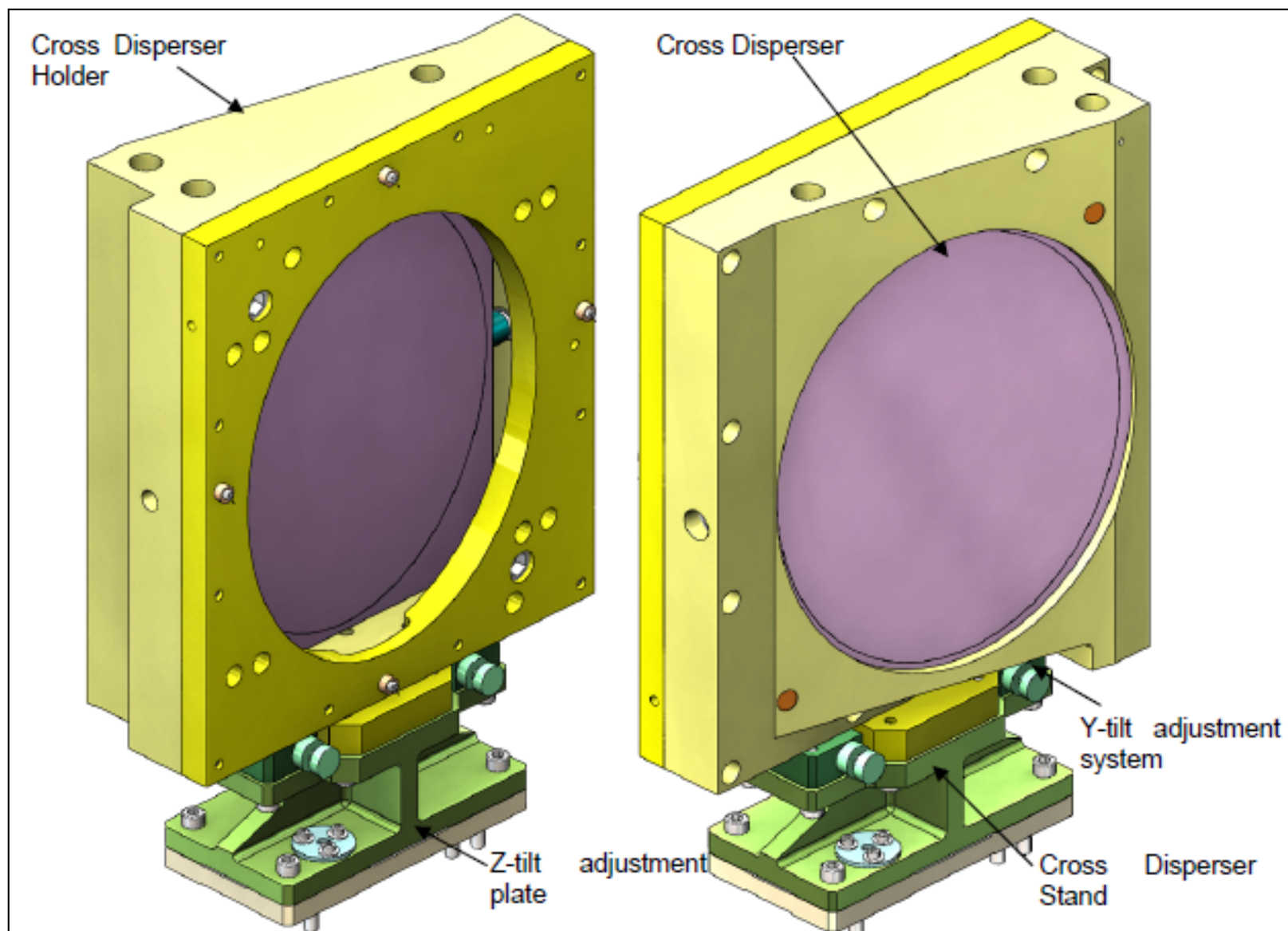


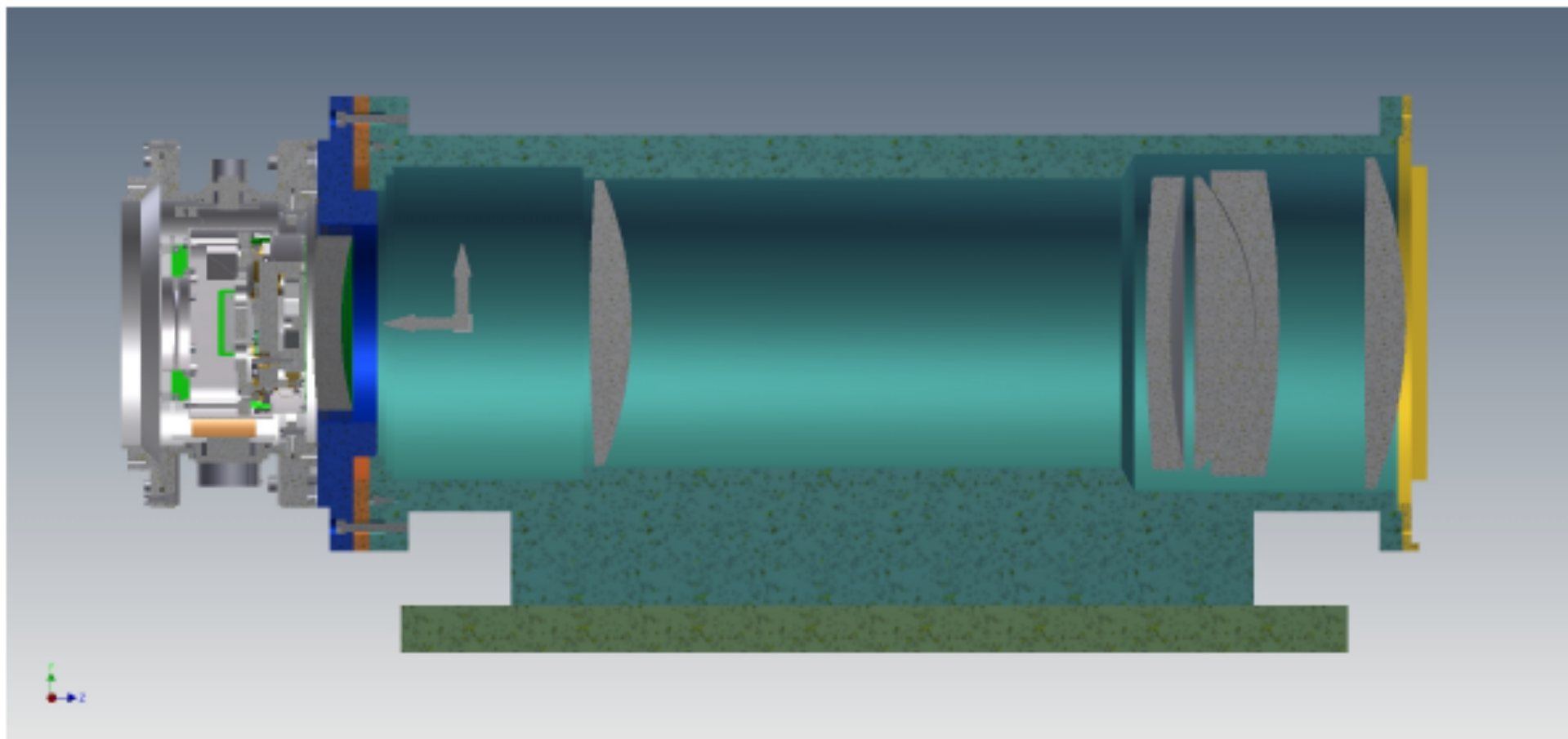


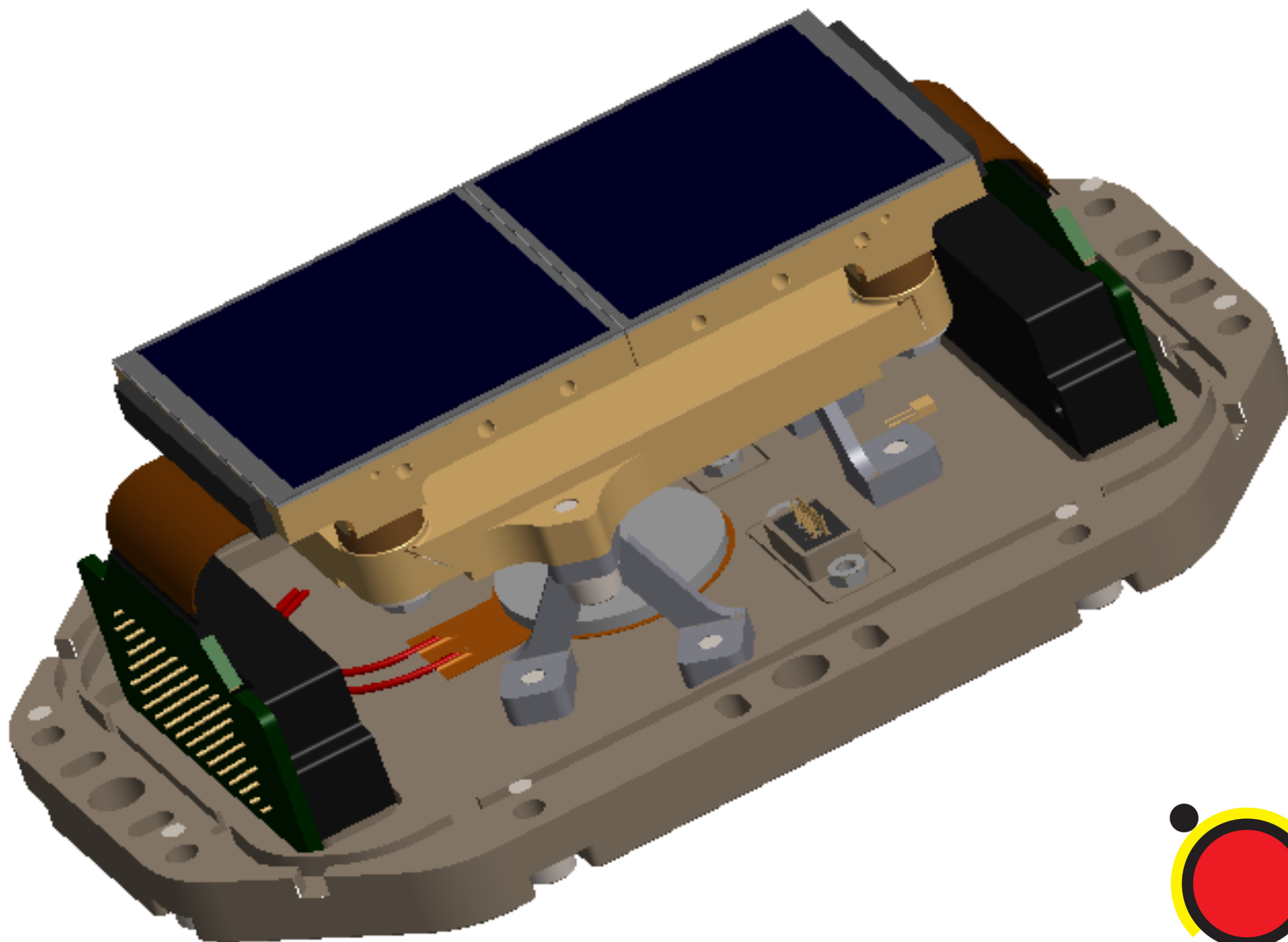


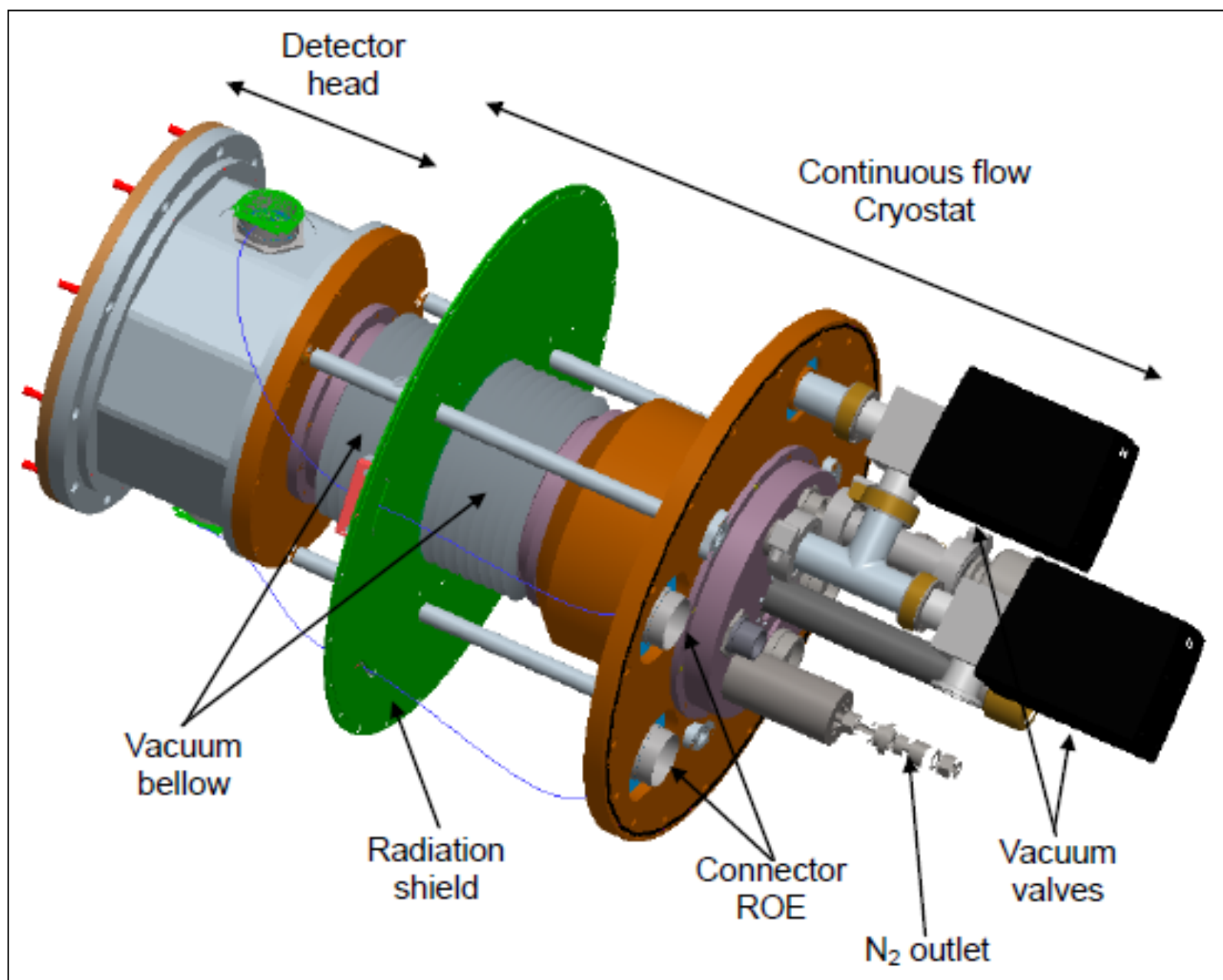








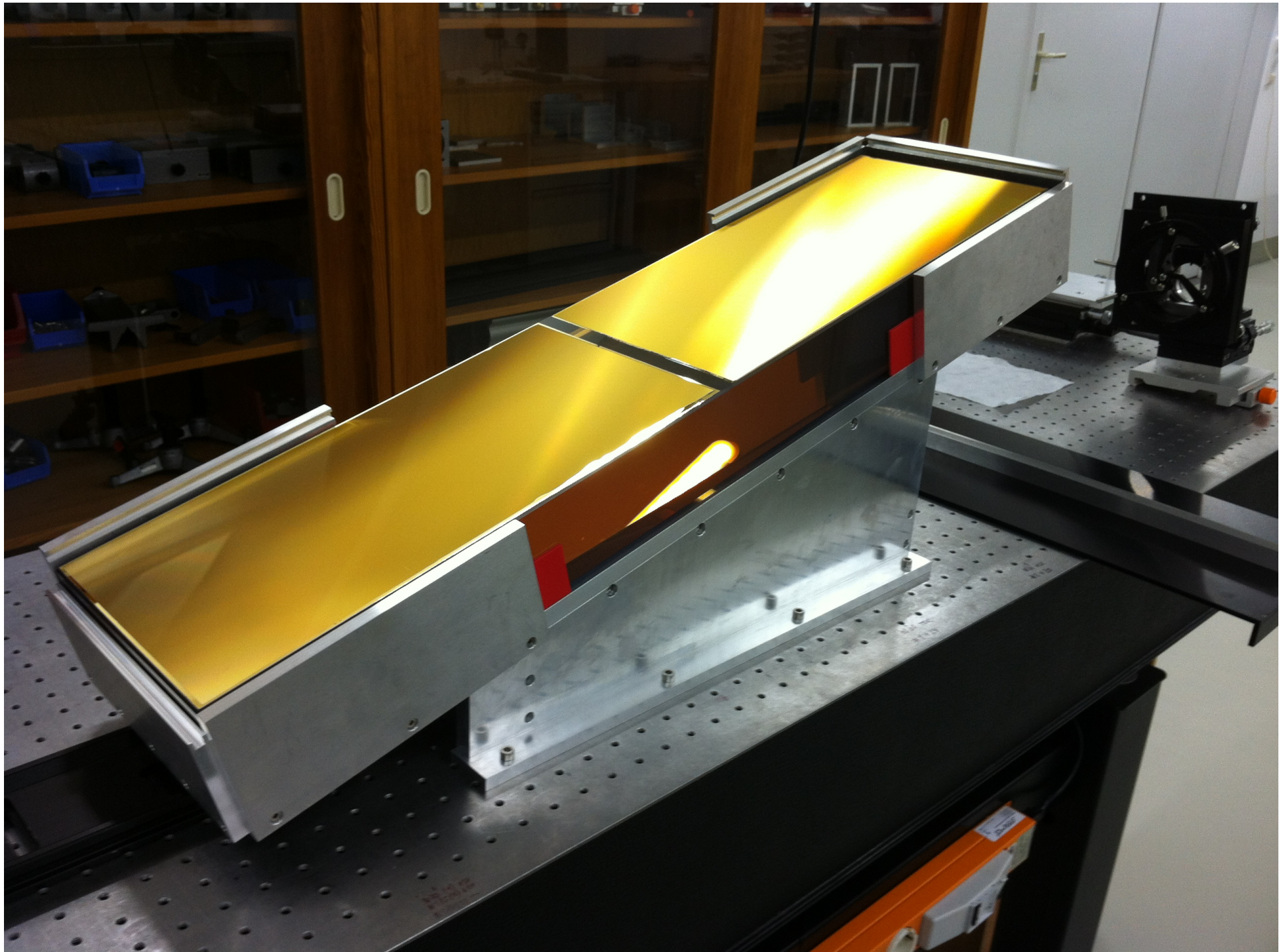


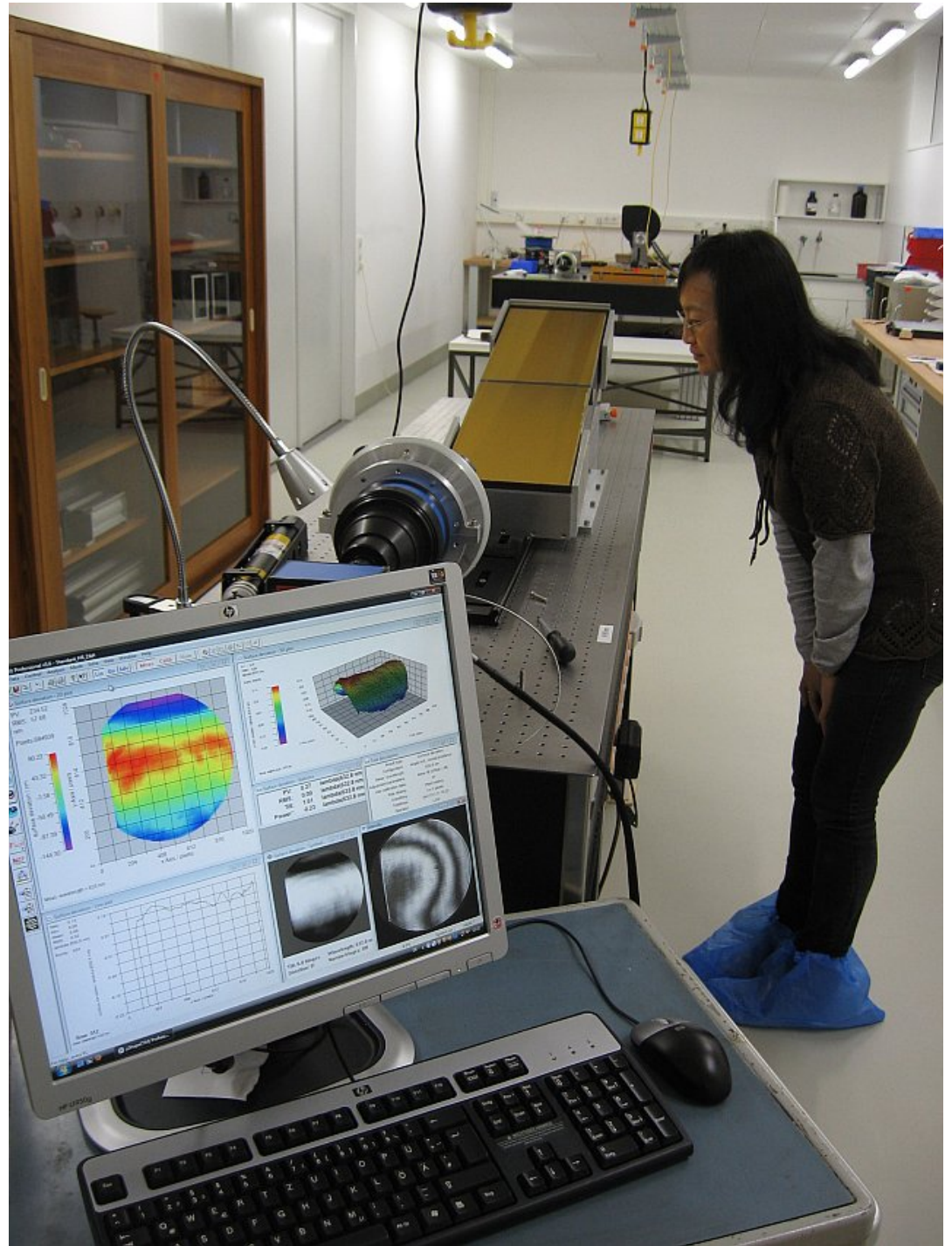
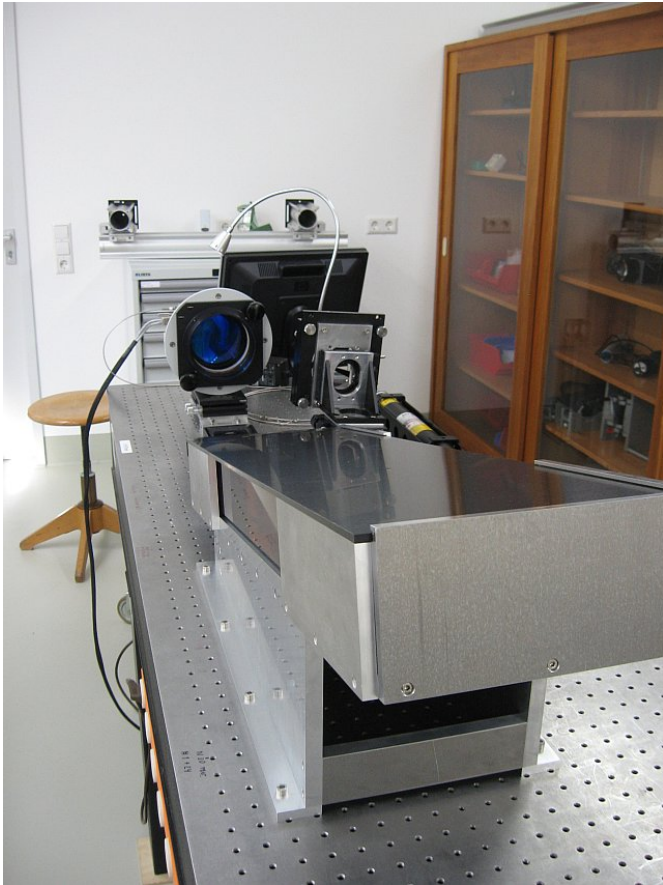


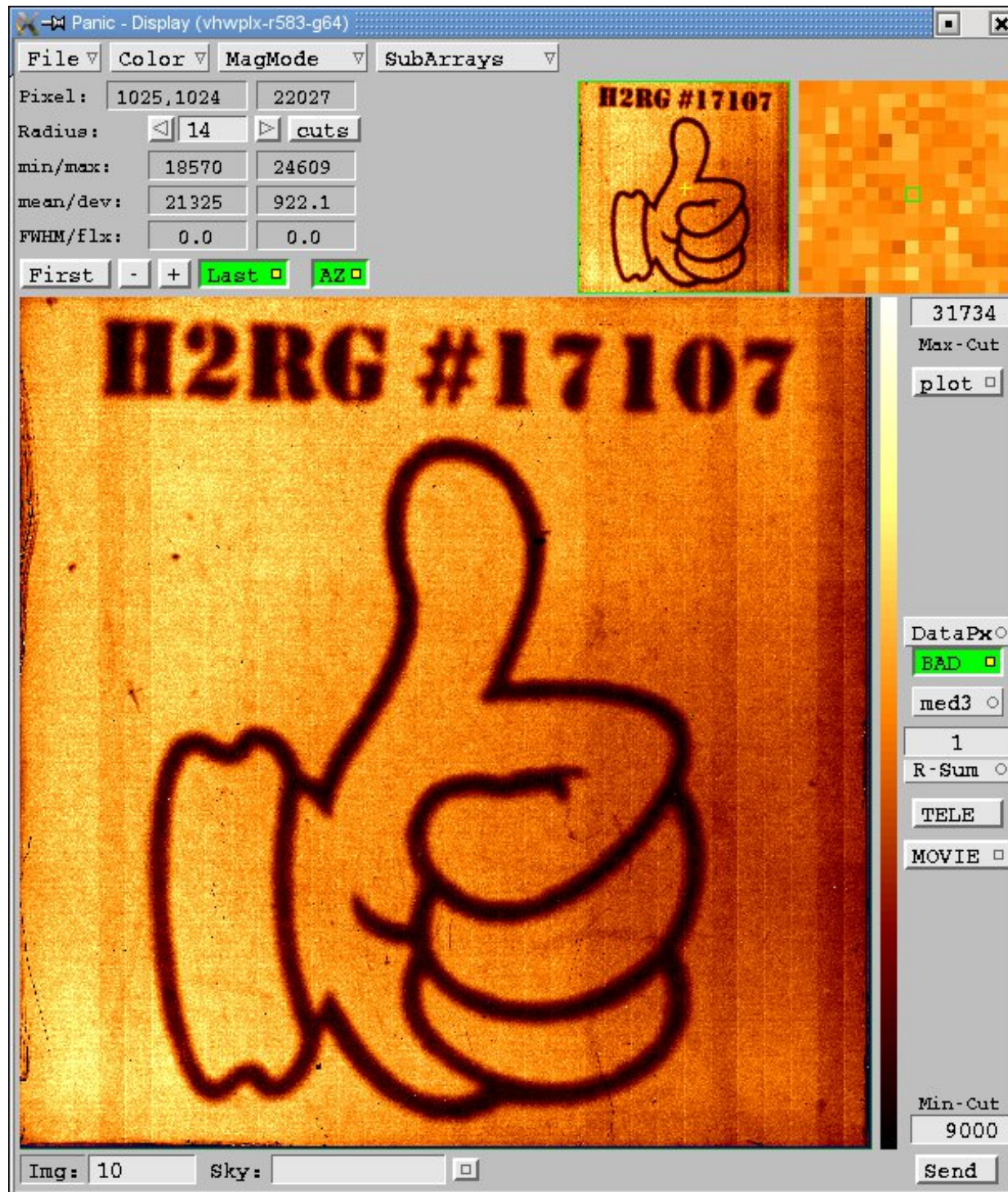
CARMENES goes shopping

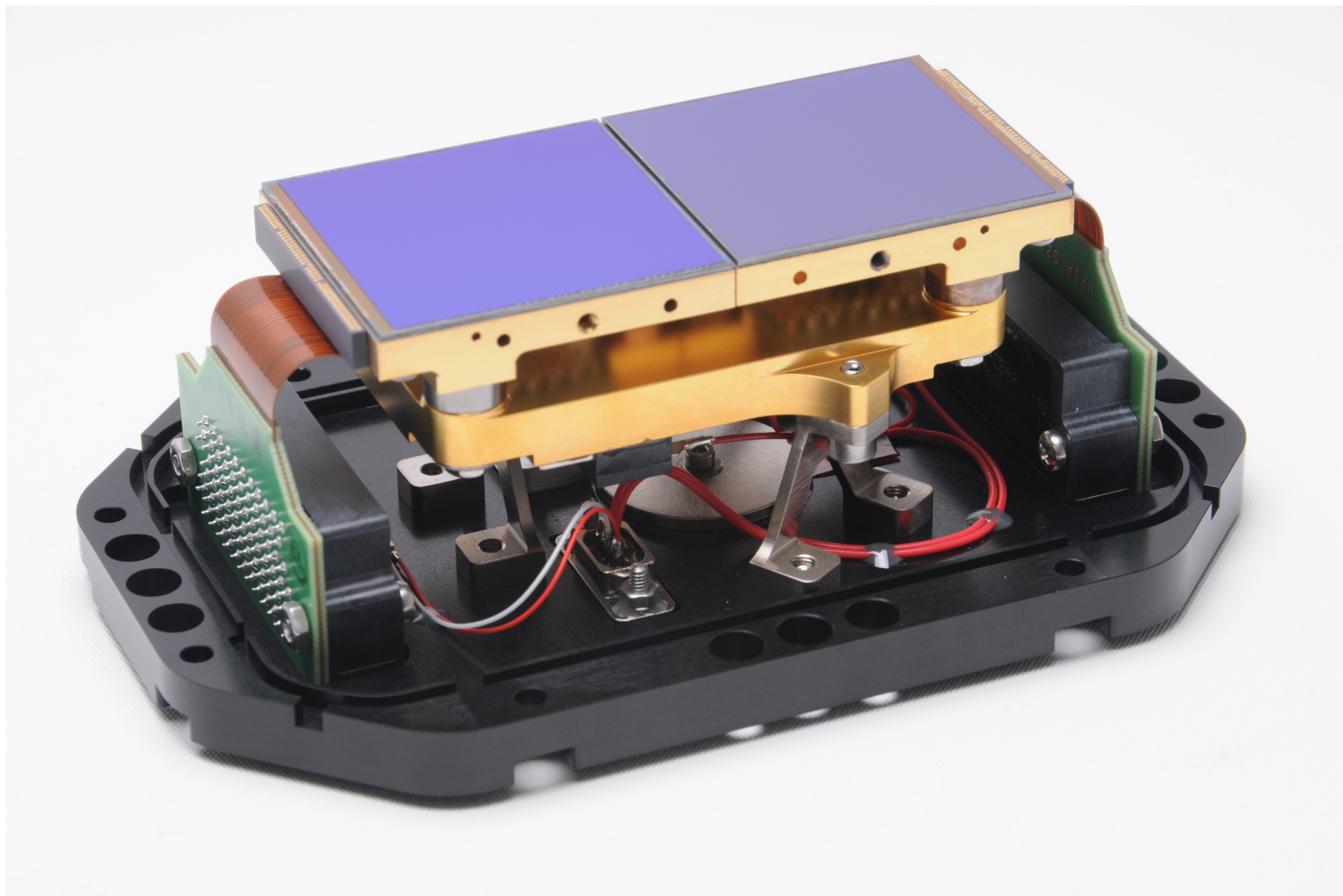


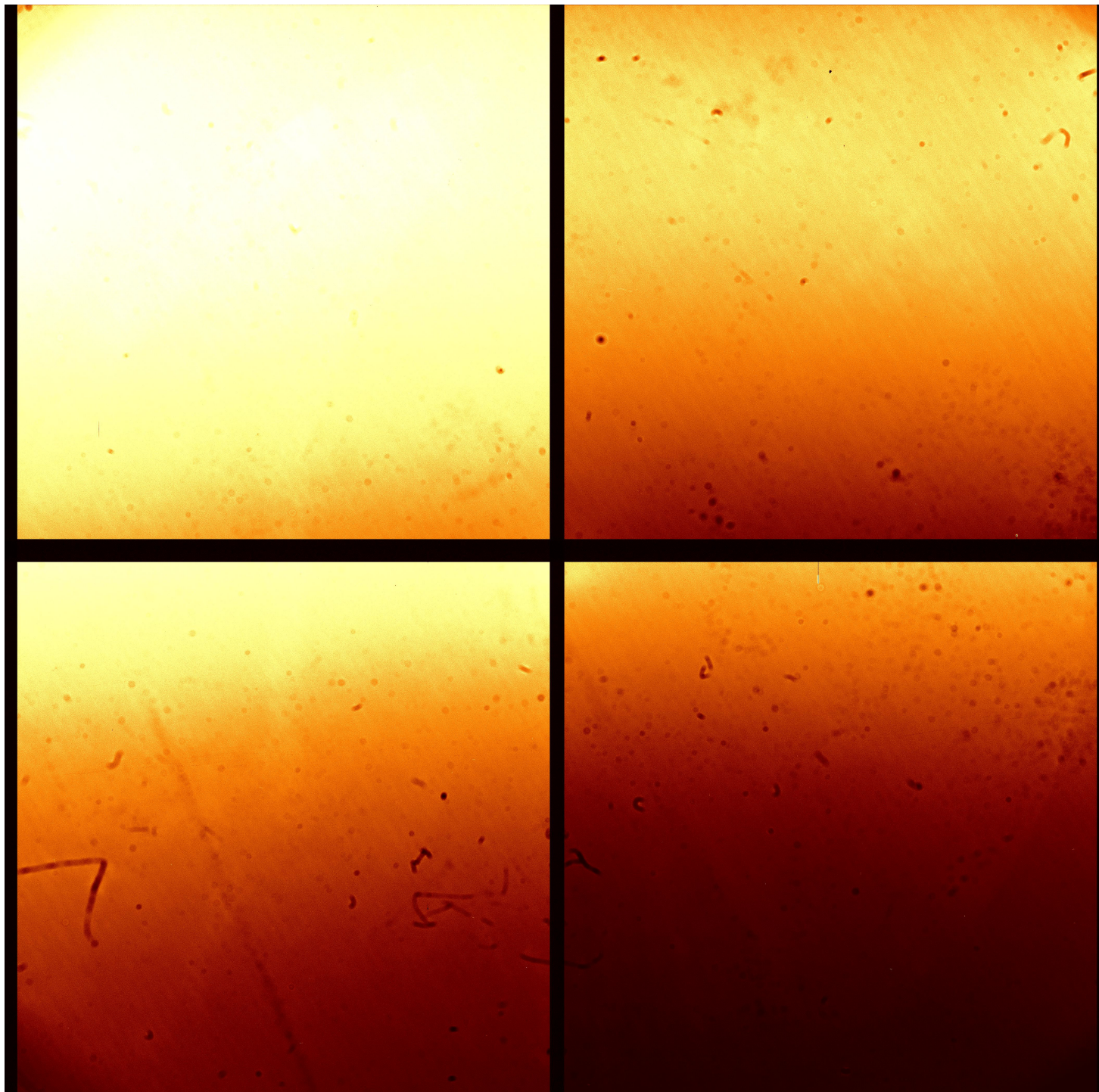
Component	Company	Status	Price (kEUR)
NIR & VIS échelle grating mosaics	Newport, USA	Verification	705
NIR detector (2+1)	Teledyne, USA	Integration	760
VIS detector (1+1)	e2v, UK/France	Integration	121
NIR cooling unit	SDMS, France & ESO, Germany	Verification	34
VIS camera	FISBA, Switzerland	Assembly (final)	200
NIR camera and detector filters	Winlight, France	Assembly (final)	314
NIR & VIS collimator and folding mirrors	Winlight, France	Assembly	260
NIR & VIS image slicers	Kaufmann, Ger.	VIS: being tested; NIR: ordered	15
Vacuum tanks + turbopumps	NTG & Pfeiffer, Germany	Acceptance next week	~300
Mechanics (mounts, front-end, cal-units...), CMOS electronics	Being manufactured in consortium workshops		
Other (CCD electronics, cross dispersers, fibres+, optical benches, lamps, computers...)	Already manufactured or being ordered		

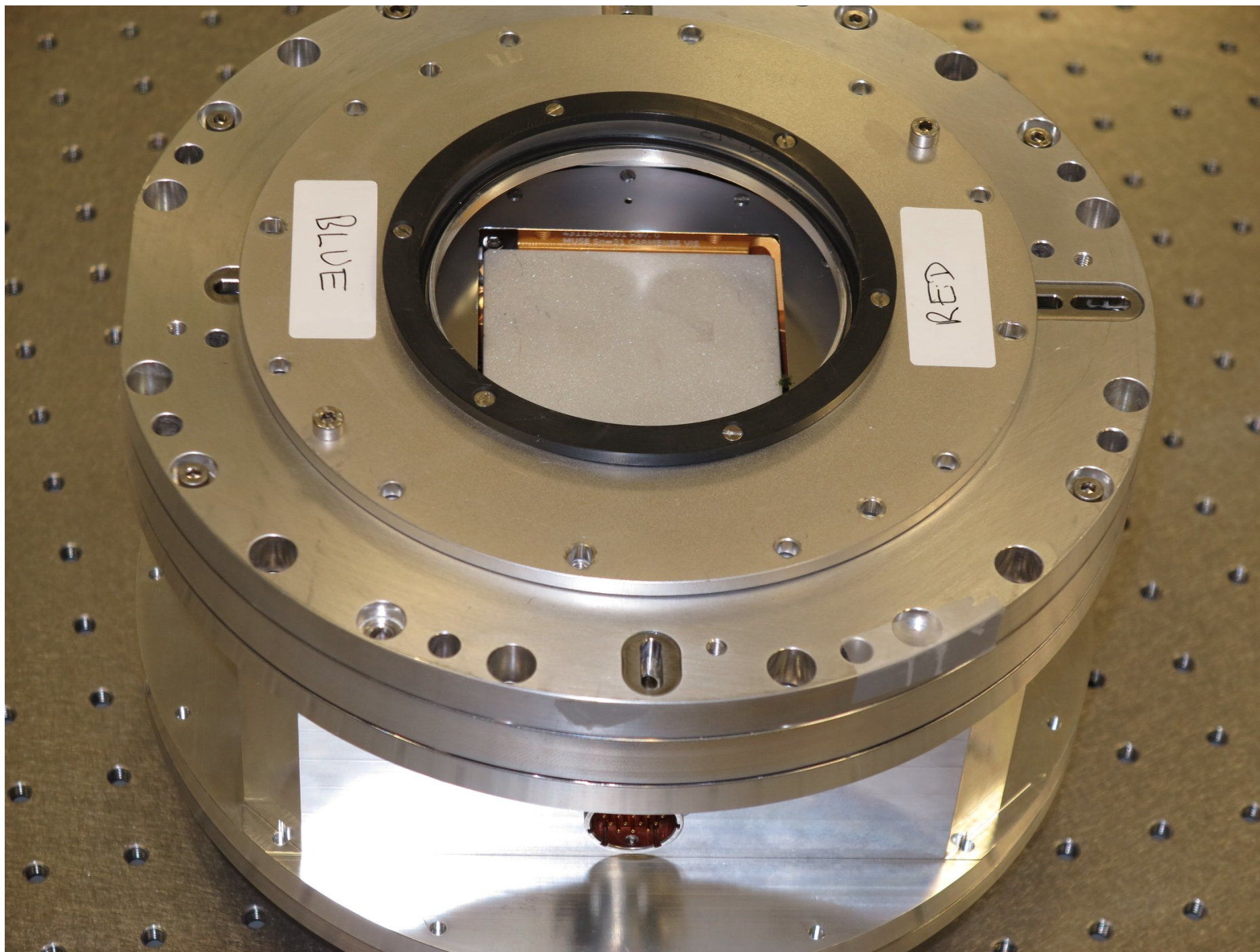


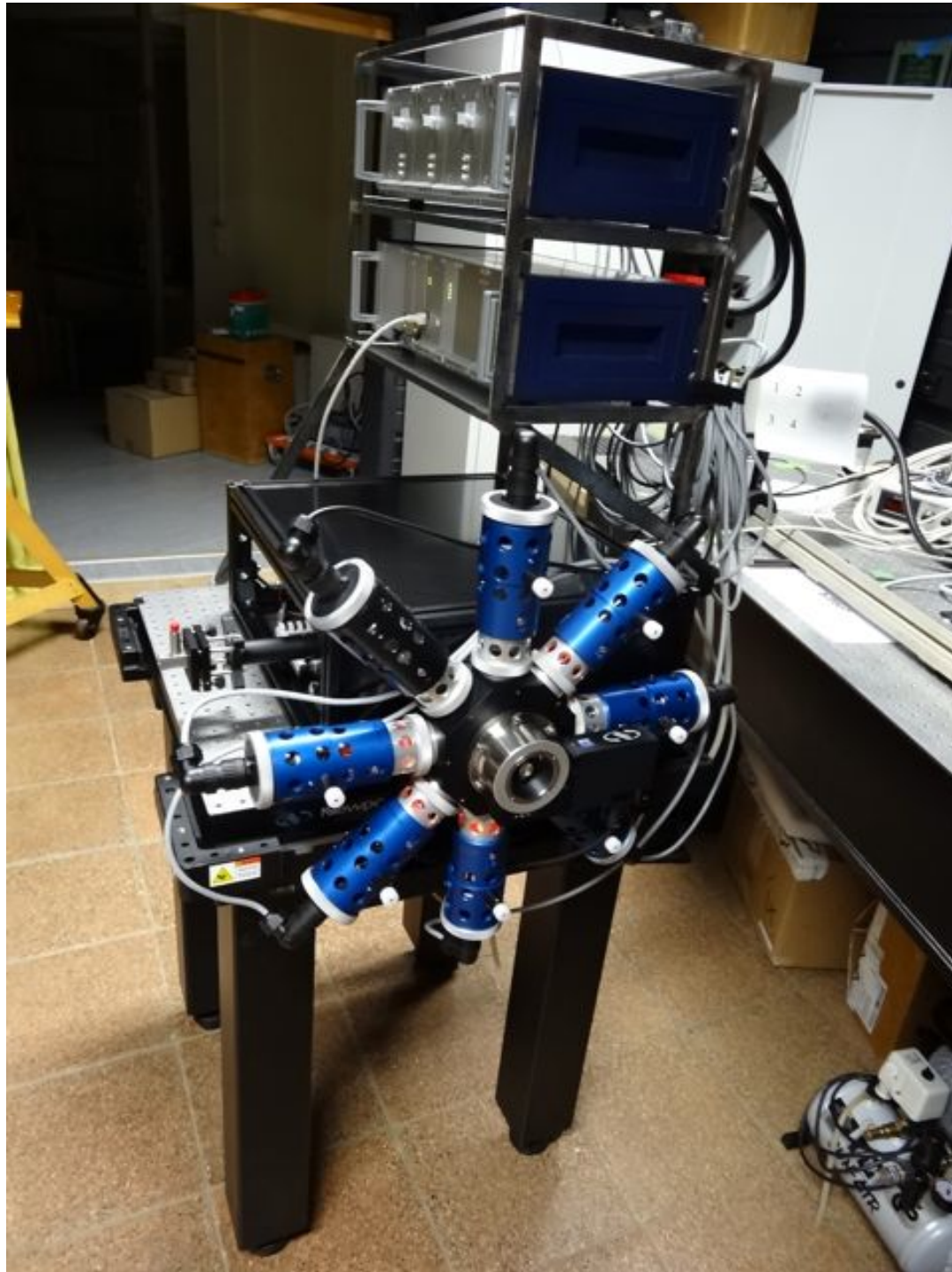


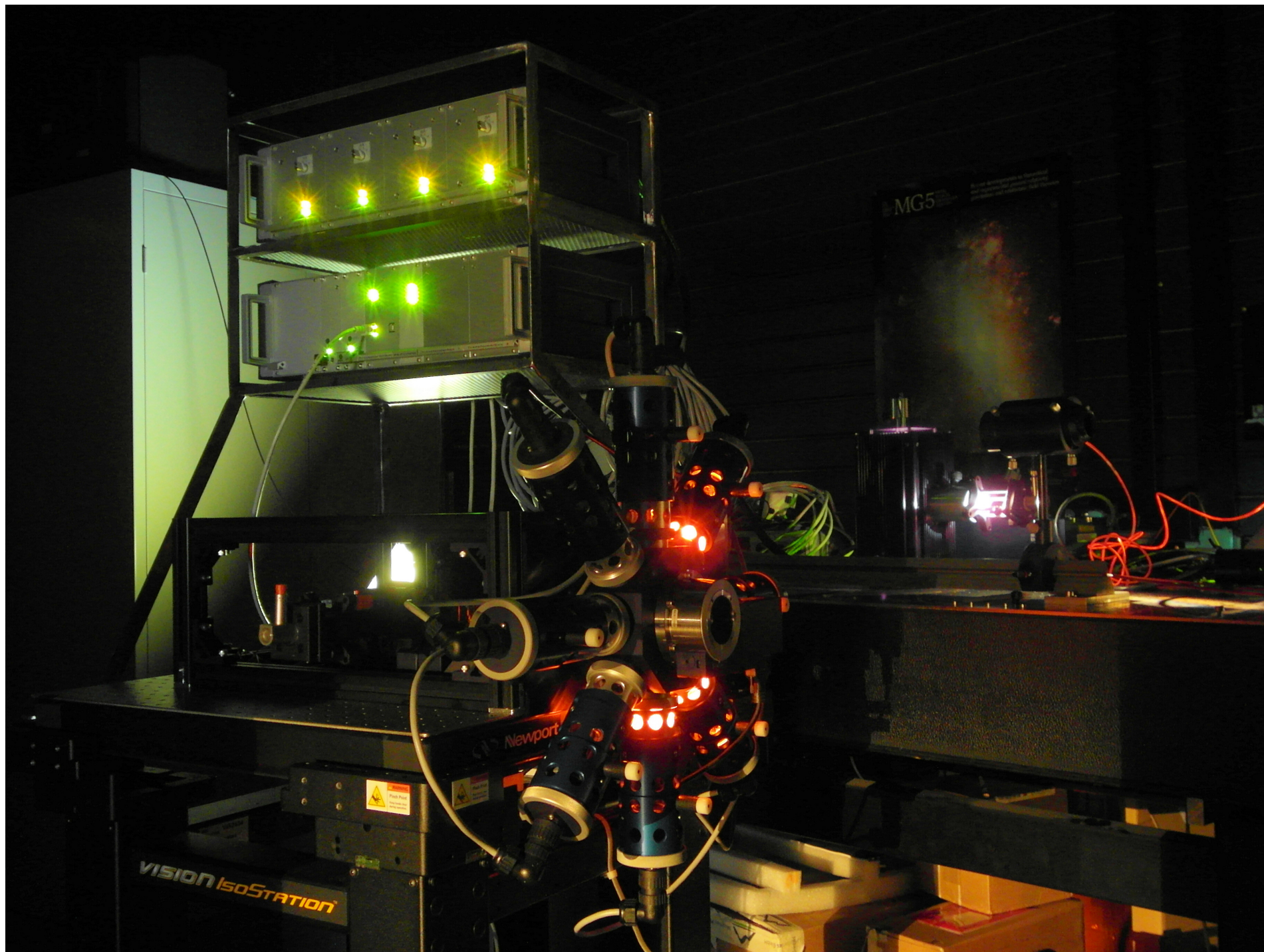


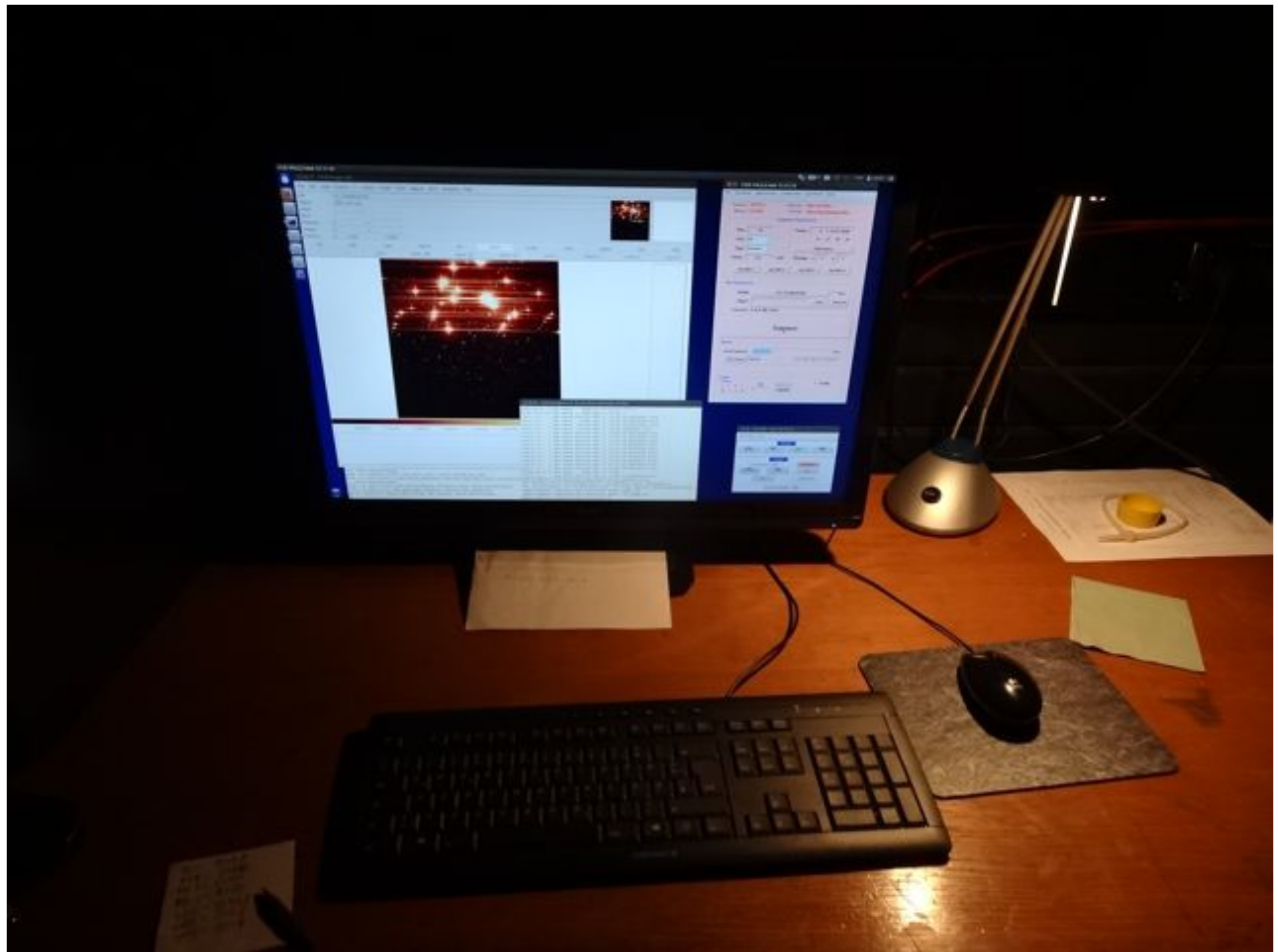


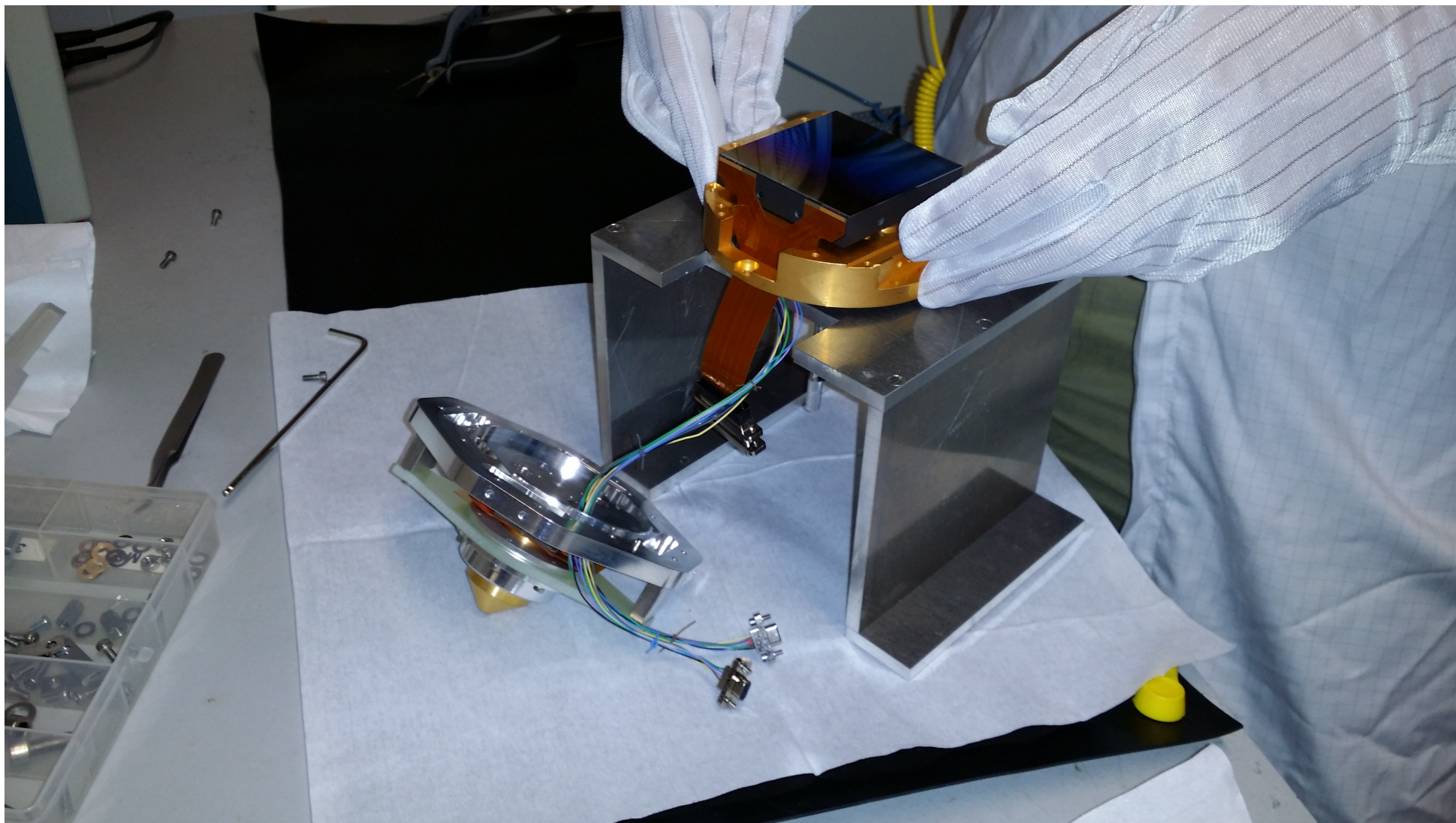


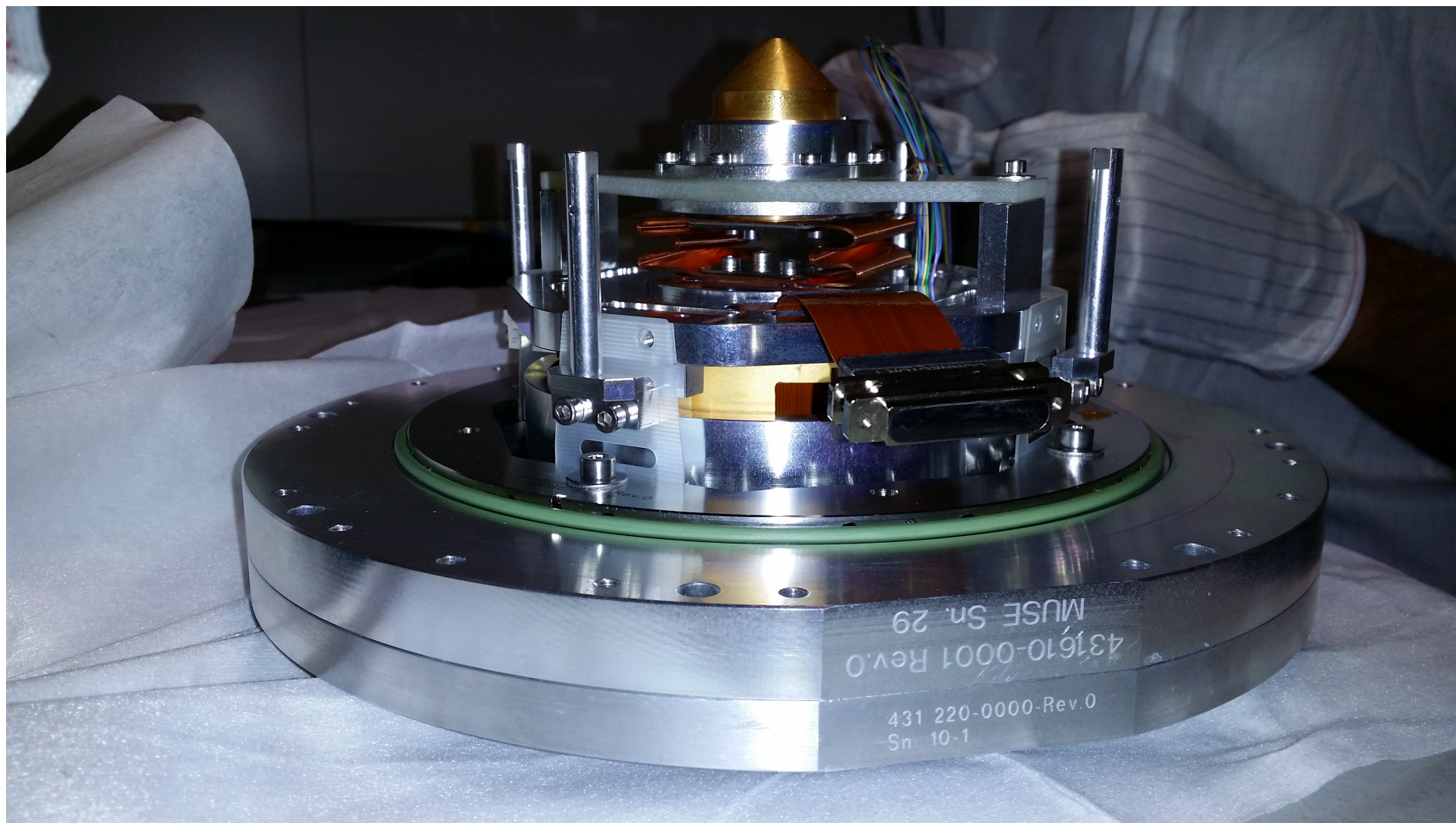


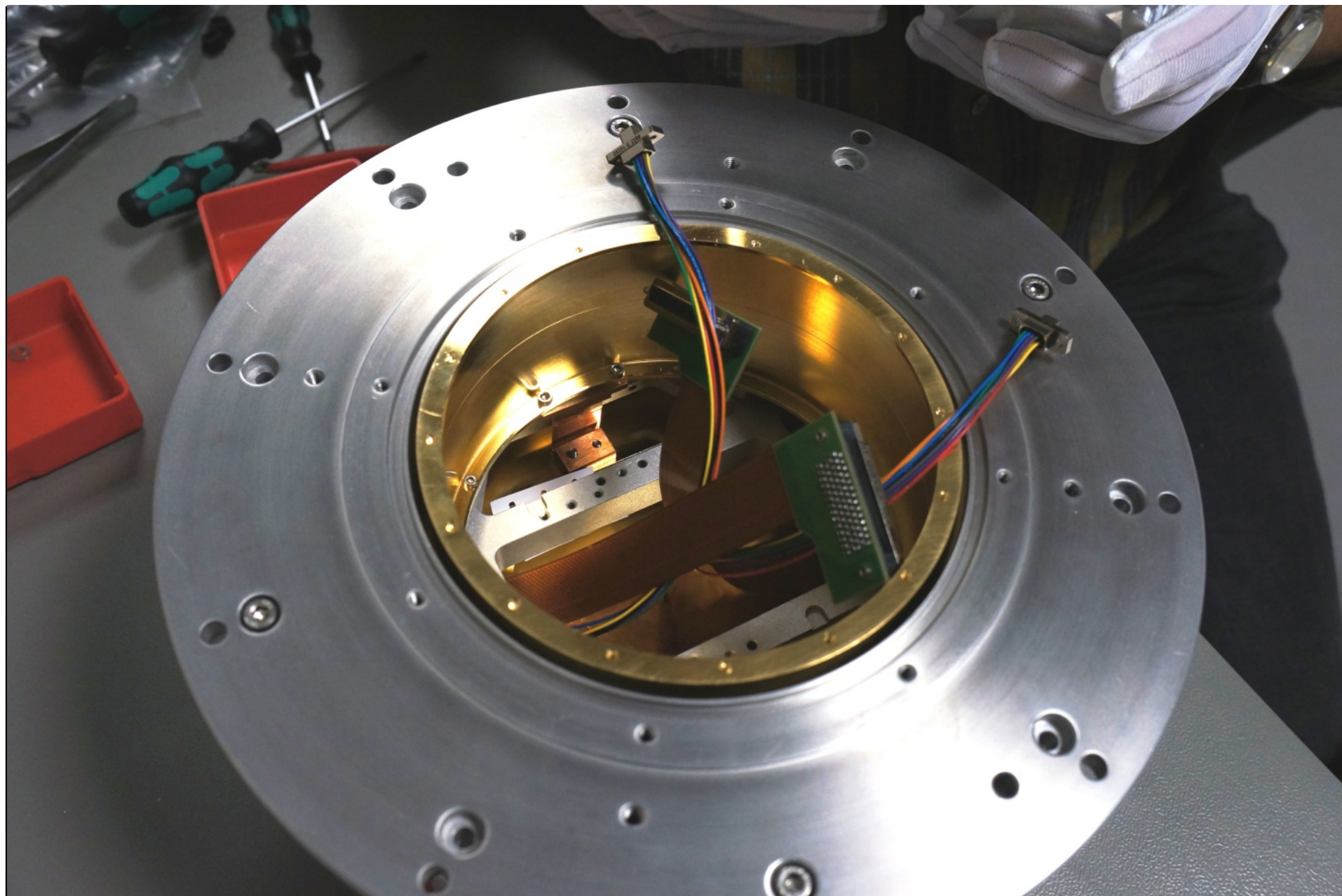


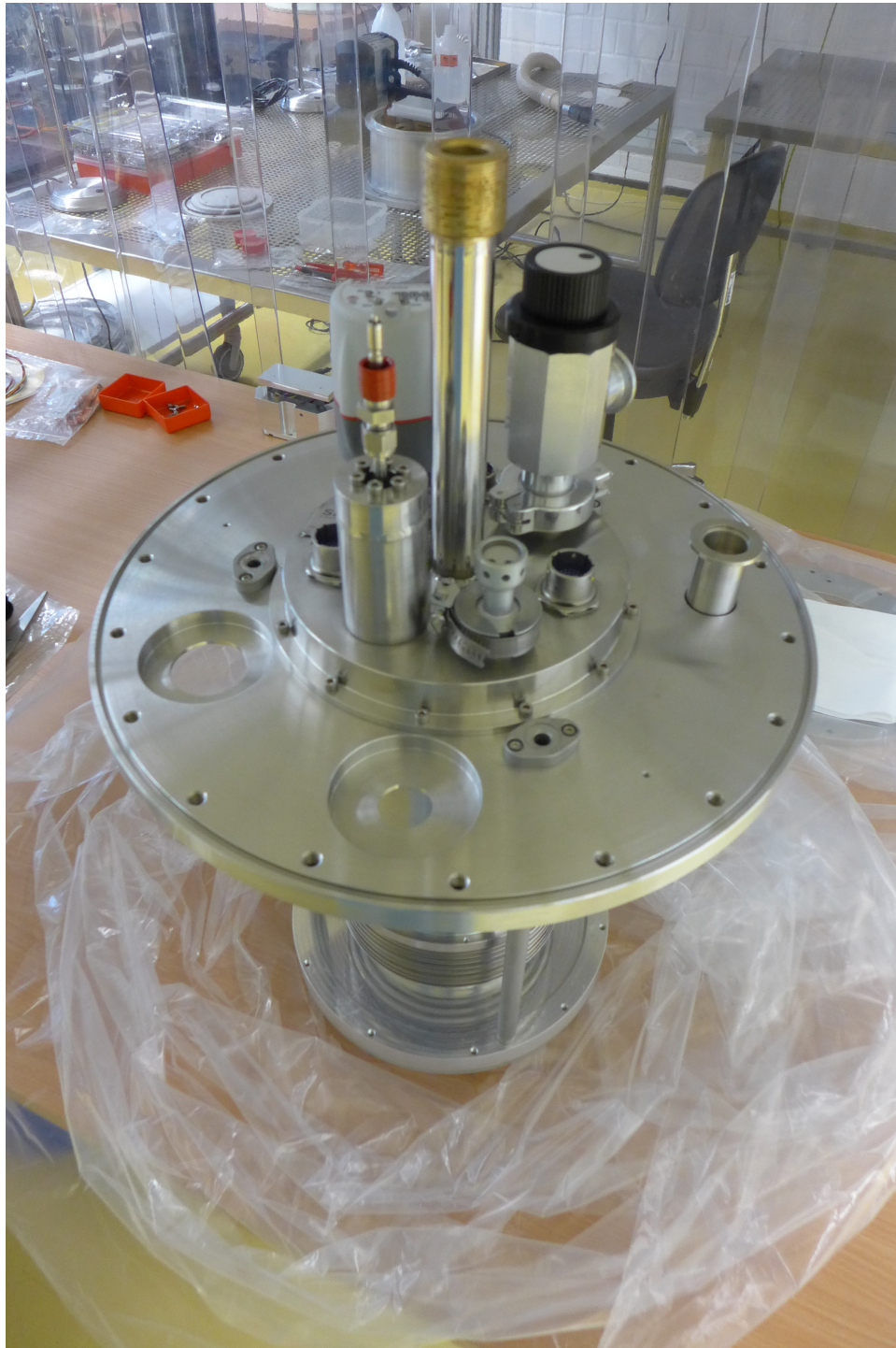
















Noticias > Ciencia y tecnología

Imprimir

Un nuevo instrumento permitirá buscar planetas parecidos a la Tierra en Calar Alto

- El instrumento se llama Carmenes y es único en el mundo
- Detectará variaciones de velocidad en el movimiento de estrellas
- Tiene una precisión y una estabilidad inéditas hasta ahora



Lo + visto

Lo último

- El Atlético de Madrid gana la Liga de manera heroica en el Camp Nou
- Nadal se medirá a Djokovic en la final del Abierto de Italia
- El Madrid busca la 'Novena' de baloncesto
- Djokovic se muestra más sólido que Nadal y se apunta el Master de Roma
- Al menos 30 niños mueren en Colombia en el incendio del autobús en el que viajaban
- Sergio Rodríguez lleva al Madrid a la final avasallando al Barça
- Marc Márquez hace historia con su quinta victoria consecutiva
- Simeone, genio y figura 'partido a partido'
- Marc Márquez logra en Le Mans su quinta 'pole' consecutiva de esta temporada
- El Real Madrid cae derrotado frente al Maccabi en la final de la Euroliga









carmenes

CARMENES, science prep.



The SWG's aim: **to define *the best* target sample**
(the 300 brightest, lowest-mass M dwarfs)

The best target sample?



- Comprehensive stellar characterisation and data compilation...
- **CARMENCITA:**
CARMENES Cool
dwarf **I**nformation
and **d**a**T**a **A**rchive
- “CARMENES input
catalogue”



CARMENCITA: the catalogue



Selection criteria:

- $\delta > -23$ deg (-13 deg)
- The ***brightest*** M dwarfs with the ***latest*** SpTs (i.e., M0V $J < 7.0$ mag, M1V $J < 7.5$ mag... M5V $J < 9.5$ mag...)
- Single (no SB, no companion $\rho < 5$ arcsec)

2100+ stars catalogued up to now $\rightarrow$ 300

Three different subsamples, 100 stars each,
classed by mass and rotational velocity $v \sin i$

CARMENCITA: which data

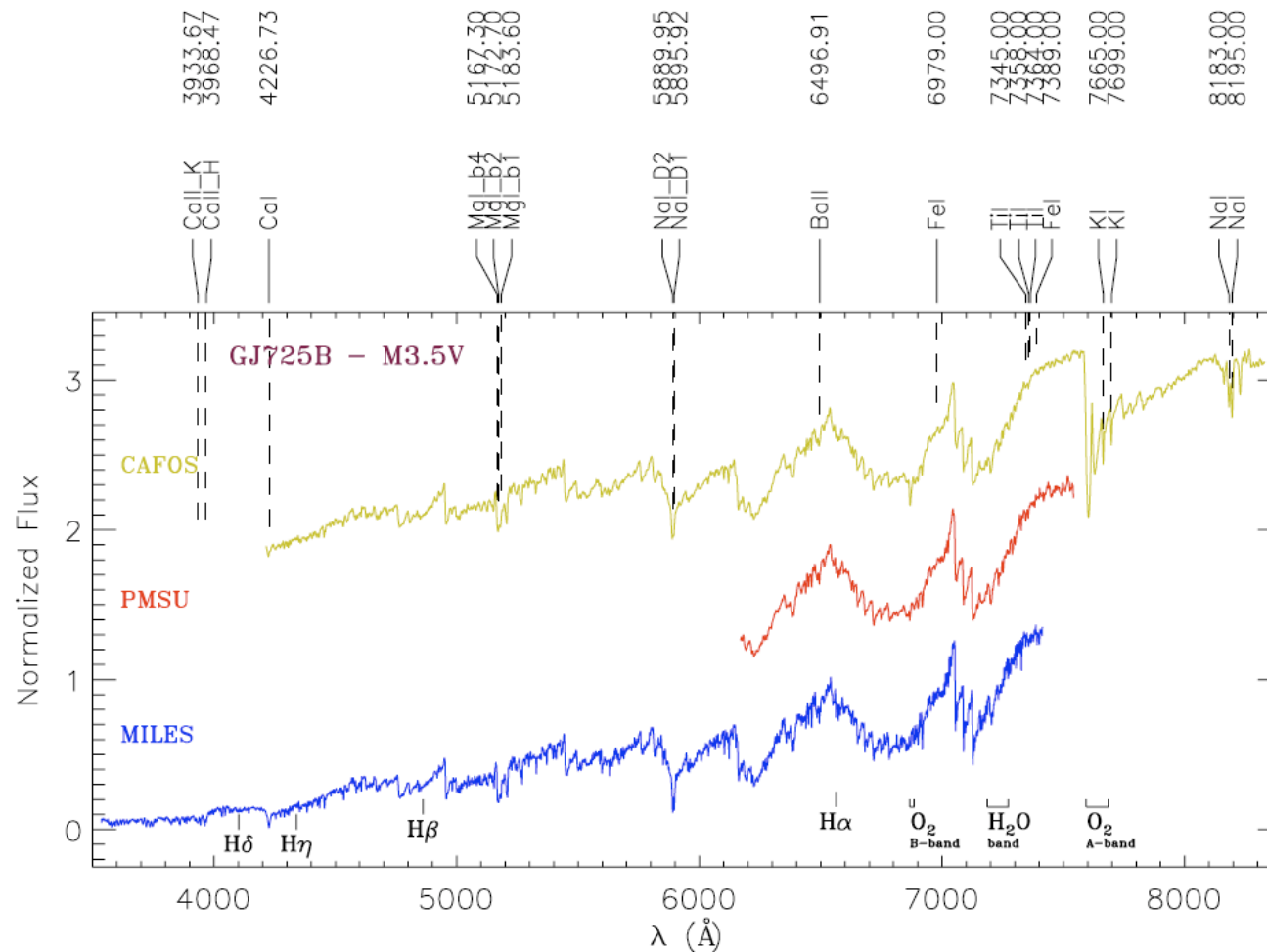


Karmn | Comp | Flags | SS | Name | GJ | SpT | RA_J2000 |
DE_J2000 | **muRA_masa-1** | **muDE_masa-1** | **Vr_kms-1** |
pi_mas | **d_pc** | **U_kms-1** | **V_kms-1** | **W_kms-1** | **FUV_mag** |
NUV_mag | **u_mag** | **BT_mag** | **B_mag** | **g_mag** | **VT_mag** |
V_mag | **Ra_mag** | **r_mag** | **i_mag** | **z_mag** | **IN_mag** |
J_mag | **H_mag** | **Ks_mag** | **W1_mag** | **W2_mag** | **W3_mag** |
W4_mag | **WideCompanion** | **WideWDS** | **Widerho_arcsec** |
WideCompanionSpT | **WideCompanionJ_mag** |
WideCompanionFeH | **CloseMultiplicity** | **CloseWDS** |
Closerho_arcsec | **pEWHalpha_A** | **1RXS** | **CRT_s-1** | **HR1** |
HR2 | **vsini_kms-1** | **P_d** | **Flare** | **MovingGroup** | **TiO5** |
CaH2 | **VO1** | **PC1** | **PC2...** | **zeta** | **MV_mag** | **Teff_K** |
logg | **R_Rsol** | **L_Lsol** | **M_Msol** | **Age_Ga** |
LoRes_spectrum | **HiRes_spectrum** | **LoRes_image** |
HiRes_image | RV | Planet | Origin | Class | Notes

CARMENCITA: preparation



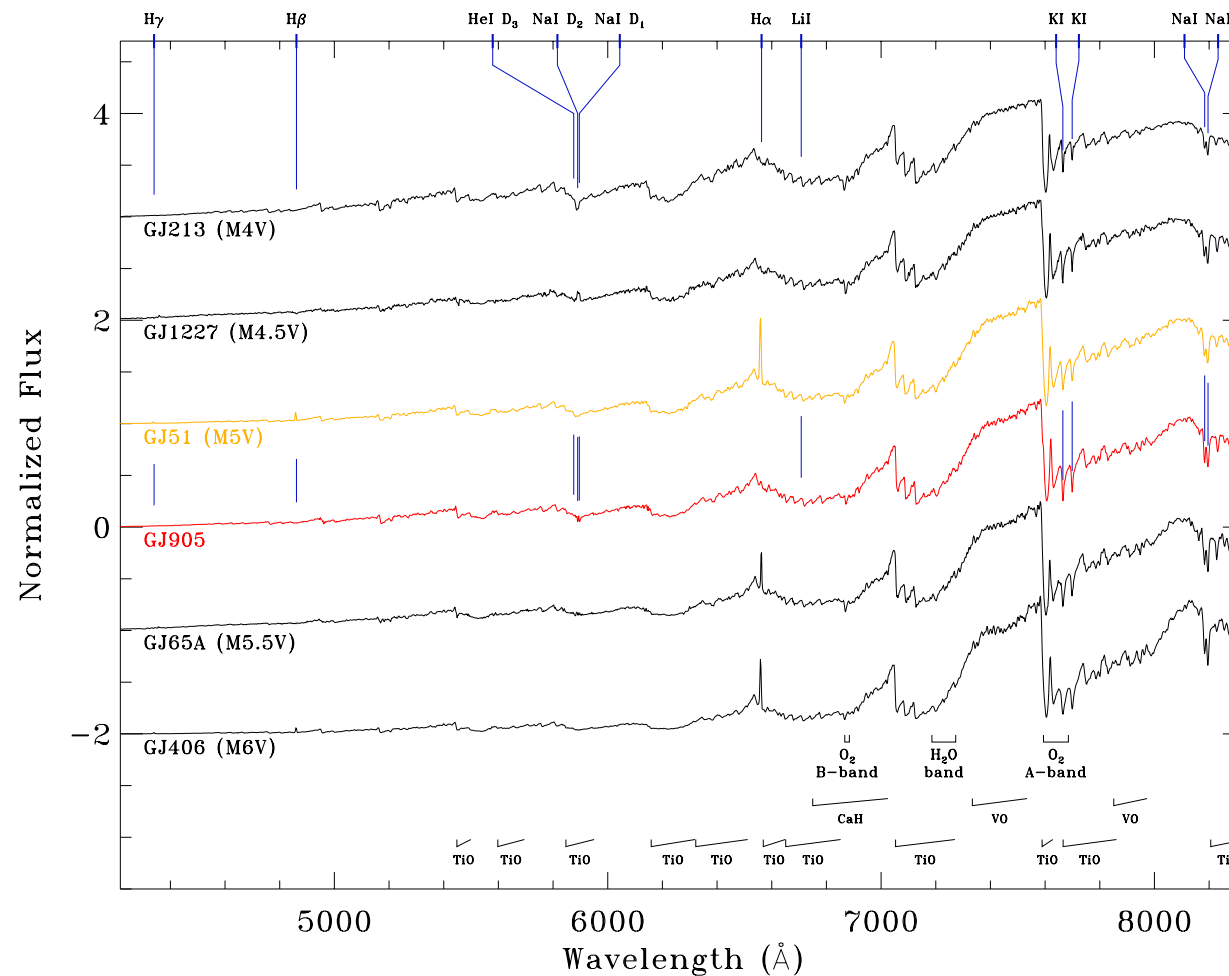
- **Low-resolution spectroscopy** (CAFOS, IDS): SpT, pEW(H α)



CARMENCITA: preparation



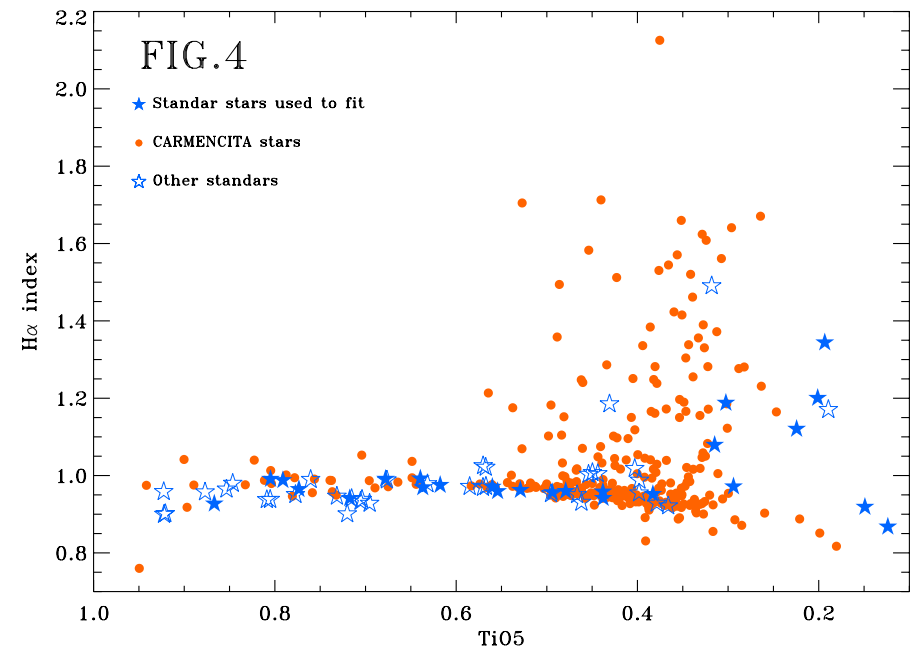
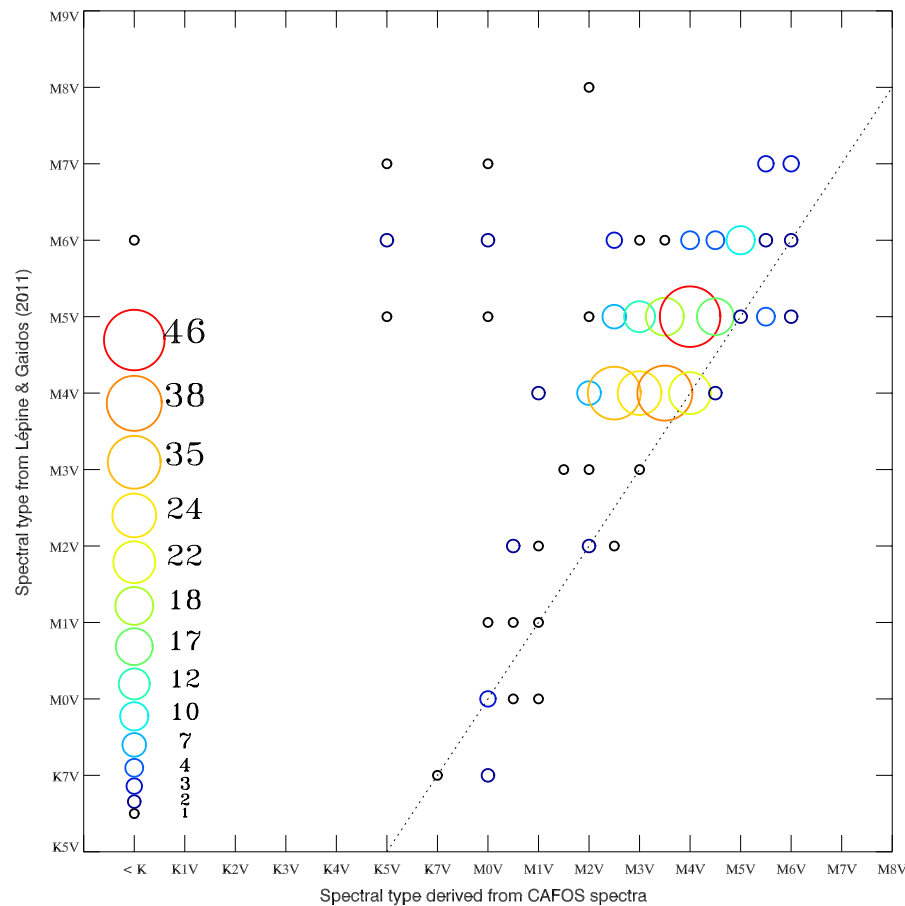
- **Low-resolution spectroscopy** (CAFOS, IDS): SpT, pEW(H α)



CARMENCITA: preparation



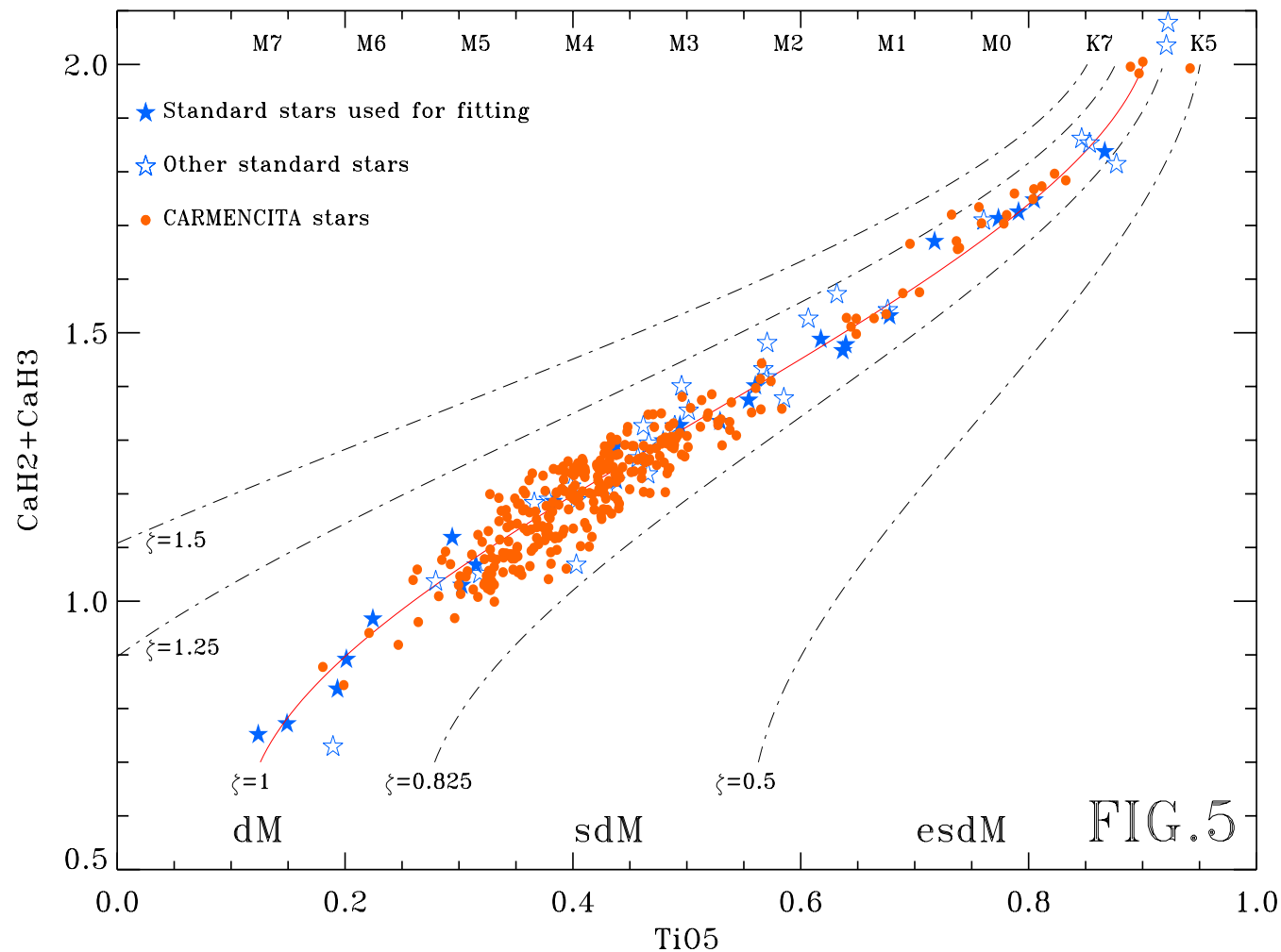
- **Low-resolution spectroscopy** (CAFOS, IDS): SpT, pEW(H α)



CARMENCITA: preparation



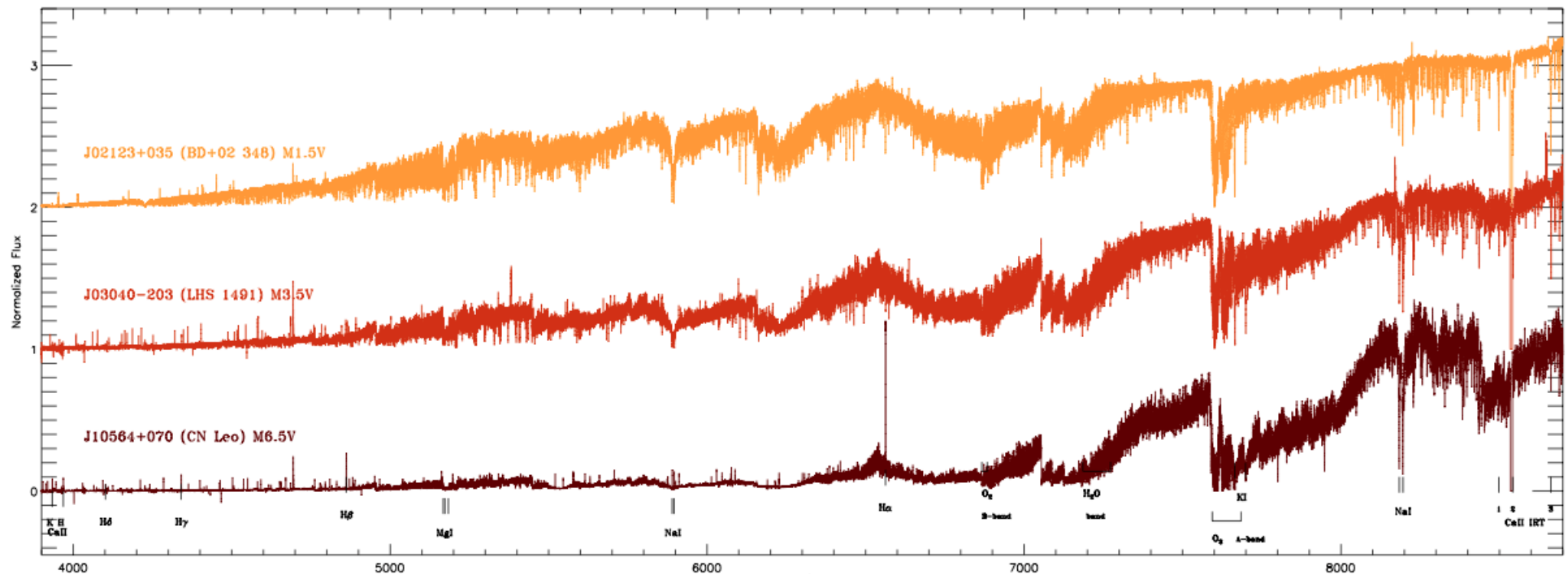
- **Low-resolution spectroscopy** (CAFOS, IDS): SpT, pEW(H α)



CARMENCITA: preparation



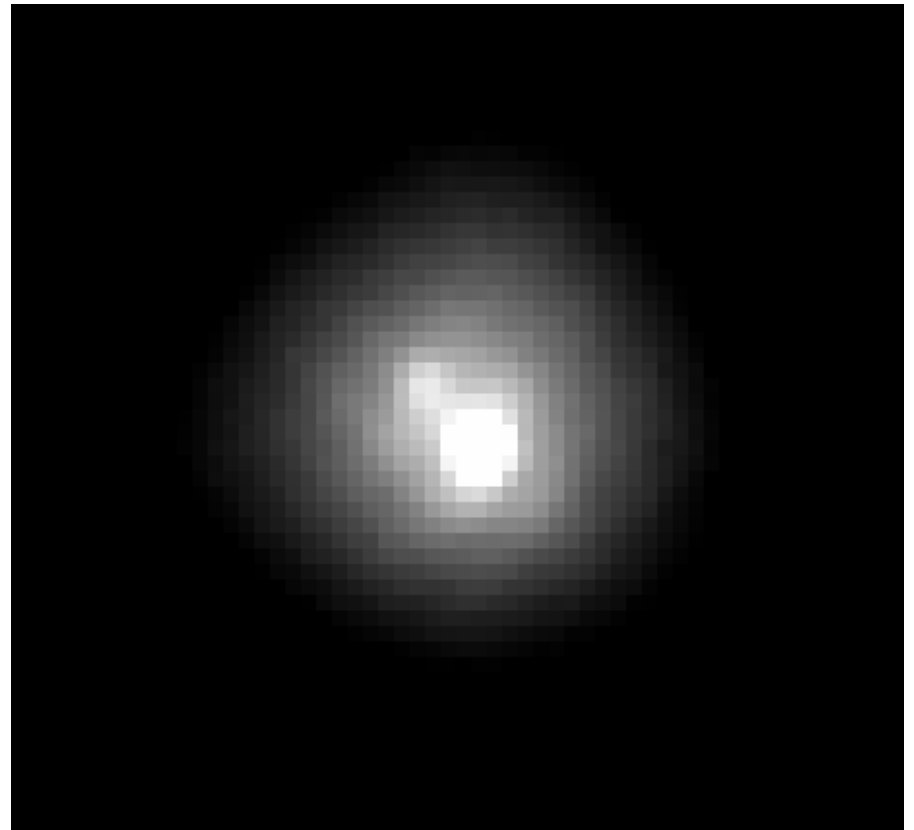
- **High-resolution spectroscopy** (CAFÉ, FEROS, HRS): V_r , $v \sin i$, other activity indicators, spec. multiplicity ($N > 1$)



CARMENCITA: preparation

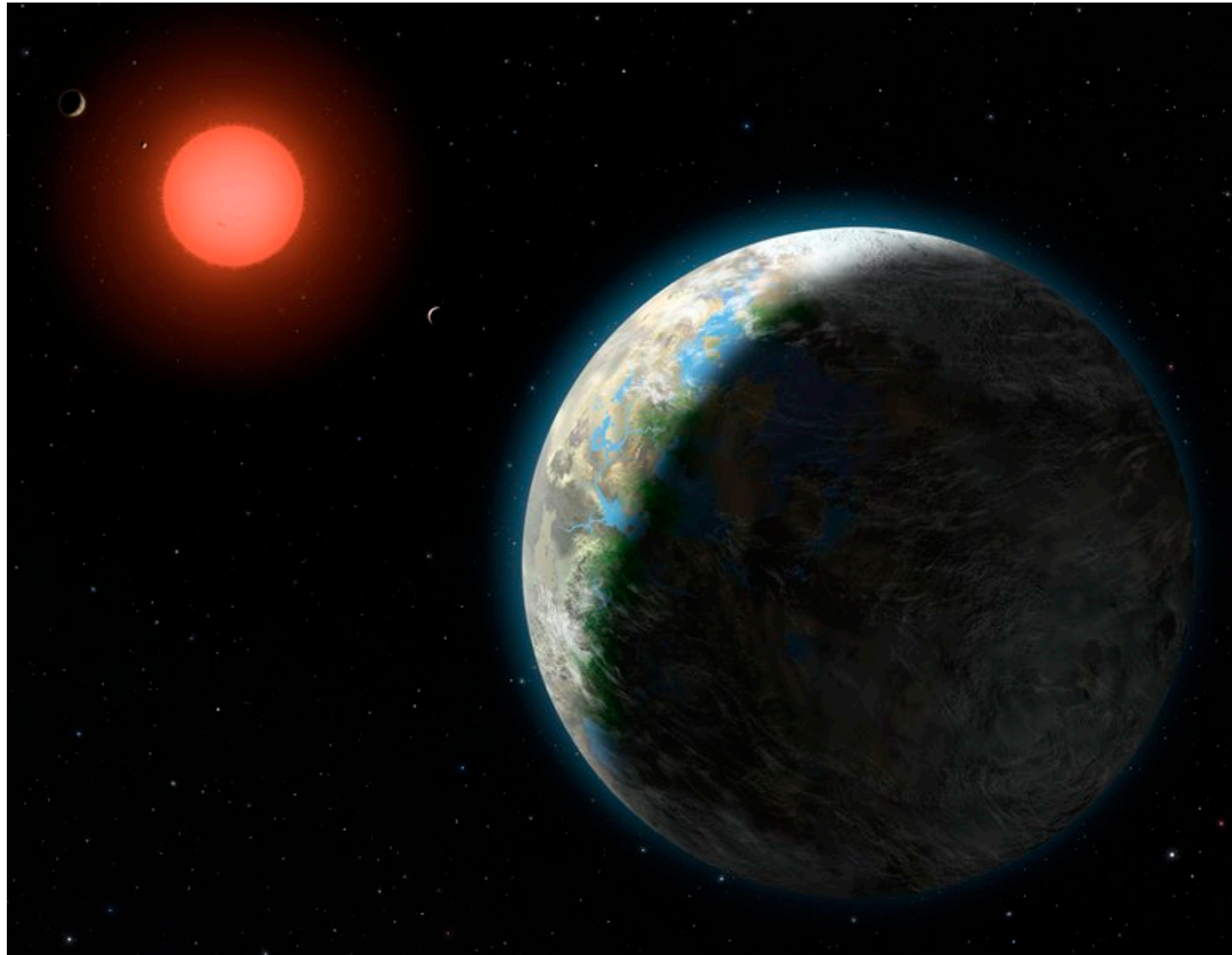


- **High-resolution imaging:** close resolved multiplicity
- Compilation from the literature
- Our own observations with **FastCam** (e.g., GJ 1081 AB, $\rho \approx 0.2$ arcsec)
- Near future: AstraLux?



Is there anybody out there?

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



Is there anybody out there?



Is there anybody out there?



69

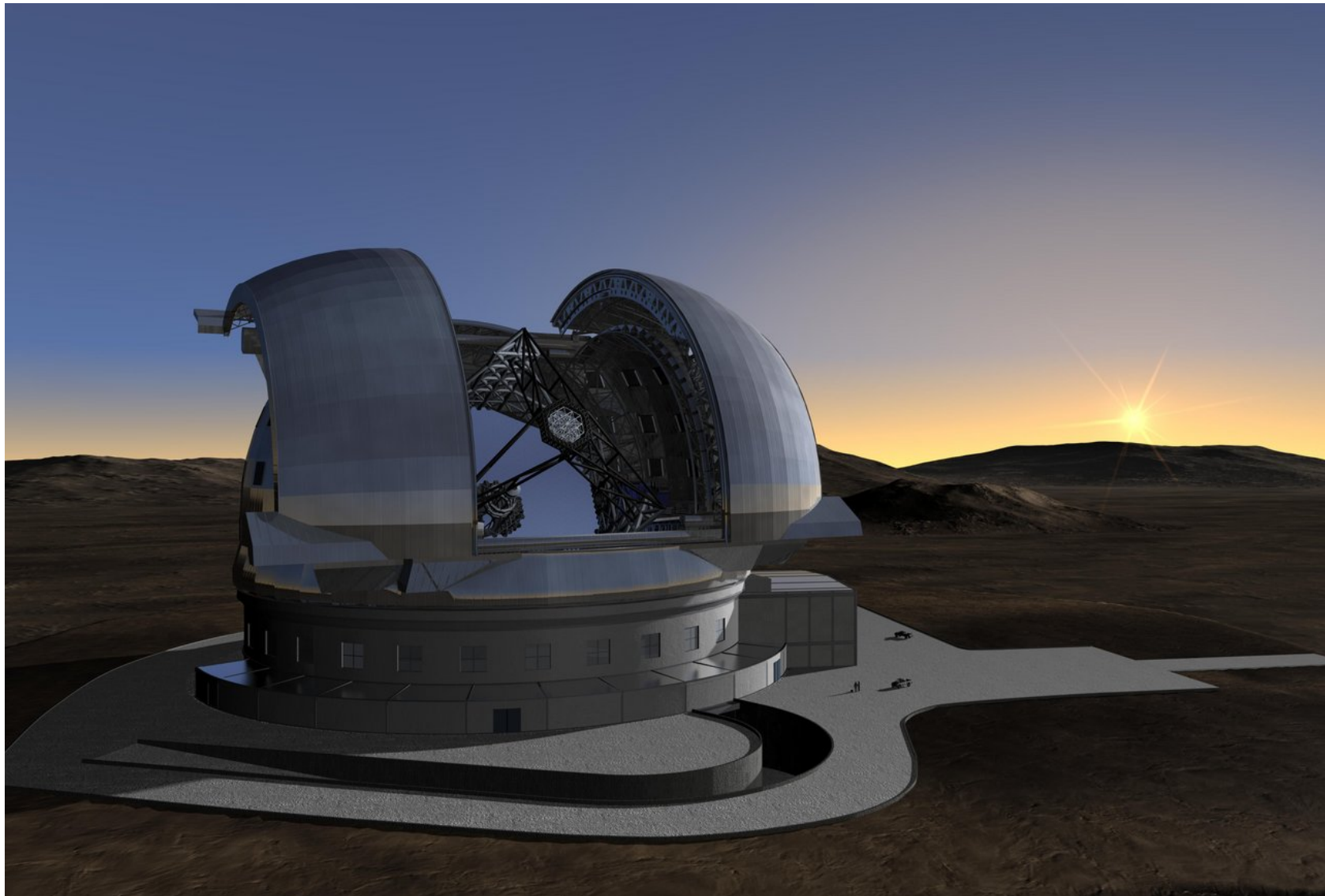
Is there anybody out there?



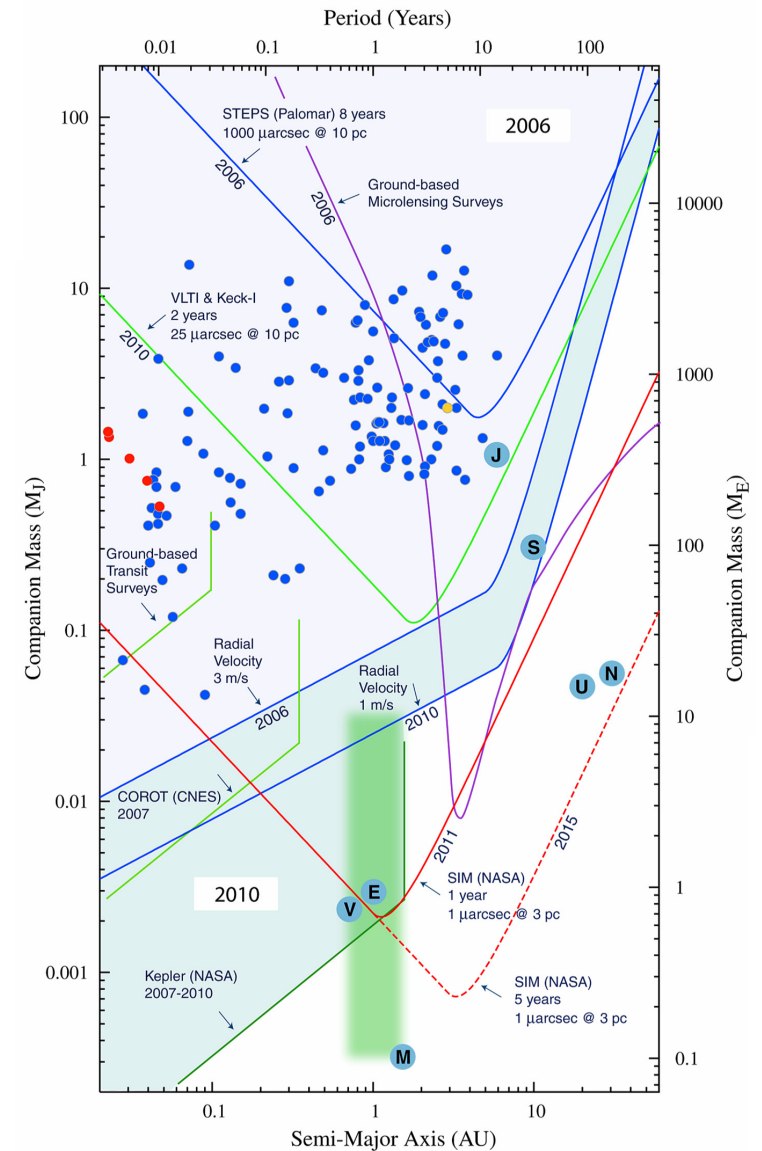
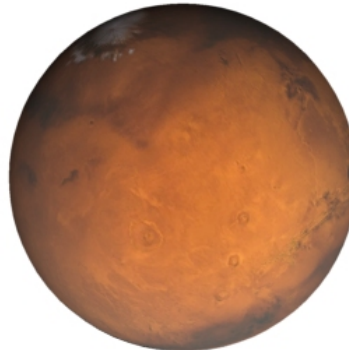
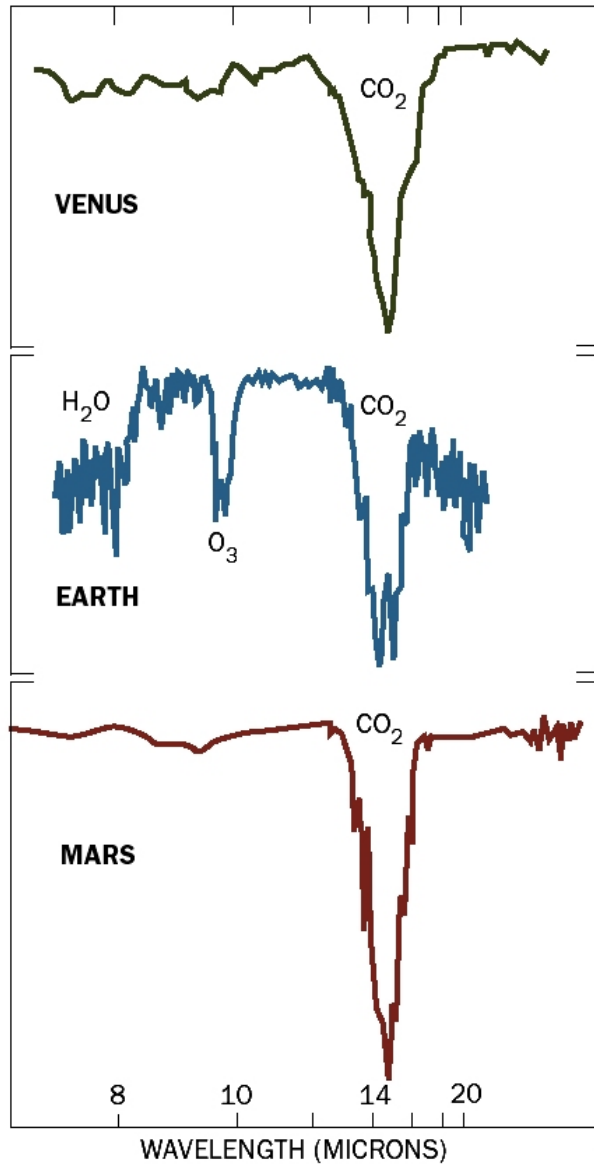
Is there anybody out there?



Is there anybody out there?



Is there anybody out there?





carmenes

Public

Project

Institutions

People

Gallery

Publications

Conferences

Spectrographs

Private

Referees

Towards the detection of exoearths

CARMENES [*kár-men-es*] (**Calar Alto high-Resolution search for M dwarfs with Exoearths with Near-infrared and optical Échelle Spectrographs**) is a next-generation instrument being built for the 3.5m telescope at the Calar Alto Observatory by a consortium of German and Spanish institutions. It consists of two separated spectrographs covering the wavelength ranges from 0.5 to 1.0 μm and from 1.0 to 1.7 μm with spectral resolutions $R = 82,000$, each of which shall perform high-accuracy radial-velocity measurements ($\sim 1 \text{ m s}^{-1}$) with long-term stability. The fundamental science objective of CARMENES is to carry out a survey of ~ 300 late-type main-sequence stars with the goal of detecting low-mass planets in their habitable zones. We aim at being able to detect $2 M_{\text{Earth}}$ planets in the habitable zone of M5V stars. The CARMENES first light is expected to occur in Summer 2015.

<http://carmenes.caha.es/>



<http://carmenes.caha.es/>



carmenes

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*
- Pathfinder for E-ELT instrumentation
- *And what about Calar Alto?*