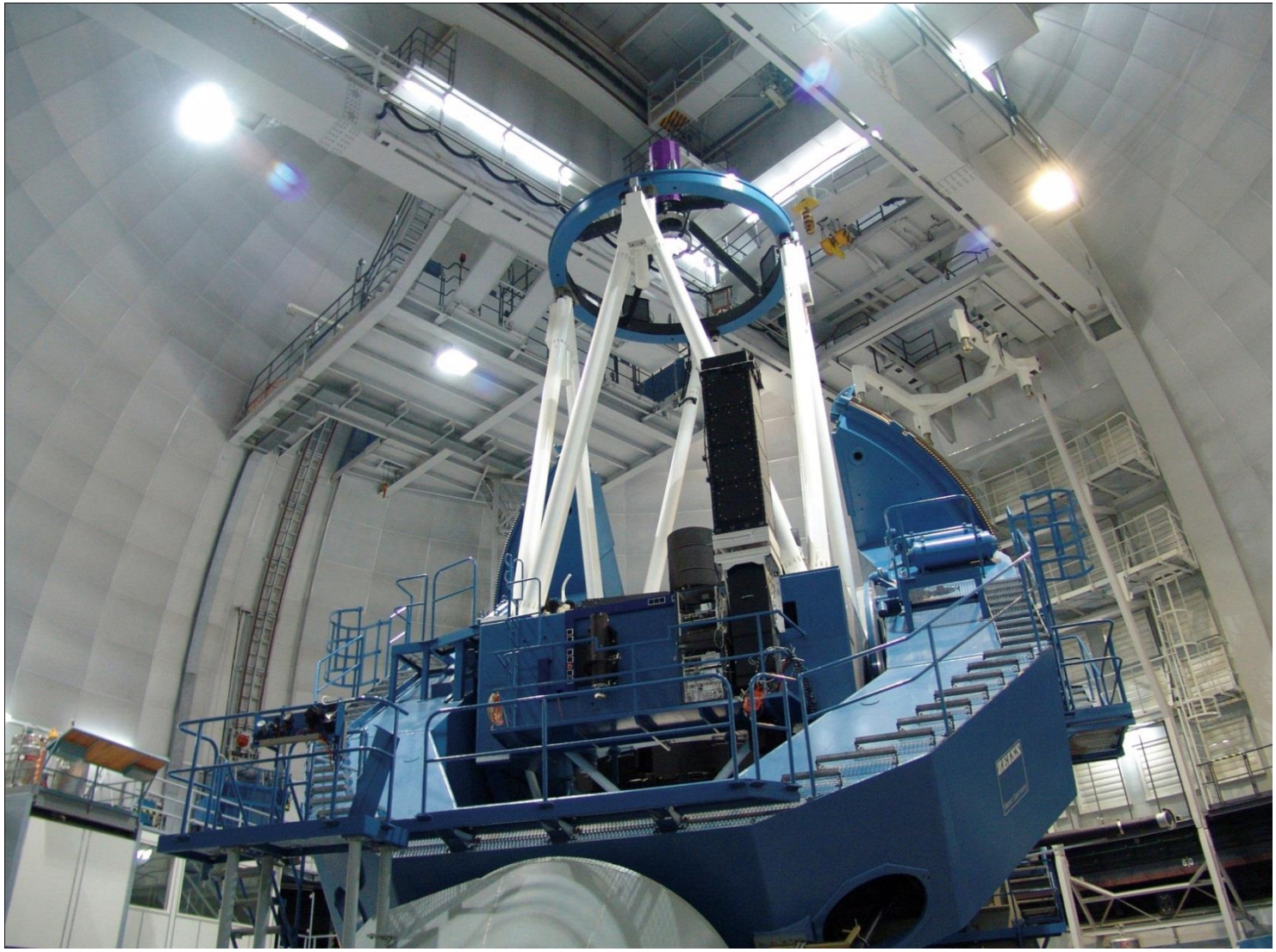
A New High-Resolution Spectrograph

Andreas Quirrenbach
and the CARMENES Consortium

The 3.5m Telescope on Calar Alto



CARMENES – the Acronym

- **C**alar **A**lto
- High-**R**esolution Search for
- **M** Dwarfs with
- **E**xo-Earths
- With **N**ear-Infrared and Optical
- **E**chelle **S**pectrographs

The CARMENES Consortium

- Landessternwarte Königstuhl, U Heidelberg, Germany
- Insitut für Astrophysik, U Göttingen, Germany
- MPI für Astronomie, Heidelberg, Germany
- Thüringer Landessternwarte, Tautenburg, Germany
- Hamburger Sternwarte, U Hamburg, Germany

- Instituto de Astrofísica de Andalucía, Granada, Spain
- Universidad Complutense de Madrid, Madrid, Spain
- Institut de Ciències de l'Espai, Barcelona, Spain
- Instituto de Astrofísica de Canarias, Tenerife, Spain
- Centro de Astrobiología, Madrid, Spain

- Centro Astronómico Hispano-Alemán

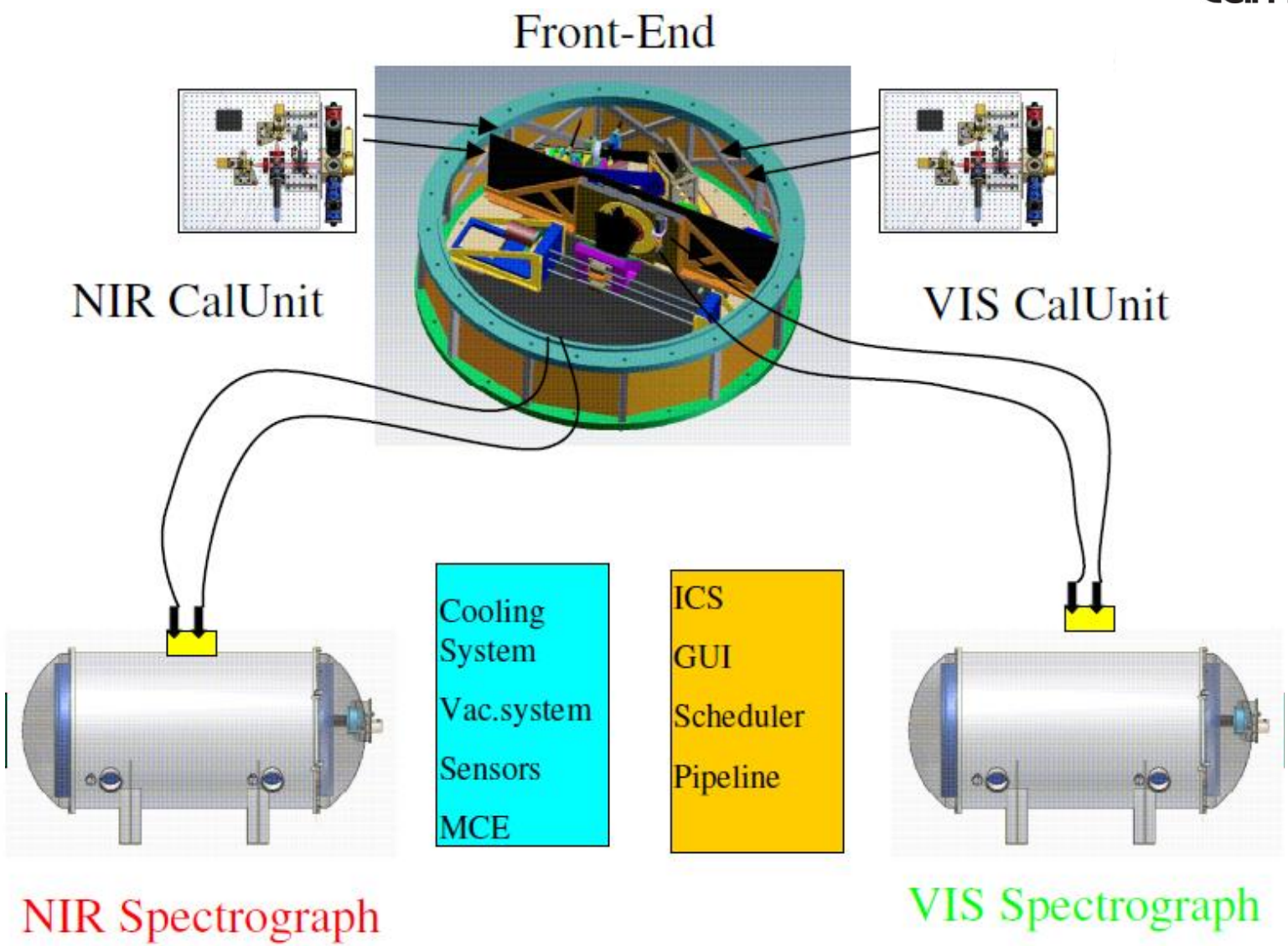
Stellar sample

- **S1: 100 stars with M < 0.25 $M_\odot$ (SpType M4 and later)**
- **S2: 100 stars with 0.30 > M > 0.25 $M_\odot$ (SpType M3-M4)**
- **S3: 100 stars with 0.60 > M > 0.30 $M_\odot$ (SpType M0-M2; bright)**

Sample	Spectral type	Mass ($M_\odot$)	J	#
S1	≥M6	≤0.15	≤10.5	12
S1	M5 & M5.5	0.15–0.20	≤10	35
S1	M4 & M4.5	0.20–0.25	≤9.5	143
S2	M3 & M3.5	0.25–0.30	≤9	198
S3	M2 & M2.5	0.30–0.40	≤8.5	121
S3	M1 & M1.5	0.40–0.50	≤8	78
S3	M0 & M0.5	0.50–0.60	≤7.5	55

$\langle d_{S1+S2+S3} \rangle$ = 13 pc

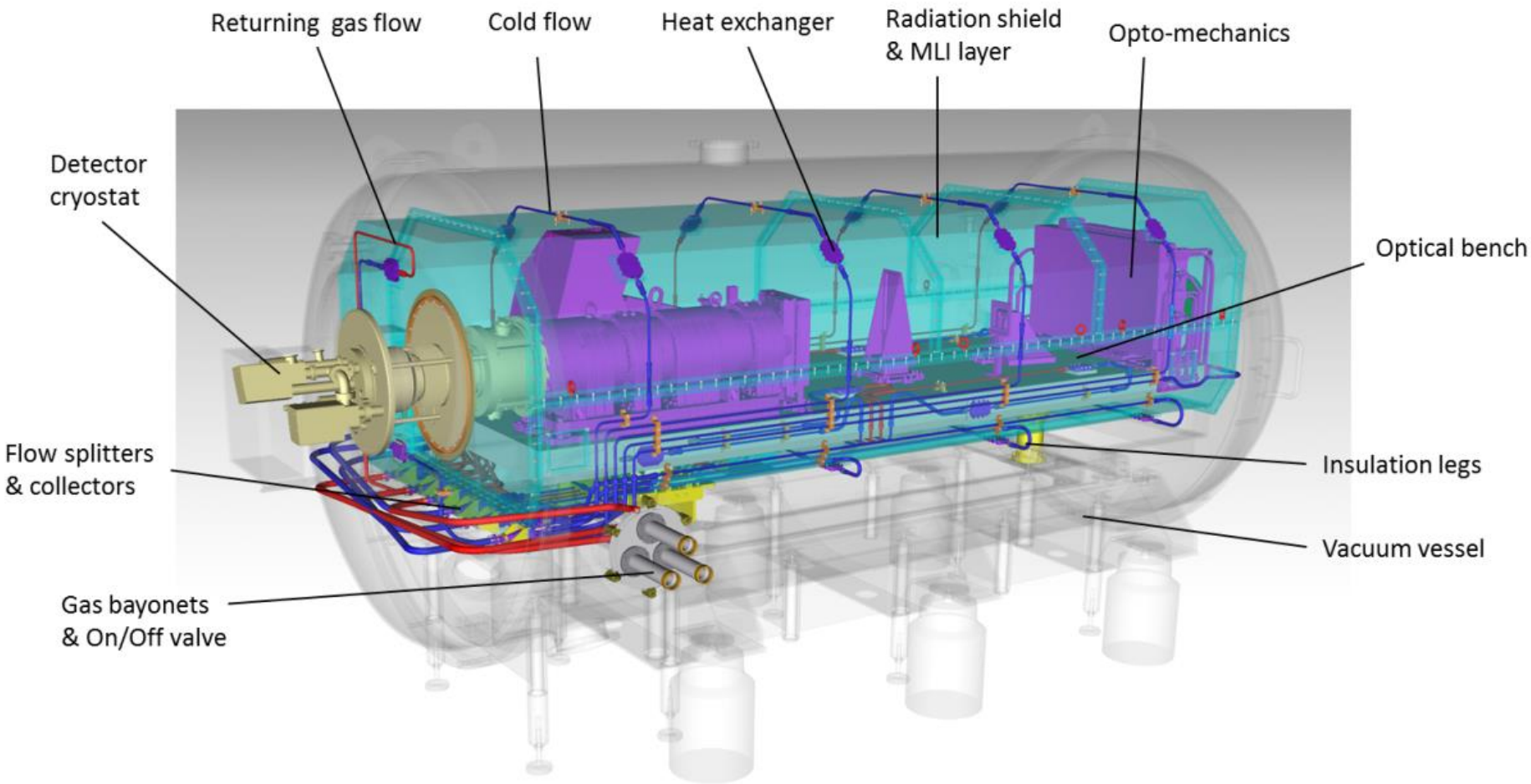
Instrument Overview



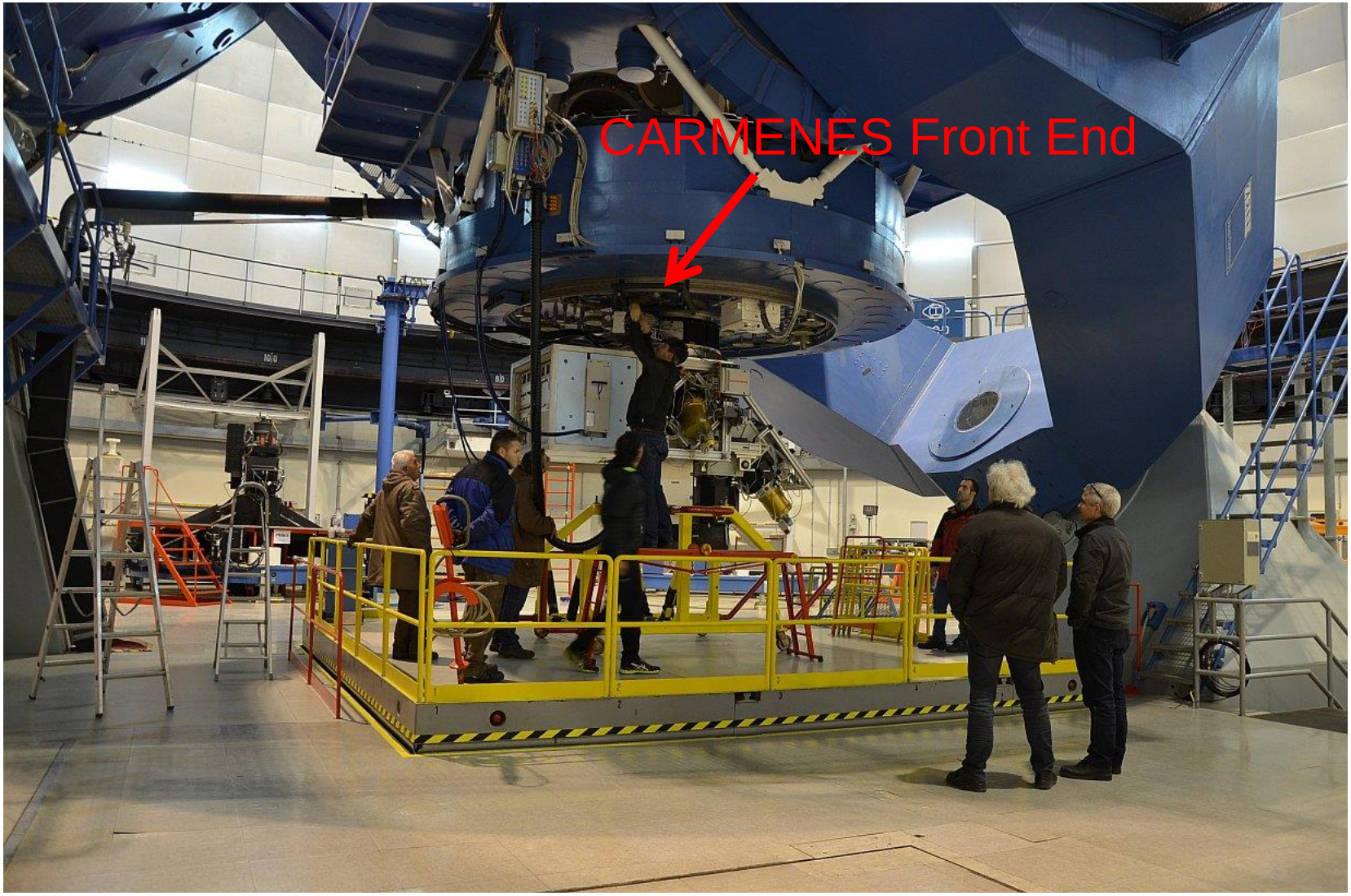
Properties of Spectrographs

- Optical spectrograph
  - 0.53 … 1.05 µm, R = 94,600
  - Precision ~1 m/s
  - Vacuum tank, temperature stabilized
  - 4k x 4k deep depletion CCD detector
- Near-Infrared spectrograph
  - 0.95 … 1.7 µm, R = 80,400
  - Vacuum tank, cooled to 140K, stabilized
  - Precision goal 1 m/s
  - Two 2k x 2k HAWAII-2RG 2.5 µm detectors

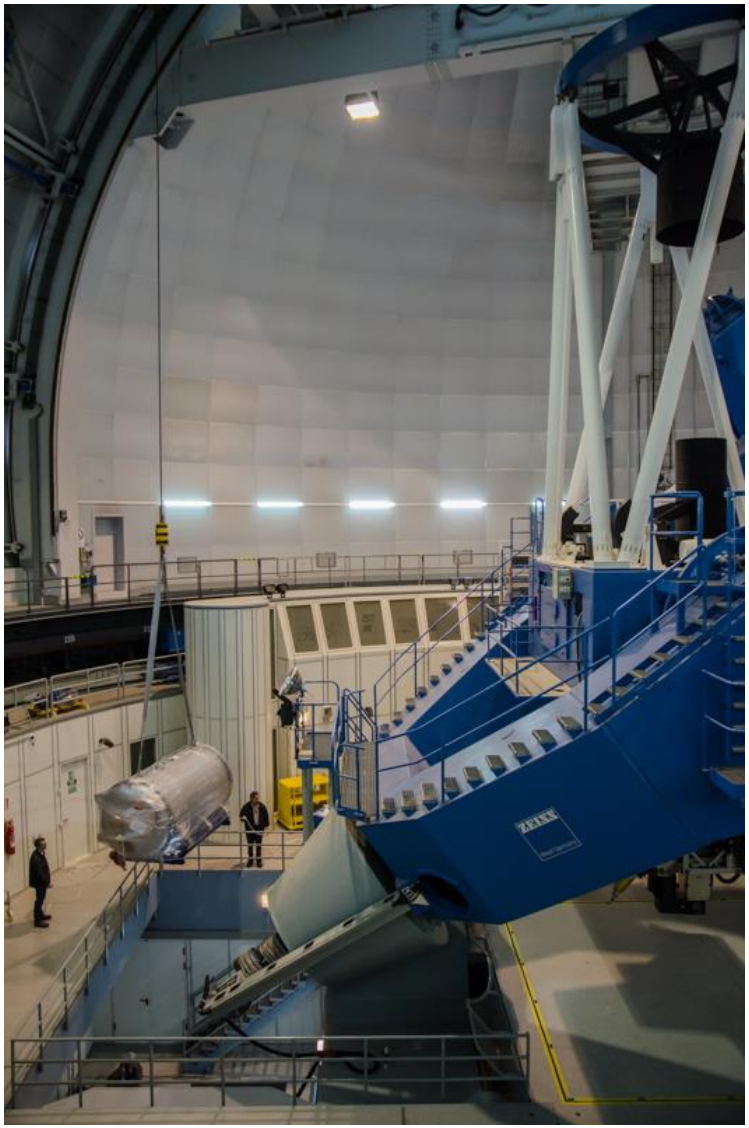
Spectrograph and Vacuum Tank Layout



CARMENES Front End at the Calar Alto 3.5m (April 2015)



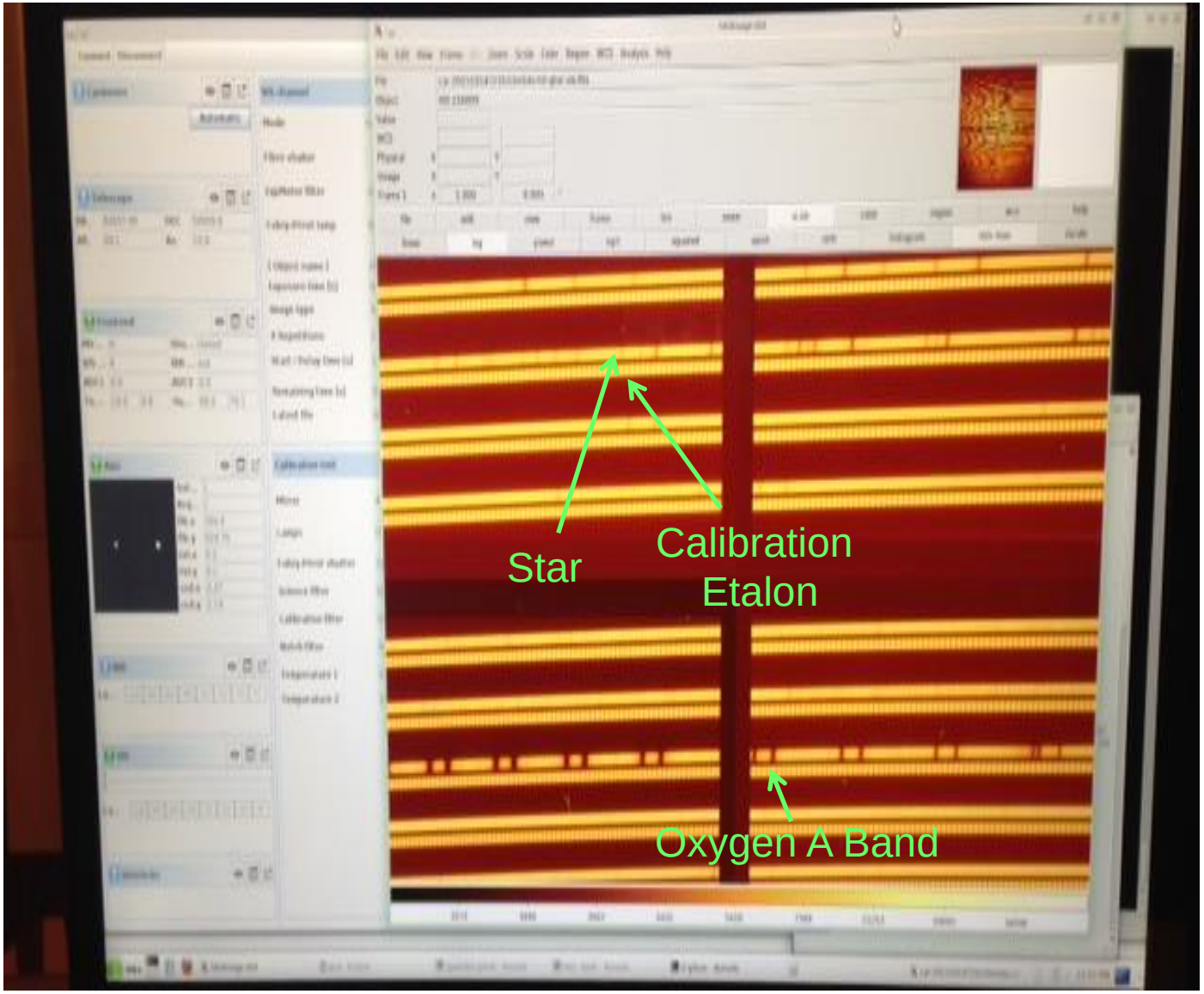
Installation of the VIS Vacuum Tank at CAHA



Lifting the NIR Spectrograph into the Dome

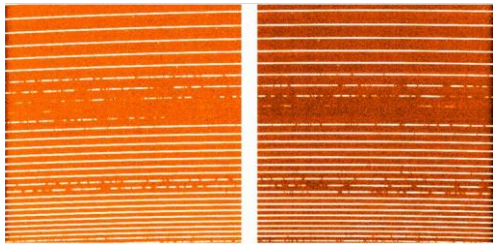
NIR Spectrograph Installed at CAHA

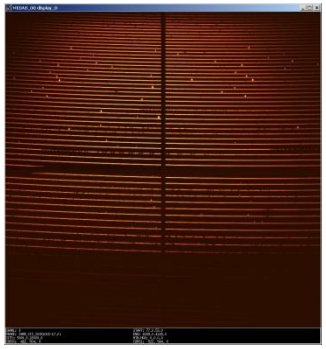
Getting Spectra!



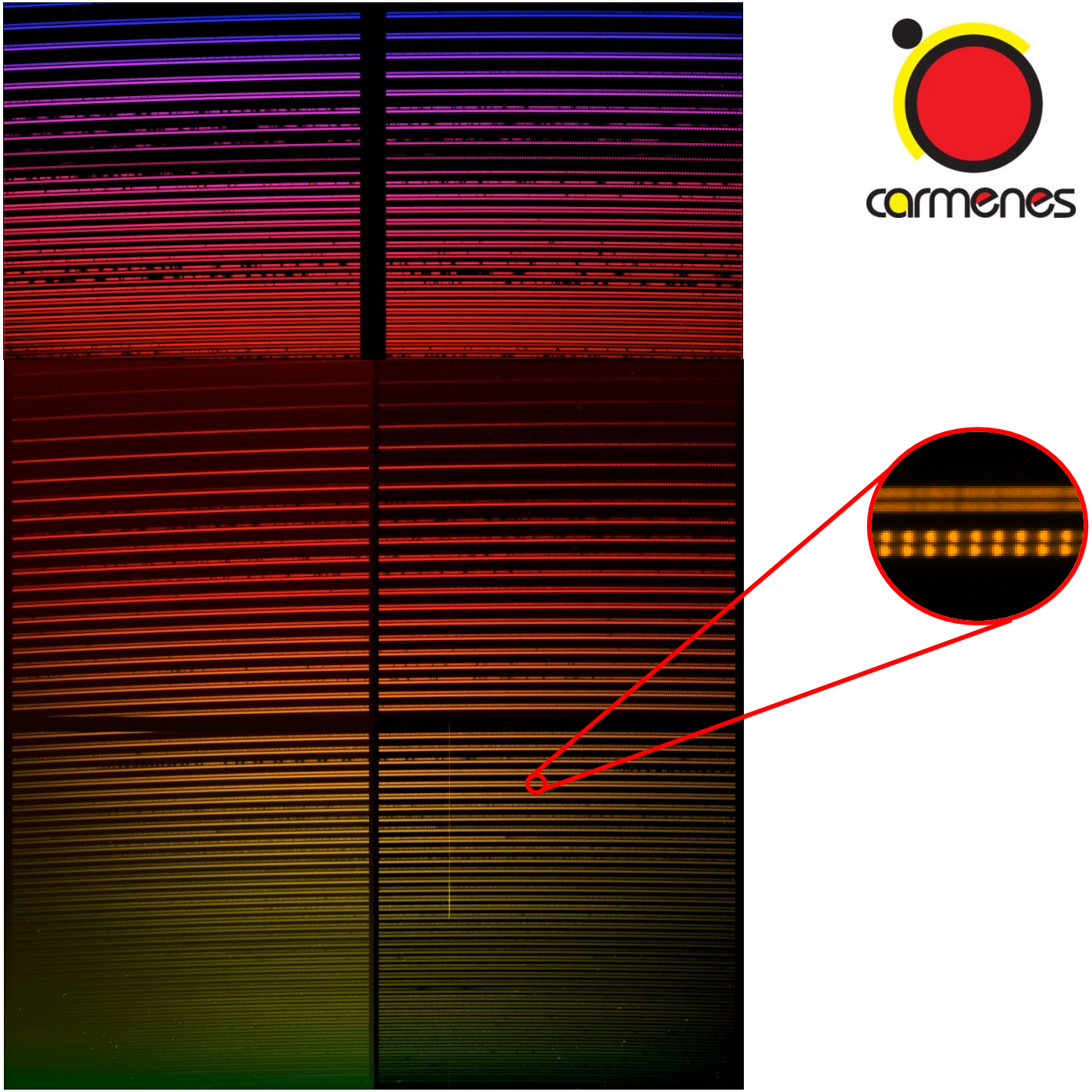
"First Light" for both spectrographs simultaneously on Nov 09, 2015

NIR: 2× 2k×2k
VIS: 4k×4k



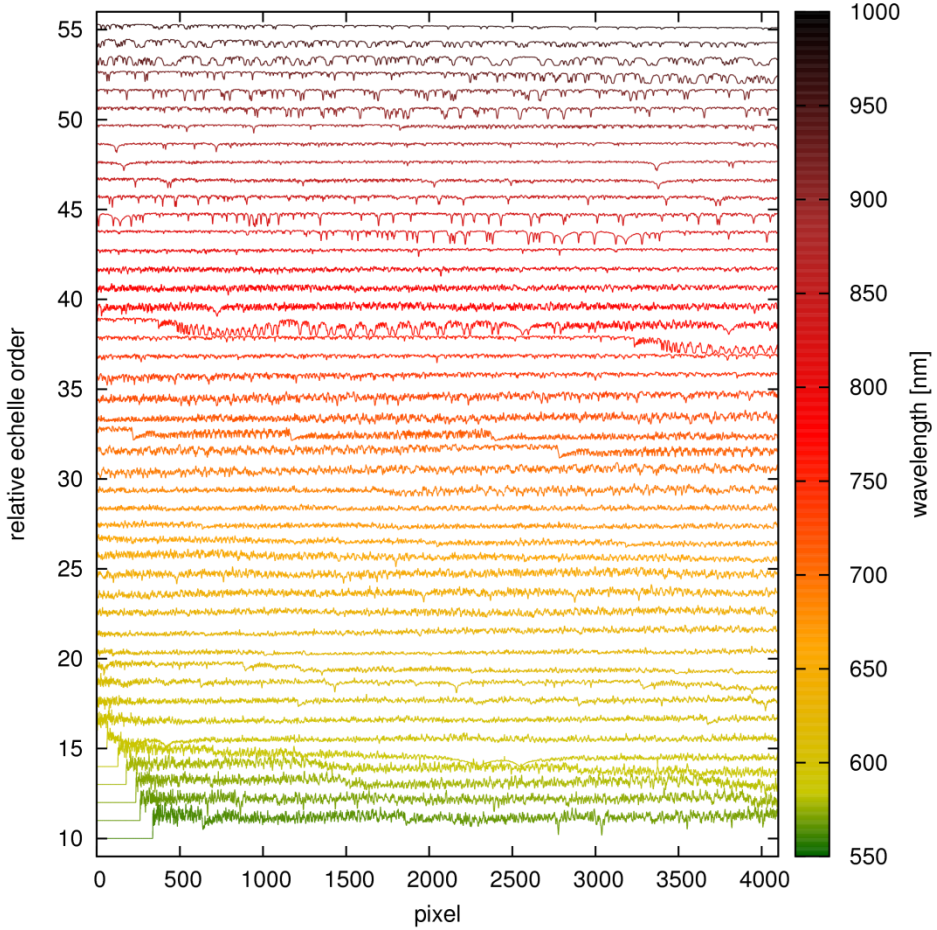


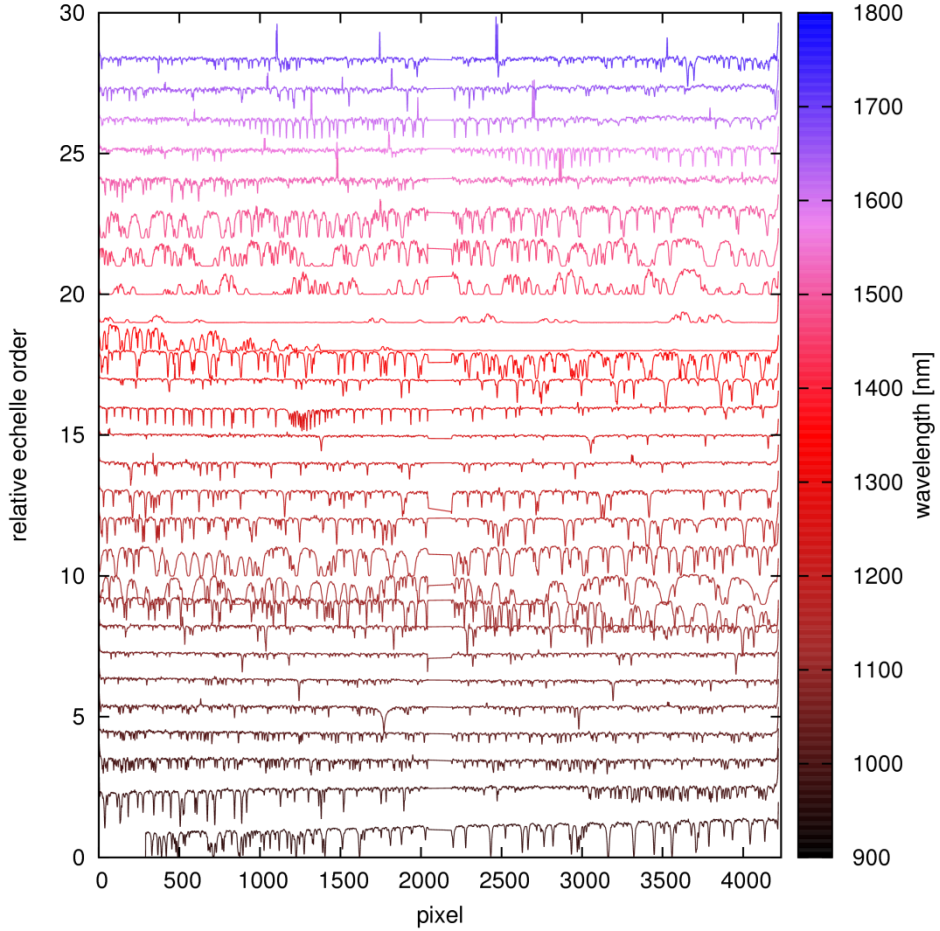
NIR 28 orders
0.96-1.71 µm



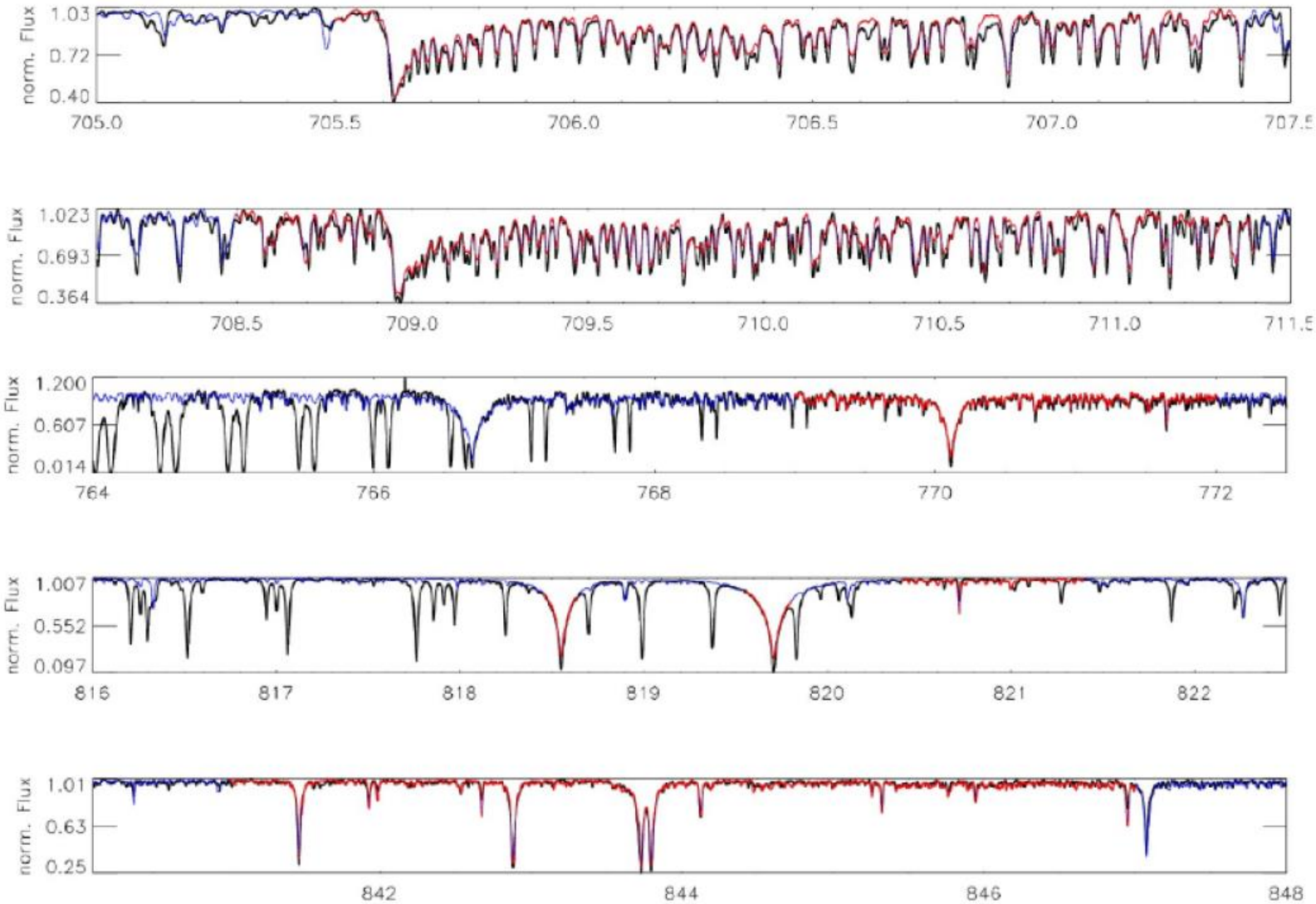
VIS 61 orders
0.52-0.96 µm

Extracted Spectra



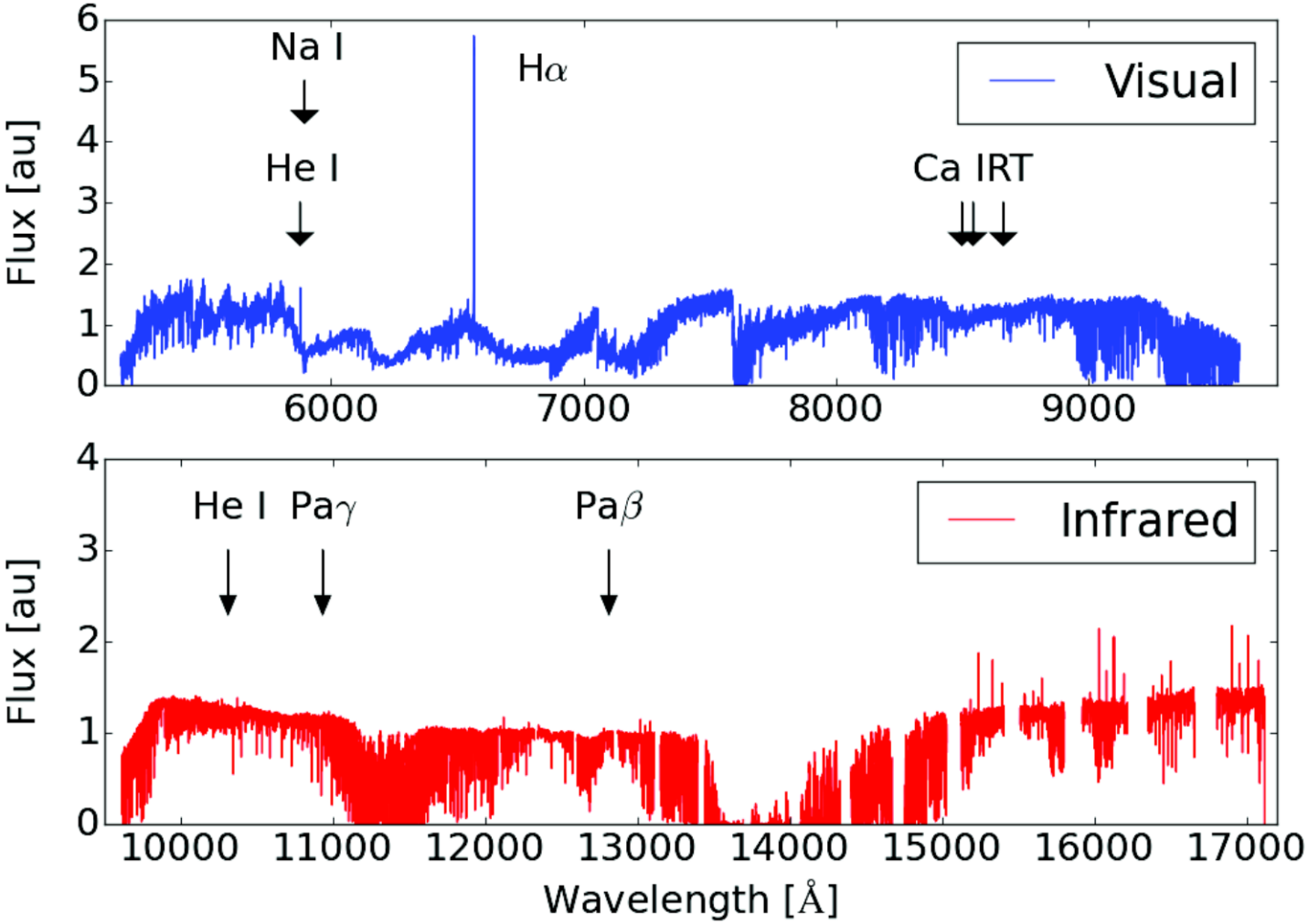


Section of CARMENES Spectrum of BD+44 2051



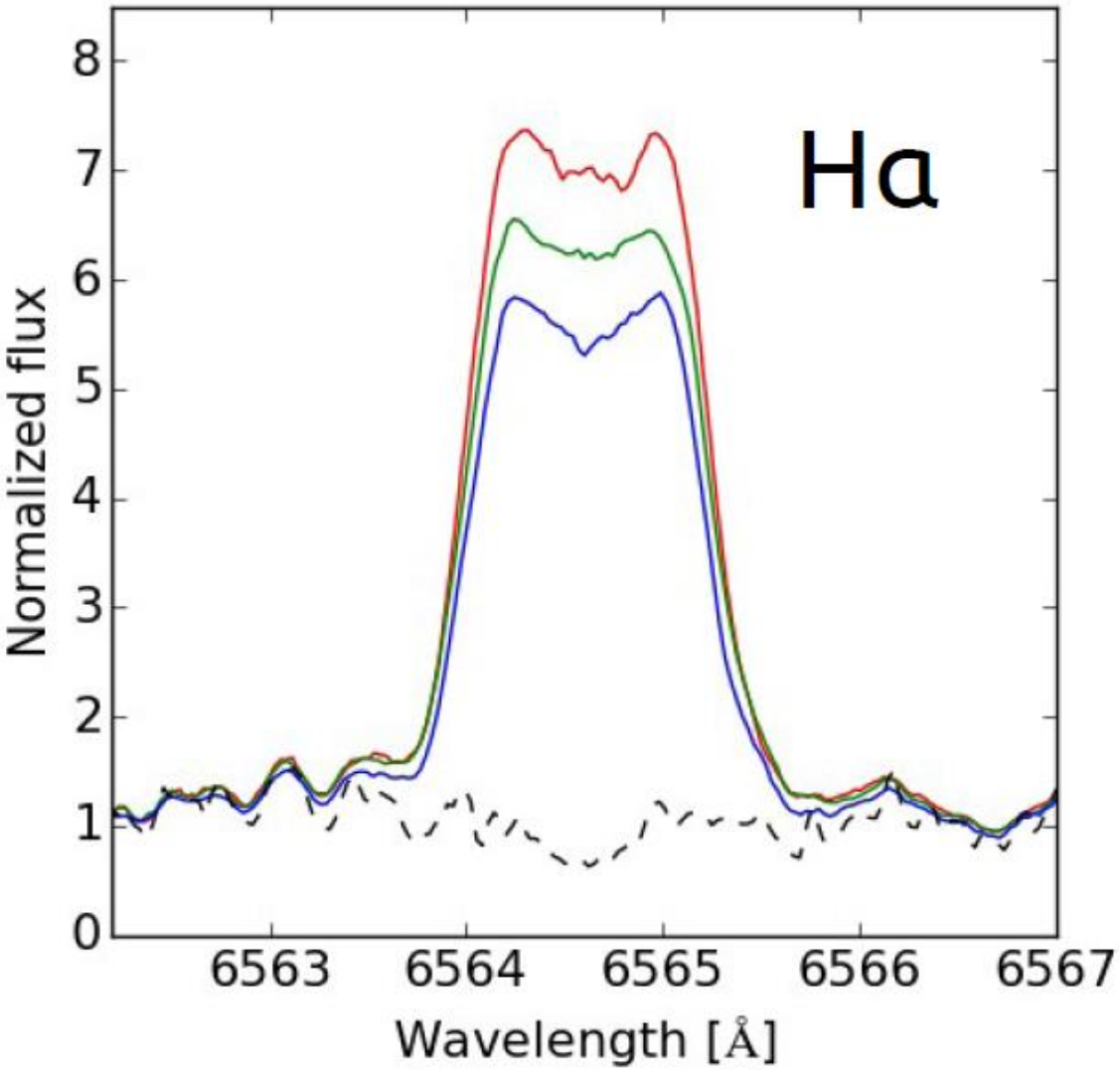
Passegger et al.

CARMENES Spectrum of YZ CMi



Cziesla et al.

Variability of Ha in YZ CMi

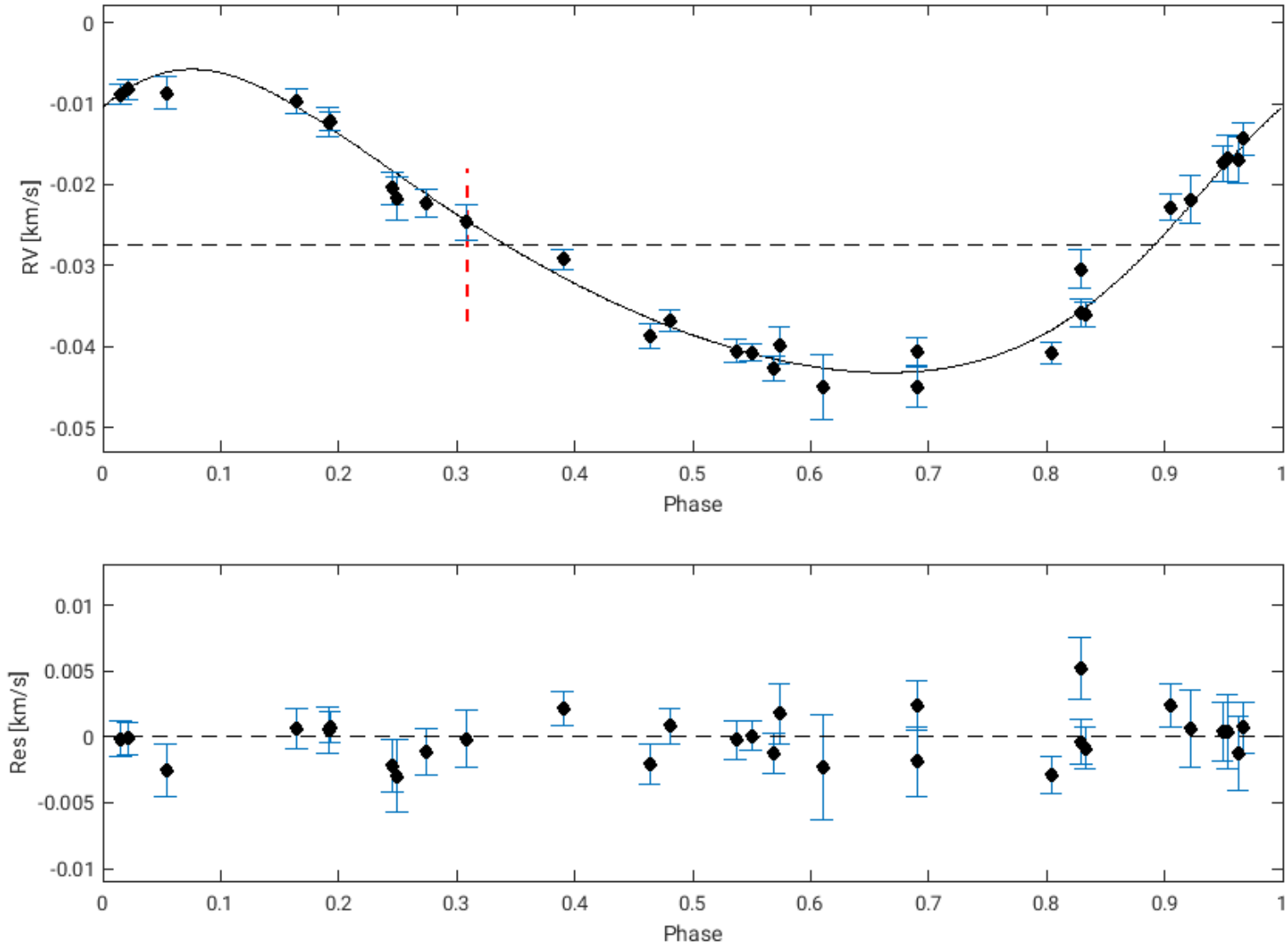


Cziesla et al.

GJ 436

CARMENES VIS – 100 days

Parameters in good agreement with Lanotte et al. (2014)



Status of VIS Spectrograph

- Throughput and spectral quality ok
  - Very good for stellar spectroscopy
- Full data reduction pipeline working
- Many stars with $\sigma \leq 2$ m/s
  - Distribution of σ very similar to HARPS
  - For M stars limited by stellar noise, not by spectrograph
- First tests of transits ongoing
  - Rossiter-McLaughlin and atmospheres

Status of NIR Spectrograph

- Throughput and spectral quality ok
  - Very good for stellar spectroscopy
- β tests of data reduction pipeline
  - More work on telluric subtraction needed
- Recent hardware improvements
  - Fast shutter for FP, temperature control
- Recent data show $\sigma \leq 10$ m/s overall, $\sigma \approx 2$ m/s over 1 night
- Improvements of calibration planned

What We'll Get from the CARMENES Survey

- Radial velocity curves of 300 M stars
  - Precision good for terrestrial planets
  - Orbits and multiplicity
  - Very nearby stars (typically 13 pc)
  - A few transiting planets ($\Rightarrow$ follow-up)
- Detailed information on target stars
  - R = 82,000 spectra from 0.53 to 1.7μm
  - Key activity indicators (Hα, Ca IR triplet)
  - Line variability and RV jitter
- Excellent instrument for transit follow-up

What CARMENES Can Do for You

- 20% of observing time available through open calls for proposals
- High-quality high-resolution spectra for stellar astrophysics (down to J ≈ 11)
- Radial velocities optimized for red stars
  - Including Rossiter-McLaughlin effect
- Stellar library (O to M) to appear soon
- M star spectra (one per star) public in mid-2017

Postdocs Wanted!
Come Talk to Me!

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