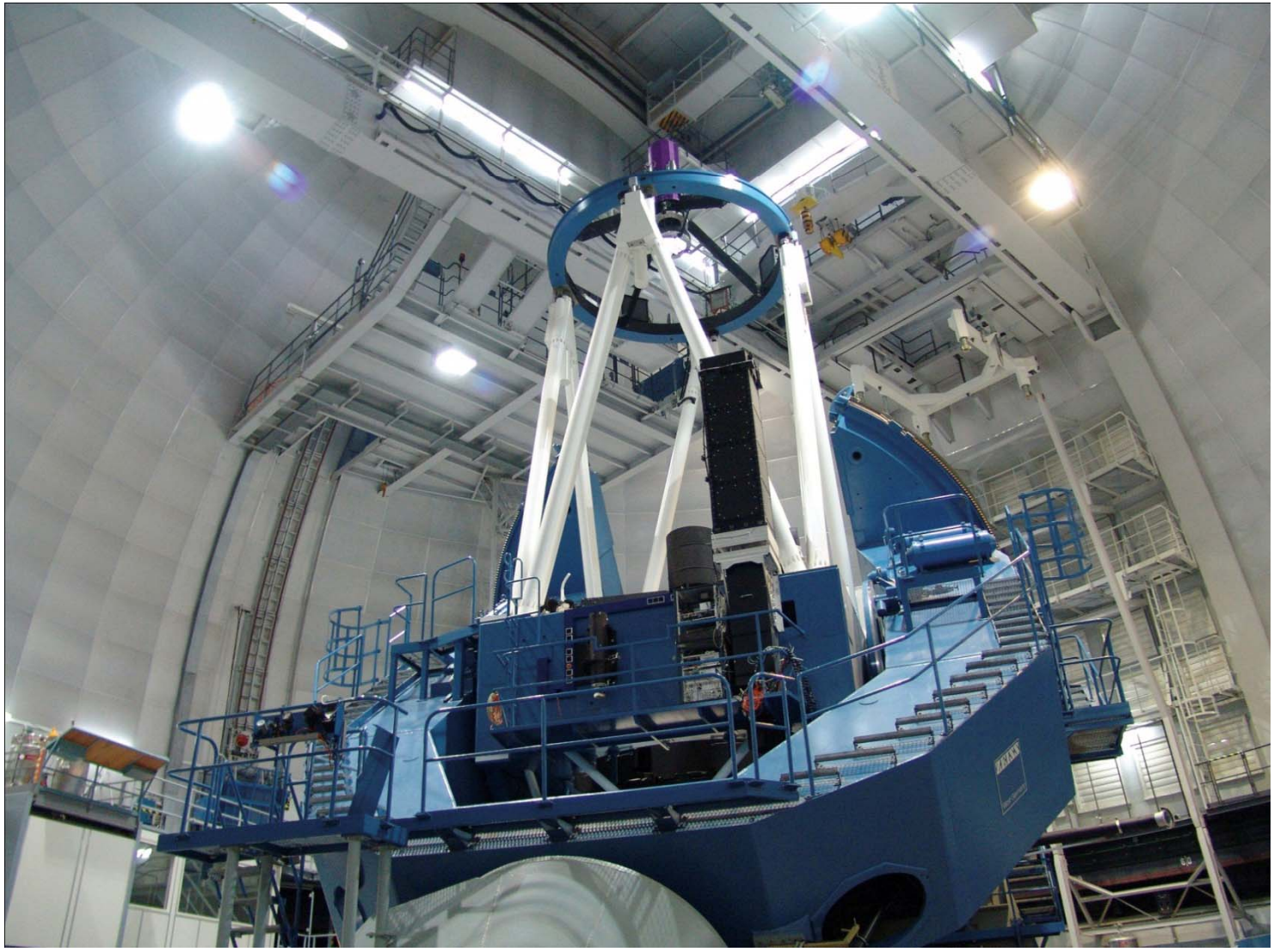
Instrument Status Overview

Andreas Quirrenbach
and the CARMENES Consortium

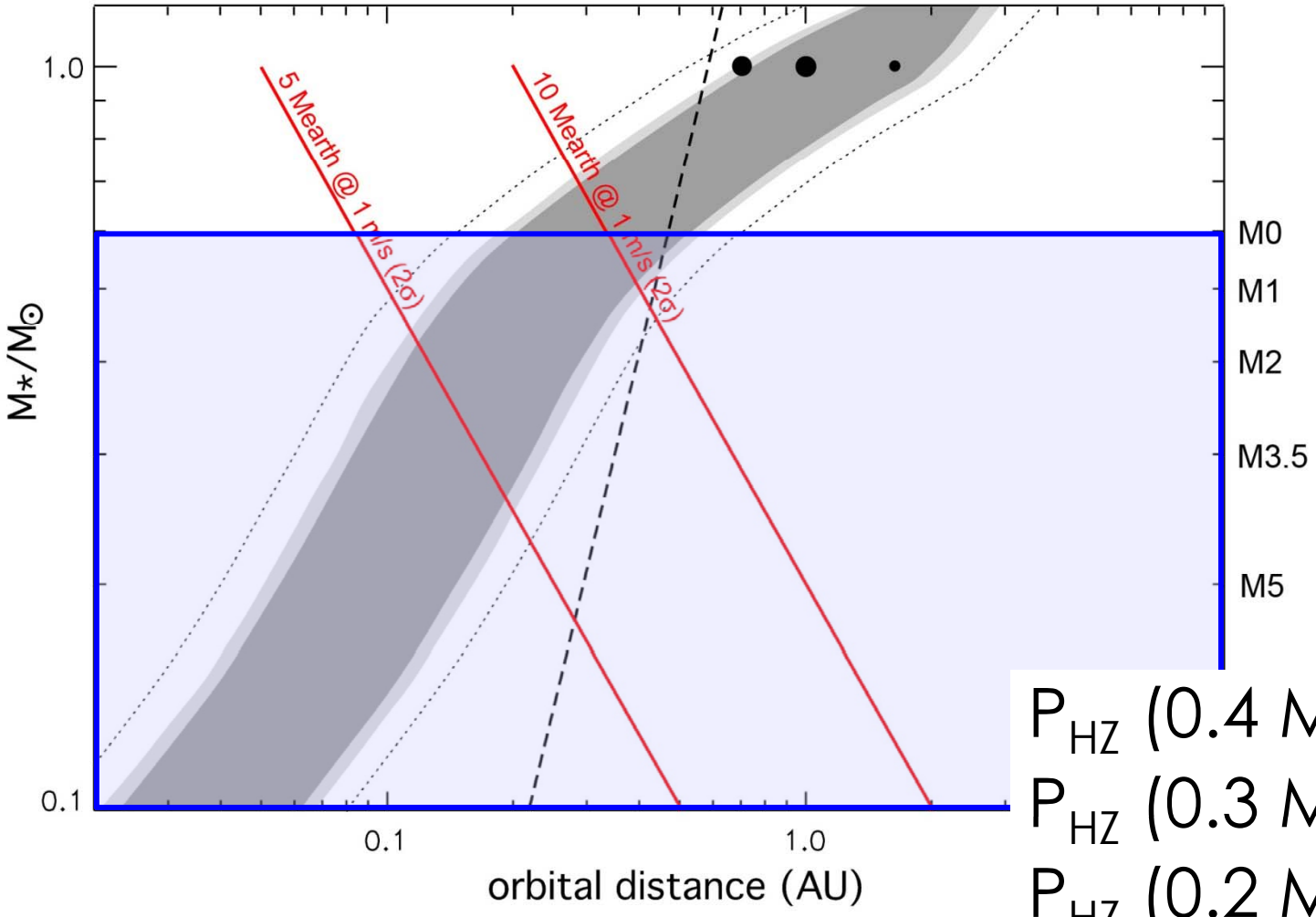
The 3.5m Telescope on Calar Alto (Southern Spain)



Goals and Plan for CARMENES

- Search for Earth-like "habitable" planets around low-mass stars (M-stars)
  - Number and formation mechanisms
  - Properties and "habitability" $\Rightarrow$ follow-up
- Radial velocity survey of 300 M stars
  - Simultaneously in visible light and near-IR
- At least 50 data points per star
  - 600 nights needed
  - Guaranteed in contract with observatory

A “shortcut”: M-type dwarfs

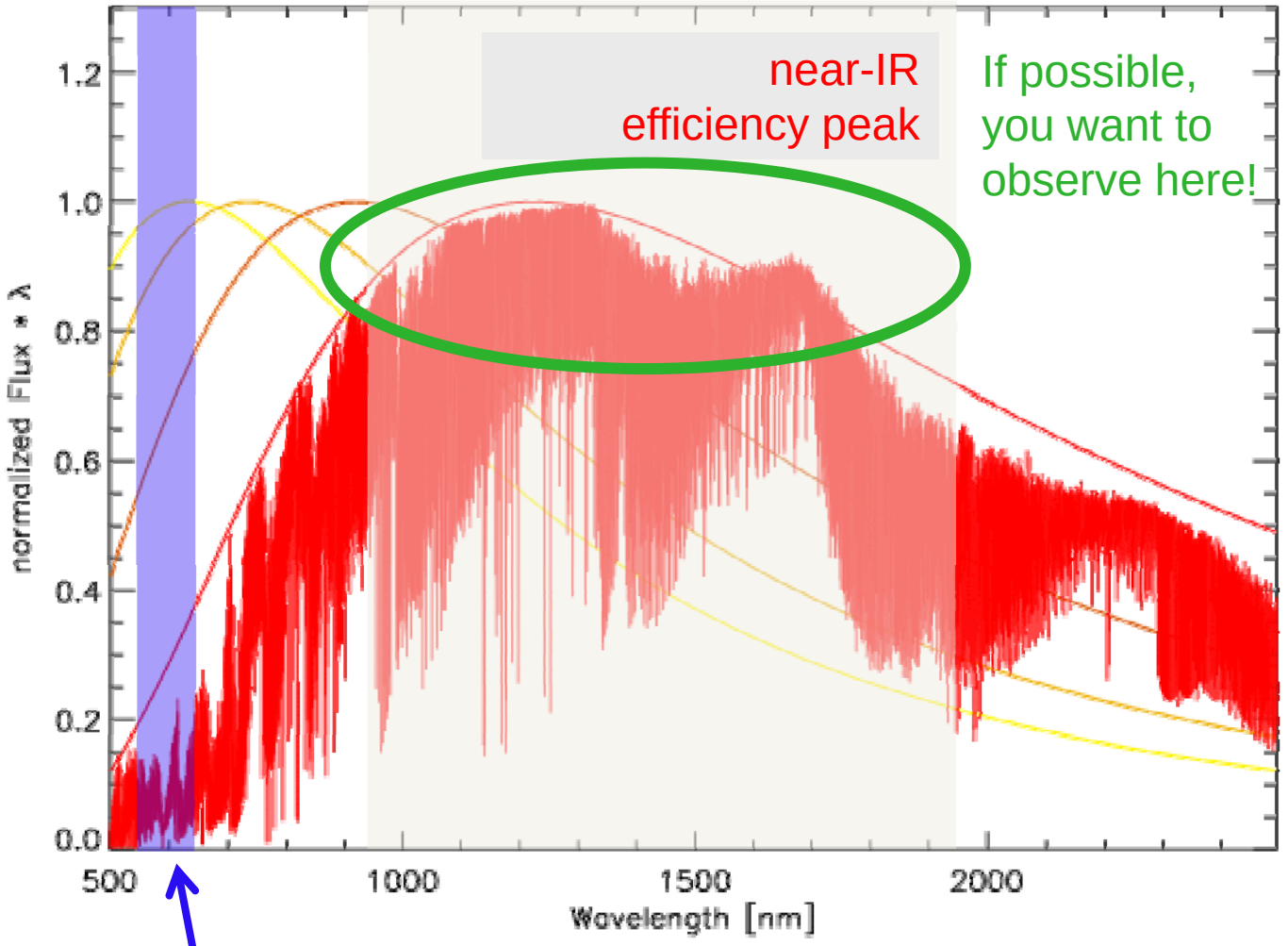


P_{HZ} (0.4 $M_\odot$) = 25 d

P_{HZ} (0.3 $M_\odot$) = 18 d

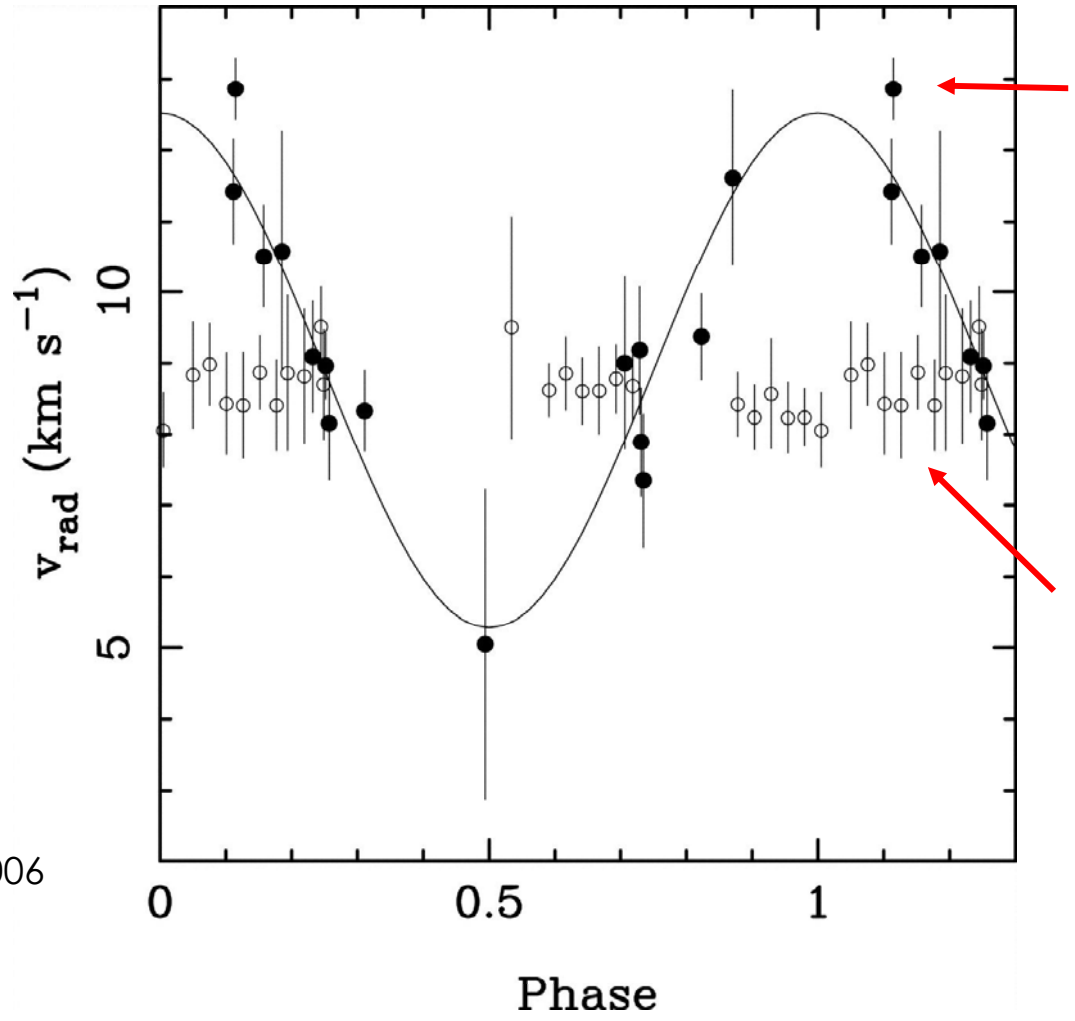
P_{HZ} (0.2 $M_\odot$) = 12 d

The SED of M-type stars



"classical" *visible light* RV instruments

Let's talk about jitter



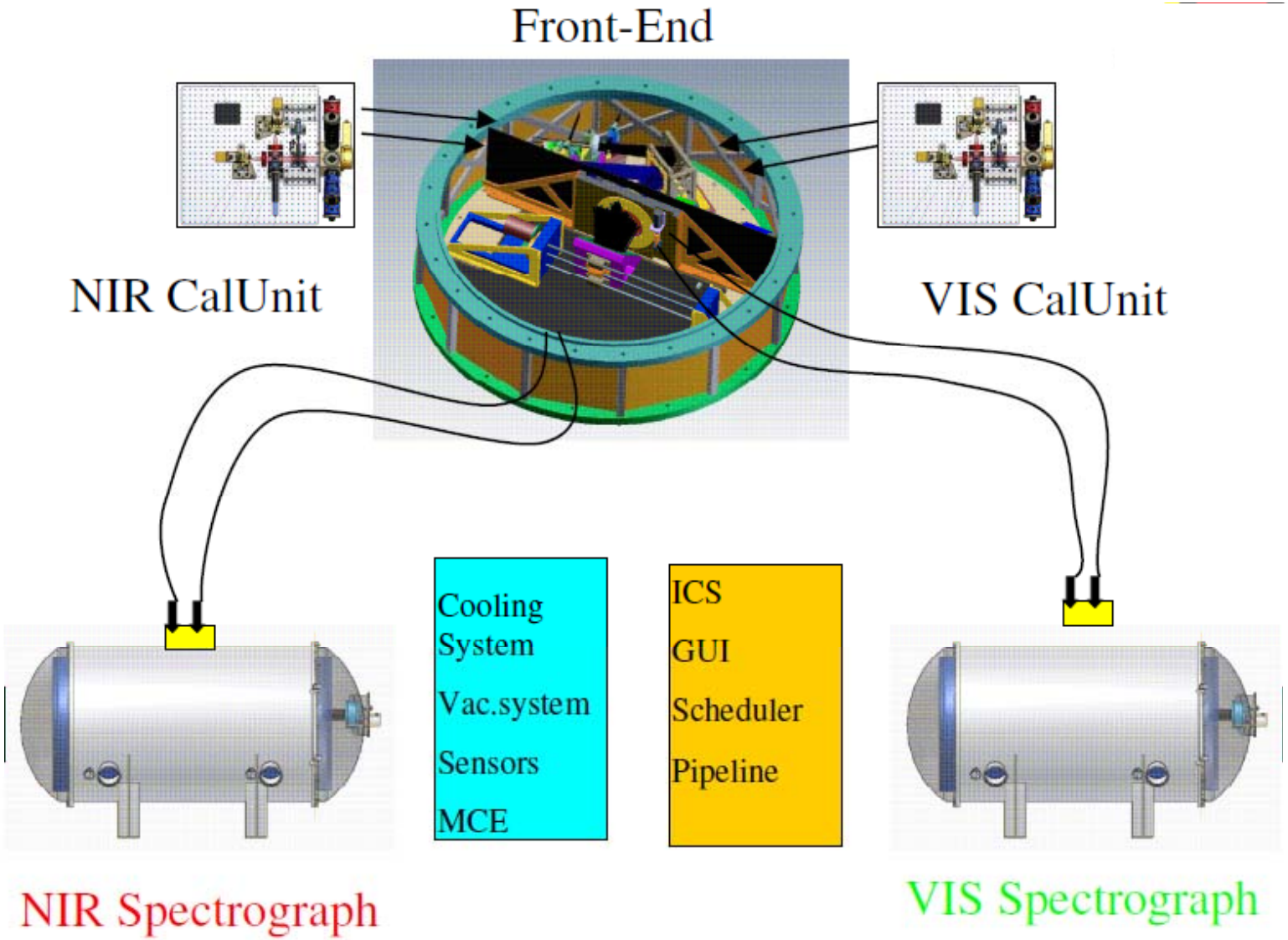
Martin et al. 2006

RV curve of the active M9 dwarf LP-944 20

Guiding Principles for Instrument

- Single-purpose instrument
  - Design driven by survey requirements
- High stability for terrestrial planet detection
  - Thermal and mechanical stability
  - Stable input
  - No moving parts in spectrographs
- High resolution for slow rotators
- Large wavelength coverage for discrimination against intrinsic variability
- High efficiency for faint stars

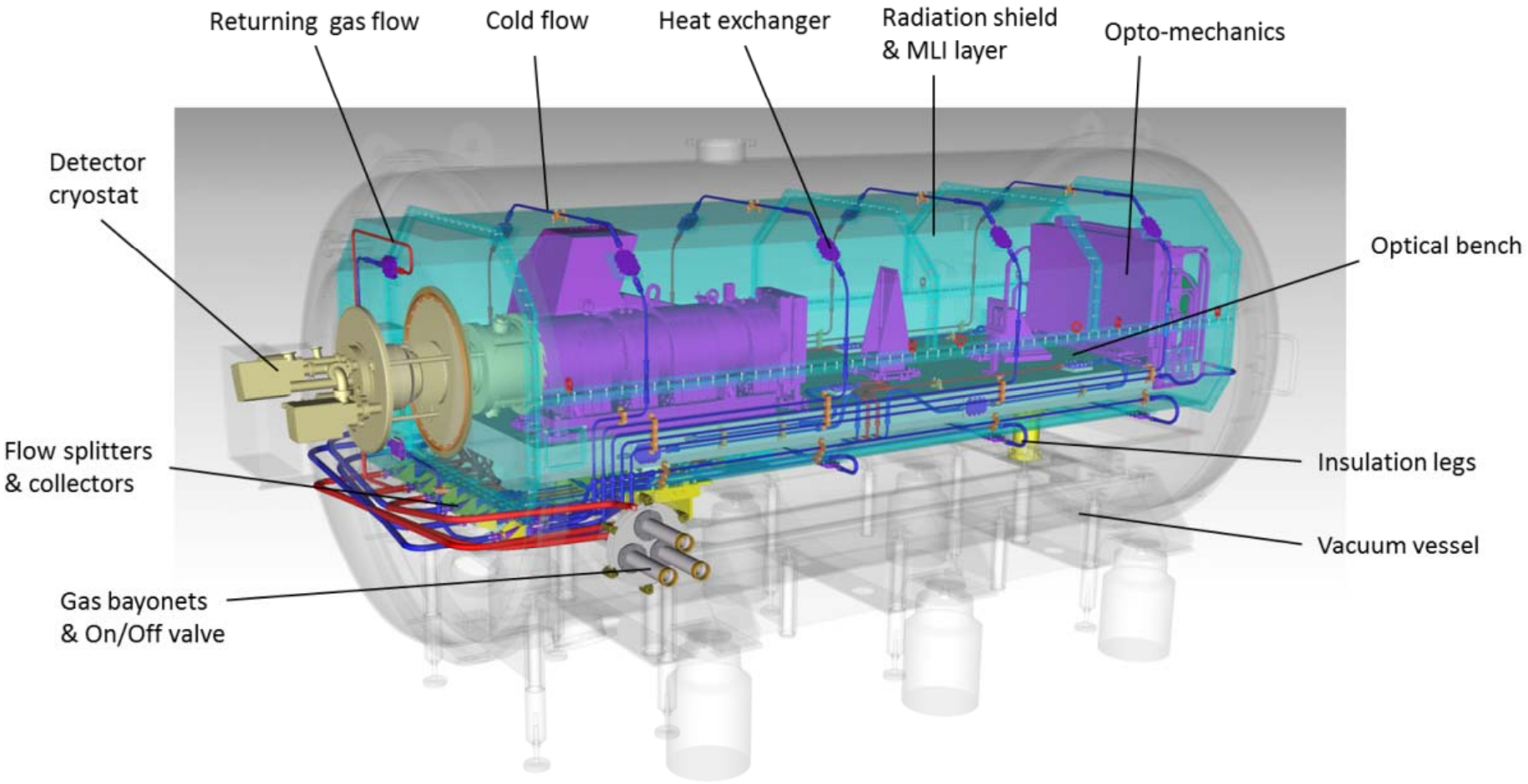
Instrument Overview



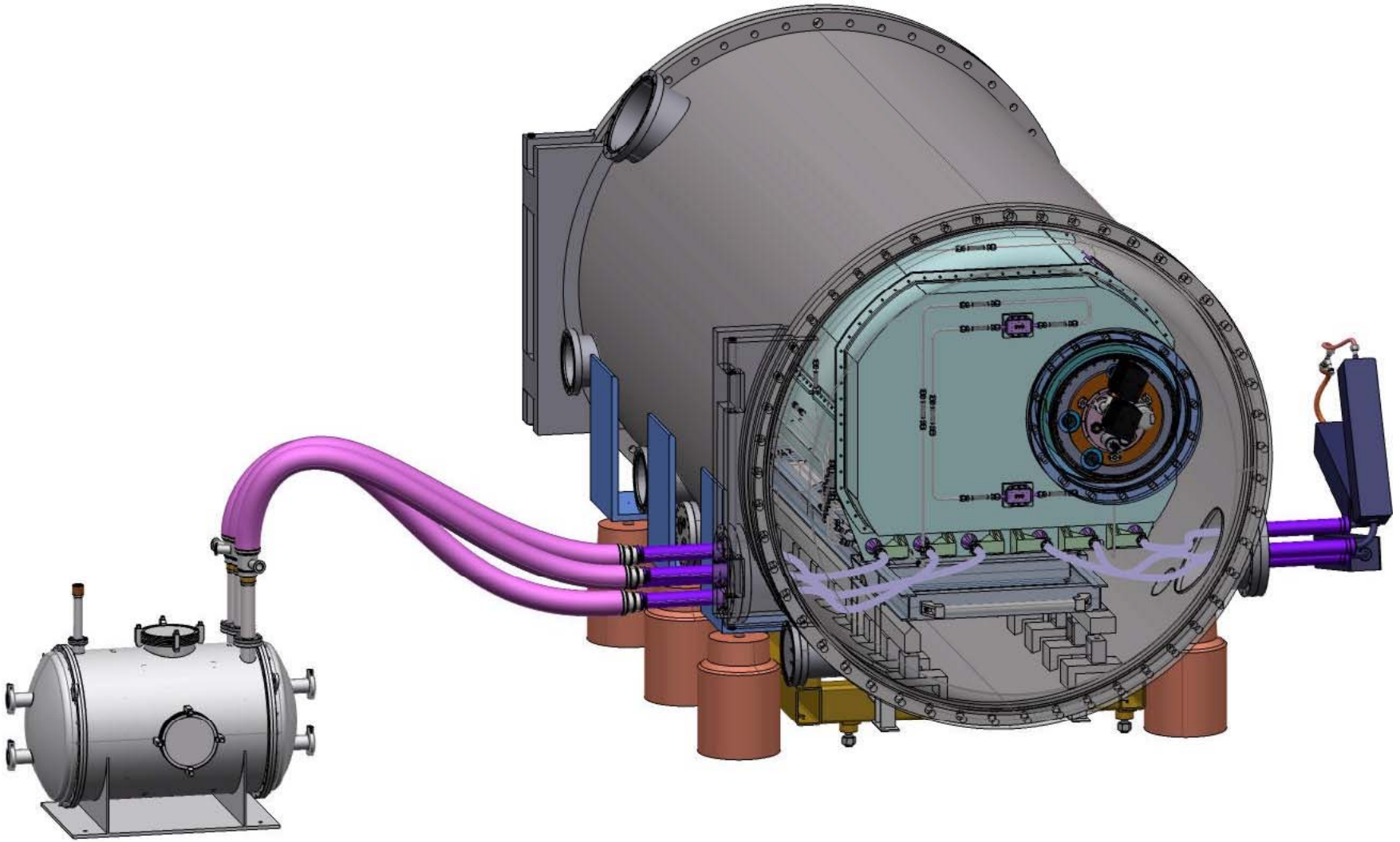
Properties of Spectrographs

- Optical spectrograph
  - 0.53 … 1.05 µm, R = 82,000
  - Precision ~1 m/s
  - Vacuum tank, temperature stabilized
  - 4k x 4k deep depletion CCD detector
- Near-Infrared spectrograph
  - 0.95 … 1.7 µm, R = 82,000
  - 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

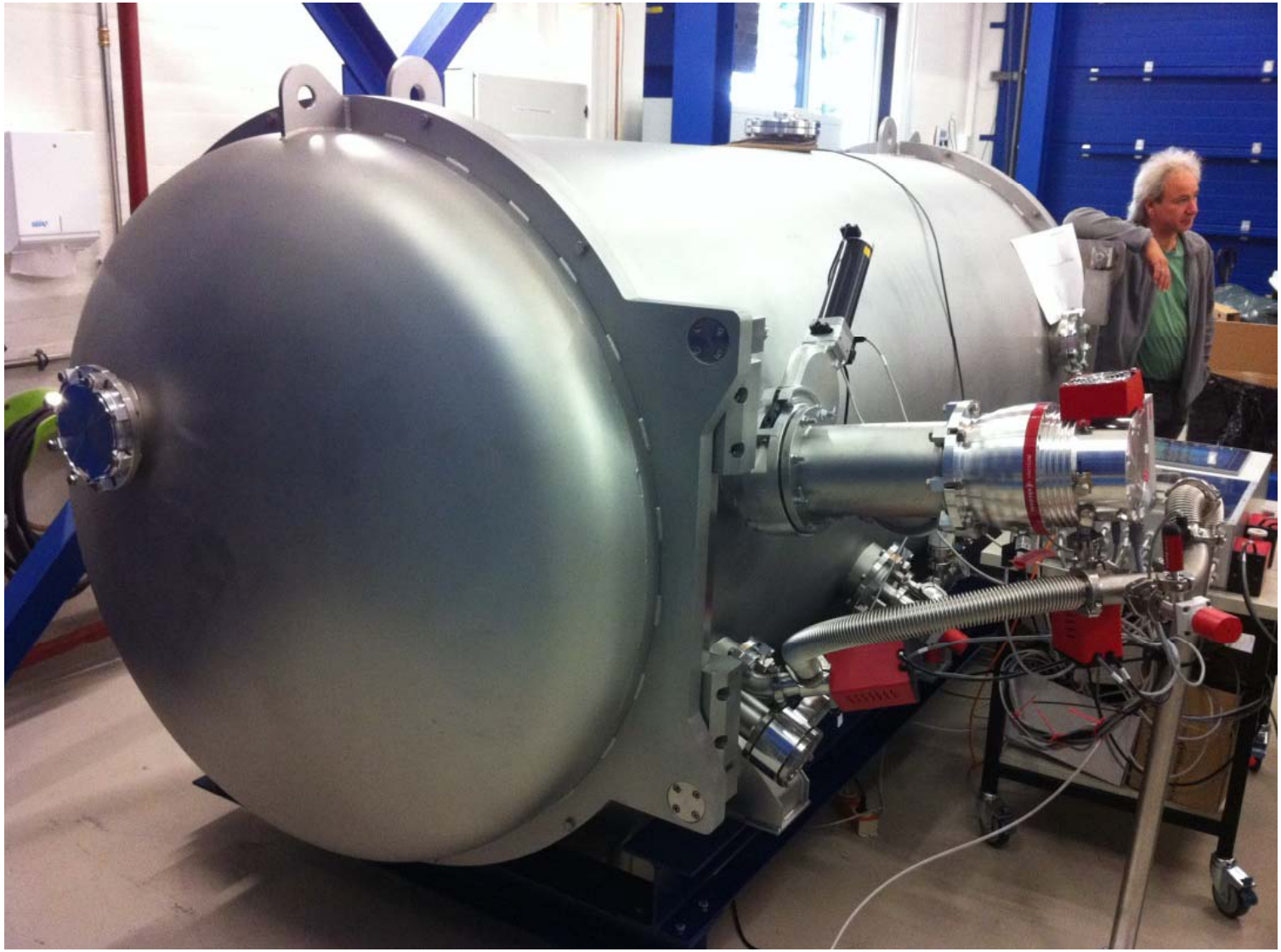


Near-IR Vacuum Tank with Cooling System

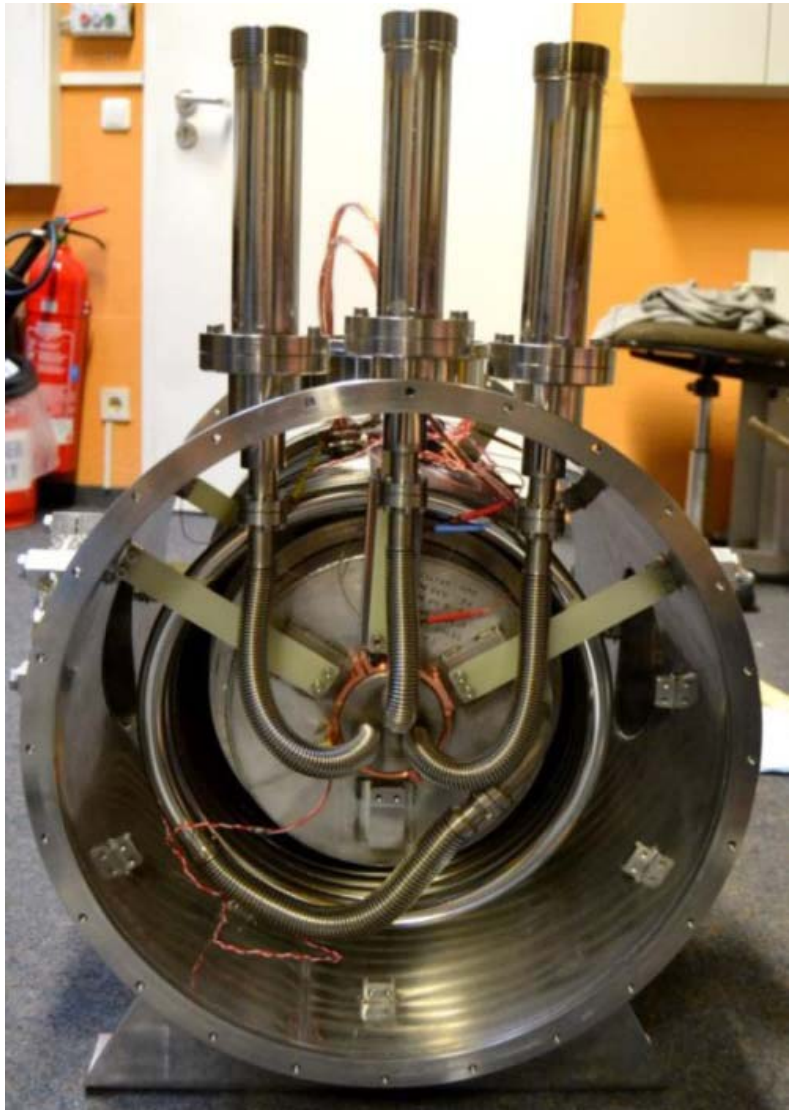


Acceptance of Vacuum Vessels

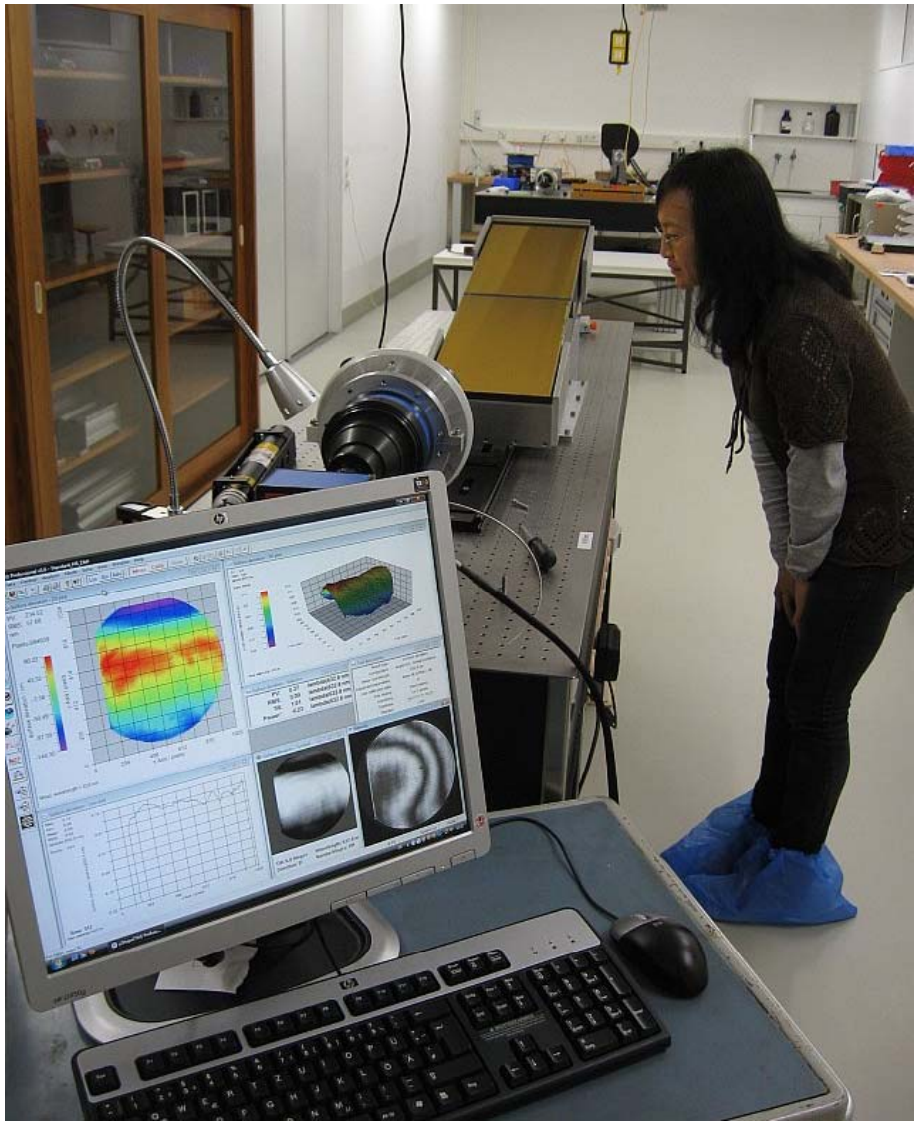
Integration of the Vacuum System



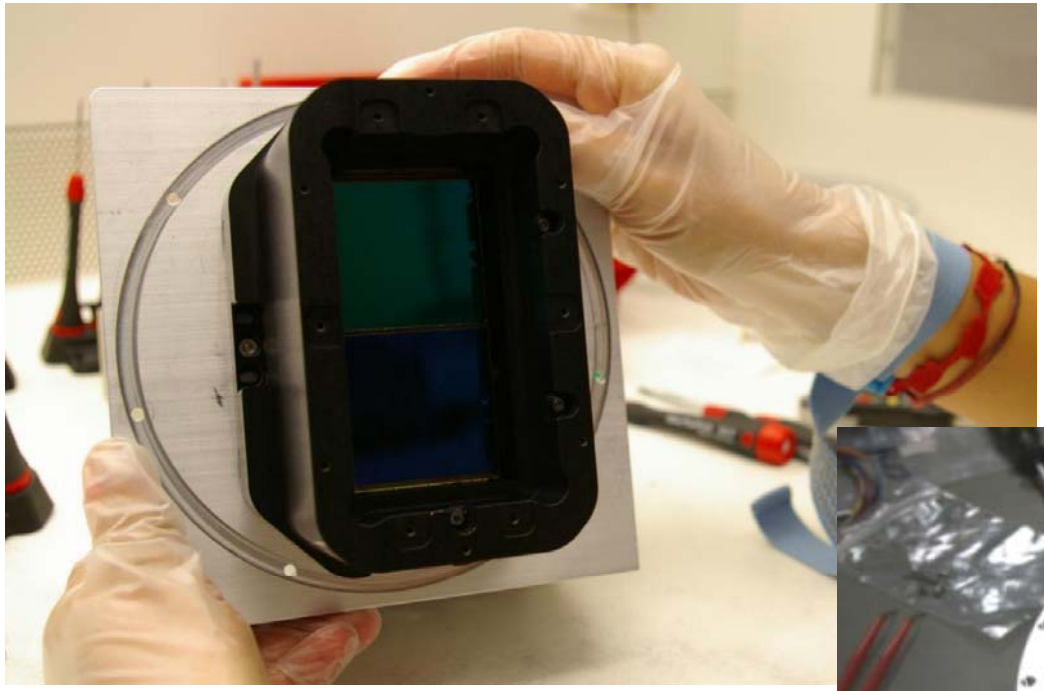
Nitrogen Gas Preparation Unit

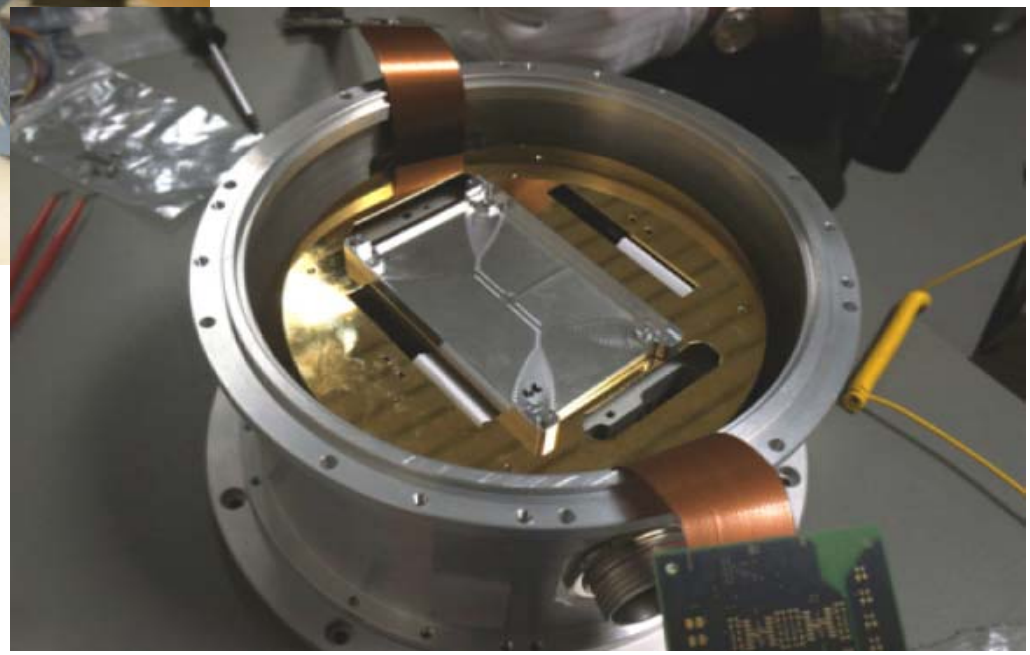


Inspection of the Visible Echelle Grating

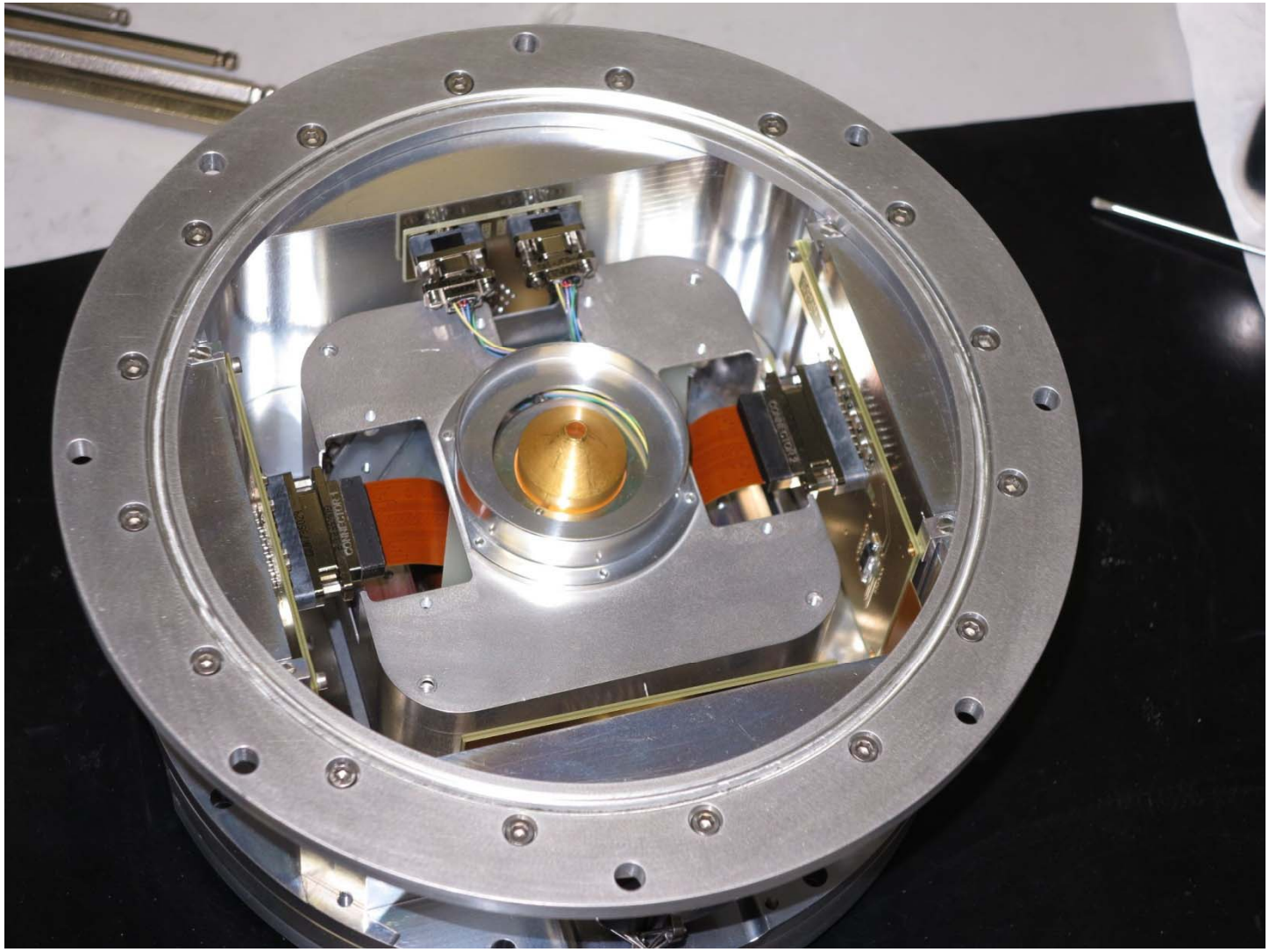


The NIR Detectors (2x HAWAII-2RG)

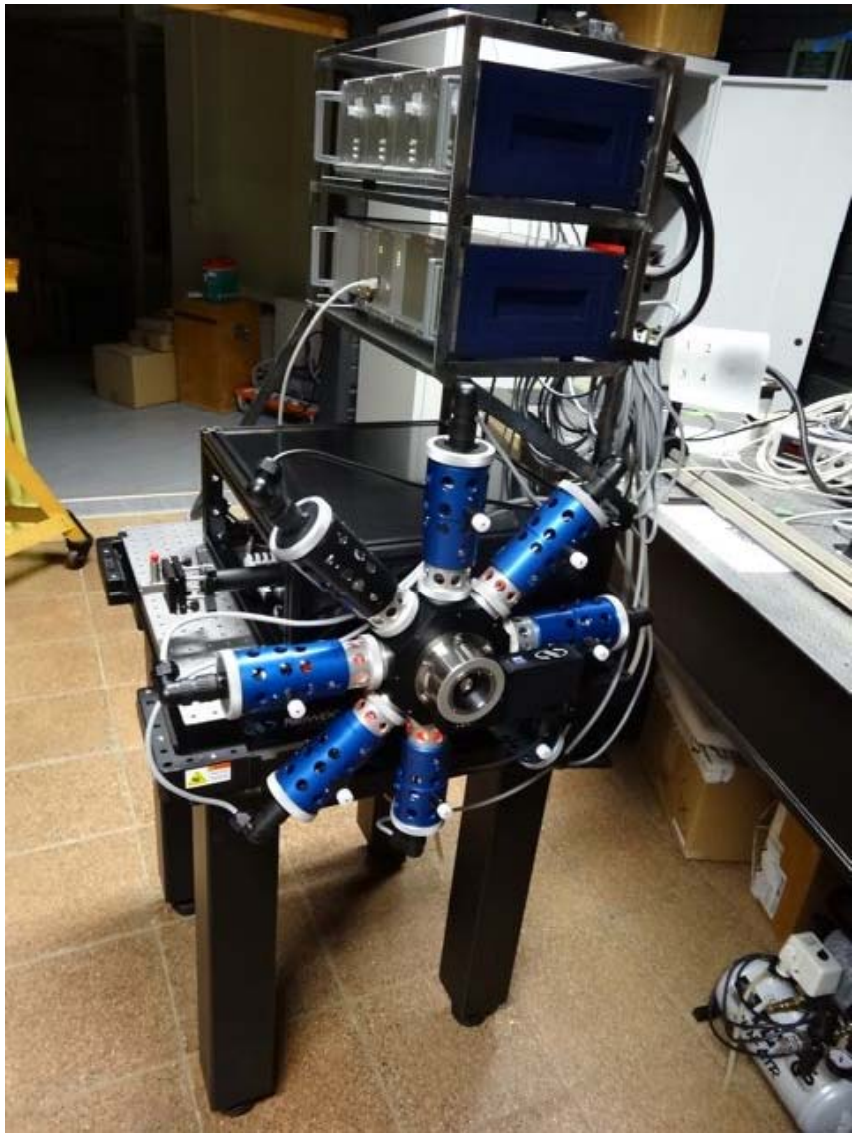




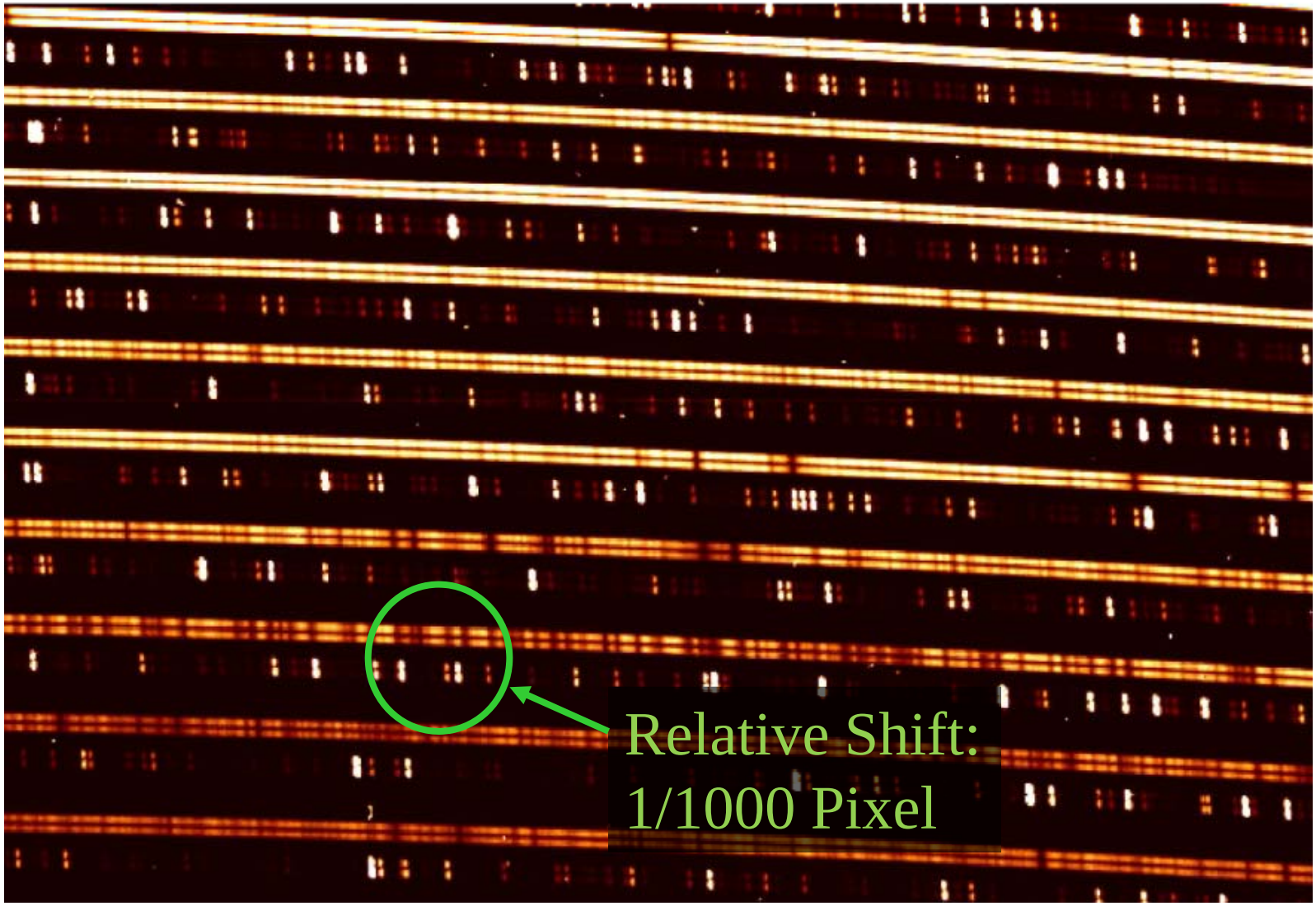
The CCD Detector Head Mounted in its Cryostat



One of the Two Calibration Units



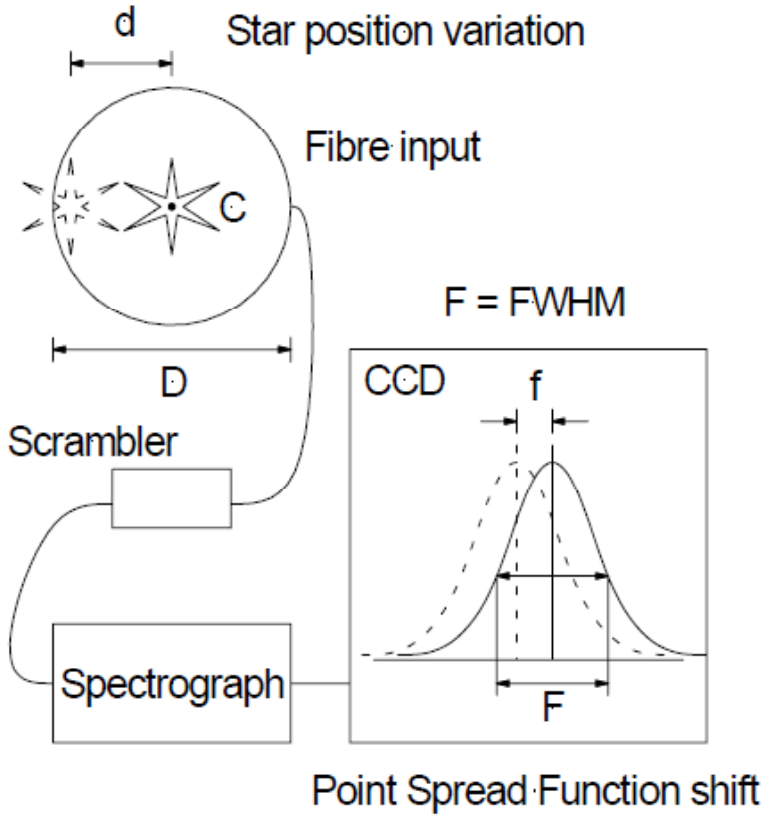
Stellar Spectrum with Calibration Lines



Requirements for RV precision

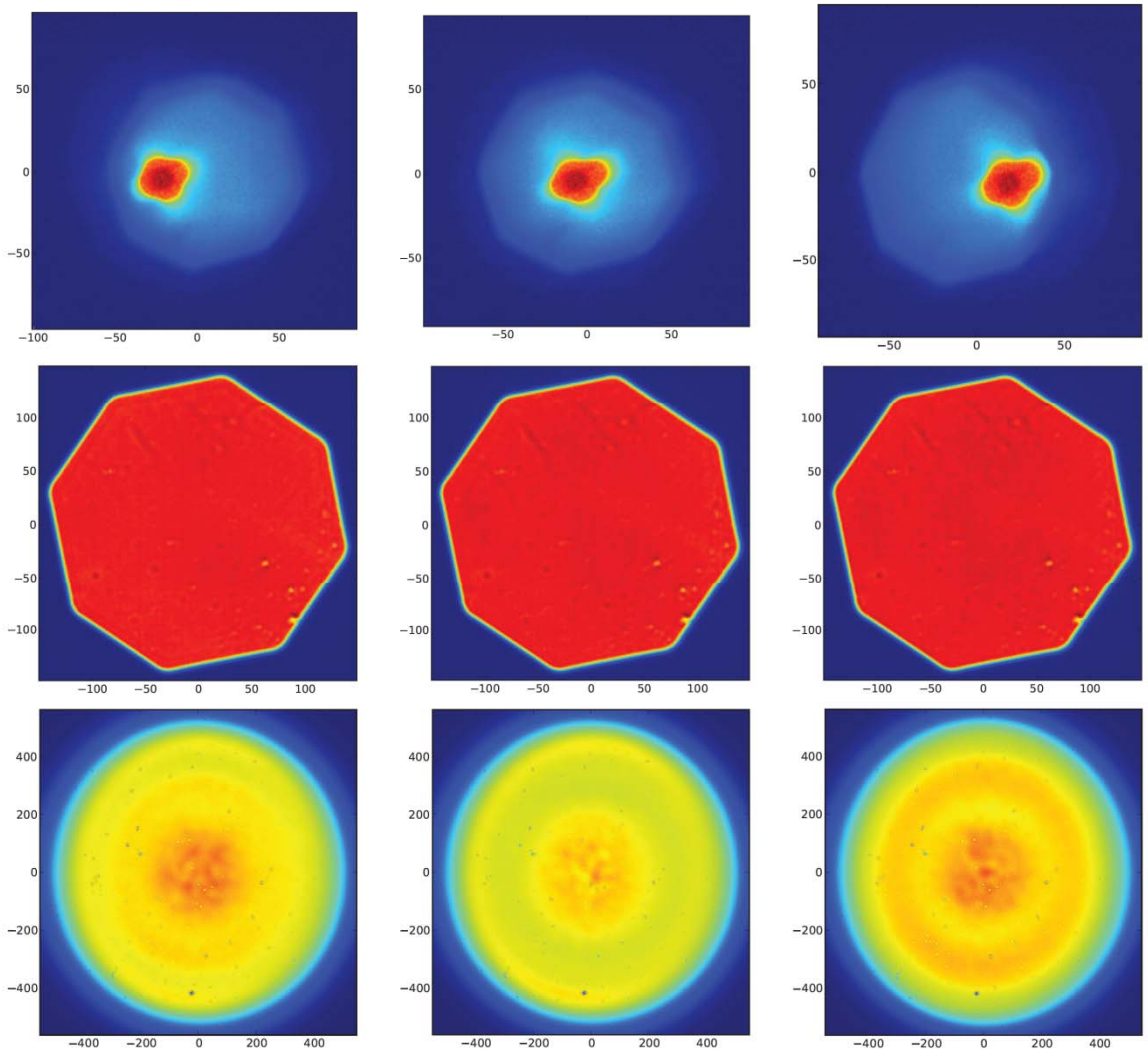
Stable slit illumination and instrument are required for high RV precision.

- Highly stable injection of light in the fiber (guiding ~0.1")
- Achieved with octagonal fiber



Avila & Singh (2008)

Tests of Octagonal Fibers

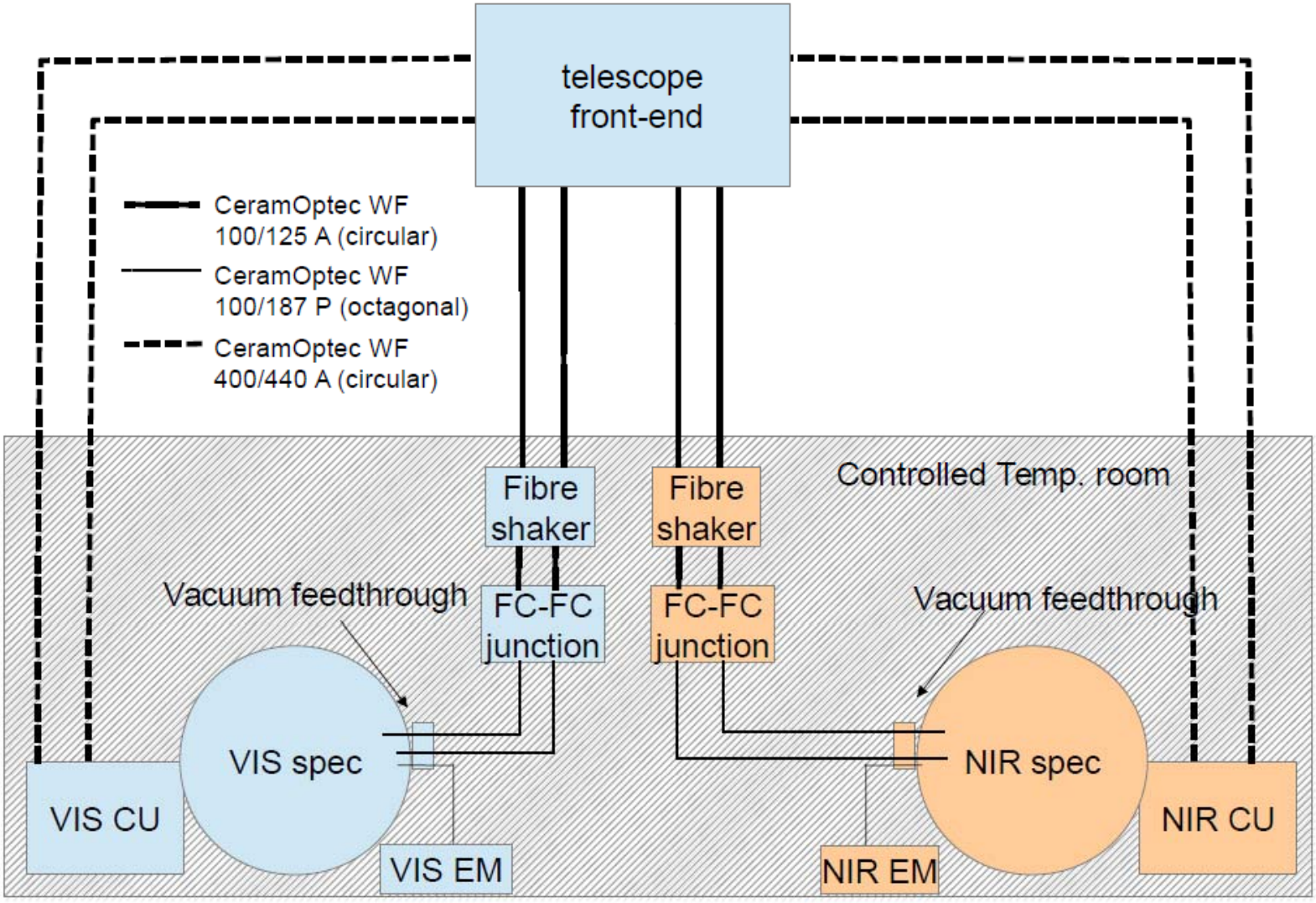


Input

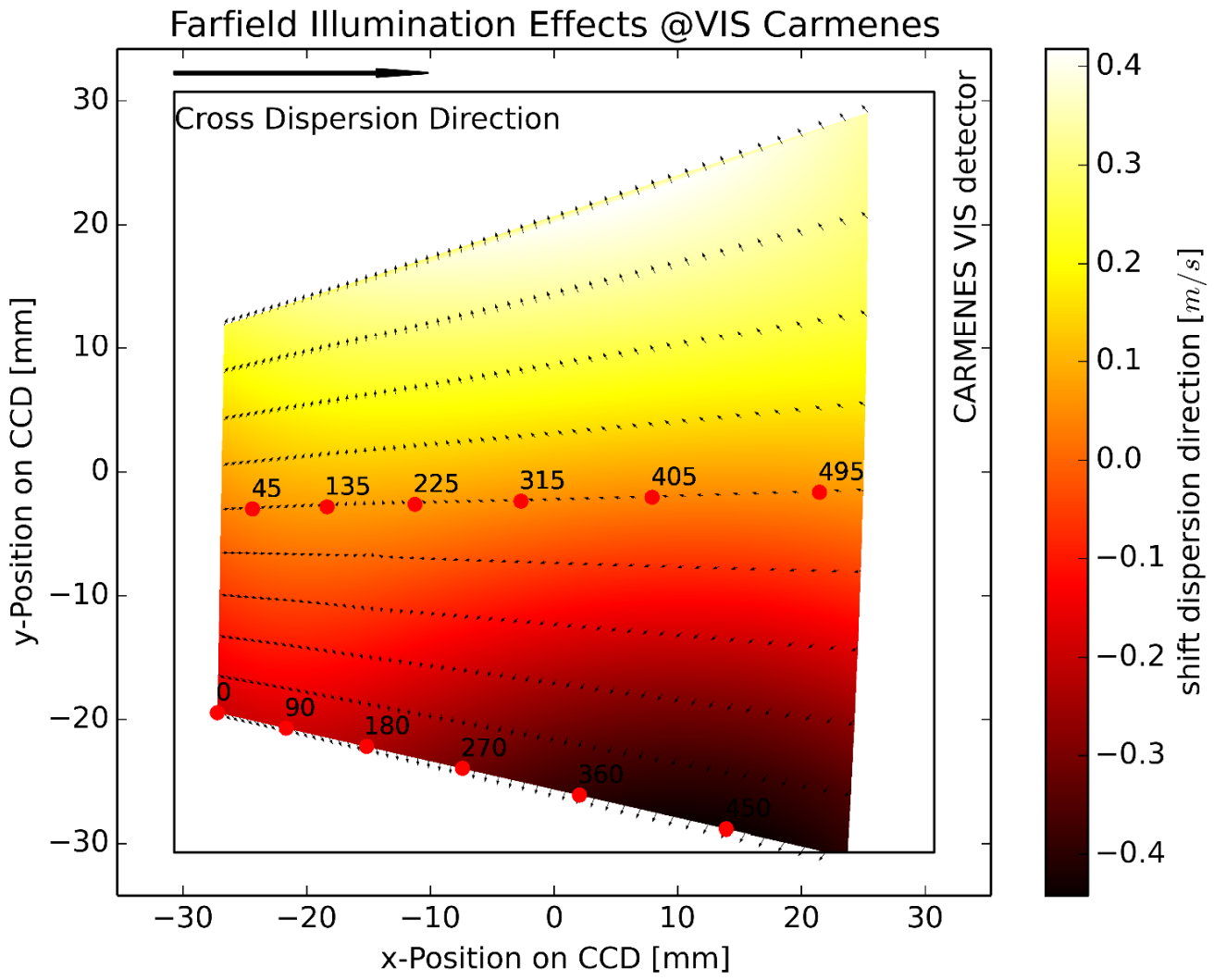
Near Field

Far Field

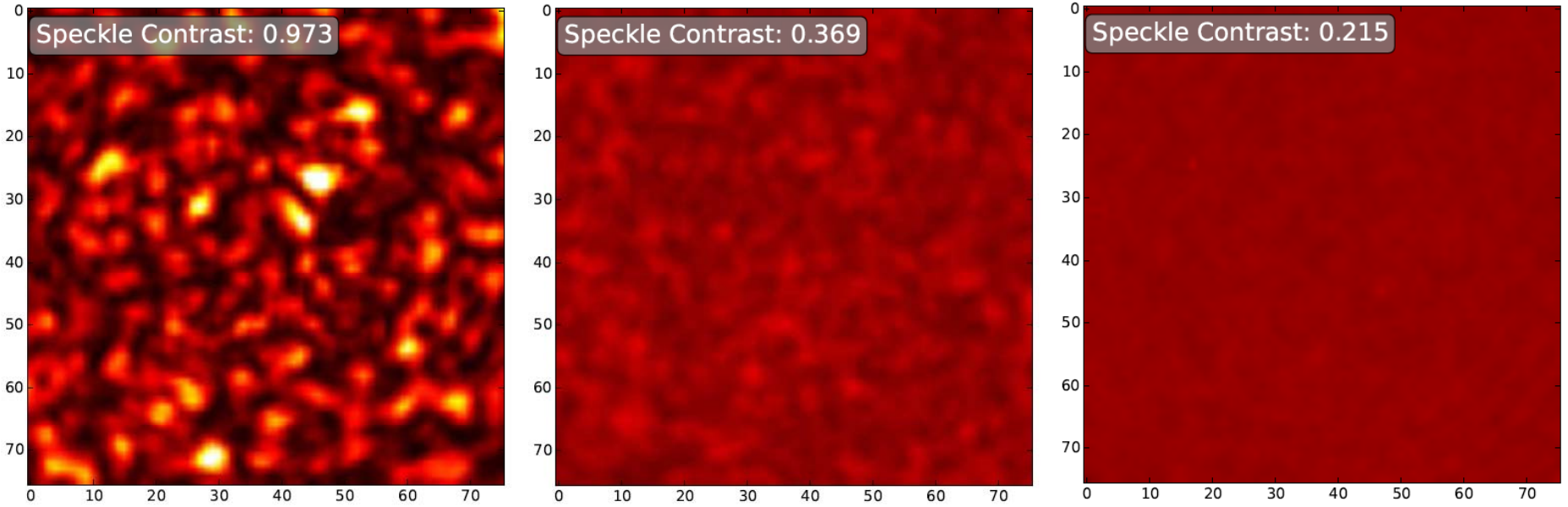
Layout of CARMENES Fiber Links



Propagation of Fiber Far Field through Spectrograph Optics



Effect of Fiber Agitation



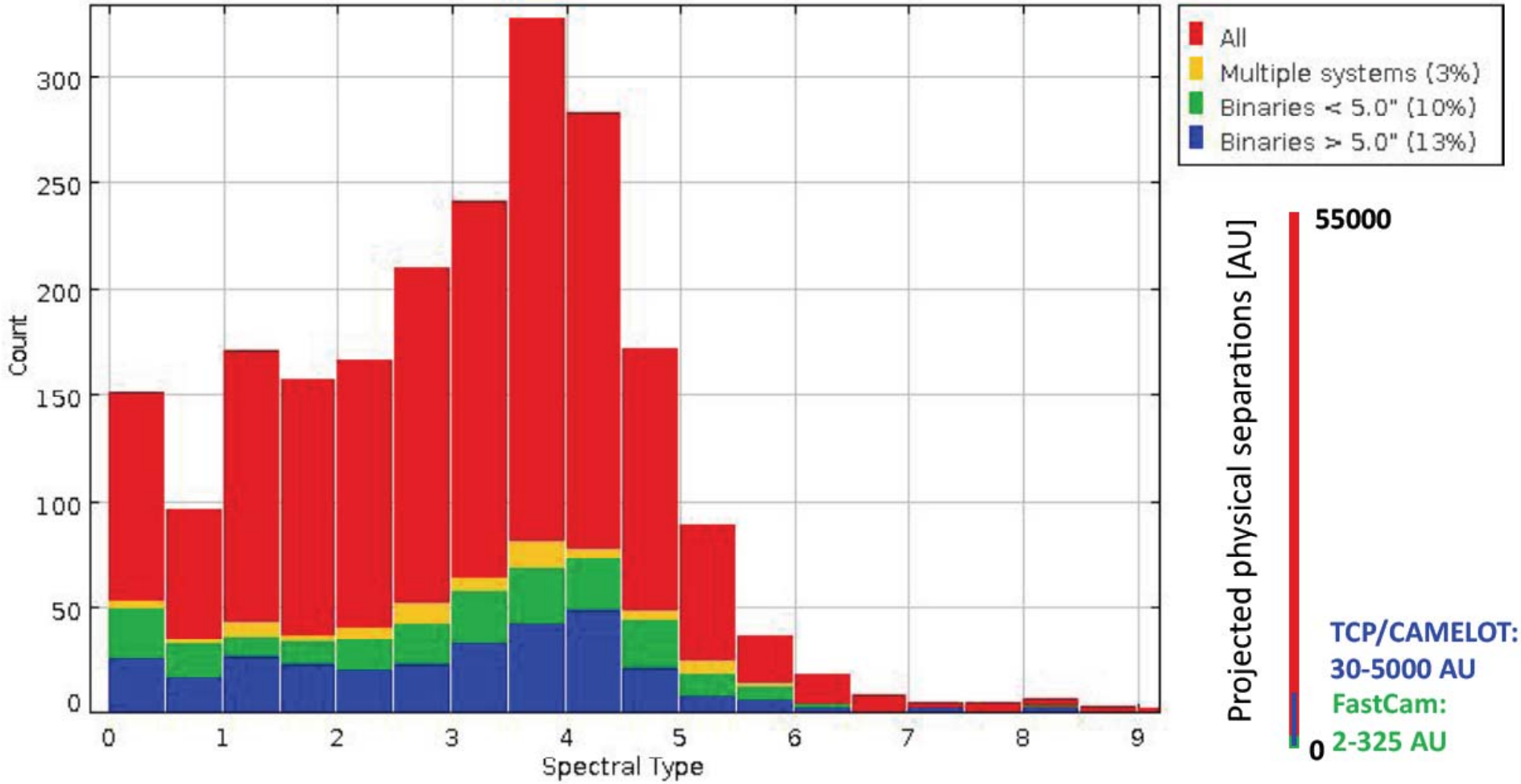
Stellar sample

- **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)**

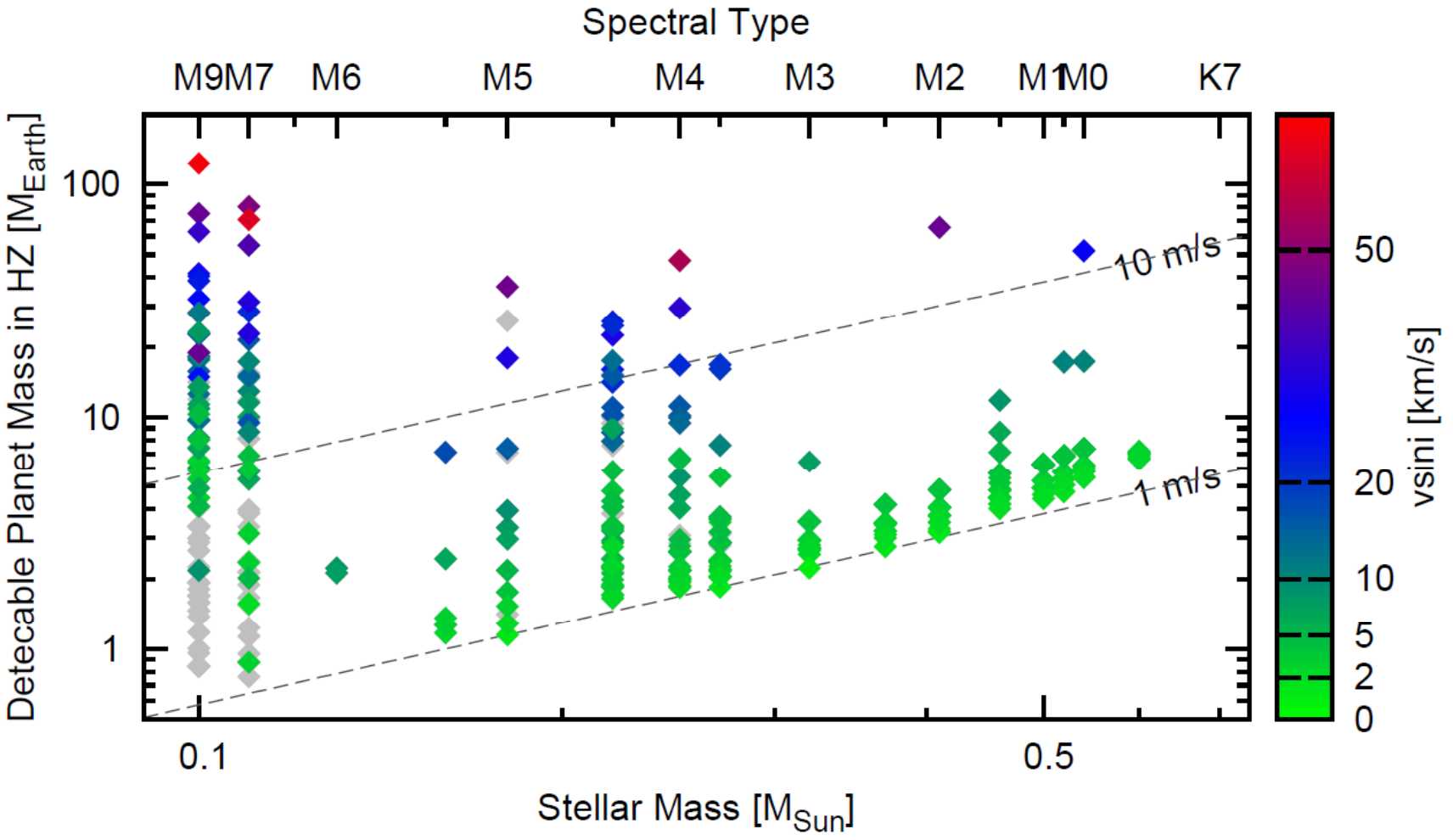
Sample	Spectral type	Mass ($M_\odot$)	J	#
S1	$\geq$M6	$\leq$0.15	$\leq$10.5	12
S1	M5 & M5.5	0.15–0.20	$\leq$10	35
S1	M4 & M4.5	0.20–0.25	$\leq$9.5	143
S2	M3 & M3.5	0.25–0.30	$\leq$9	198
S3	M2 & M2.5	0.30–0.40	$\leq$8.5	121
S3	M1 & M1.5	0.40–0.50	$\leq$8	78
S3	M0 & M0.5	0.50–0.60	$\leq$7.5	55

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

Survey Preparation: Identification of Binaries



Detectability simulations



The CARMENES Consortium

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- 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

Time Line

Project Start	11/2010
Preliminary Design	to 07/2011
Final Design	07/2011 – 12/2012
Construction	01/2013 – 08/2015
Commissioning	09/2015 – 12/2015
Data Taking	01/2016 – 12/2018

Conclusions: What we'll get

- 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