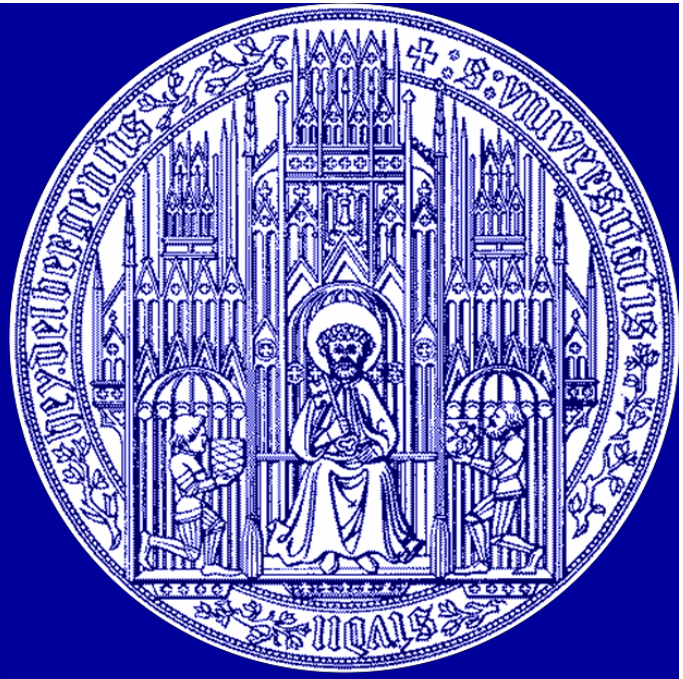


Precise Radial Velocity Measurements in the Near Infrared

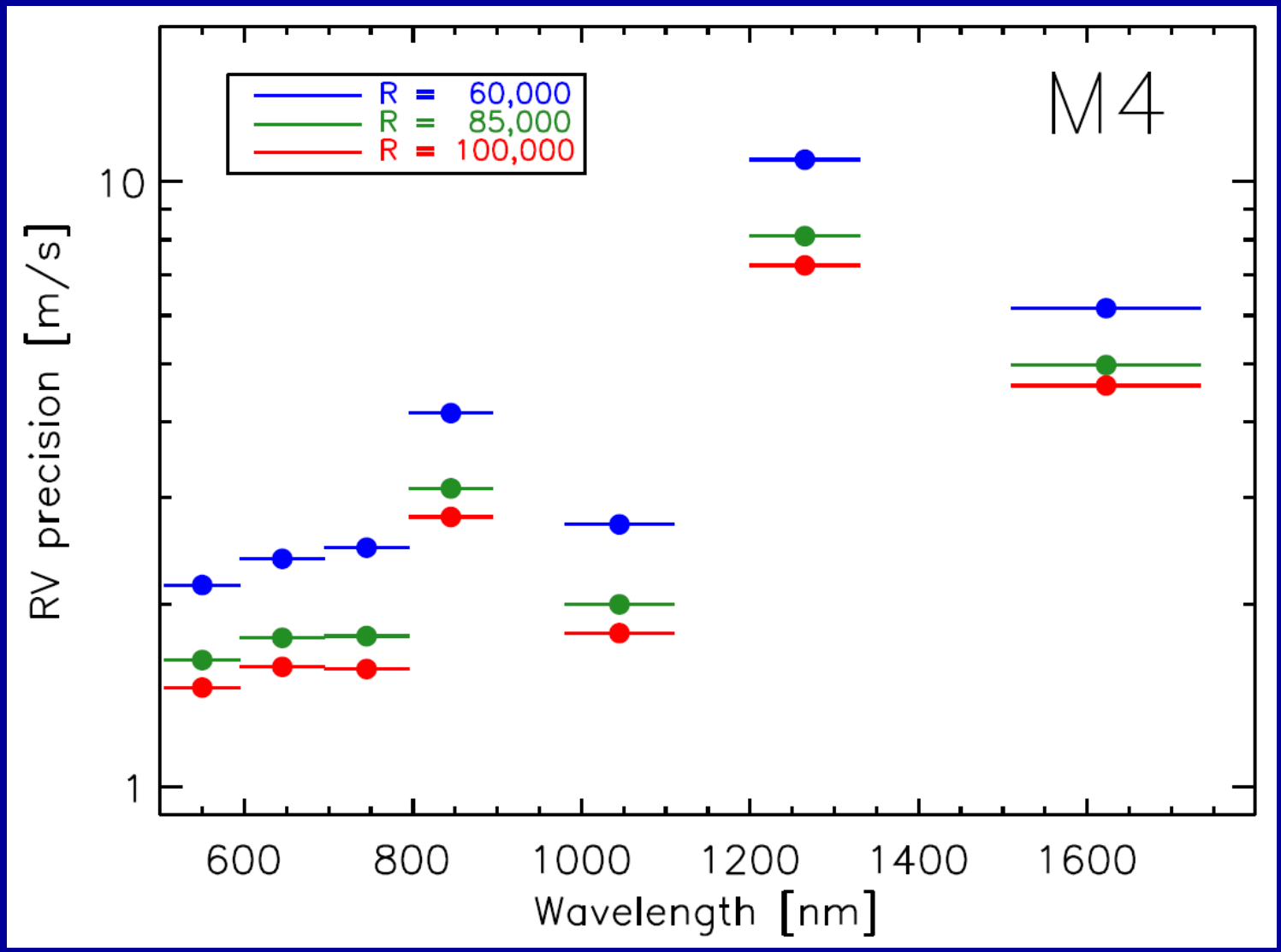
Andreas Quirrenbach

Landessternwarte Heidelberg

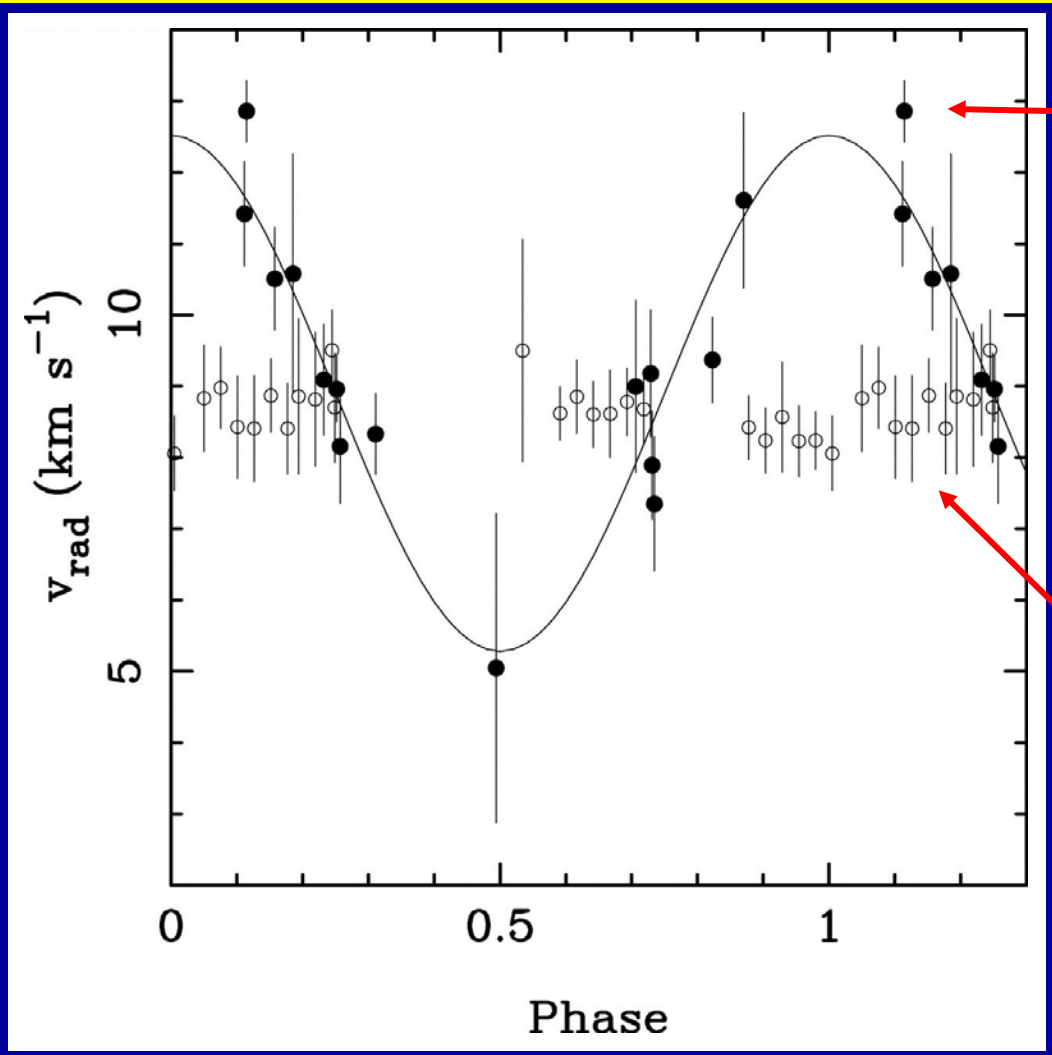
Why Measure Radial Velocities in the Near-IR?

- SED of cool objects (e.g., M dwarfs)
  - Most of the photons emitted in the NIR
  - But need to take information content into account
- Radial-velocity noise from stellar atmosphere
  - Stellar oscillations, star spots
  - In general smaller at larger wavelengths
- Highest gain from large simultaneous wavelength coverage
  - Simple approach: diagnostic tool
  - More sophisticated: model and correct variations

Radial Velocity Precision (Relative Scale)



RV Curve of the Active M9 Dwarf LP-944 20

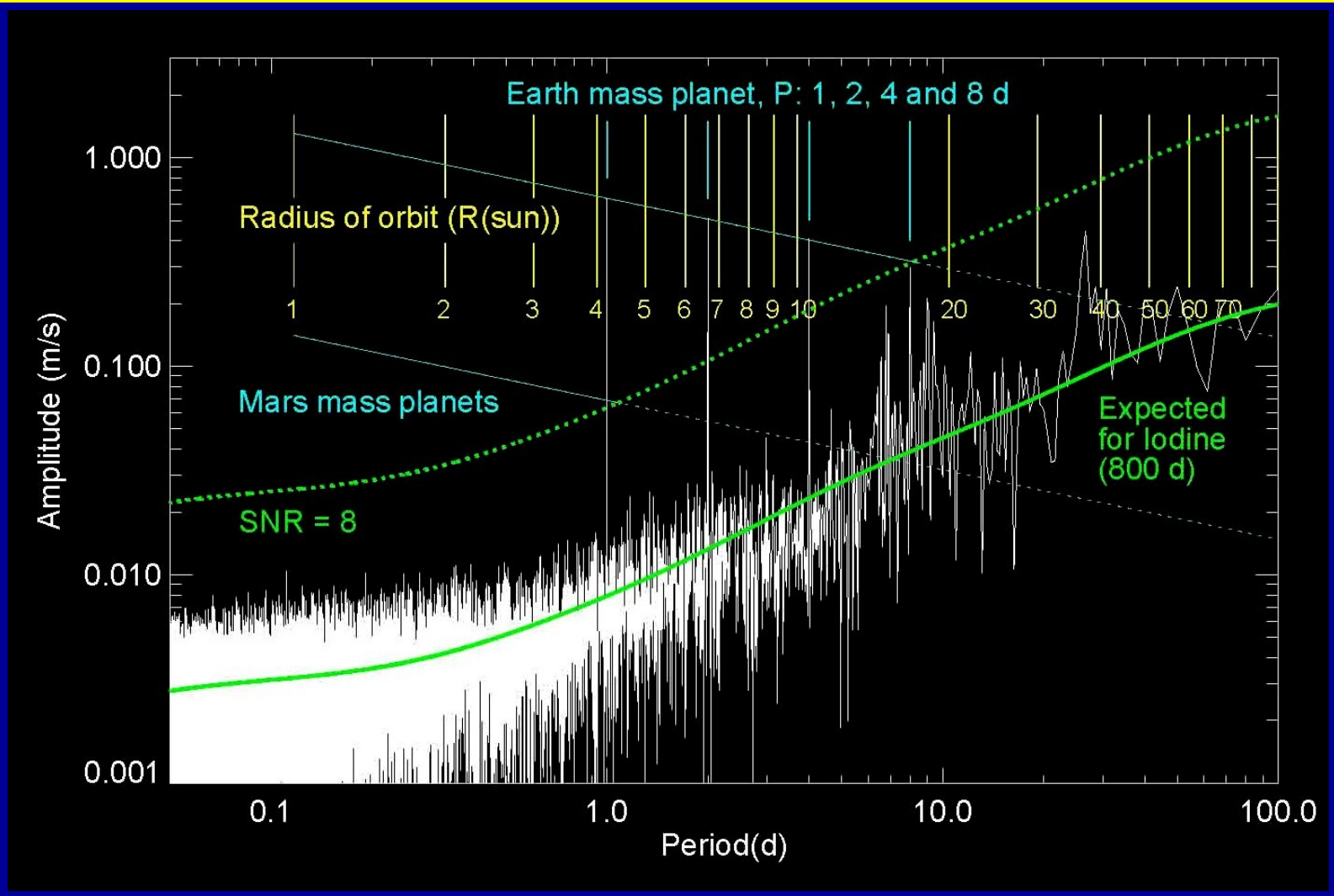


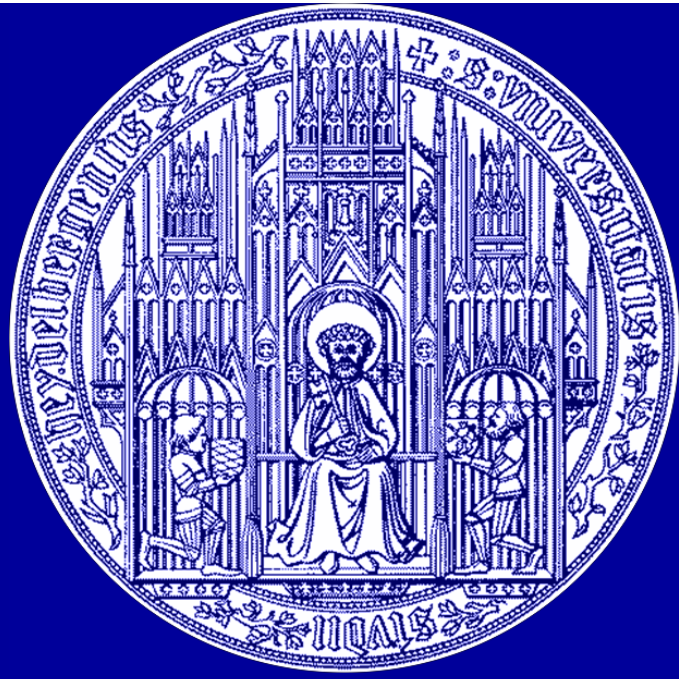
UVES (visual)

NIRSPEC (nIR)

Martin et al. (2006)

Noise from Solar Photosphere (Based on BISON Data)



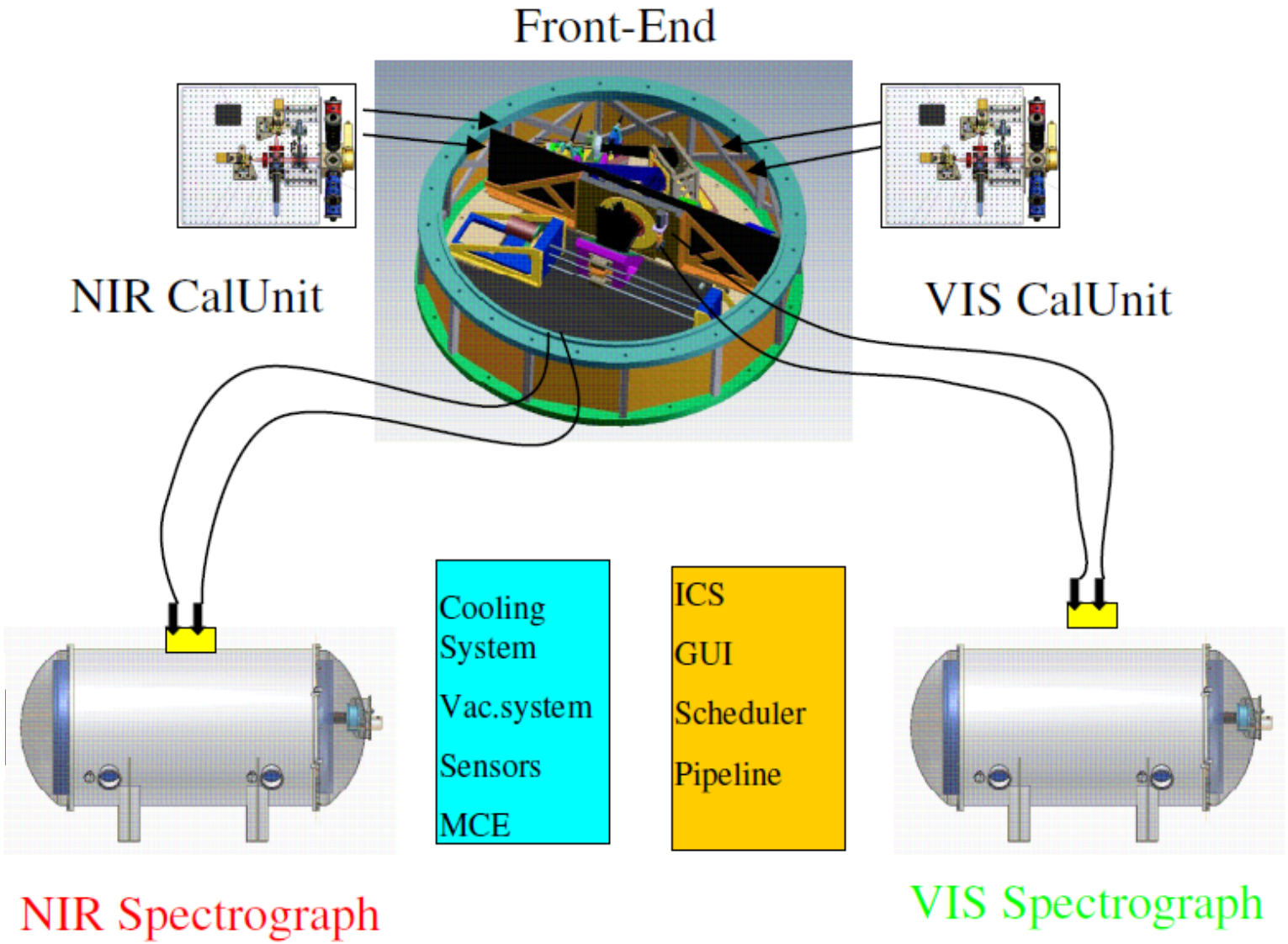


Searching for Habitable Planets around M Dwarfs

Goals and Plan for CARMENES

- Search for Earth-like "habitable" planets around low-mass stars (M-stars)
  - Number and formation mechanisms
  - Properties and "habitability"
- Survey of 300 M stars
  - Simultaneously in visible light and near-infrared
  - ≥50 data points per star
  - ≥600 nights needed
  - Survey from 2015 - 2018
  - Guaranteed in contract with CSIC and MPG

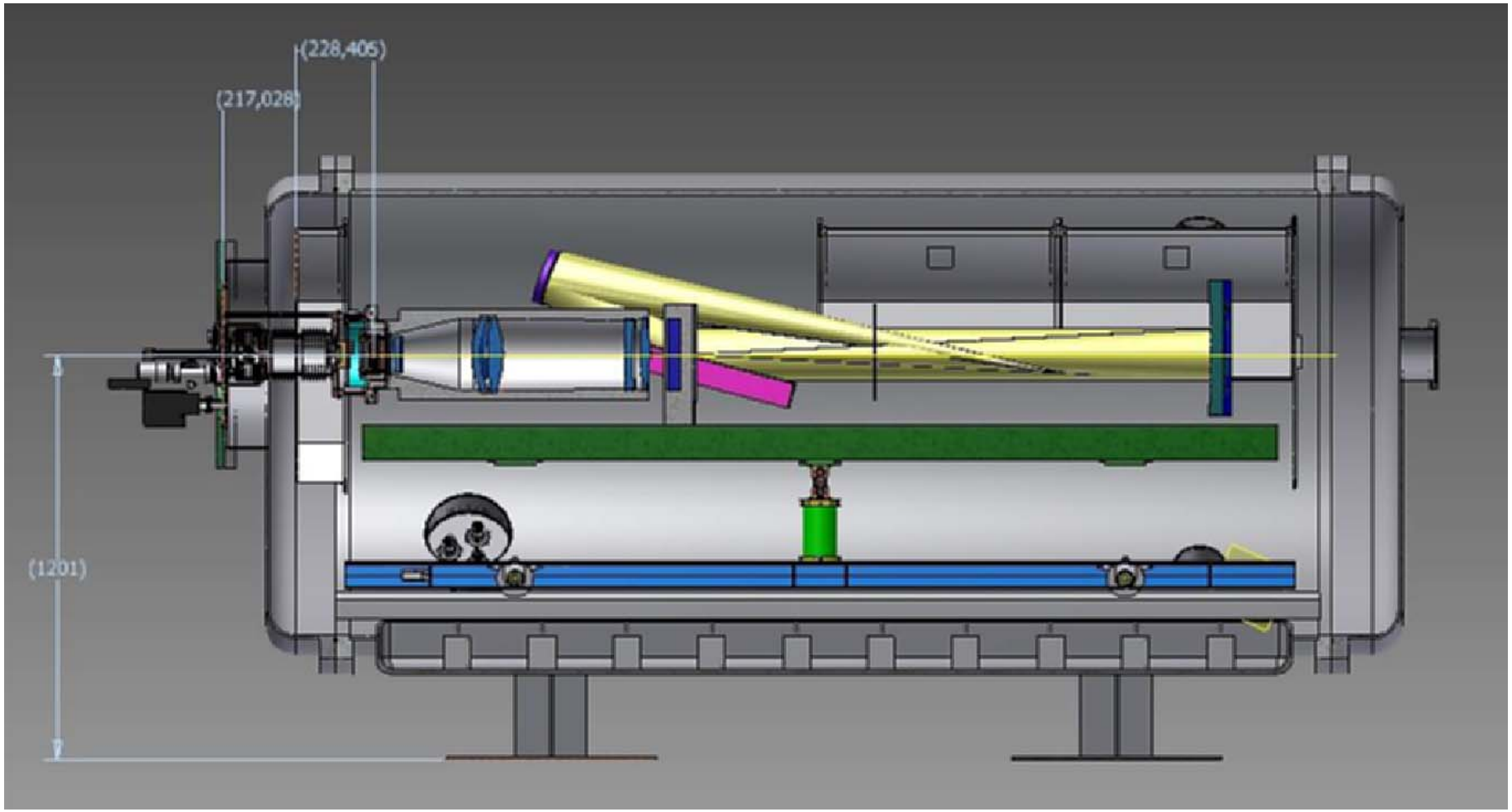
Instrument Overview



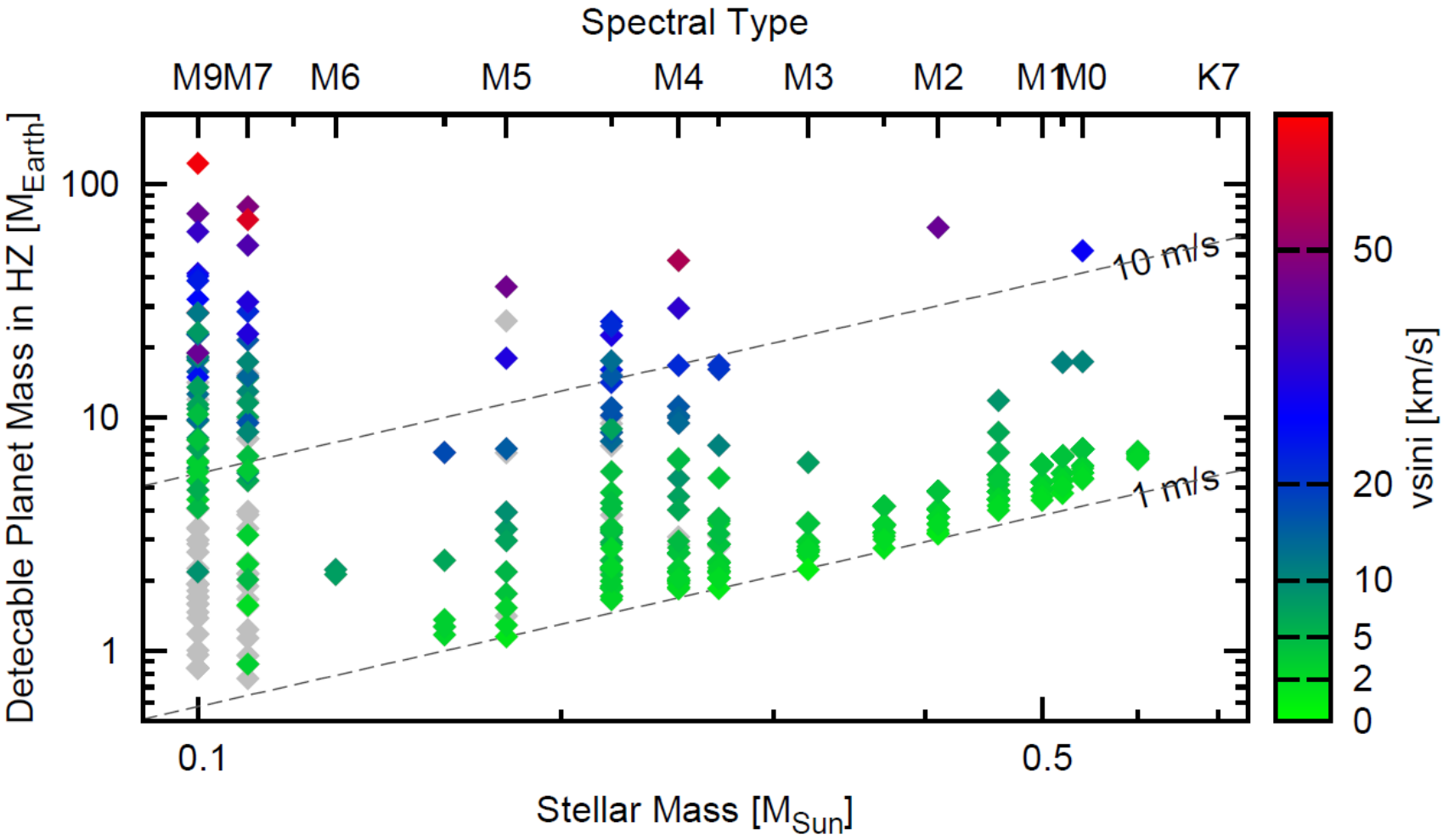
Properties of Spectrographs

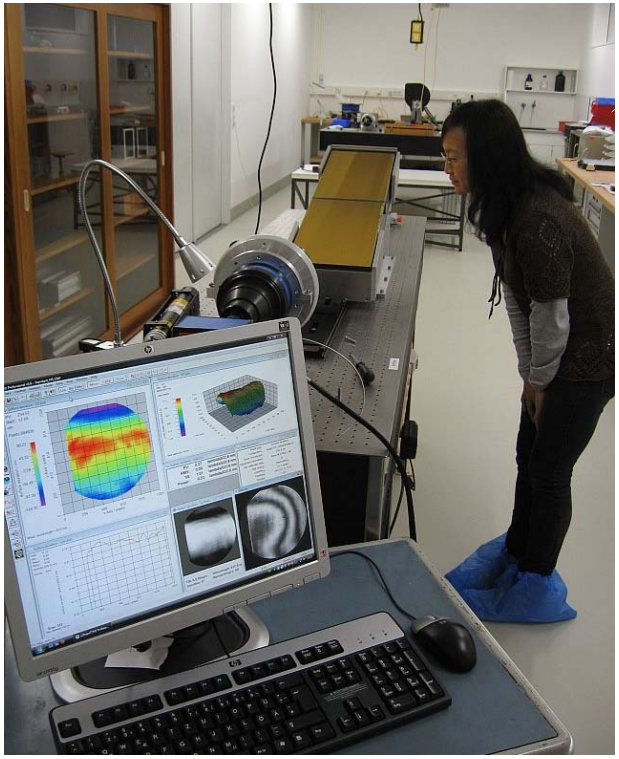
- Optical spectrograph
  - 0.53 … 1.05 µm, R = 82,000
  - Precision ~1 m/s
  - Vacuum tank, temperature stabilized
  - 4k x 4k deep depletion CCD detector
- Near-Infrared spectrograph
  - 0.95 … 1.7 µm, R = 82,000
  - Vacuum tank, cooled to 140K, stabilized
  - Precision goal 1 m/s
  - Two 2k x 2k Hawaii 2.5 µm detectors

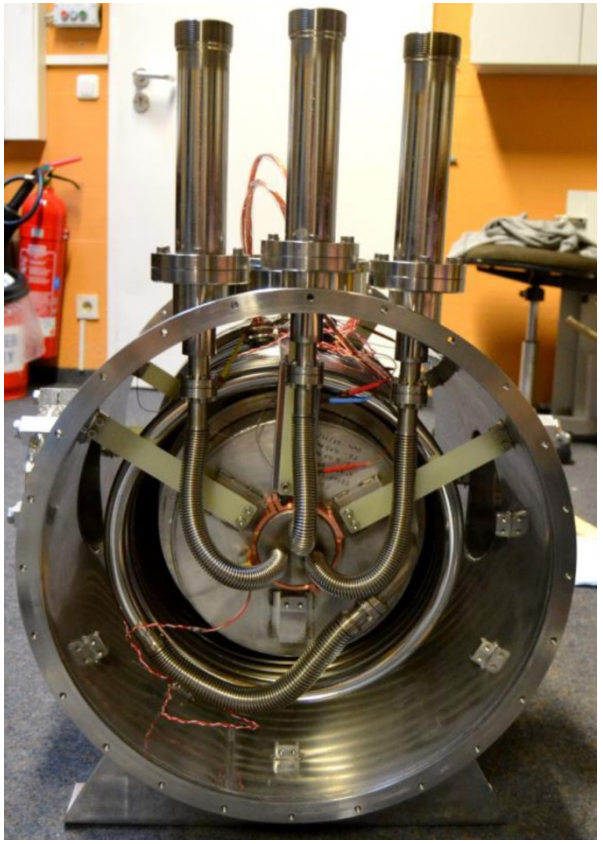
Spectrograph and Vacuum Tank Layout



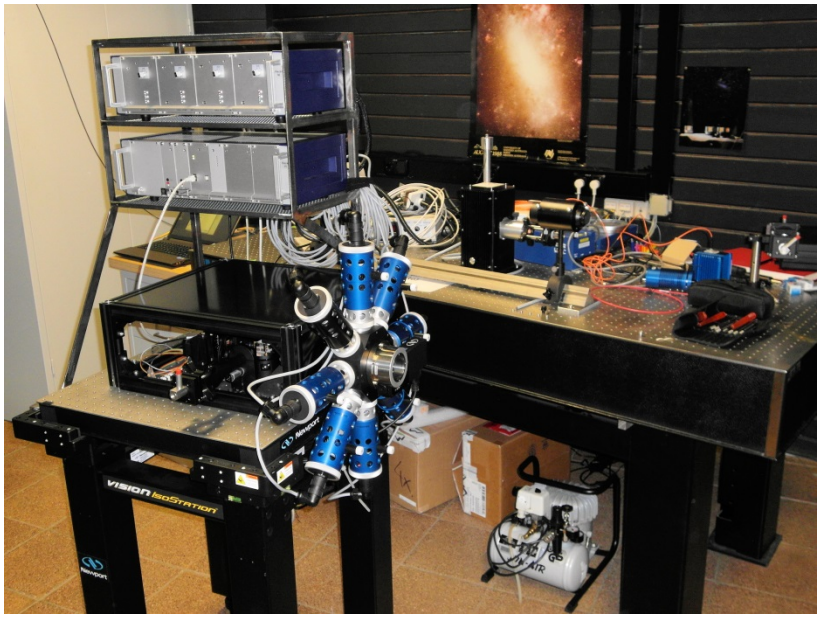
Detectability Simulations

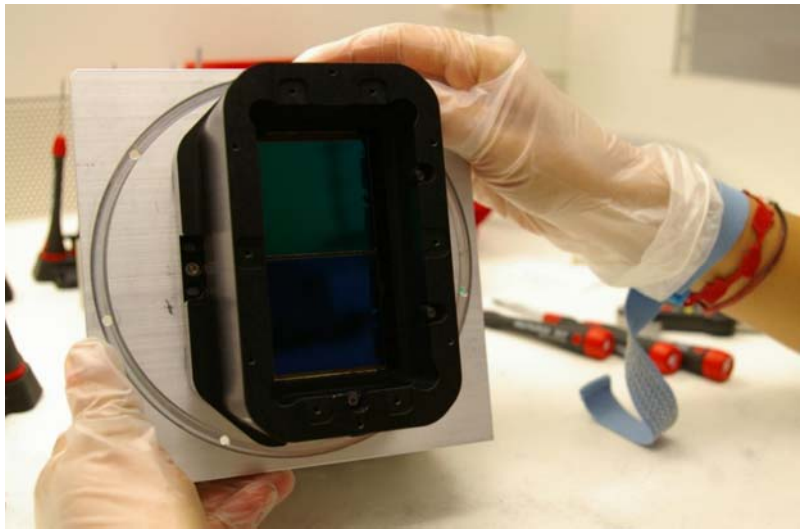






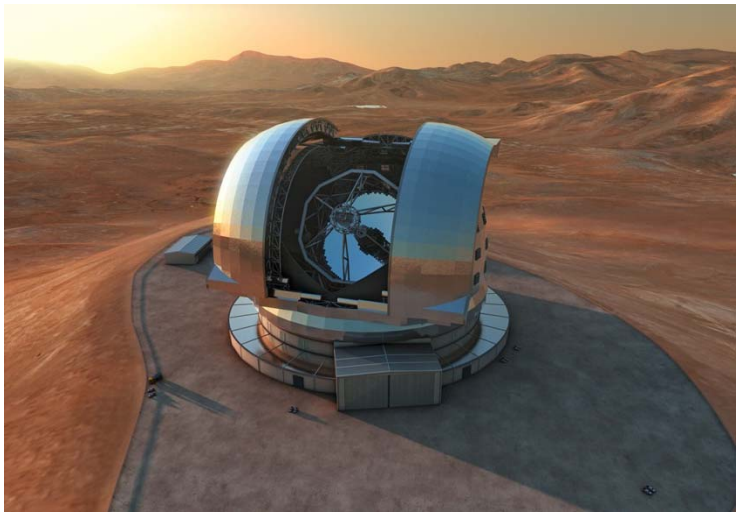
carmenes





carmenes

HIRES



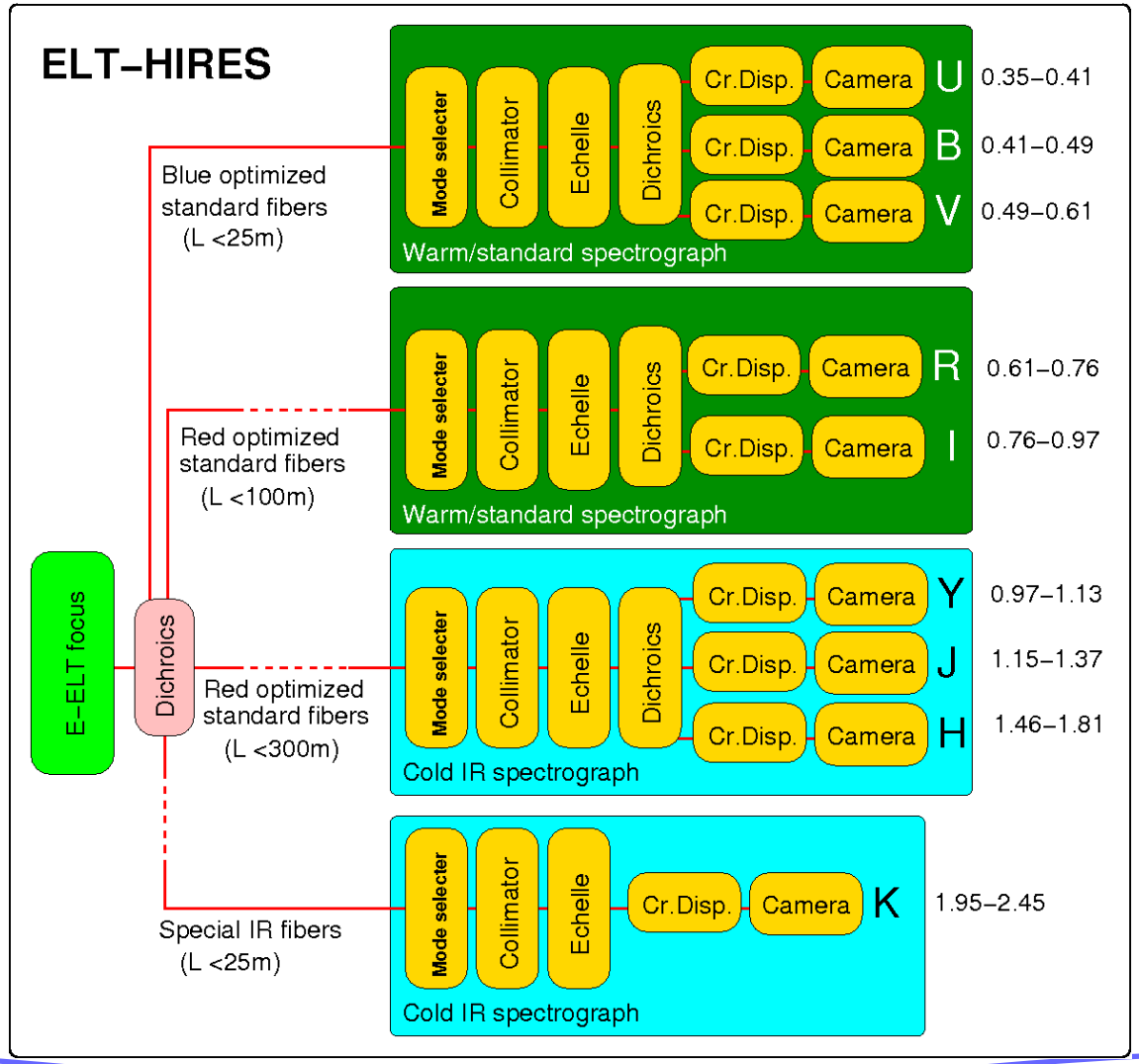
3.5m

39m

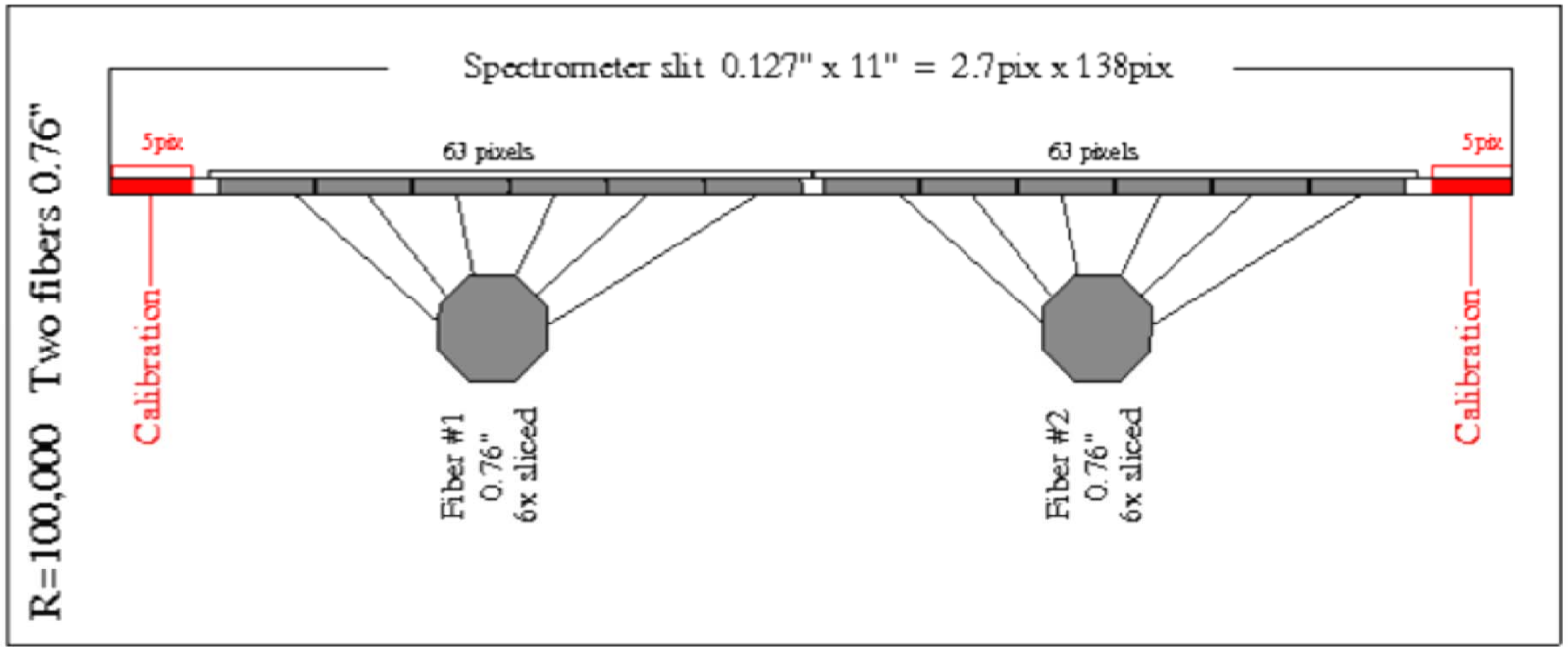
HIRES Top-Level Requirements

- **Spectral resolution ≥ 100,000**
- **Spectral coverage UBVRIZYJHK, no substantial gaps**
- **As blue as practical (370 (?) nm)**
- **Wavelength calibration: Espresso like in the visual, not critical in the IR (?)**
- **Stability: Espresso like in the visual, in the IR TBD**
- **S/N = 10,000 photon noise limited after calibration, over one night**
- **Throughput: ~8 mag S/N = 10,000 per res element in 100 min**

"Latte Macchiato" Concept



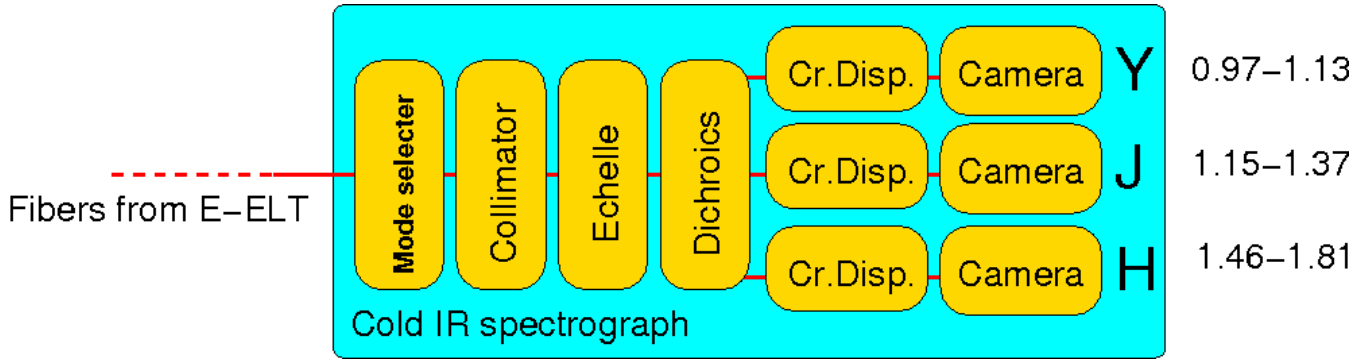
Slicing is Mandatory

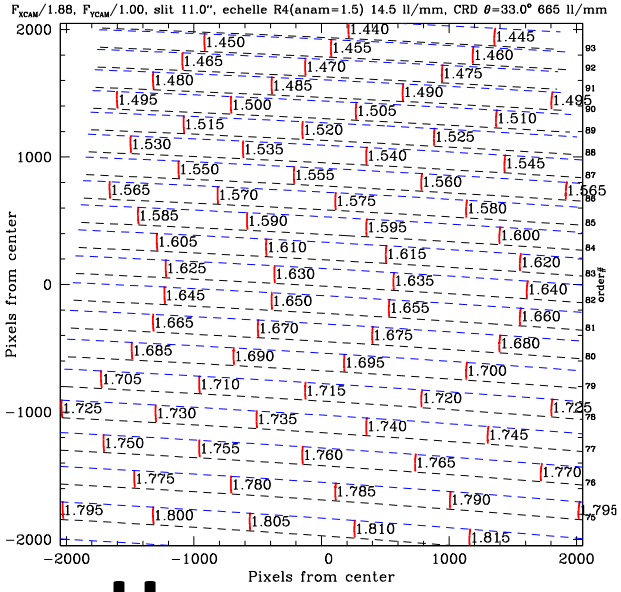


$$R = 10^4 \left(\frac{L_{\text{grating}}}{1\ \text{m}}\right)\left(\frac{\theta_{\text{slit}}}{1''}\right)^{-1}\left(\frac{D_{\text{Tel}}}{39\ \text{m}}\right)^{-1}$$

HIRES *cross-dispersed spectral format*

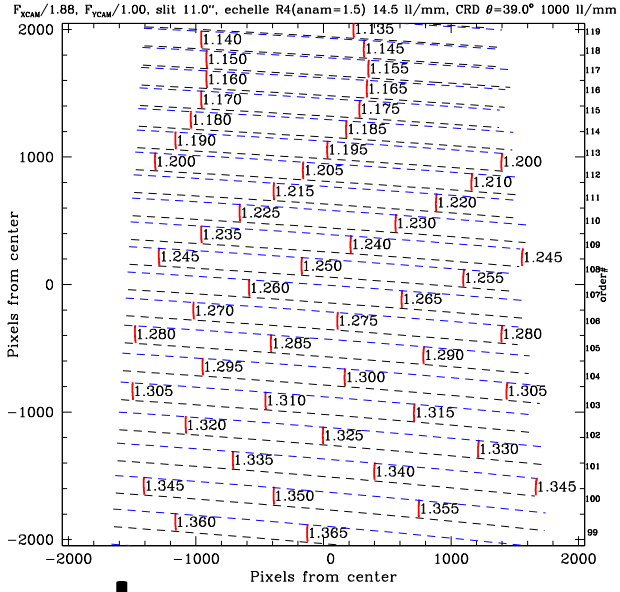
Same format for all observing modes





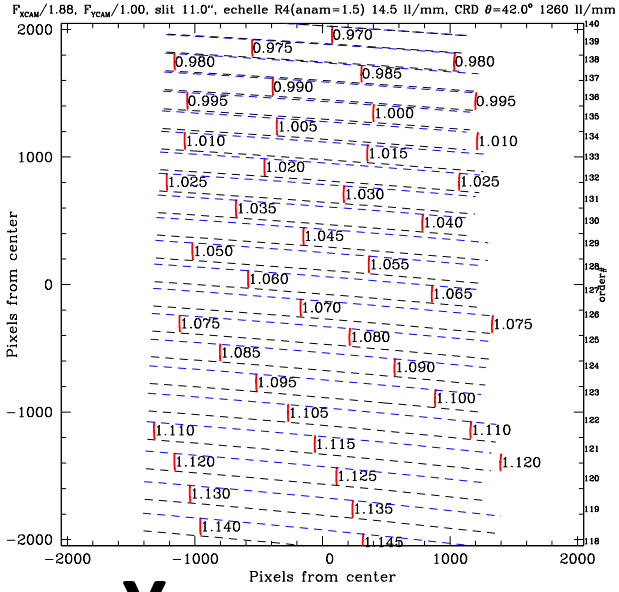
H 1.45-1.81 µm

orders 74-93



J 1.16-1.38 µm

orders 99-119



Y 0.97-1.14 µm

orders 118-140

Conclusions

- CARMENES will perform high-precision RV measurements simultaneously in visible and near-IR
- Promising approach for breaking the “stellar noise” barrier in RV measurements
- Current instrument concepts carry over to ELT, but slicing ($\Rightarrow$ long slit) is required