CARMENES: Calar Alto high-Resolution search for M dwarfs with Exo-earths with Near-infrared and Visible Echelle Spectrographs

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and the CARMENES Consortium

Calar Alto Observatory in Southern Spain

The 3.5m Telescope

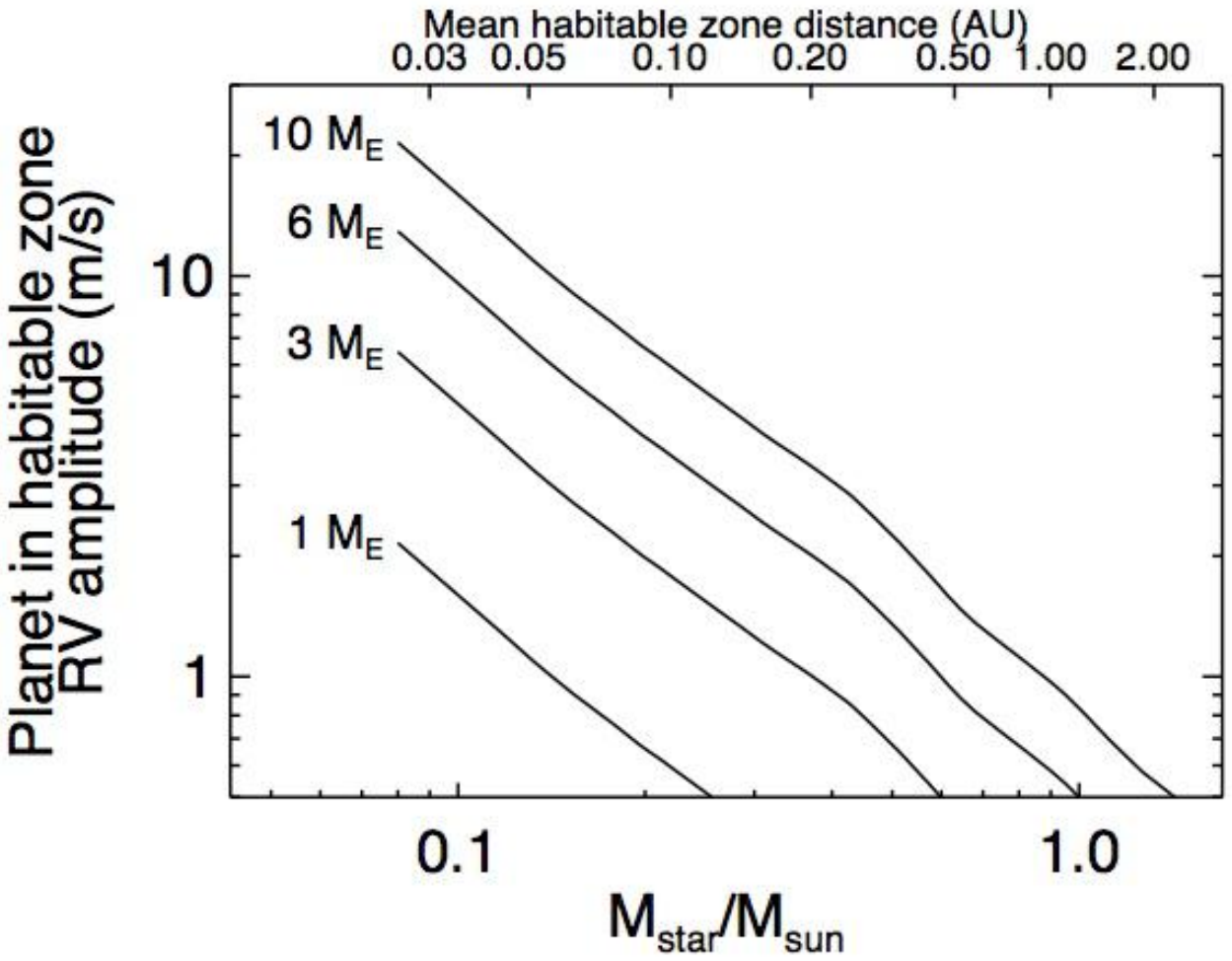
The CARMENES Consortium

- Landessternwarte Königstuhl, U Heidelberg, Germany
- Instituto de Astrofísica de Andalucía, Granada, Spain
- Universidad Complutense de Madrid, Madrid, Spain
- Institut de Ciències de l'Espai, Barcelona, Spain
- Insitut für Astrophysik, U Göttingen, Germany
- MPI für Astronomie, Heidelberg, Germany
- Thüringer Landessternwarte, Tautenburg, Germany
- Instituto de Astrofísica de Canarias, Tenerife, Spain
- Hamburger Sternwarte, U Hamburg, Germany
- Centro de Astrobiología, Madrid, Spain

Goal and Baseline Plan for Calar Alto Radial-Velocity Survey

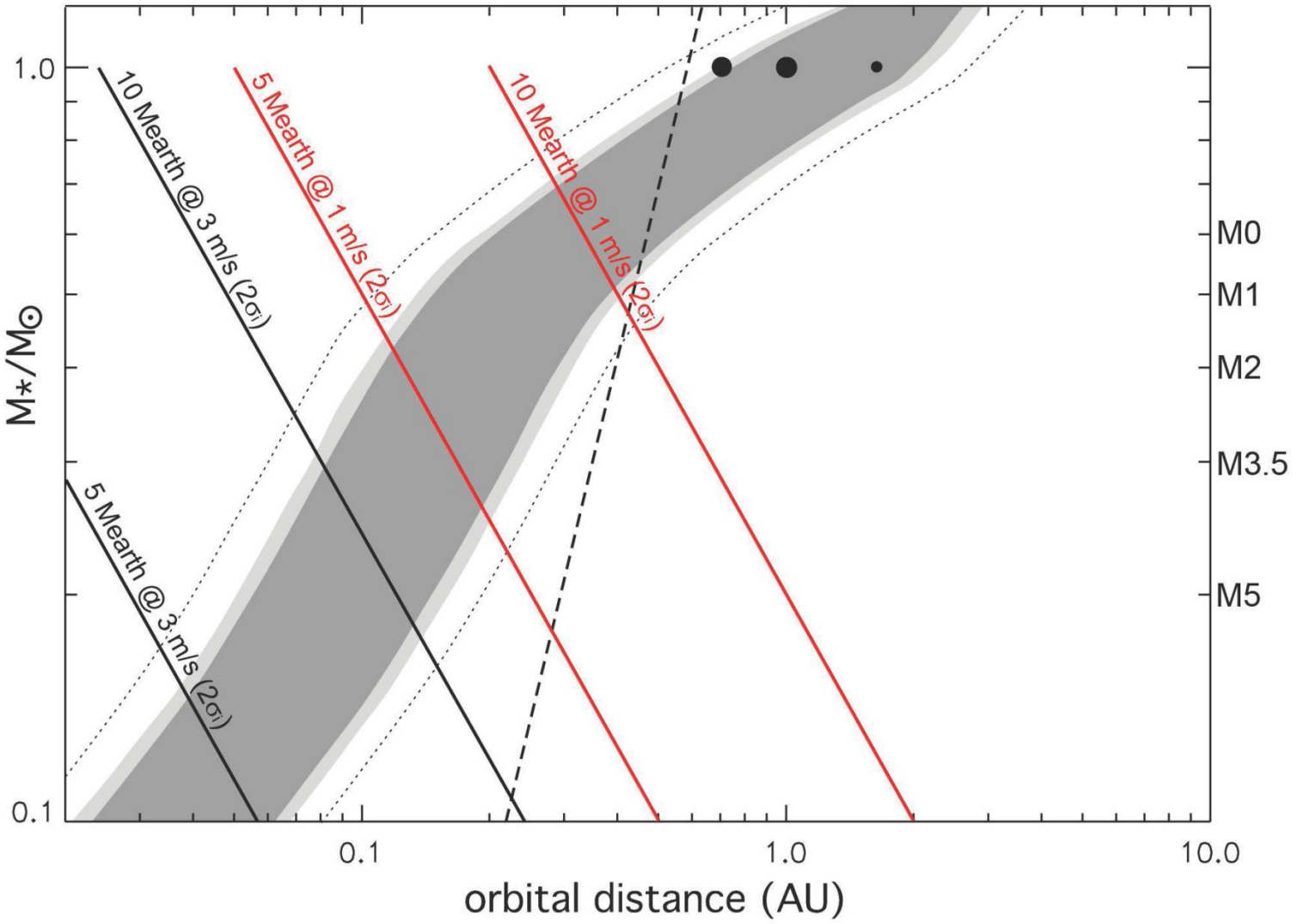
- Goal: Find terrestrial planets in habitable zones of low-mass stars
  - Number and formation mechanism
  - Some of them transiting ⇒ targets for follow-up (incl. JWST)
- Monitor ≈300 M dwarfs
  - Simultaneous near-IR and visible ⇒ RV and activity
- 10 measurements per season per field
  - With half-hour integrations ⇒ 100 clear nights / yr
- Use most (all?) of bright time for five years

The Case for M Stars

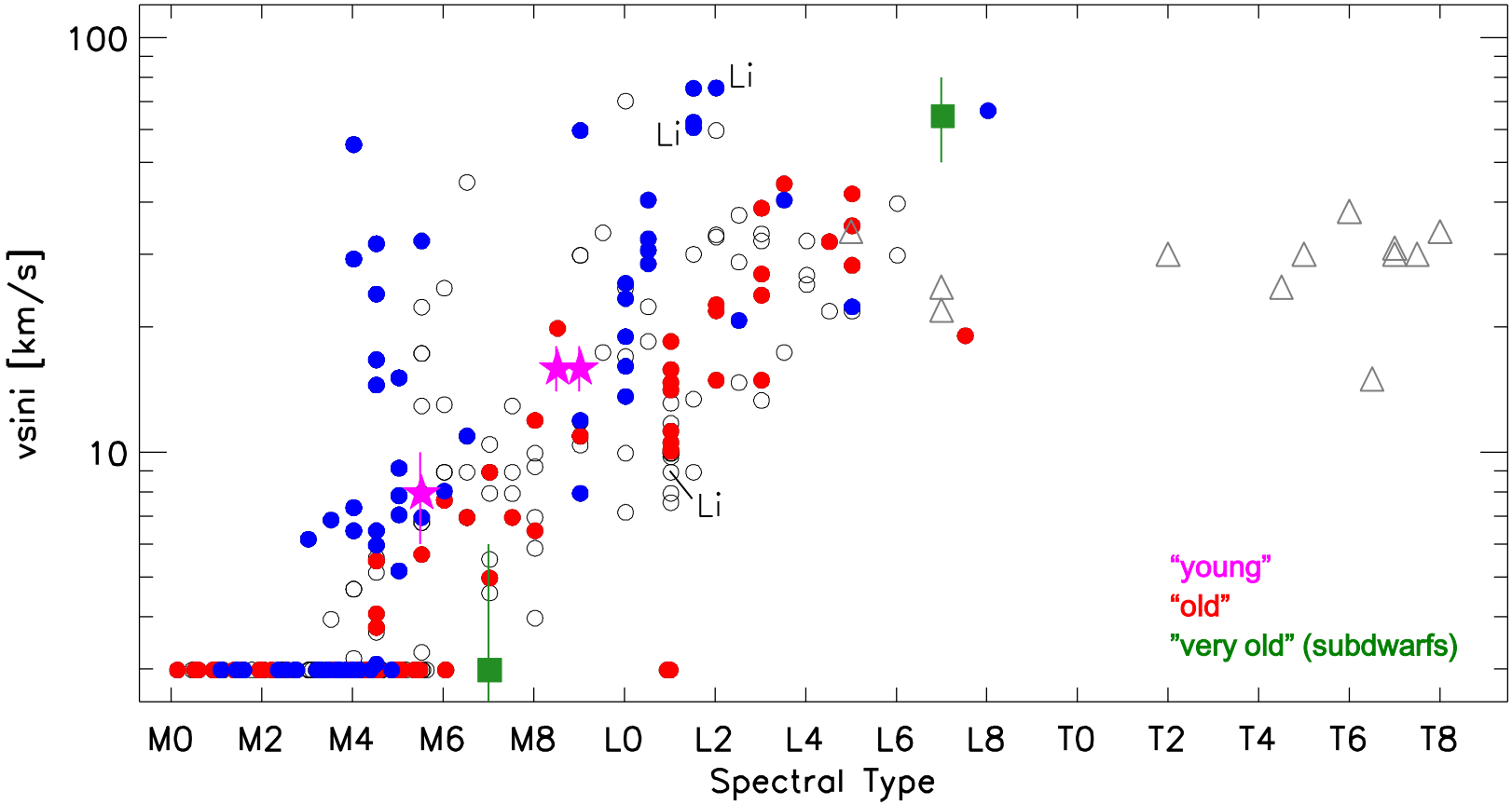


The lower the star mass, the higher the RV for planets in the habitable zone

The Habitable Zone of M Stars

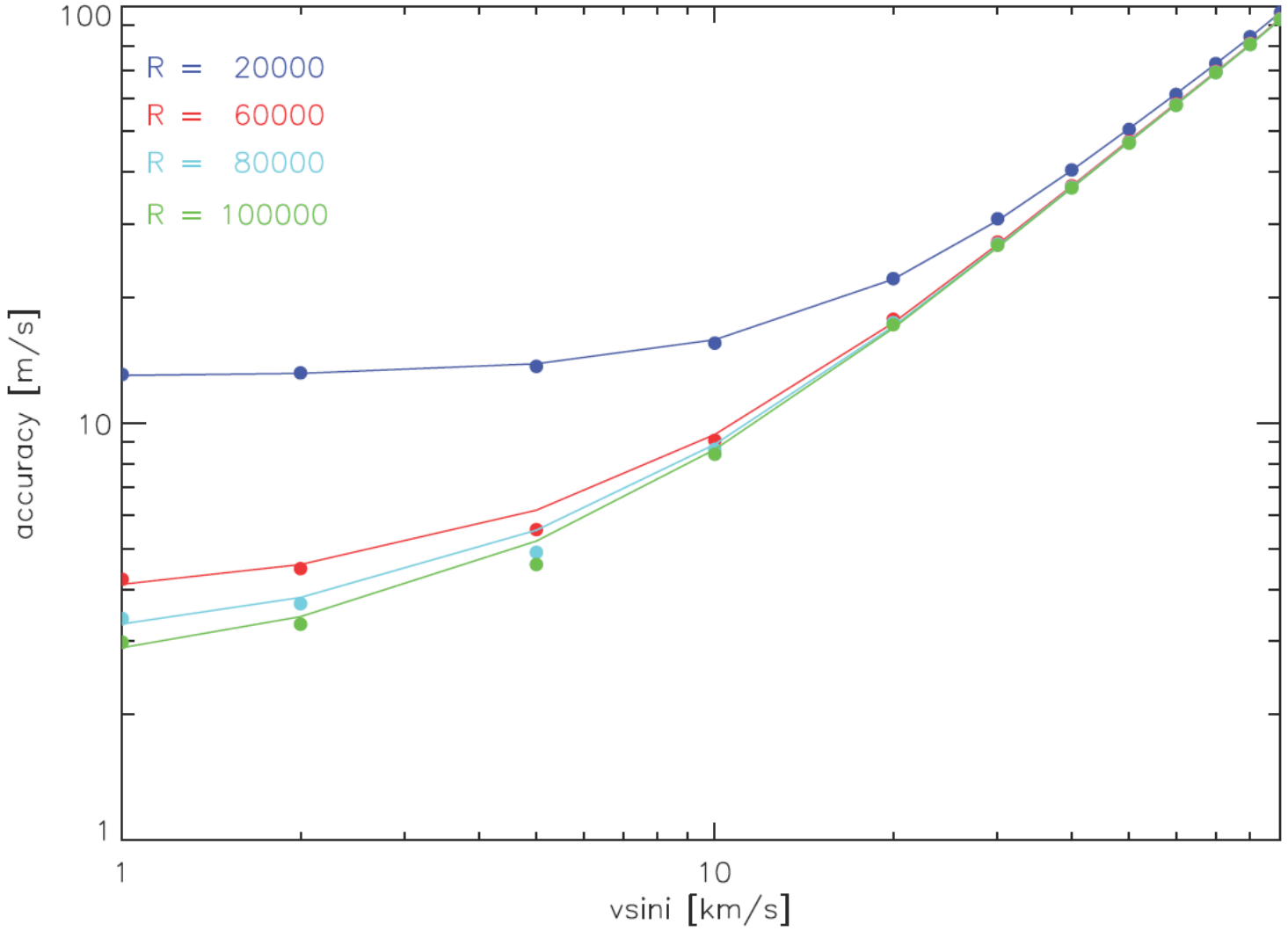


Rotation in Low-Mass Objects

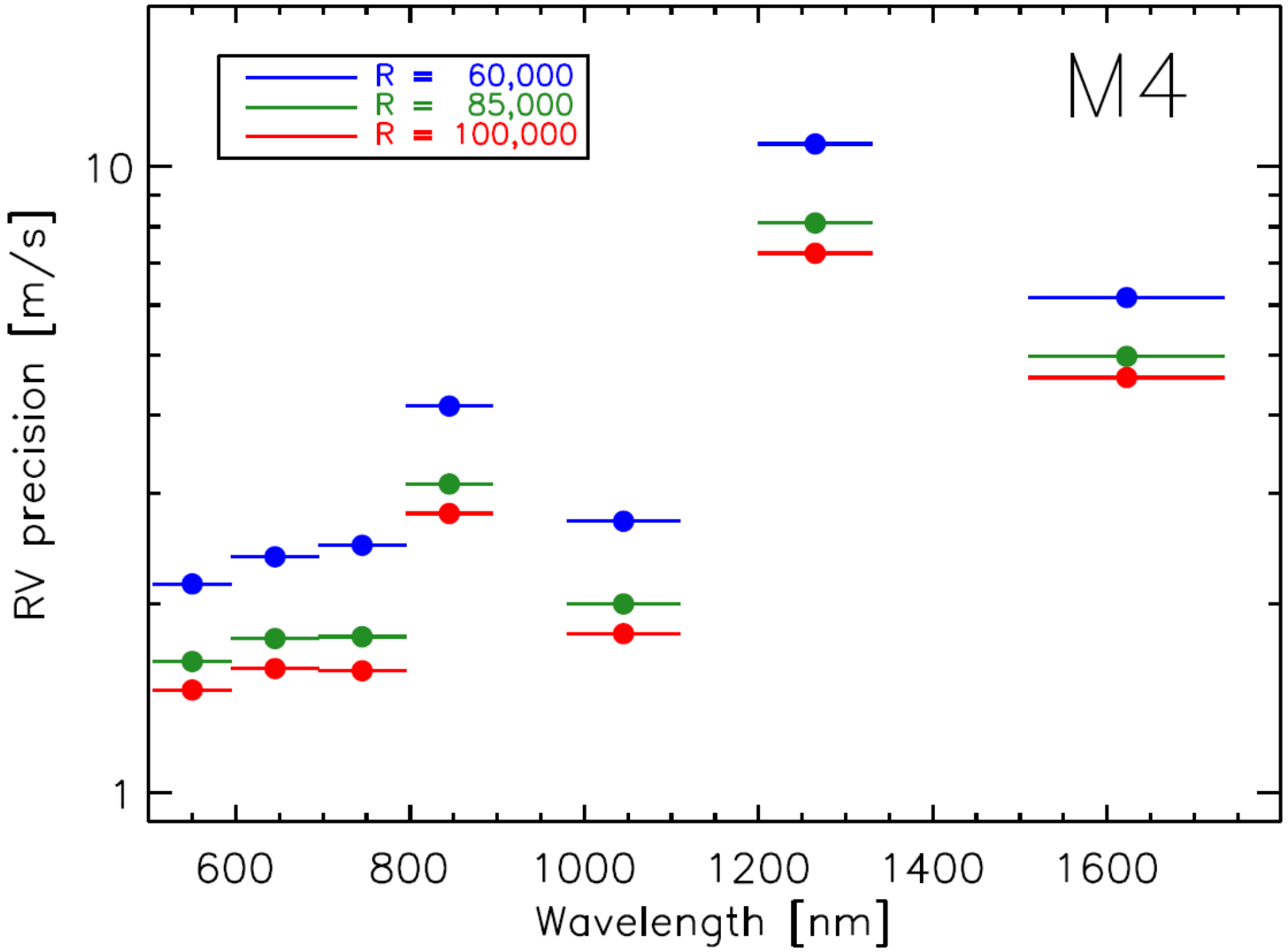


Reiners & Basri, 2008

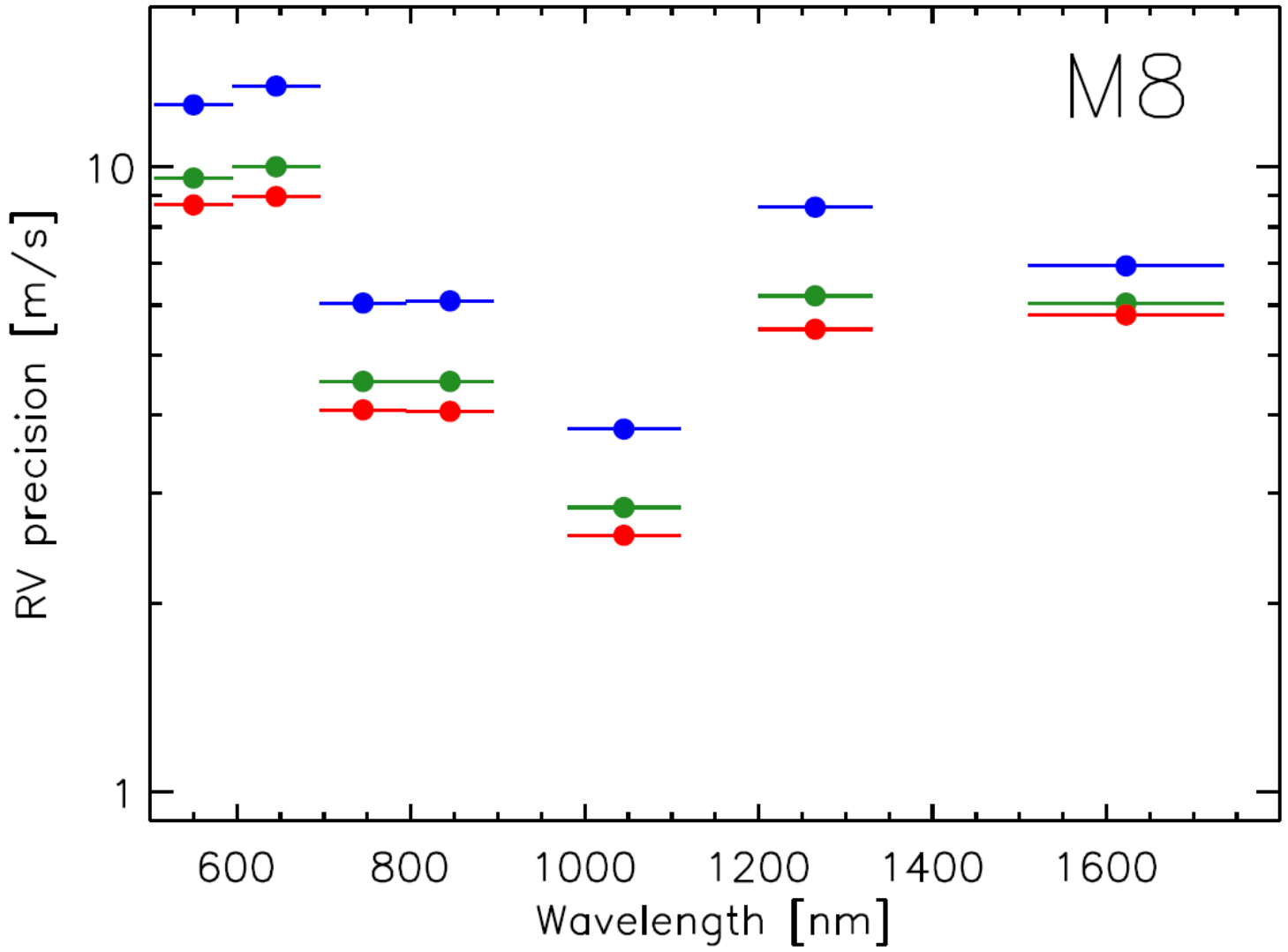
Accuracy Achievable for Different Rotation Rates



Relative Precision Achievable for M4 Star in Visible and near-IR



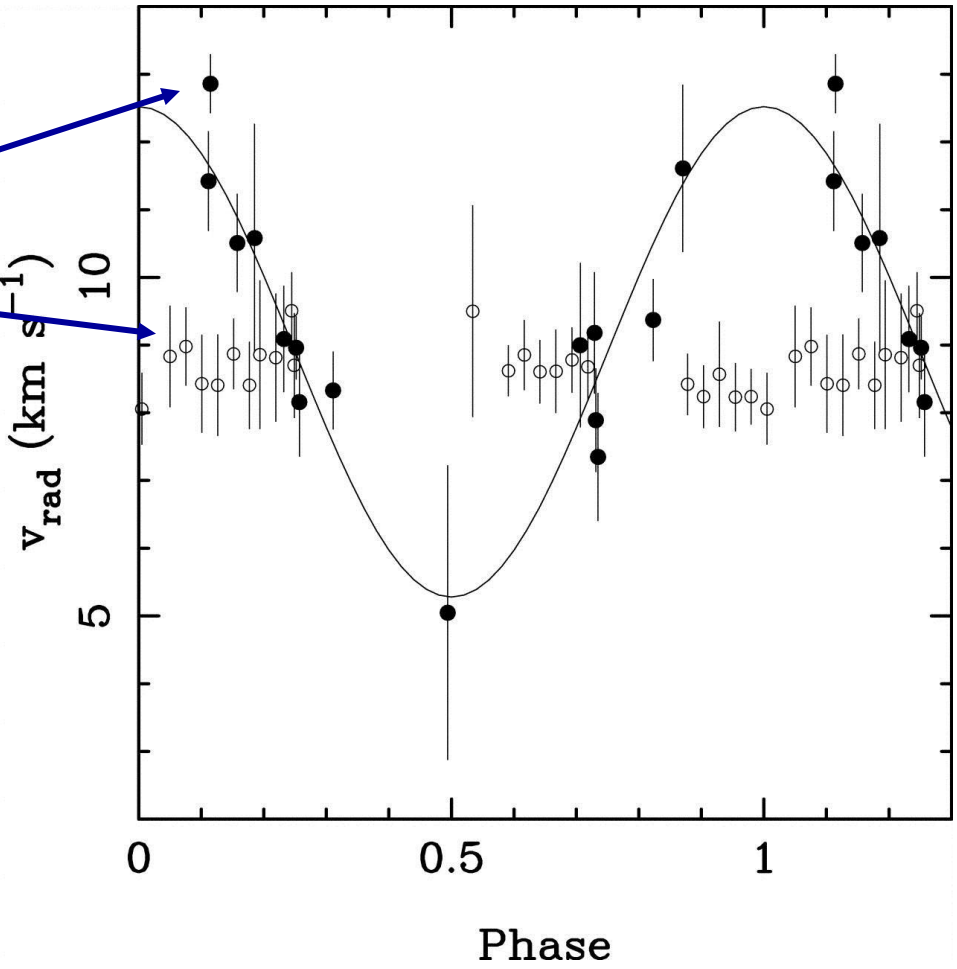
Relative Precision Achievable for M8 Star in Visible and near-IR



Radial Velocities: Optical and IR

optical

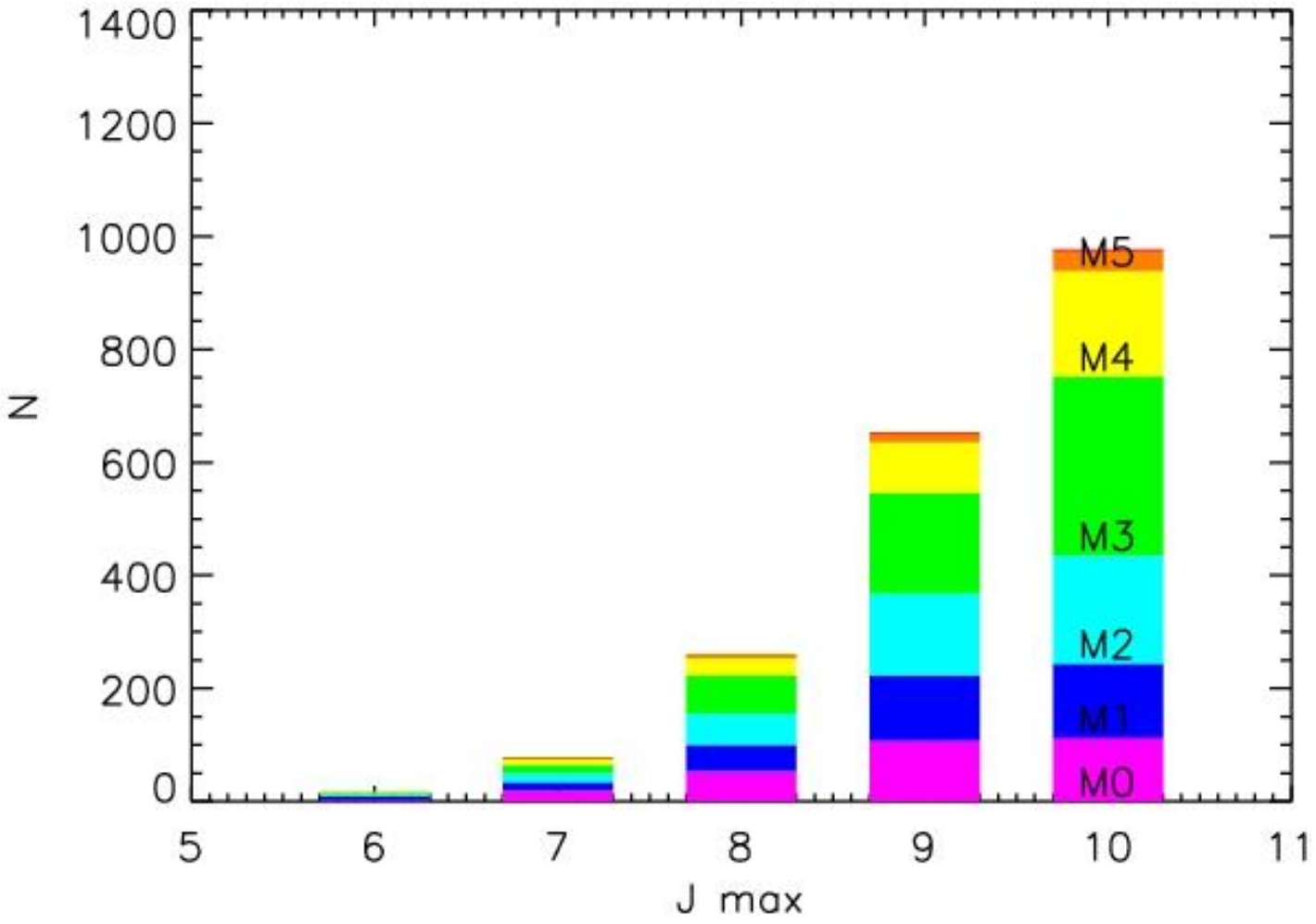
IR



Activity!

Martin et al., 2006

Number of M Dwarfs Accessible from Calar Alto



Sample Selection

- Sample 1: 100 stars with $m < 0.25\ M_\odot$
- Sample 2: 100 stars with $0.25\ M_\odot < m < 0.35\ M_\odot$
- Sample 3: 100 stars with $m > 0.35\ M_\odot$
- Start with ~450 stars, throw out unsuitable stars after a few observations

Spectrograph Characteristics

- Visible-light spectrograph
  - 0.53 … 1.05 μm, R = 80,000
  - 59 echelle orders
  - RV precision ~1 m/s
  - Vacuum tank, temperature stabilized
  - 2k × 4k detector
- Near-IR spectrograph
  - 0.95 … 1.8 μm, R = 85,000
  - 31 echelle orders
  - Vacuum tank, cooled to -30°C, stabilized
  - RV precision goal 1 m/s, limited by sky calibration
  - Two 2k × 2k Hawaii 1.7 μm detectors

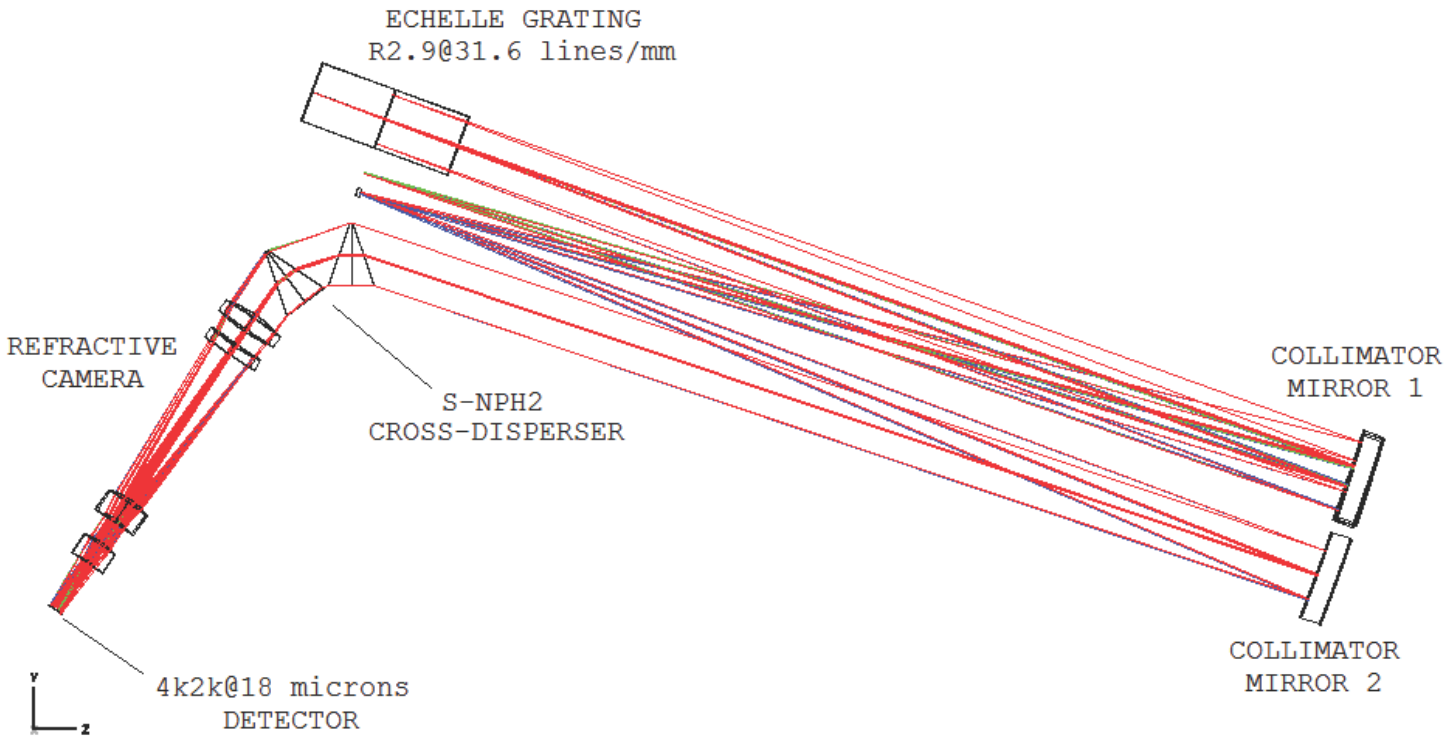
Fiber Feed

- Object and sky fibers from prime or Cassegrain focus to coudé laboratory
- Separate fibers for visible and near-IR
  - Dichroic beam splitter at front end
  - Atmospheric dispersion correction
- Fiber scrambler for uniform exit pupil illumination
- Image slicer
  - Modified Bowen-Walraven or fiber slicer (under investigation)

RV Calibration Strategy

- ThAr lamp
  - Adopted as baseline
  - Proven technique, but extension to IR
  - Uneven wavelength coverage
  - Difficulties due to widely different line strengths
- Stabilized etalon
  - Equally spaced lines, uniform brightness
  - Preferred solution if technically feasible
  - R&D effort started

NIR Spectrograph Optical Layout



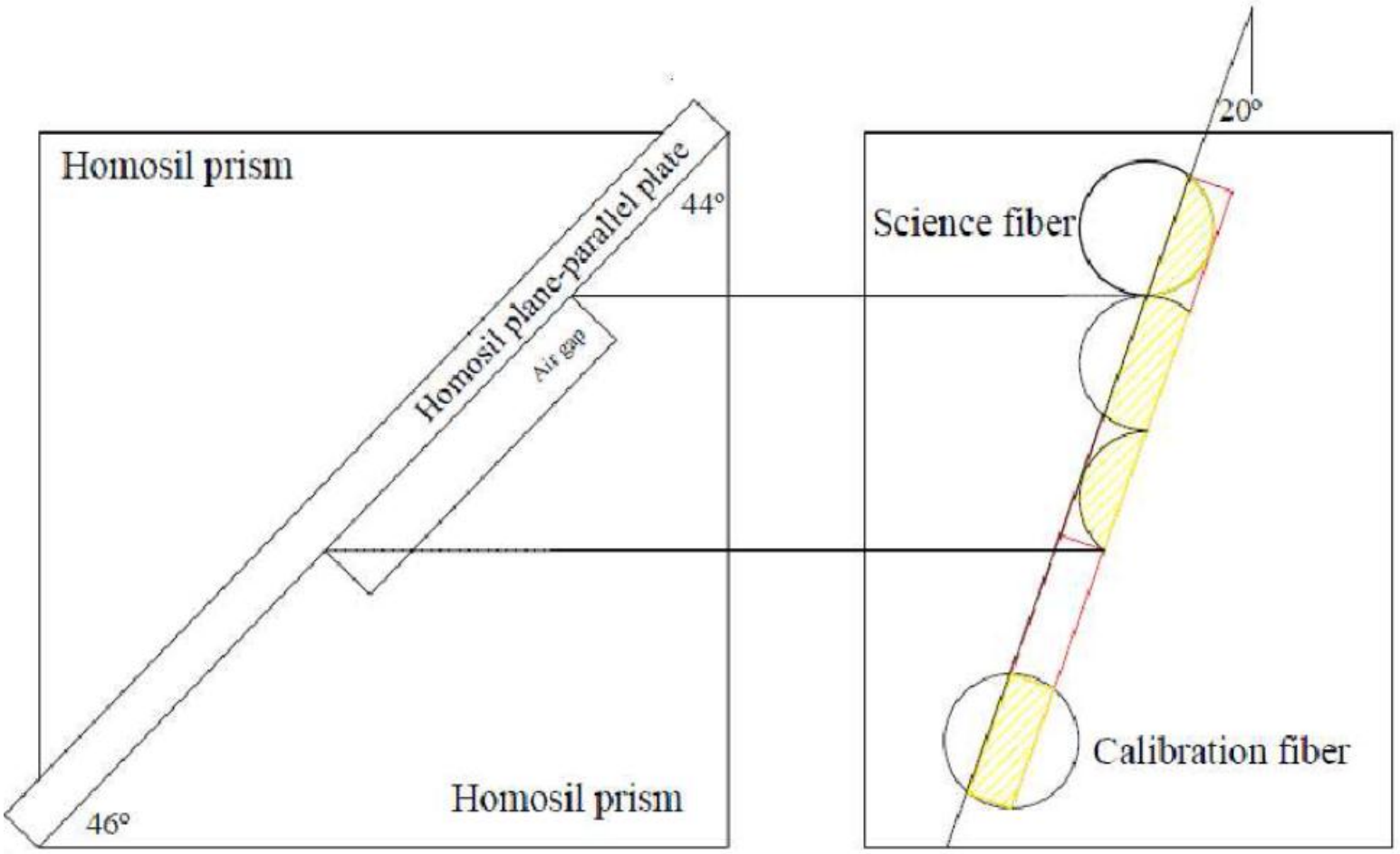
3D LAYOUT

FIBER-FED ECHELLE SPECTROGRAPH
CALAR ALTO OBSERVATORY
RESOLUTION 85000
SPEC RANGE: 0.95-1.80 microns

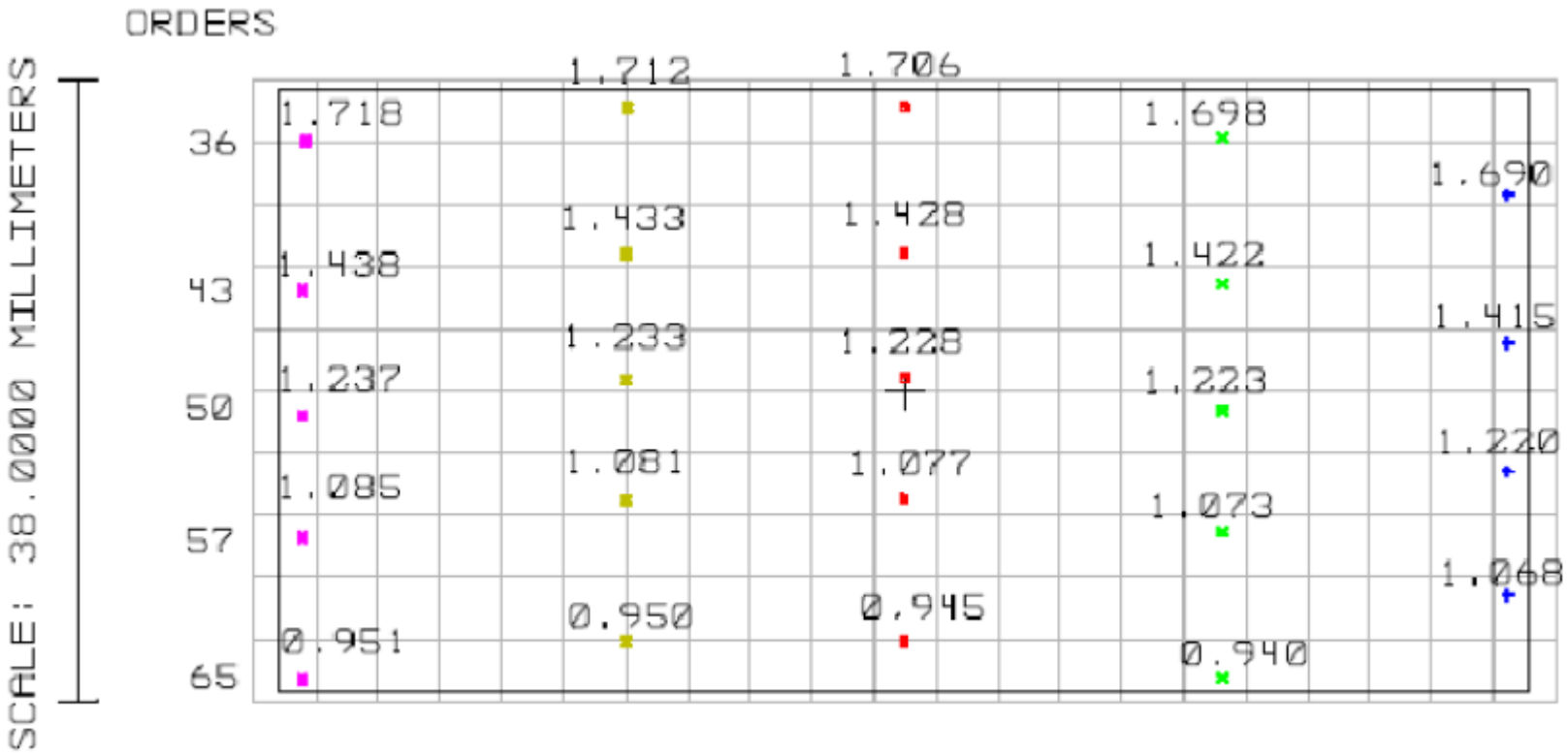
OVIDIO RABAZA CASTILLO
INSTITUTE OF ASTROPHYSICS OF ANDALUCIA
IAA-CSIC

CARMENES-NIR
CHANNEL

Image Slicer for the Near-IR Spectrograph

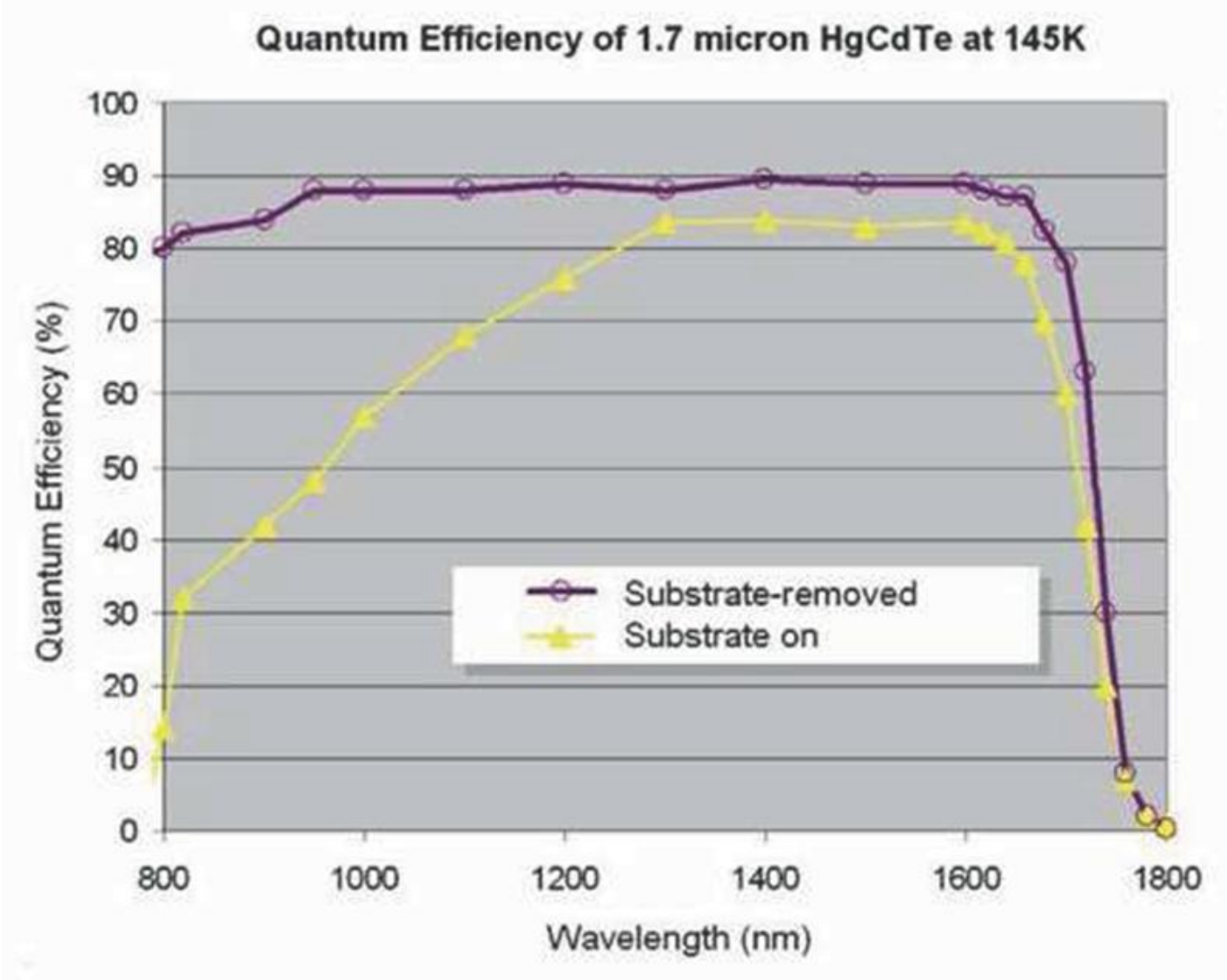


Near-IR Echelle Format

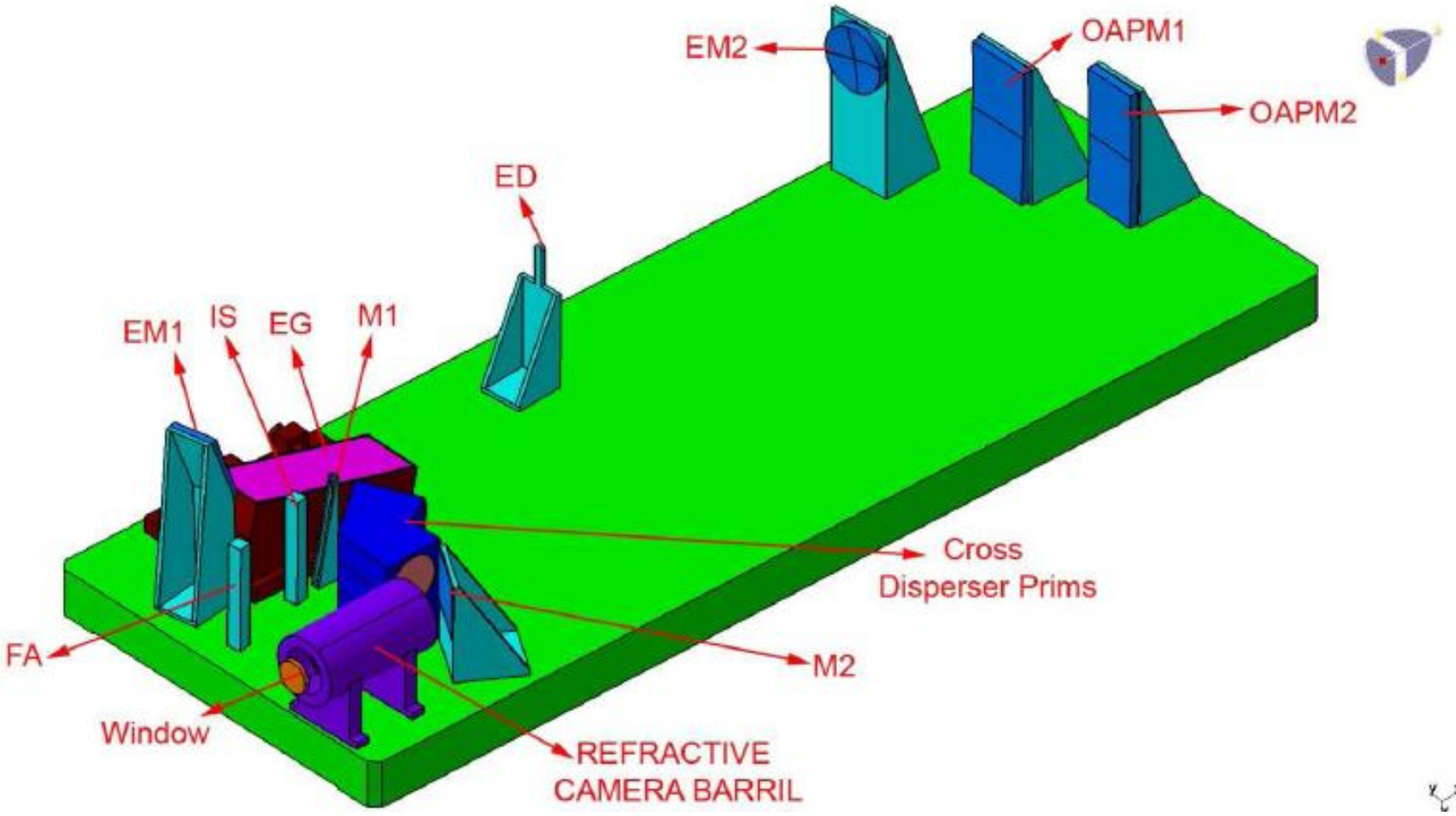


2×2 Hawaii 2RG Mosaic

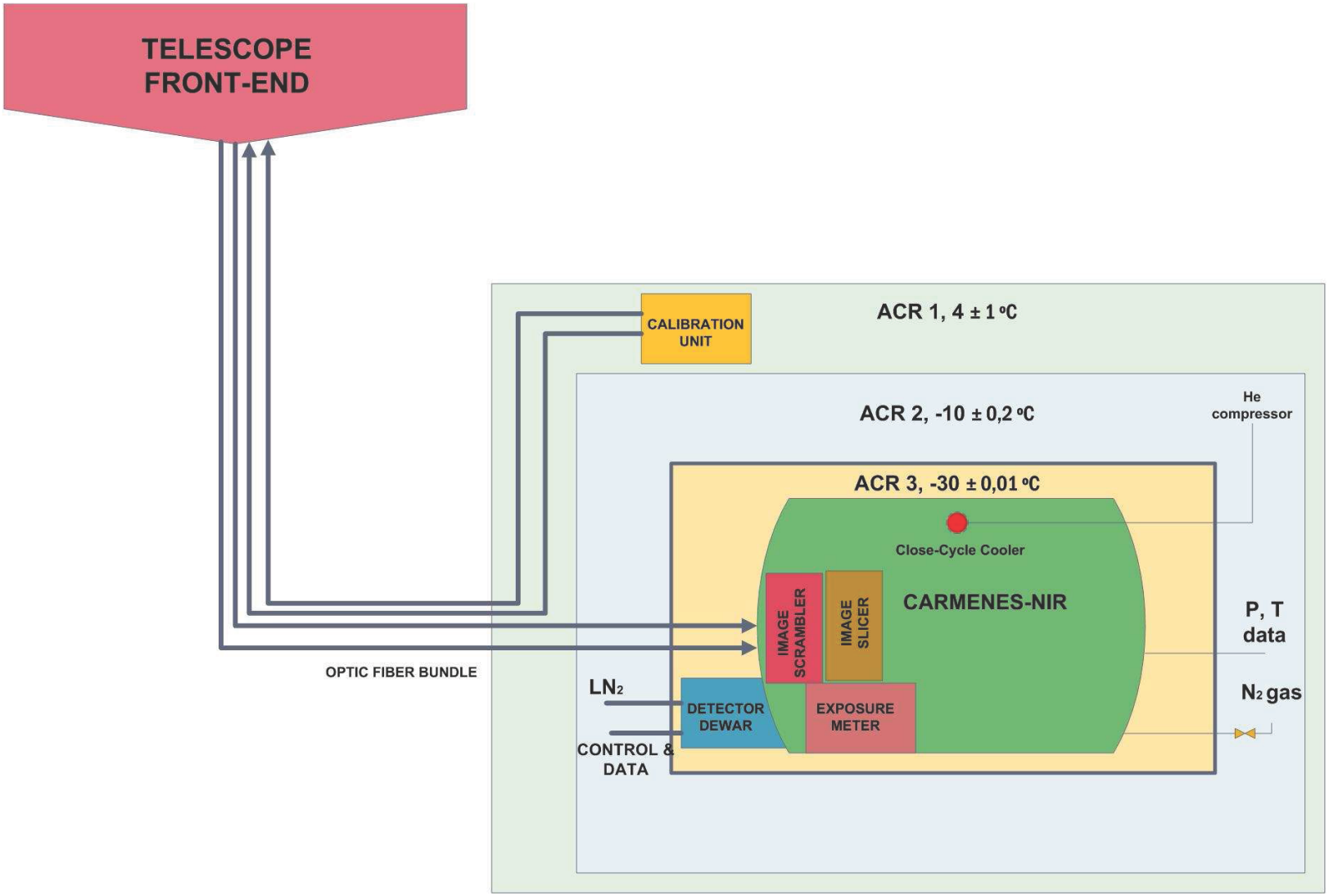
NIR Detector Efficiency



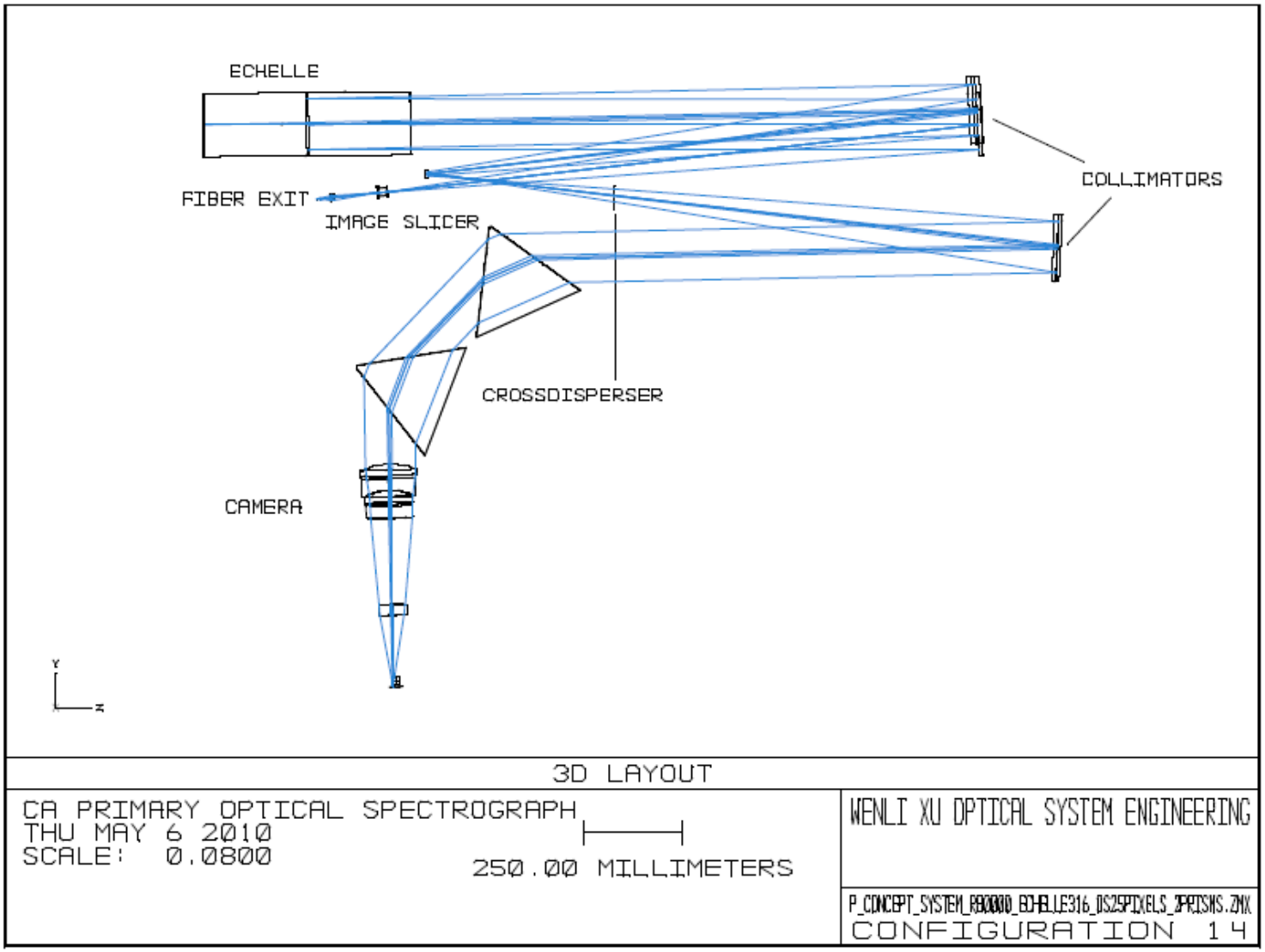
Opto-Mechanial Layout of the Near-IR Spectrograph



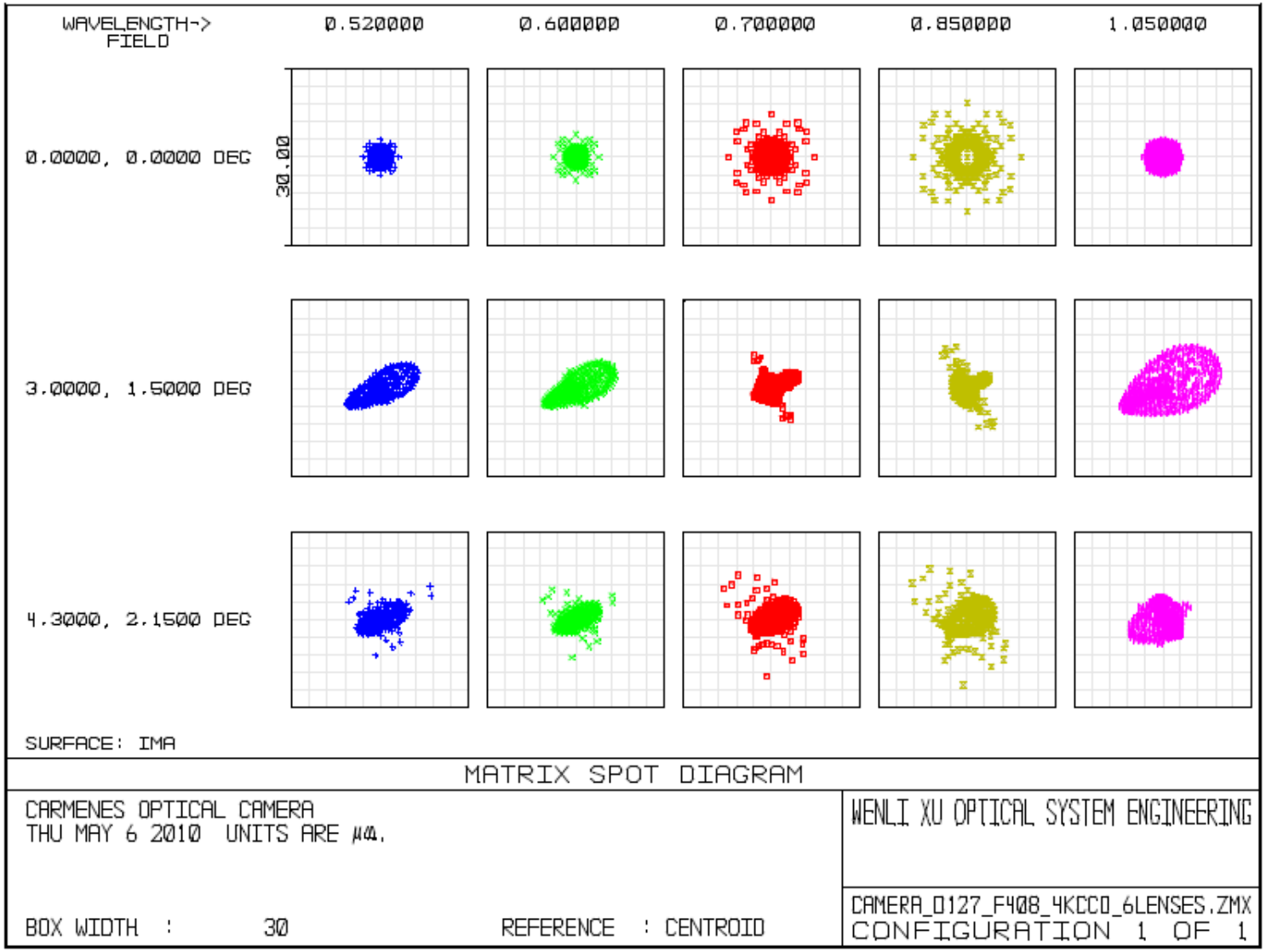
NIR Spectrograph Thermal Concept



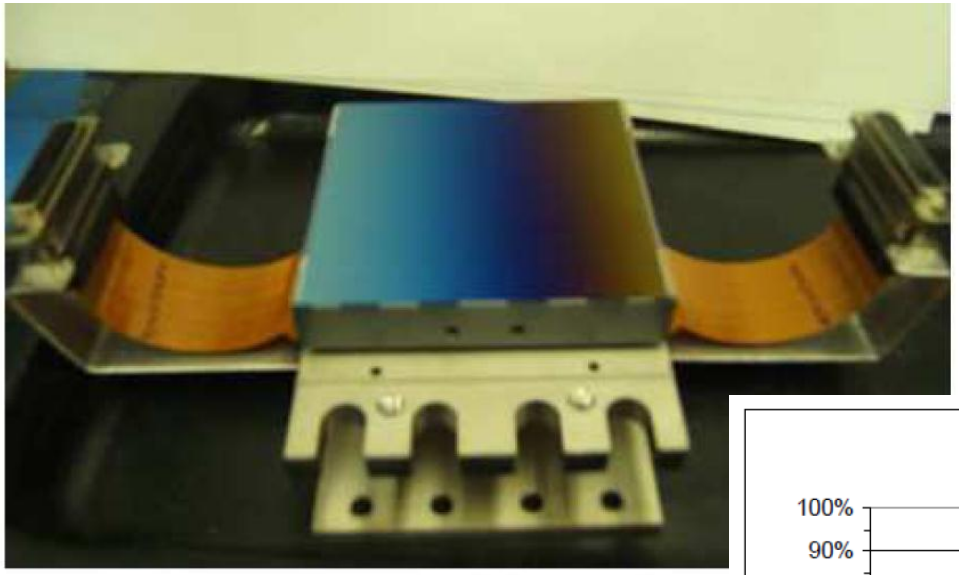
Visible Spectrograph: Optical Design

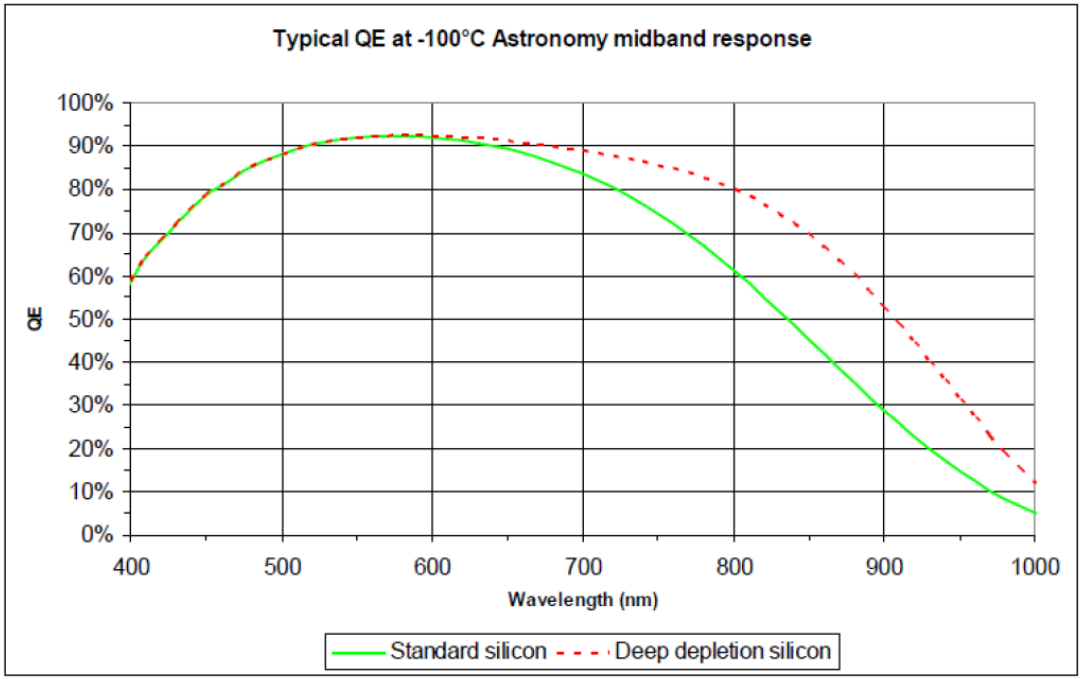


Visible Spectrograph: Spot Diagram



CCD: Deep-Depletion Device with Graded Coating





Indicative Time Line

“Official” Kick-off	11/2010
Preliminary Design	Through 04/2011
Final Design	04/2011 – 12/2011
Construction	01/2012 – 10/2013
Commissioning	11/2013 – 02/2014
CARMENES Survey	03/2014 – 12/2018