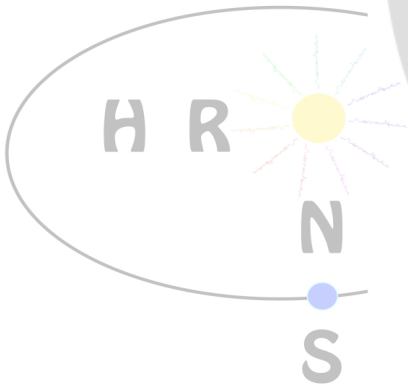
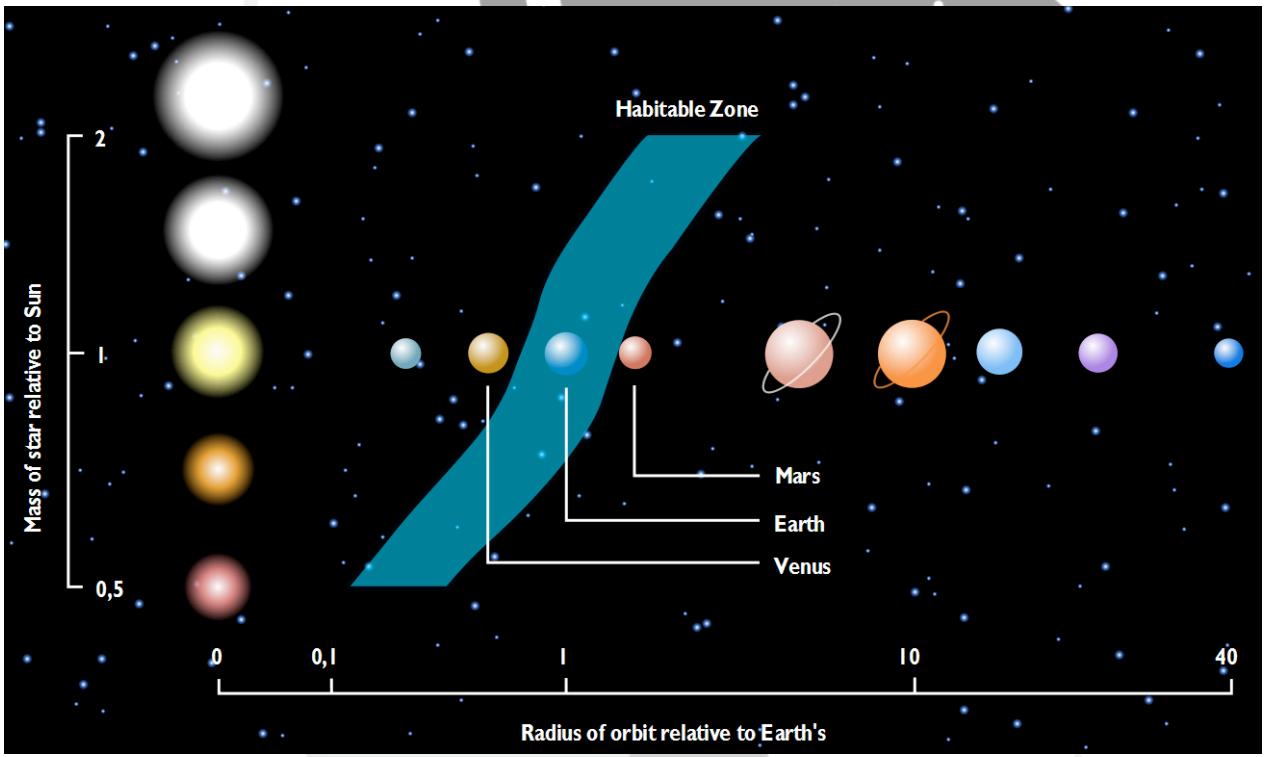
APHRODITE



Ground-Based Observing Team

Science Goals

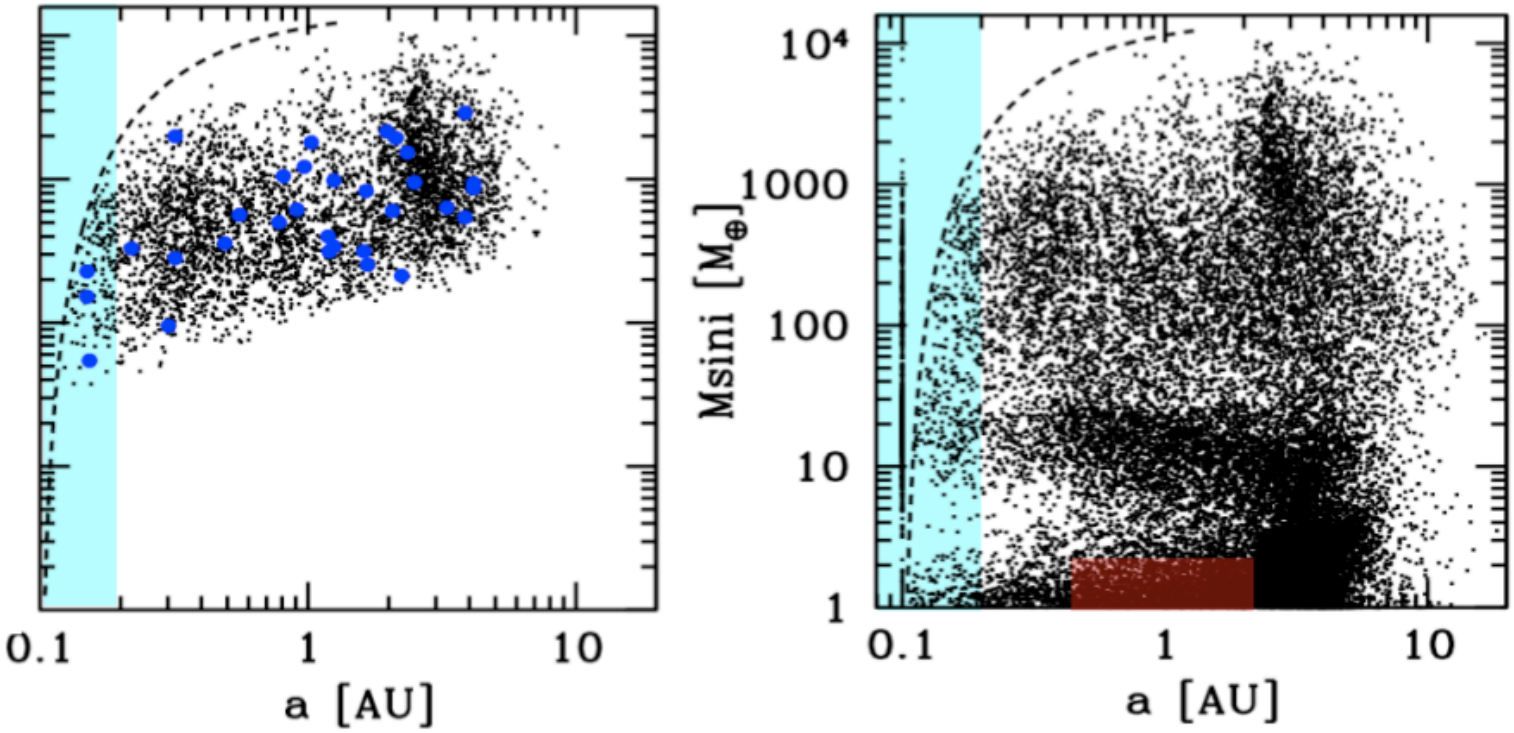
1) **Detecting Earth-like planets in the habitable zone of solar-type stars**



Earth around a G2V star @ 1 AU → K = 10 **cm/s**

Science Goals

1) **Detecting Earth-like planets in the habitable zone of solar-type stars**



Mordasini et al 2009 Ida and Lin 2004, also Miguel and Brunini 2009

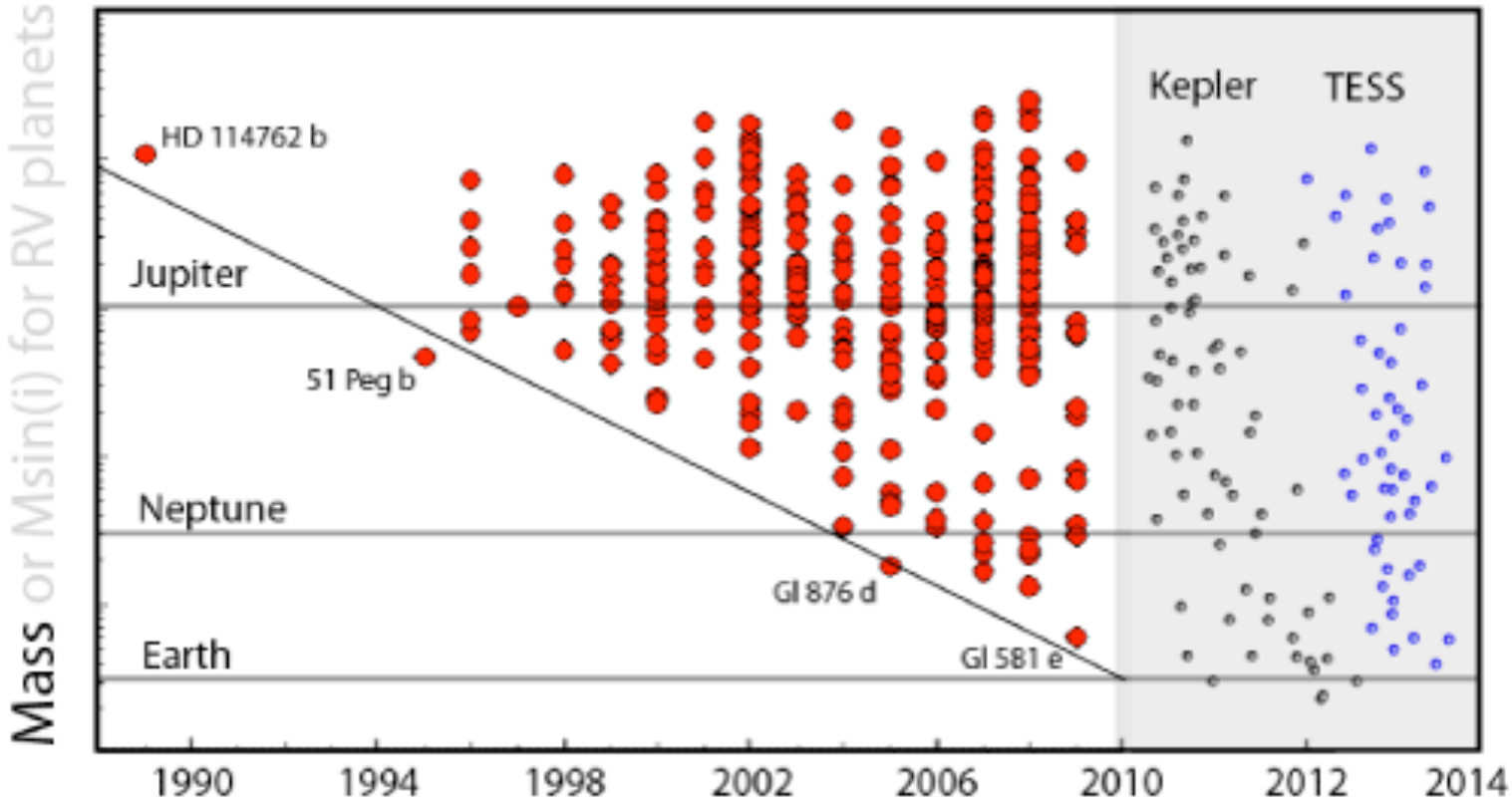
Simultaneous monitoring of GKM class stars

Science Goals

2) Confirming transiting candidates

Aim : 10 cm/s in 30 min around a V=16 star.

Simultaneous confirmation of Kepler candidates !



Science Goals

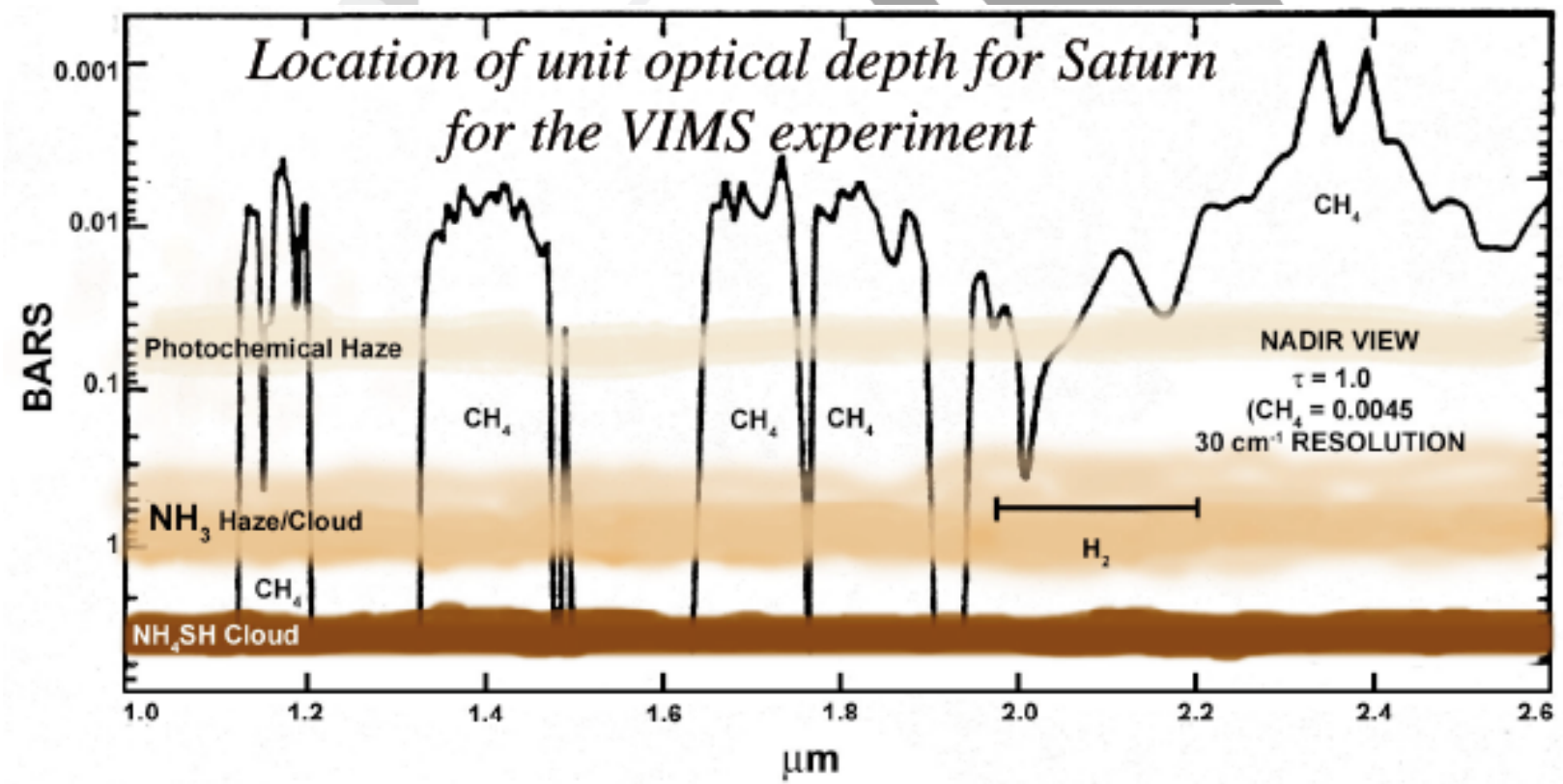
3) Study of formation, evolution and migration of EGP

Need to detect transits signatures of long-period RV planets

Science Goals

4) In depth understanding of the physical processes involved in planetary atmospheres

High resolution transit spectroscopy



Science Goals

Big questions

- How do planets form and evolve?
- Is our planetary system unique?
- Is there life elsewhere?

Science Goals

Logos and acronyms : whole program

Name : APHRODITE

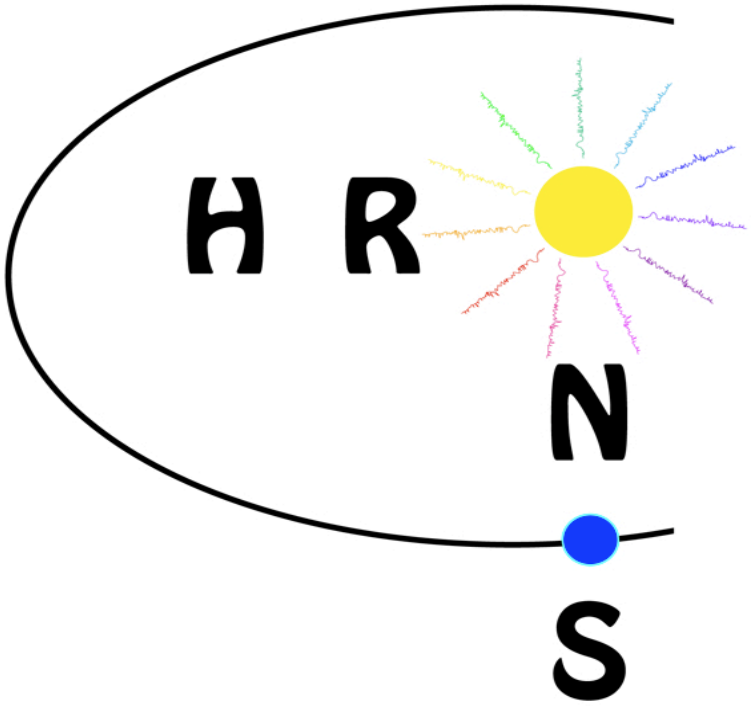
Accurate Photometry and High Resolution Detections of Inner Terrestrial Exoplanets

Science Goals

Logos and acronyms : instruments

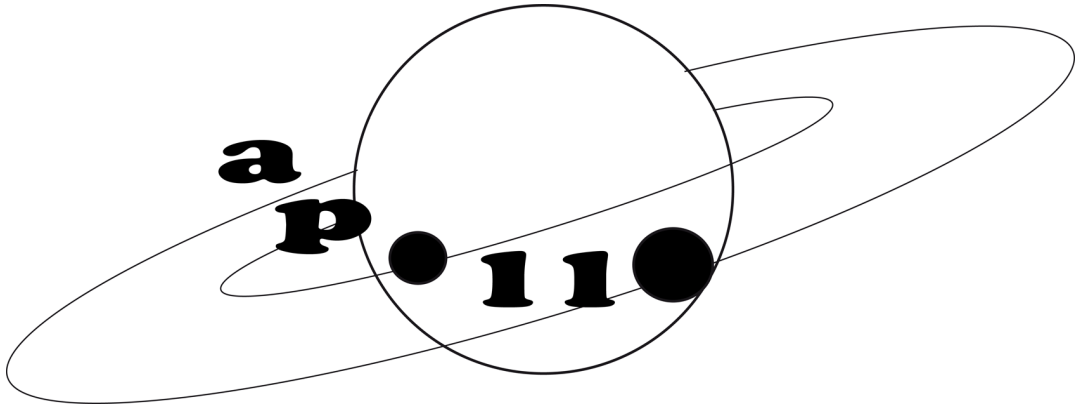
Name : CHRONOS

***C**haracterizing with **H**igh **R**esolution **O**bjects **N**earby with an **O**ptical **S**pectrometer*



Name : APOLLO

***A**ccurate **P**hotometry in the **O**ptical of **L**ots of **L**ow mass **O**bjects*



Strawman Instruments

1) CHRONOS echelle spectrograph

- Wavelength: 0.34 – 1.0 microns (optical & very near infra-red)
- Capability for multi-object spectrography
- Scale-setting requirement: Ability to detect Earth-analog with RV
- R ~ 100 000
- Repeated sampling to characterize, then average over, stellar oscillations
- Cassegrain focus
- 3 calibration techniques

2) APOLLO photometer to enable/enhance CHRONOS

- Monitor target-star variability simultaneously with spectrograph
- Large field-of-view; 2 bands simultaneously; Full Frame-Transfer CCDs
- Cadence chosen for sensitivity to p-mode oscillations

Calibration

- **Laser comb for wavelength calibration**
  - Currently available only in the optical
- **Multiple fibers for the sky**
- **Separate photometric monitoring to monitor stellar oscillations**
- **Separate feed from auxiliary telescope to monitor telluric lines**
  - APOLLO

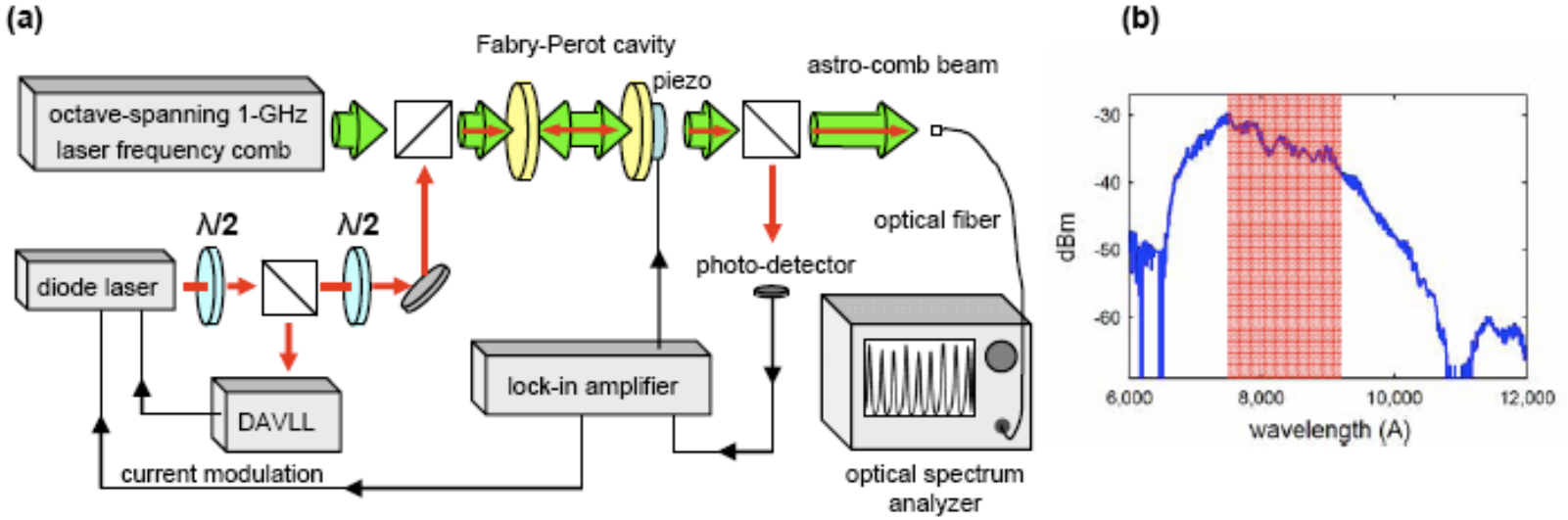
Calibration

- **Laser comb for instrument calibration (currently available only in the optical)** A laser frequency comb that enables radial velocity measurements with a precision of 1 cm s^{-1}

Chih-Hao Li,[1,2] Andrew J. Benedick,[3] Peter Fendel,[3,4] Alexander G. Glenday,[2] Franz X. Kärtner,[3]
David F. Phillips,[1] Dimitar Sasselov,[1] Andrew Szentgyorgyi,[1] and Ronald L. Walsworth[1,2]

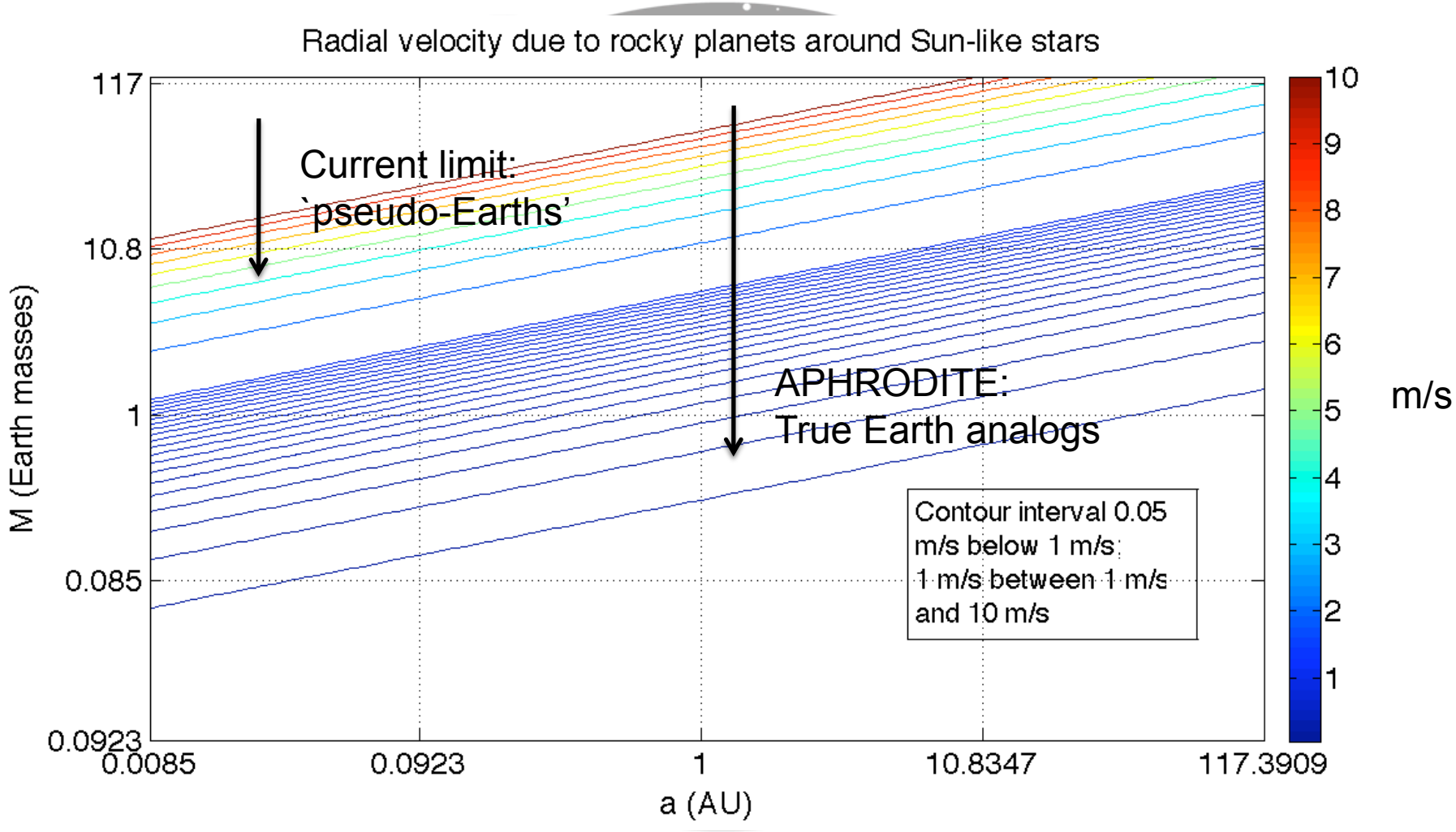
[1] *Harvard-Smithsonian Center for Astrophysics, Cambridge Massachusetts*
[2] *Department of Physics, Harvard University, Cambridge, Massachusetts*
[3] *Department of Electrical Engineering and Computer Science and Research Laboratory for Electronics, Massachusetts Institute of Technology, Cambridge, Massachusetts*
[4] *MenloSystems Inc., Newton, New Jersey*
(Dated: April 7, 2008)

Li et al., Nature, 2008



Several fibers for the sky
Separate feed from auxiliary (meter-class) telescope to monitor telluric lines

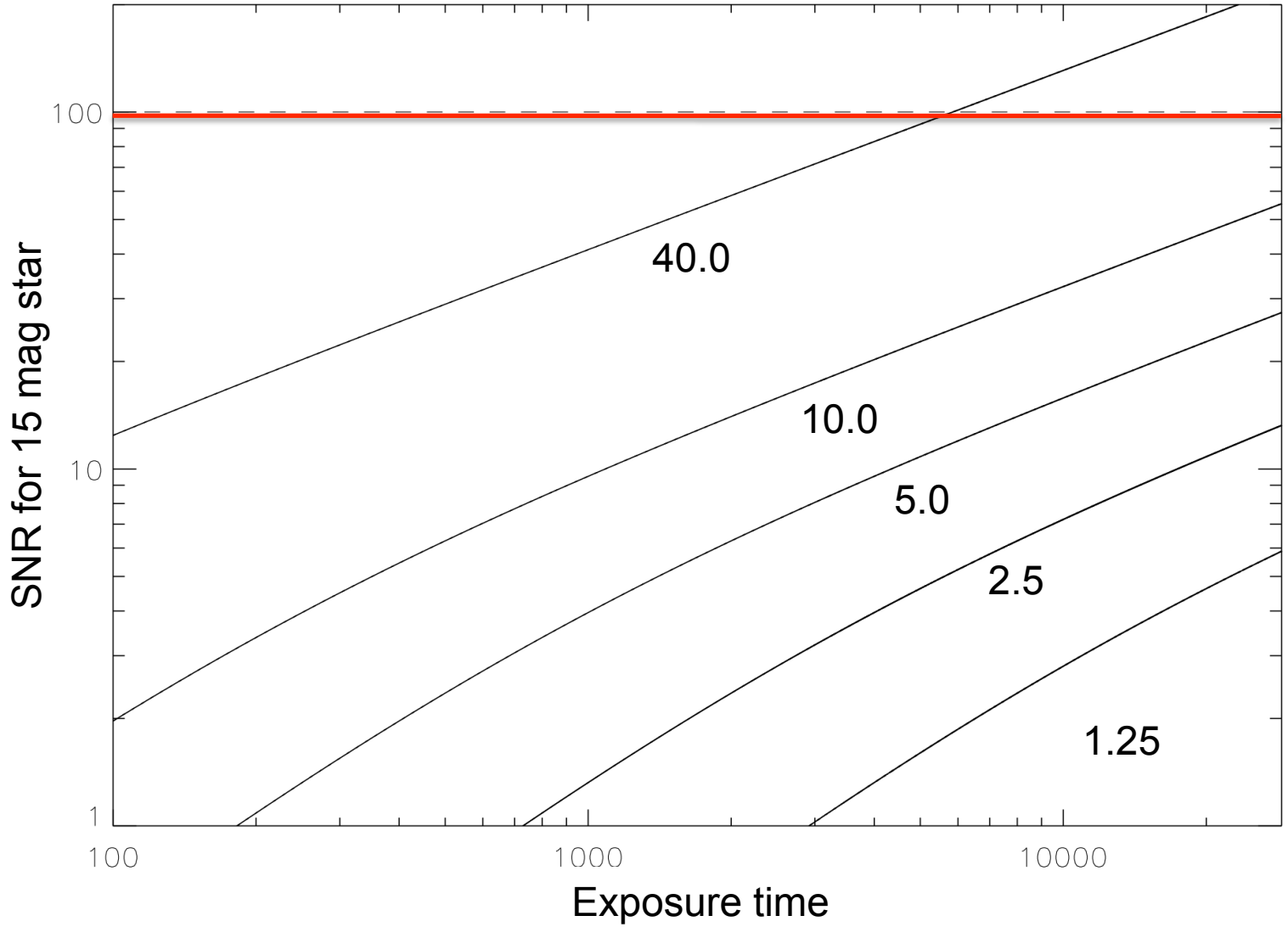
Top-level driver for instrument



Spectrometer S/N

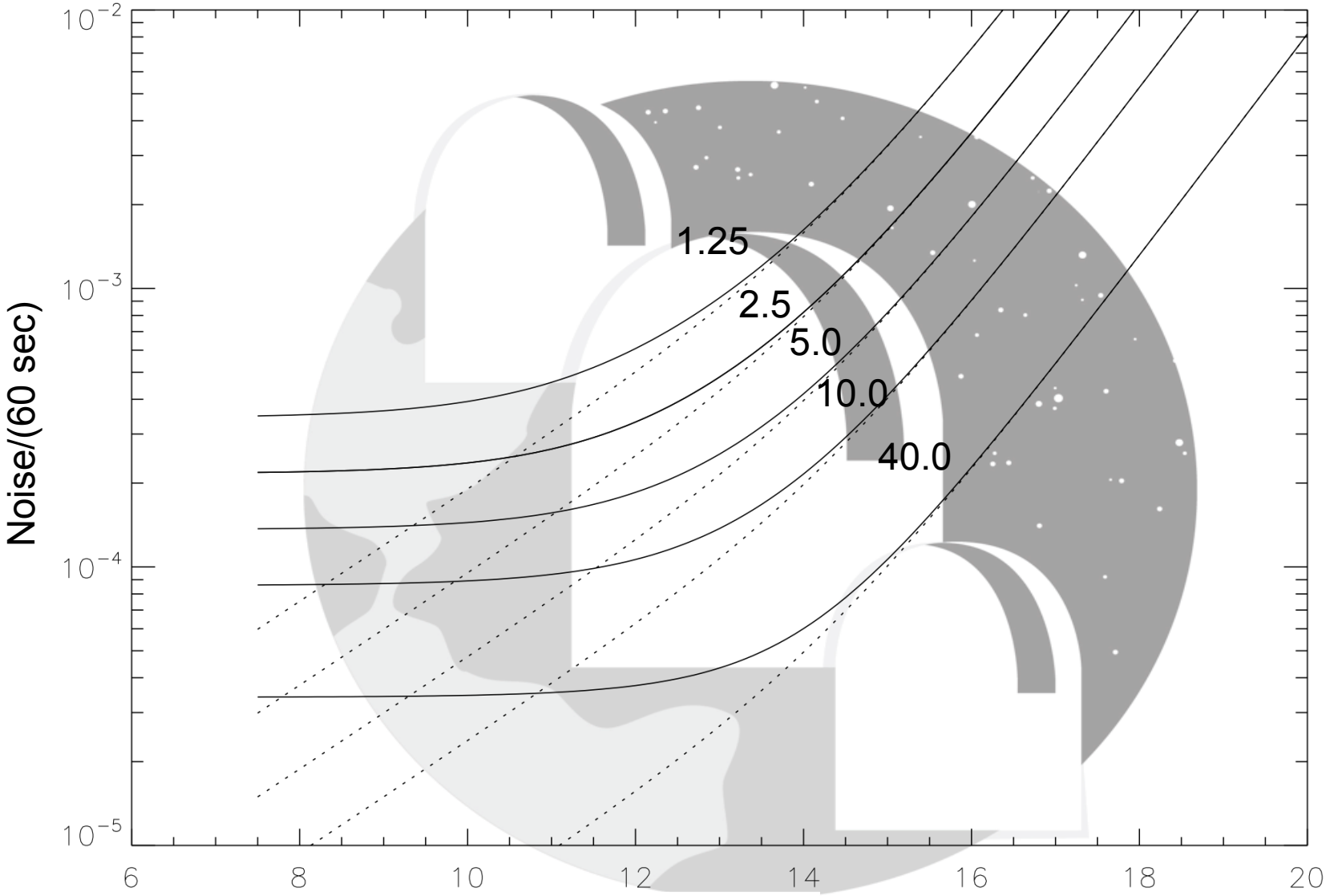
Fiducial based on HARPS data

Reff=0.025 angstroms



V=15
eta=0.1

Photometer Noise



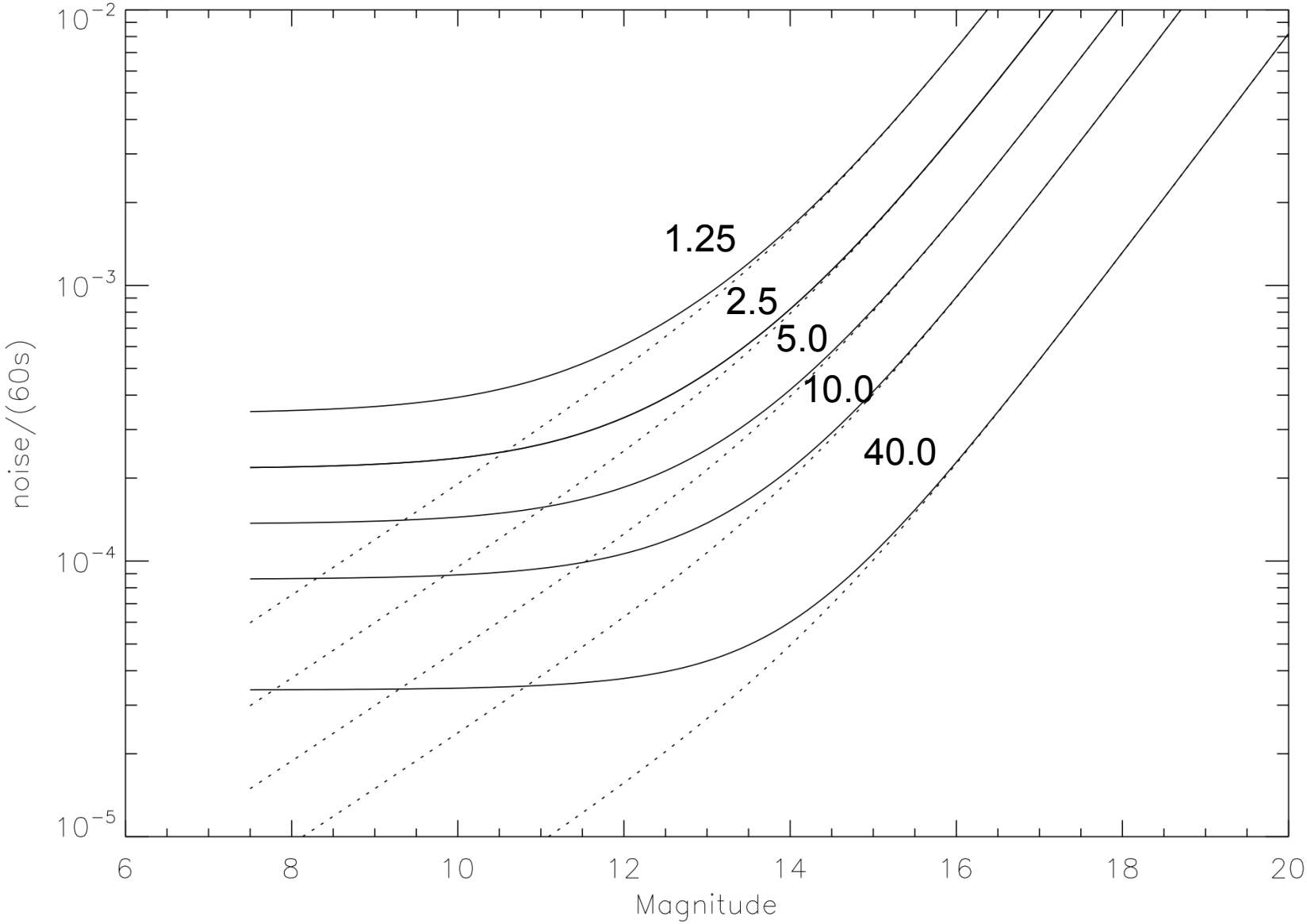
Risks Associated With This Approach

- **Instrument size scales with telescope aperture**
  - 40 m telescopes will demand instruments with mass similar to 4-m class telescopes
  - Mechanical, structures?
- **Technologies currently in embyronic stage (e.g., laser comb)**
  - Clear pathway exists for further development
- **Adequate characterisation of the atmosphere**

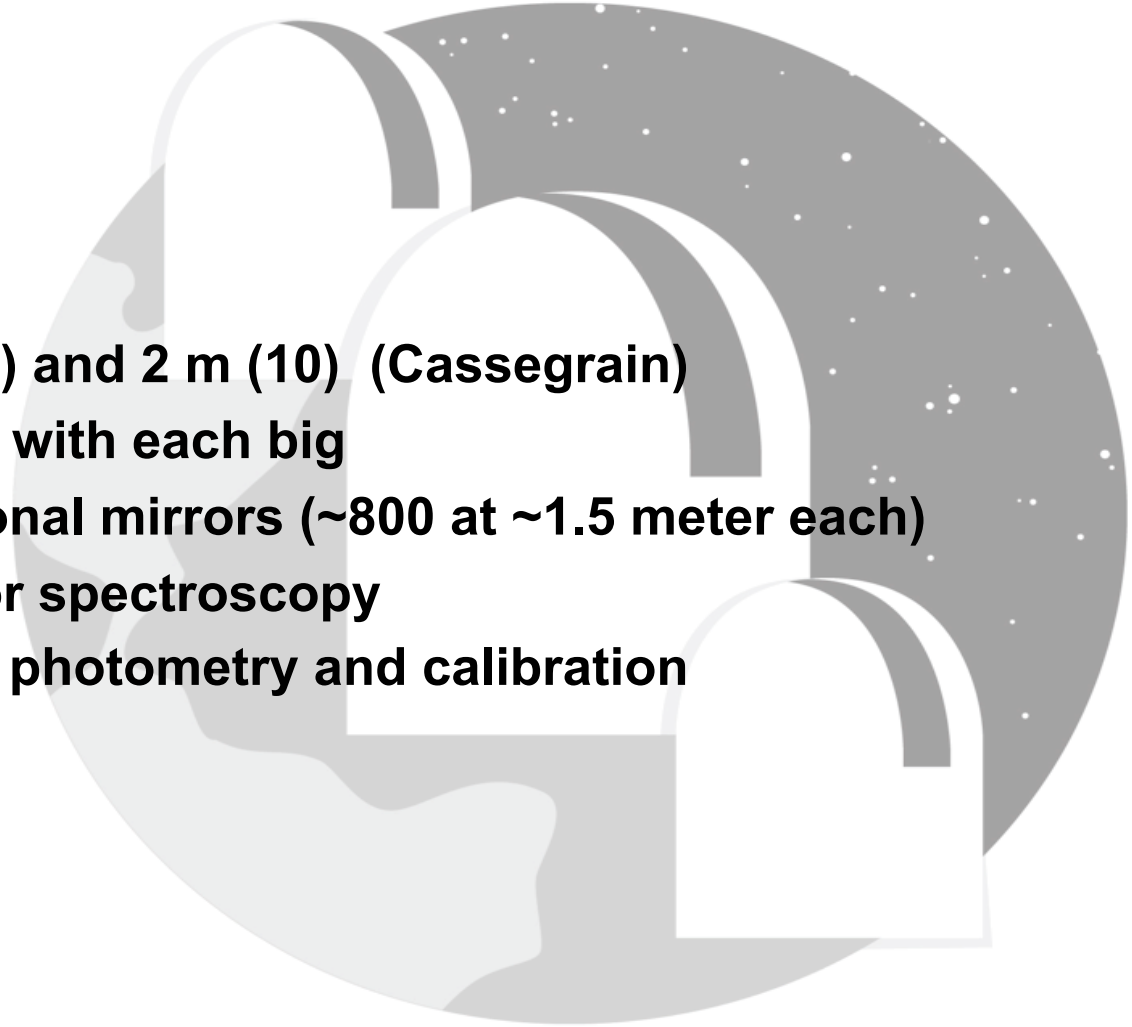
APOLLO Photometer

- Large field-of-view
- 2 bands simultaneously
- Full Frame-Transfer CCDs

Photometer noise

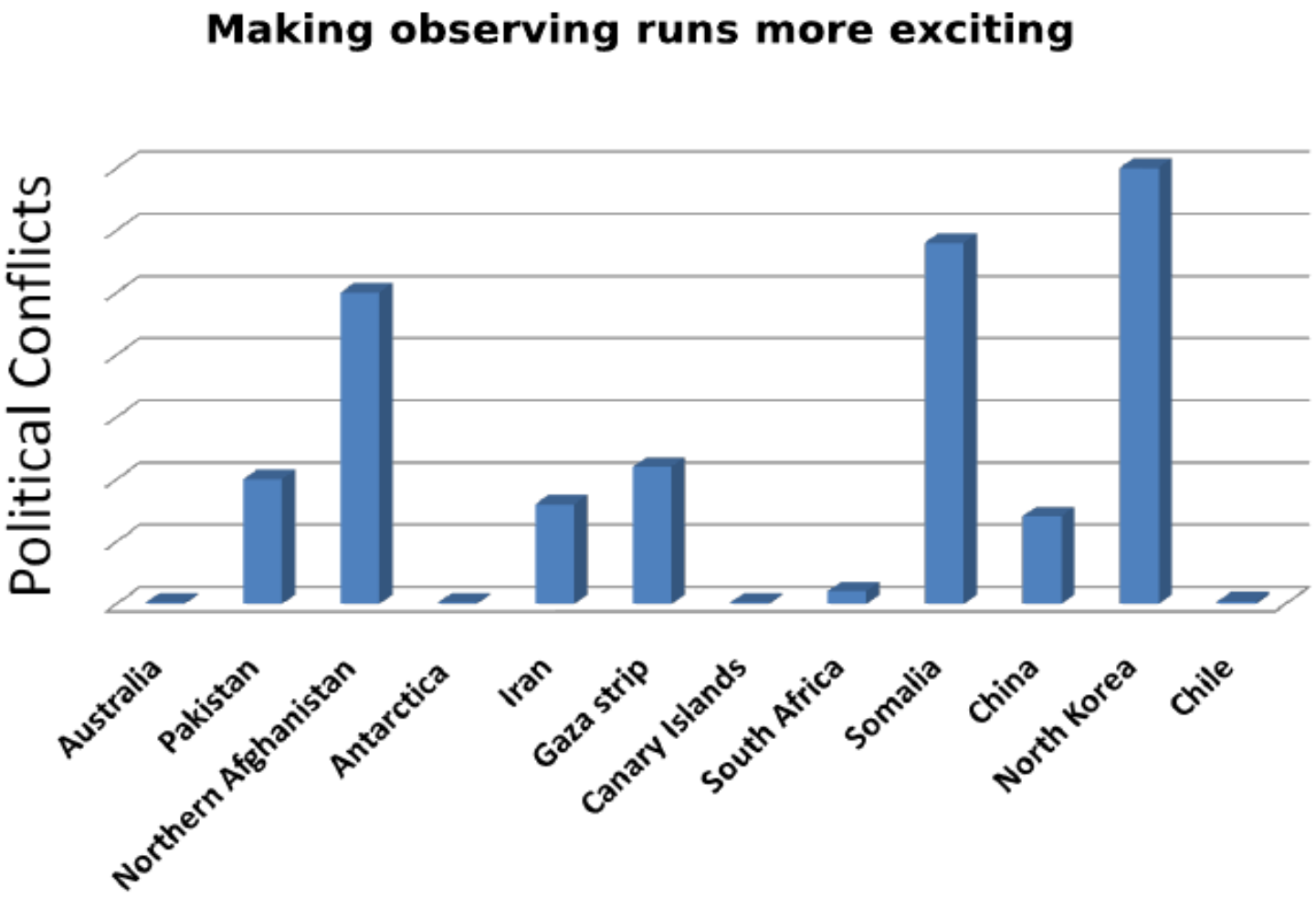


FMTS/N

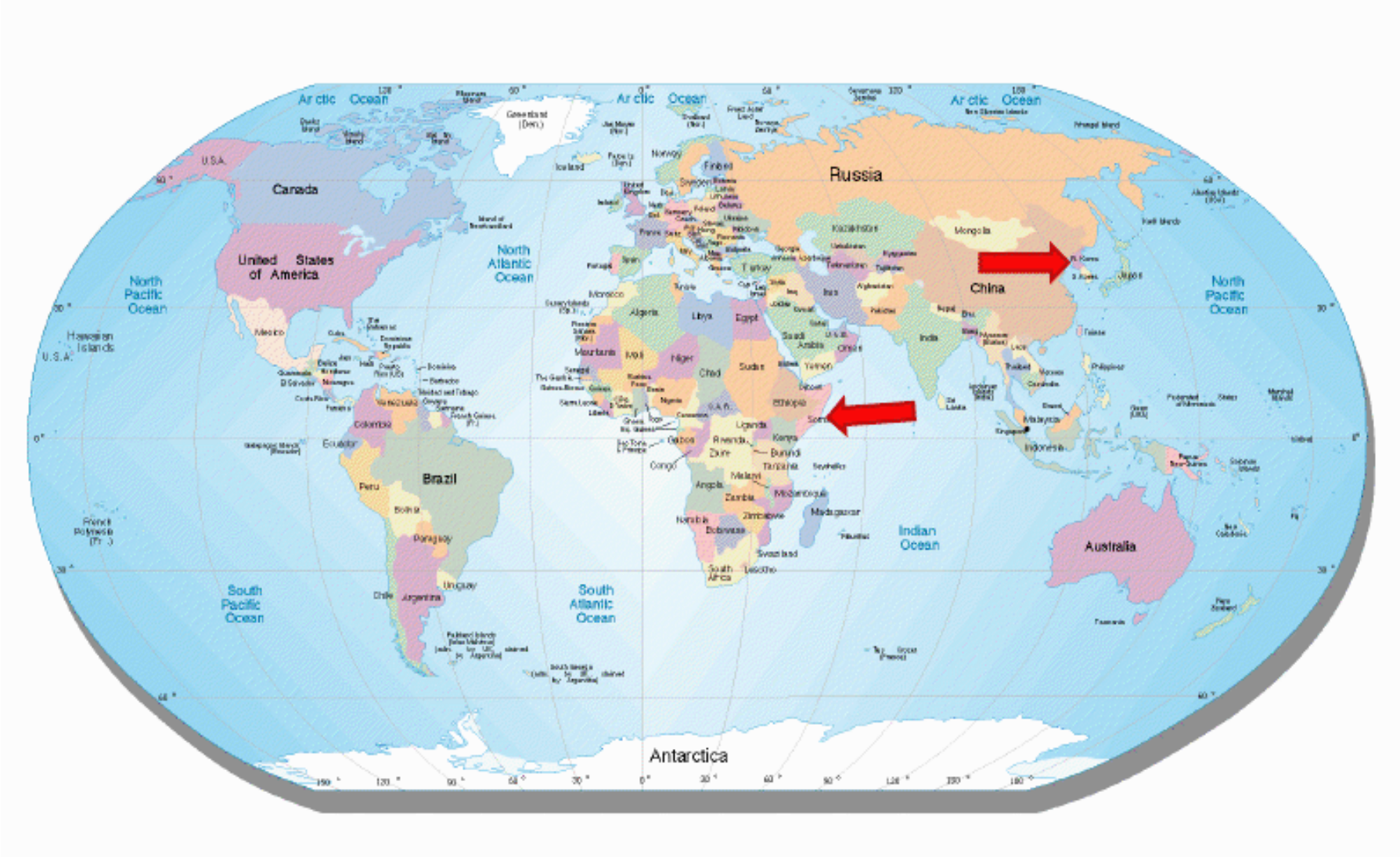


- 40 m (2) and 2 m (10) (Cassegrain)
- 2 small with each big
- Hexagonal mirrors (~800 at ~1.5 meter each)
- 40 m for spectroscopy
- 2 m for photometry and calibration

Location, Location, Location



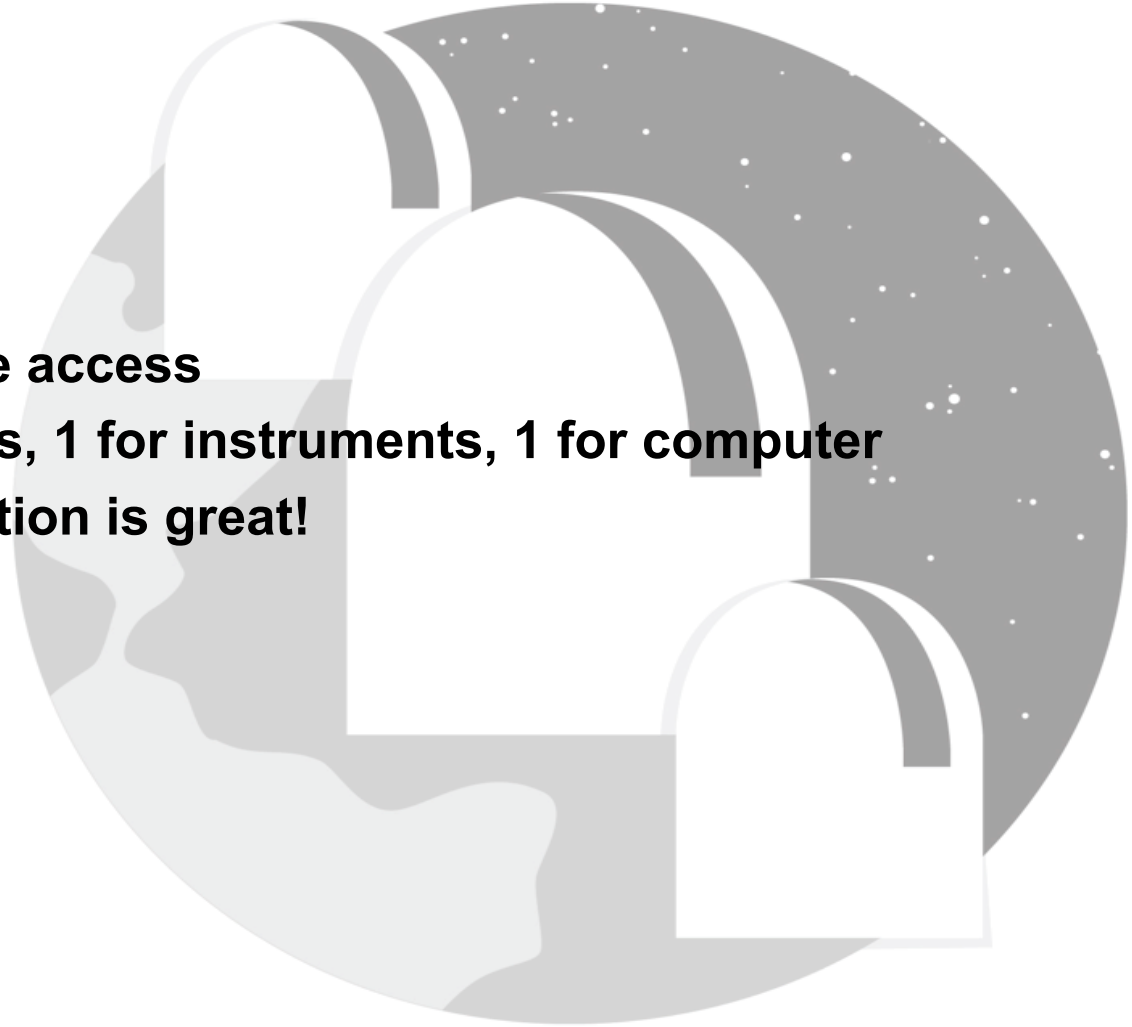
Possible Telescope Locations



Other Telescope Locations

We could also put them here...

Specifications



- Remote access
- 2 rooms, 1 for instruments, 1 for computer
- Resolution is great!

Cost

Cost Summary	
Two 40 Meter telescope	$1.5 B (one paid, one free)
Instrument	~$500 M
Ten 2 Meter	$50 M
Instrument	$10 M
Operating Cost	$15 M/yr
Total	~ $2.1 B

Risks associated with this approach

- **Unprecedented telescope aperture**
  - Mechanical, structures?
- **Technologies currently in embyronic stage (e.g., laser comb)**
  - Clear pathway exists for further development

Acknowledgements

Thanks to the whole team, to our advisor Kaspar Von Braun and Mercedes Lopez-Morales as well as the workshop organizers.