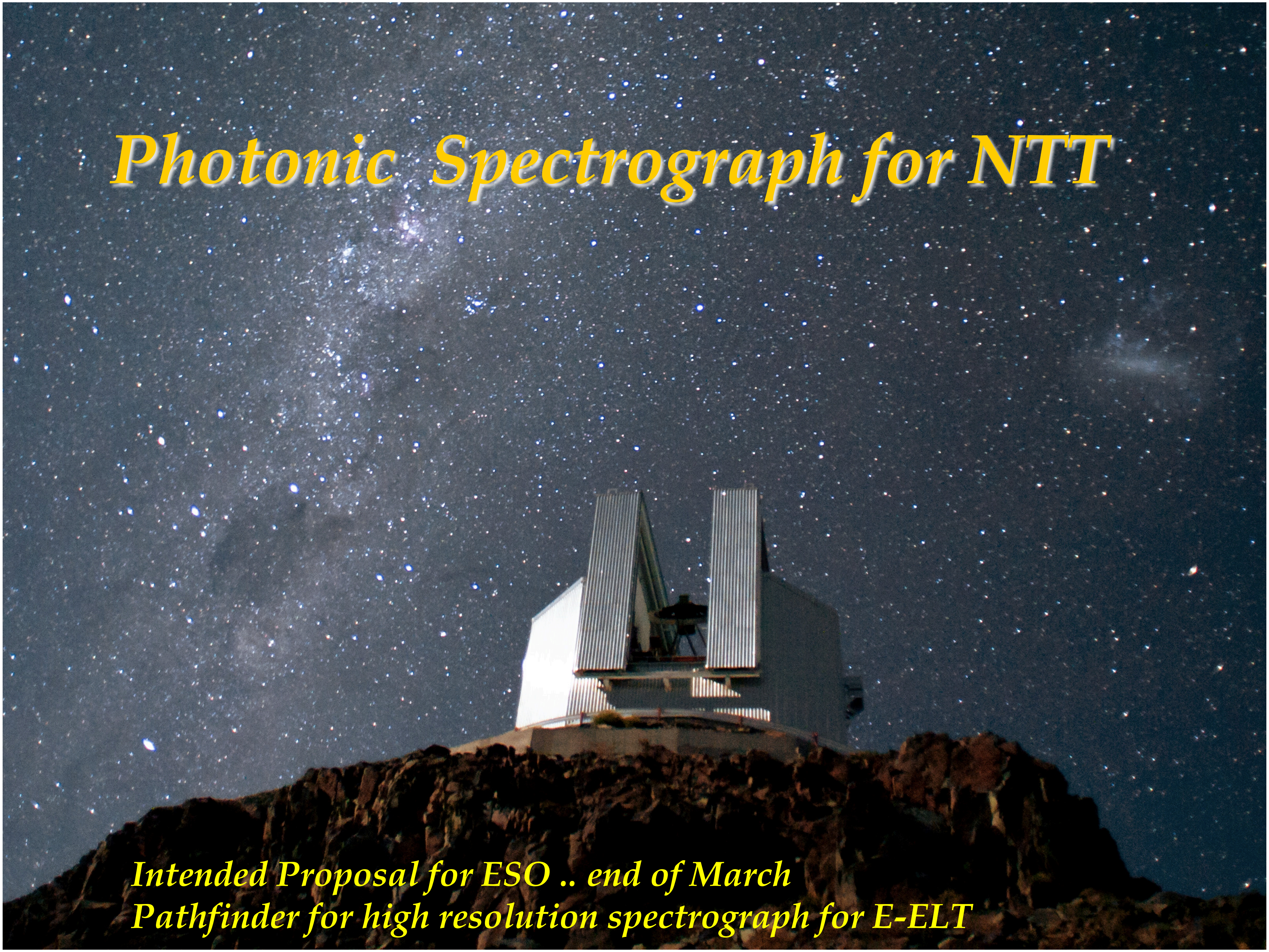

Photonic Spectrograph for NTT
Intended Proposal for ESO .. end of March
Pathfinder for high resolution spectrograph for E-ELT

Spot the high resolution infrared capability offered by ESO?

La Silla

EFOSC2 (ESO Faint Object Spectrograph 2)
HARPS (High Accuracy Radial velocity Planetary Searcher)
SofI (Son of ISAAC)

Paranal

AMBER (Near-infrared interferometric instrument)
FLAMES (Fibre Large Array Multi Element Spectrograph)
FORS2 (FOcal Reducer/low dispersion Spectrograph 2)
HAWK-I (High Acuity Wide field K-band Imager)
KMOS (K-band Multi-Object Spectrograph)
MIDI (MID-infrared Interferometric instrument)
MUSE (Multi Unit Spectroscopic Explorer)
NACO (NAOS-CONICA: High Resolution NIR Camera and Spectrograph)
OMEGACAM (Wide Field Imager for the VST at Paranal)
SINFONI (Spectrograph for INtegral Field Obs. in the NIr)
UVES (UV–Visual Échelle Spectrograph)
VIMOS (Visual Multi-Object Spectrograph)
VIRCAM (VISTA InfraRed CAMera)
XSHOOTER (UV–Visual–NIR medium resolution échelle spectrograph)

Chajnantor

LABOCA (Large Apex BOlometer CAmera)
SHFI (Swedish Heterodyne Facility Instrument)
ARTEMIS (Architectures de bolomètres pour des Télescopes à grand champ de vue dans le domaine sub-Millimétrique au Sol)
CHAMP+ (Carbon Heterodyne Array of the MPIfR)
FLASH (First Light APEX Submillimeter Heterodyne receiver)
SUPERCAM (64 pixel 329-360 GHz imaging spectrometer)

There are more details on the offered instruments and the ESO facilities on the Period 94 **Instrumentation and Facilities** page. The main characteristics of all instruments offered at La Silla, Paranal and Chajnantor in this call are described in the **Instrument summary table**. Any updates after the release of this Call will be listed on the **Late Breaking News** webpage.

The ESO proposal submission deadline is:

27 March 2014,
12:00 noon Central European Time.

Spot the Southern project?

carmenes

- **Public**
- Project
- Institutions
- People
- Gallery
- Publications
- Conferences
- Spectrographs
- **Private**
- **Referees**

Spectrographs

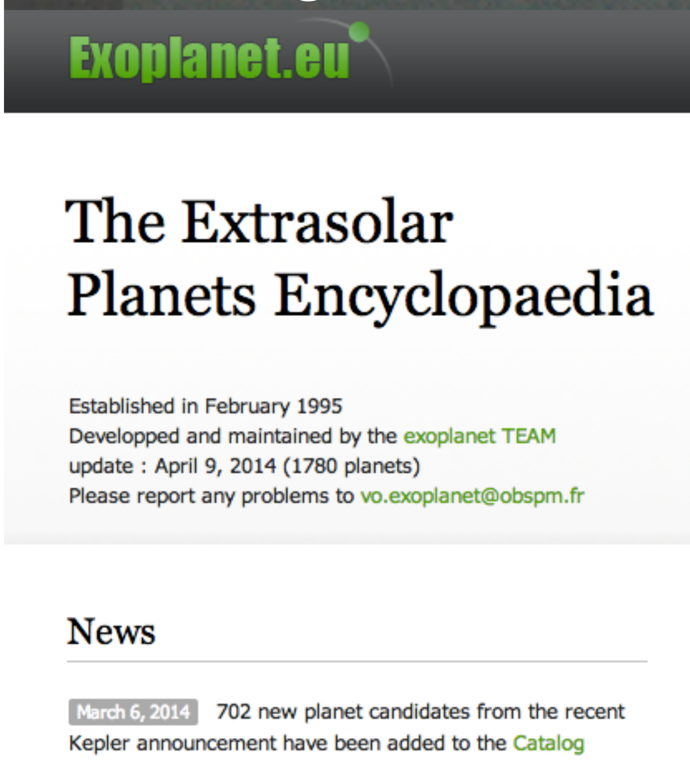
Comparable spectrographs in the near infrared

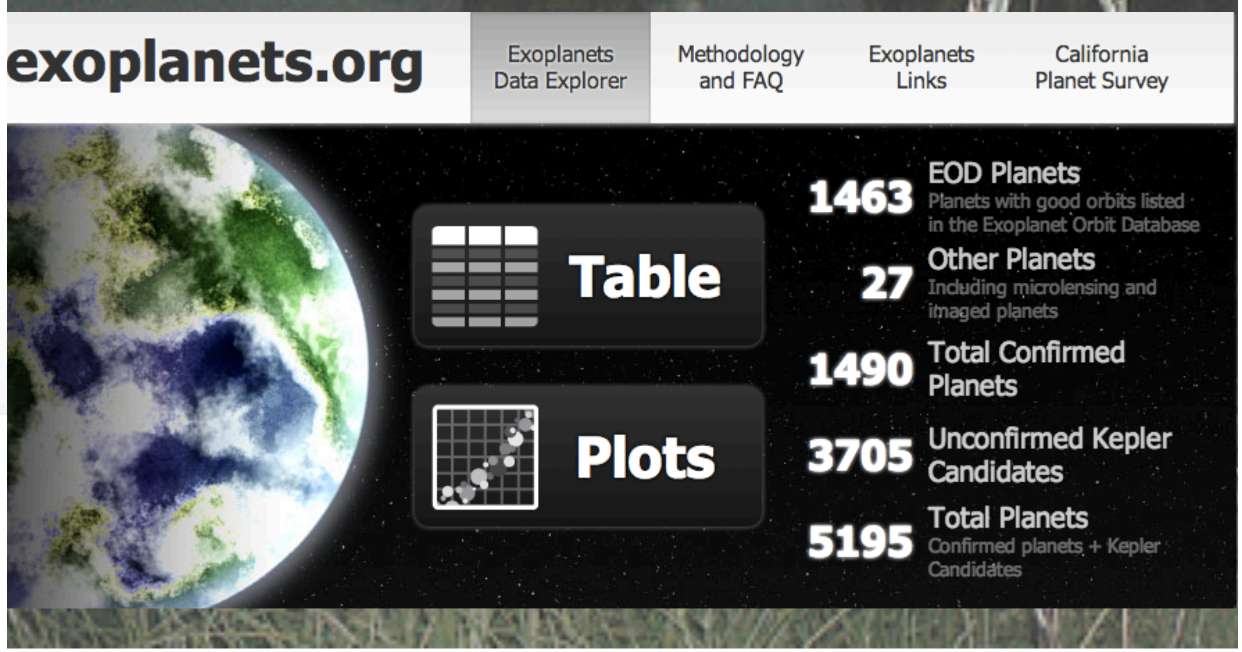
Acronym	Name	Telescope	Year
NIRSPEC	Near InfraRed SPECtrograph	Keck II	1999
PHOENIX	A cryogenic, long slit, high resolution infrared spectrograph	Gemini South	2001
CRIRES	CRyogenic high-resolution InfraRed Échelle Spectrograph	Very Large Telescope UT1	2006
TEXES	Texas Echelon Cross Échelle Spectrograph	Gemini North	2006†
T-EDI	TripleSpec - Exoplanet Discovery Instrument	Mt. Palomar 200 inch telescope	2008†
IR ET	Infrared Exoplanet Tracker	ARC 3.5 m Apache Point Observatory	2010
GIANO	A bifront infrared spectrometer highly optimized both for low and high spectral resolution	Telescopio Nazionale Galileo	2012
FIRST	Florida InfraRed Silicon immersion grating spectromeTer	T13 2.0 m Automatic Spectroscopic Telescope	2013
HPF	Habitable zone Planet Finder	Hobby-Eberly Telescope	2015
SPIRou	A nIR high-precison-RV échelle spectropolarimeter for CFHT	Canada-France-Hawai'i Telescope	2017
IRD	Infrared Doppler instrument	Subaru	>2014
SIMPLE	A "simple" high resolution near infrared spectrograph	European-Extremely Large Telescope E-ELT	>2020
NAHUAL	Near-infrAred High-resolUtion spectrogrAph for pLanet hunting	Gran Telescopio Canarias	Cancelled†
UPF	UKIRT Planet Finder	United Kingdom Infrared Telescope	Cancelled†

Motivation

Find terrestrial-mass exoplanets in the habitable zones of the nearest stars

Numerous transit survey detections, radial velocities lag behind but vital for searches of closest stars and ransit follow-up.





What limits us?

- HARPS … its limited by scrambling, not the spectrograph.
- .. and by the way they calibrate.
- .. poor at M-dwarf science (stops at 700nm)
- ~4-5% throughput
- .. and it cost about >€10m

Solution

- **Step 1 – GIANO to NTT .. working 50k spectrograph currently at TNG but not connected**
- **Step 2 – Pathfinder spectrograph for NTT incorporating new technologies**

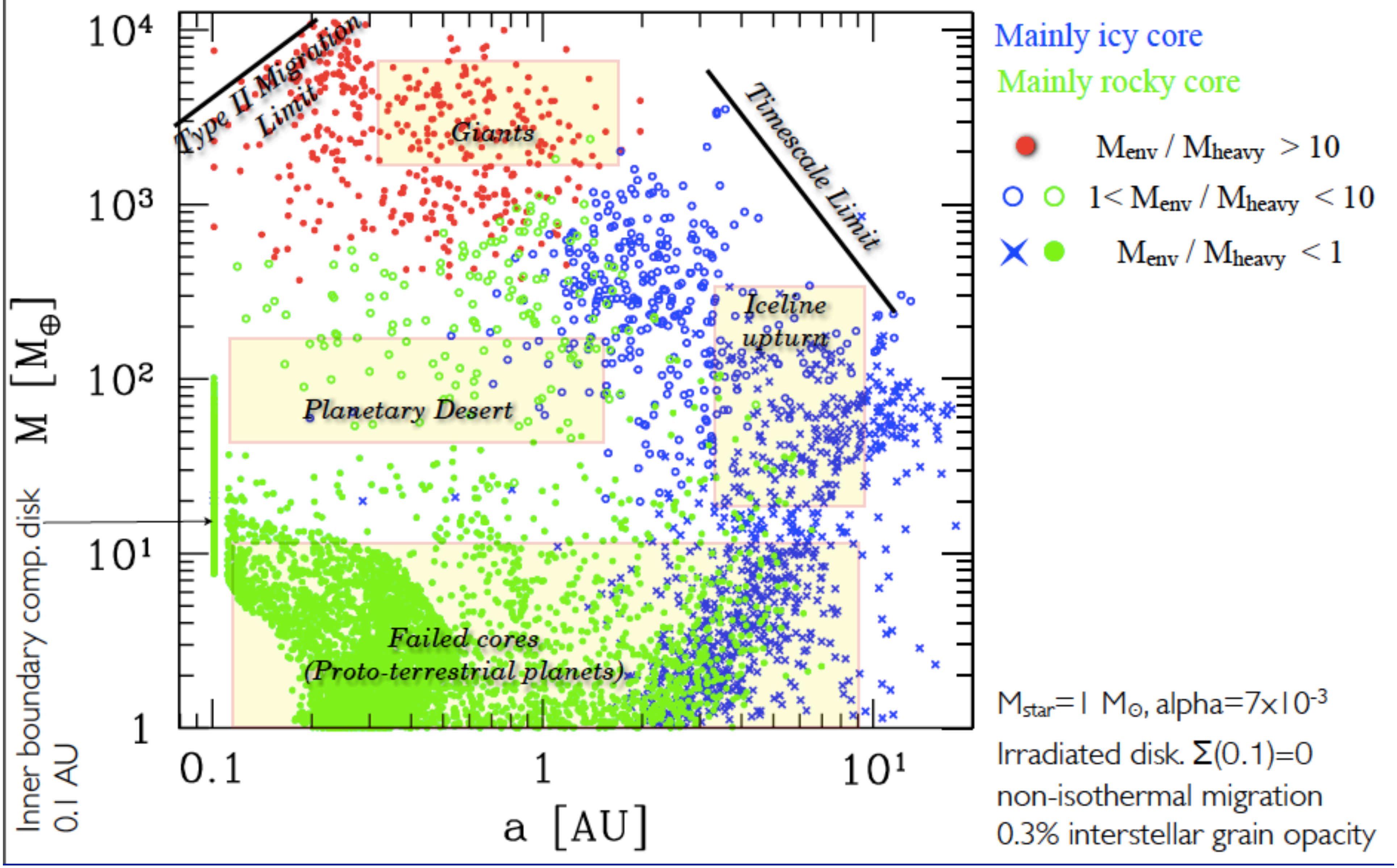
Why bother?

- **Most nearby planets are around M dwarfs**
- **Stepping stone for high resolution facility for E-ELT**

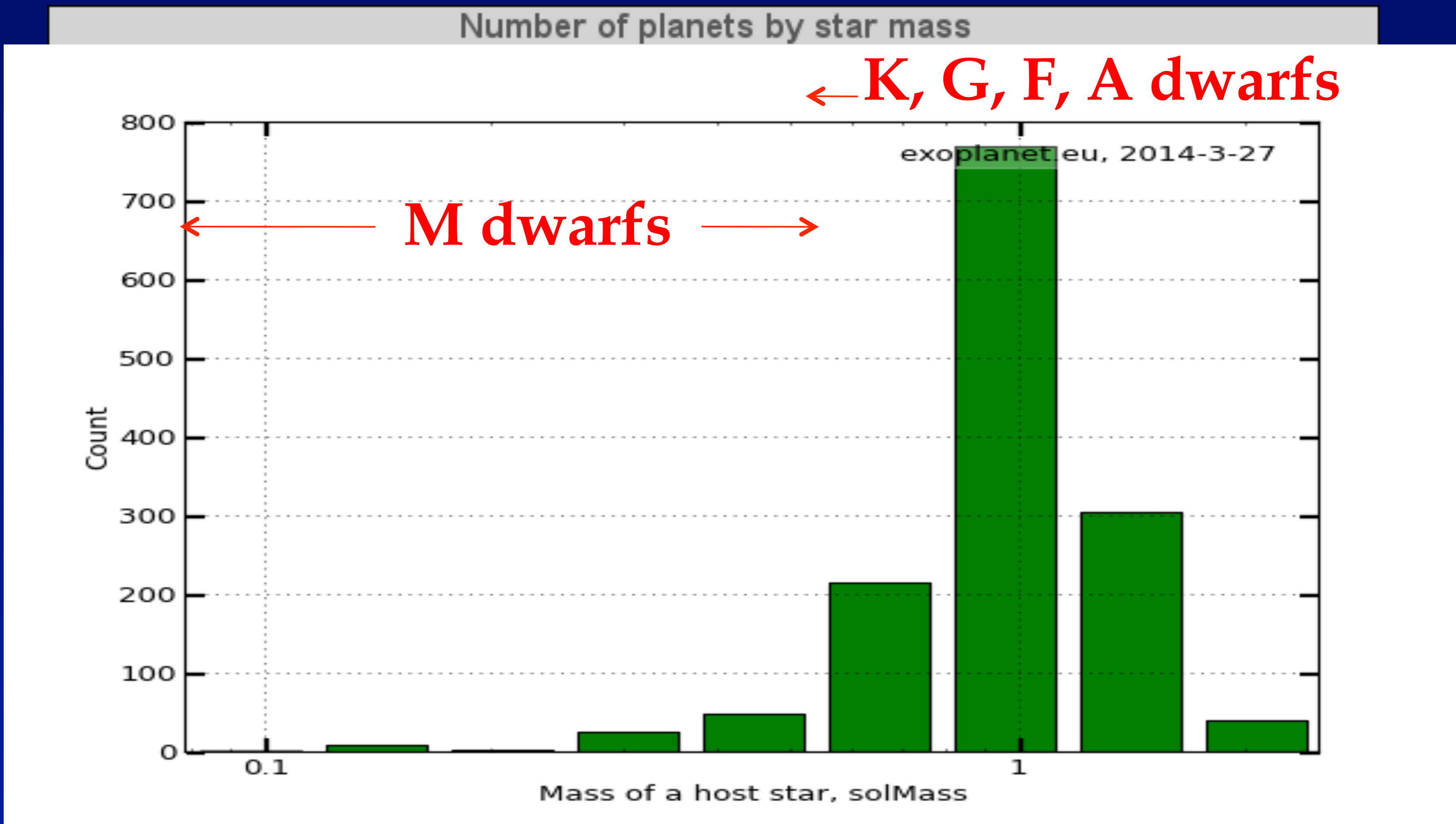
Exoplanets around the majority of stars .. including M dwarfs

Kepler (e.g., Dressing & Charbonneau 2014), Ground-based (e.g., Tuomi et al. 2014)

Theoretically .. current exoplanets are the tip of the Iceberg

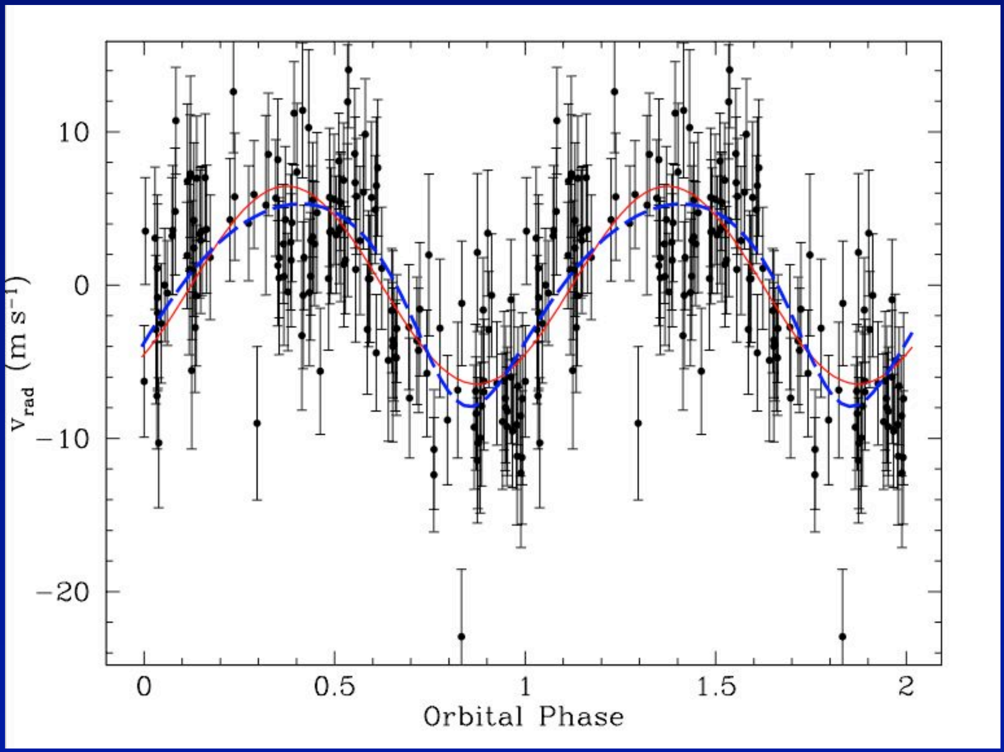


Astrophysically … a void



Optical RVs are hardwork for M dwarfs

Low mass planets are being discovered around M dwarfs but tough even with Keck



Gl876 (M4V), 4.7pc

1.9 day period

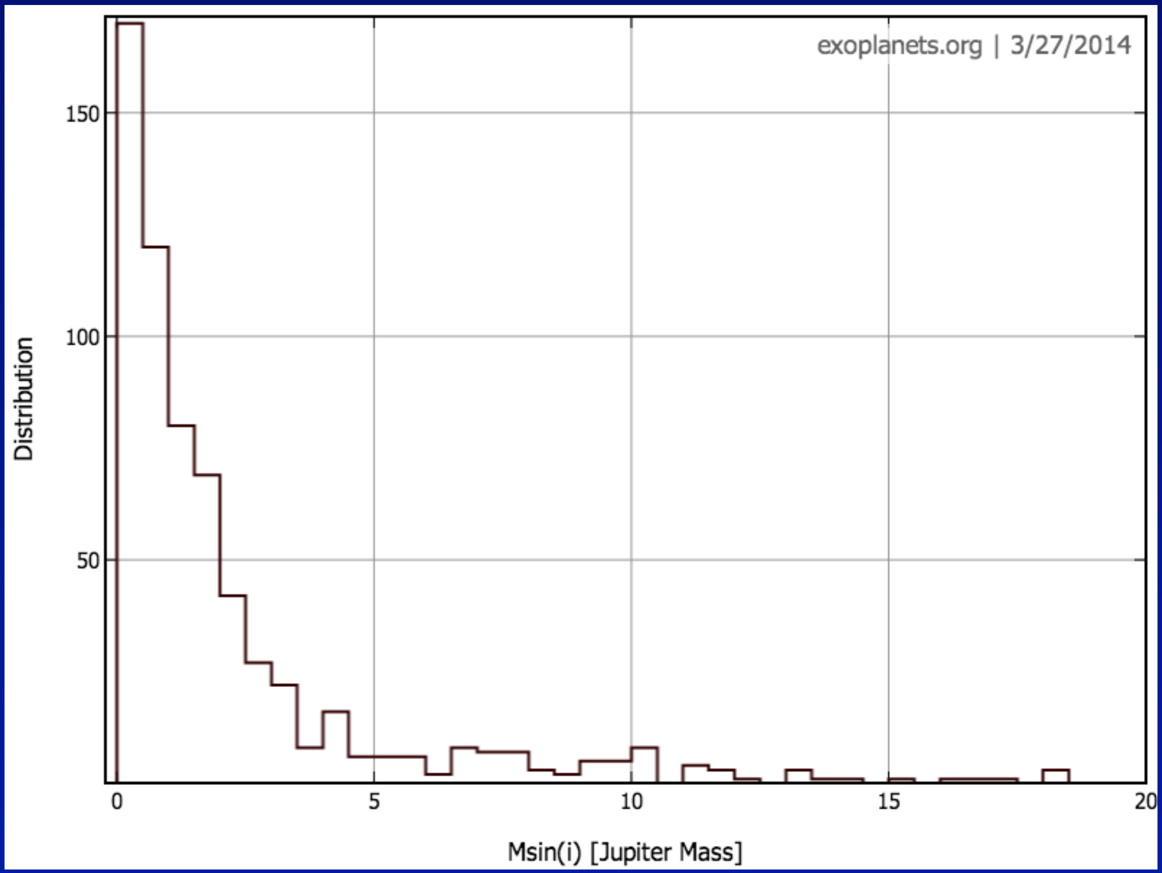
Msini=7.5M_{Earth}

1997-2005 Keck monitoring including data on 6 consecutive nights

Rivera et al. 2005

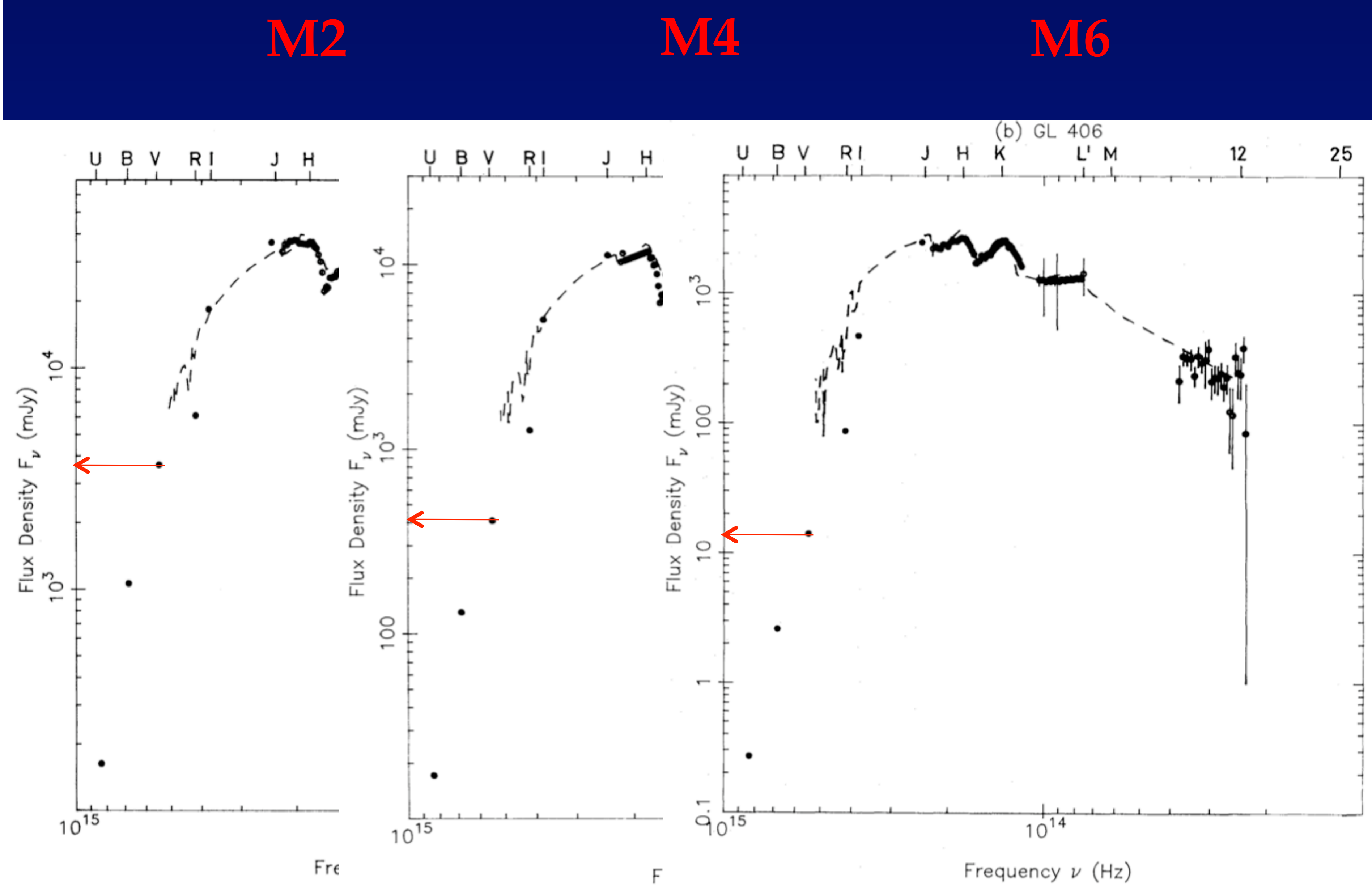
Plenty of low-mass planets though at few Earth masses we are close to detection threshold

Low-mass planets dominate despite strong bias against detection



Why the infrared?

Berriman & Reid 1987

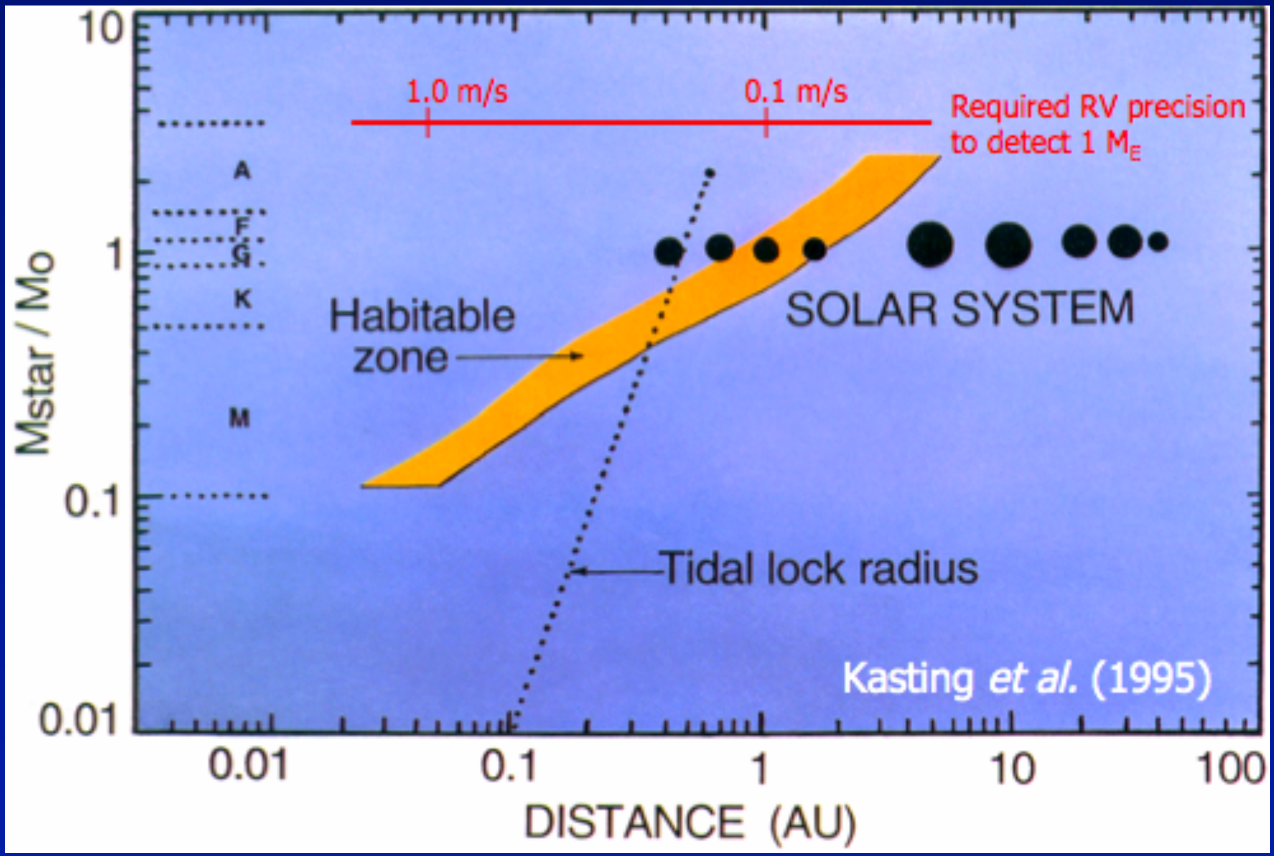


Habitable zones more accessible

- **The habitable zones of low-mass stars have shorter orbital periods**

Habitable zone inside 0.3 AU for M dwarfs

Tidally locked planets may or may not be good places to look for life



Technical challenges of RV in the NIR

- Simultaneous wavelength fiducial covering NIR is required for high precision RV spectroscopy
  - Use of ultrabroad laser comb

➡ **Simulation / Prototype**

- Significant telluric contamination in the NIR
  - Mask out ~ 30 km/s around telluric features deeper than 2%
  - At R=70,000 (2.5 mm PWV, 1.2 air-mass) this leaves 87% of Y, 34% of J, and 58% of H
  - Simulations indicate resulting 'telluric jitter' < 0.5 m/s

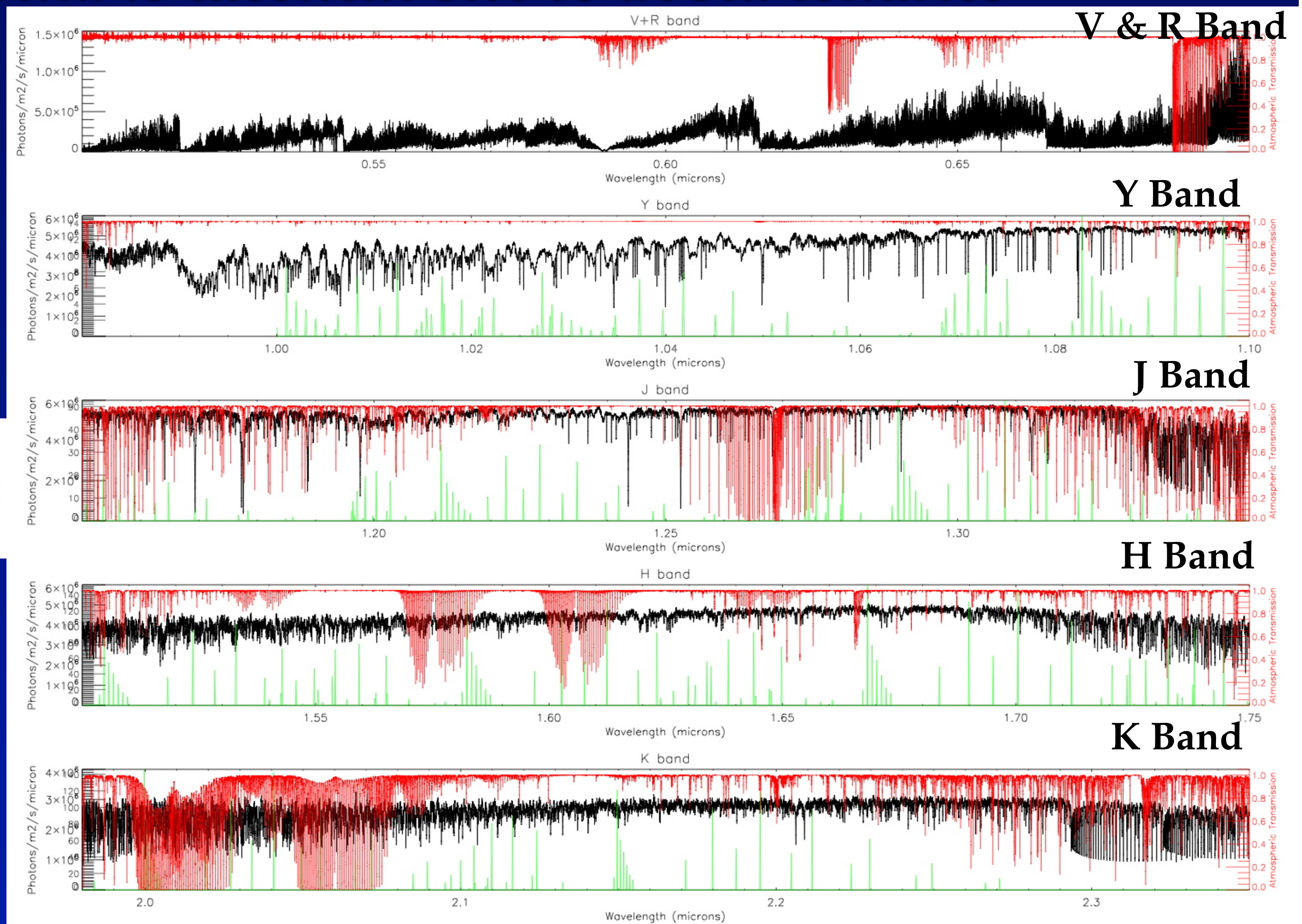
➡ **High dry site**

Atmospheric limits?

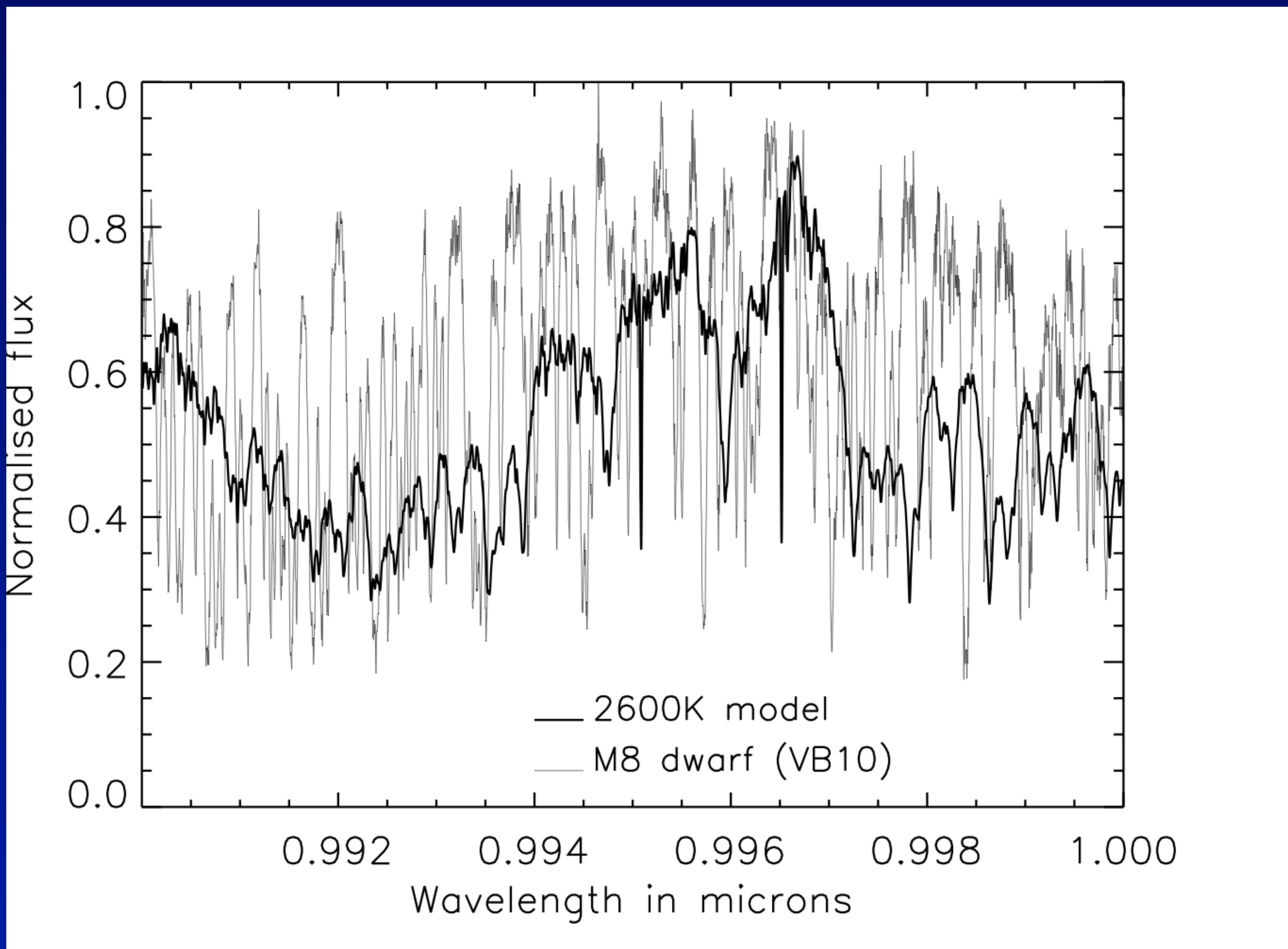
La Silla is excellent site to avoid tellurics

M6V
T_{eff} = 2800 K
Log g = 5
v sin i = 0 km/s

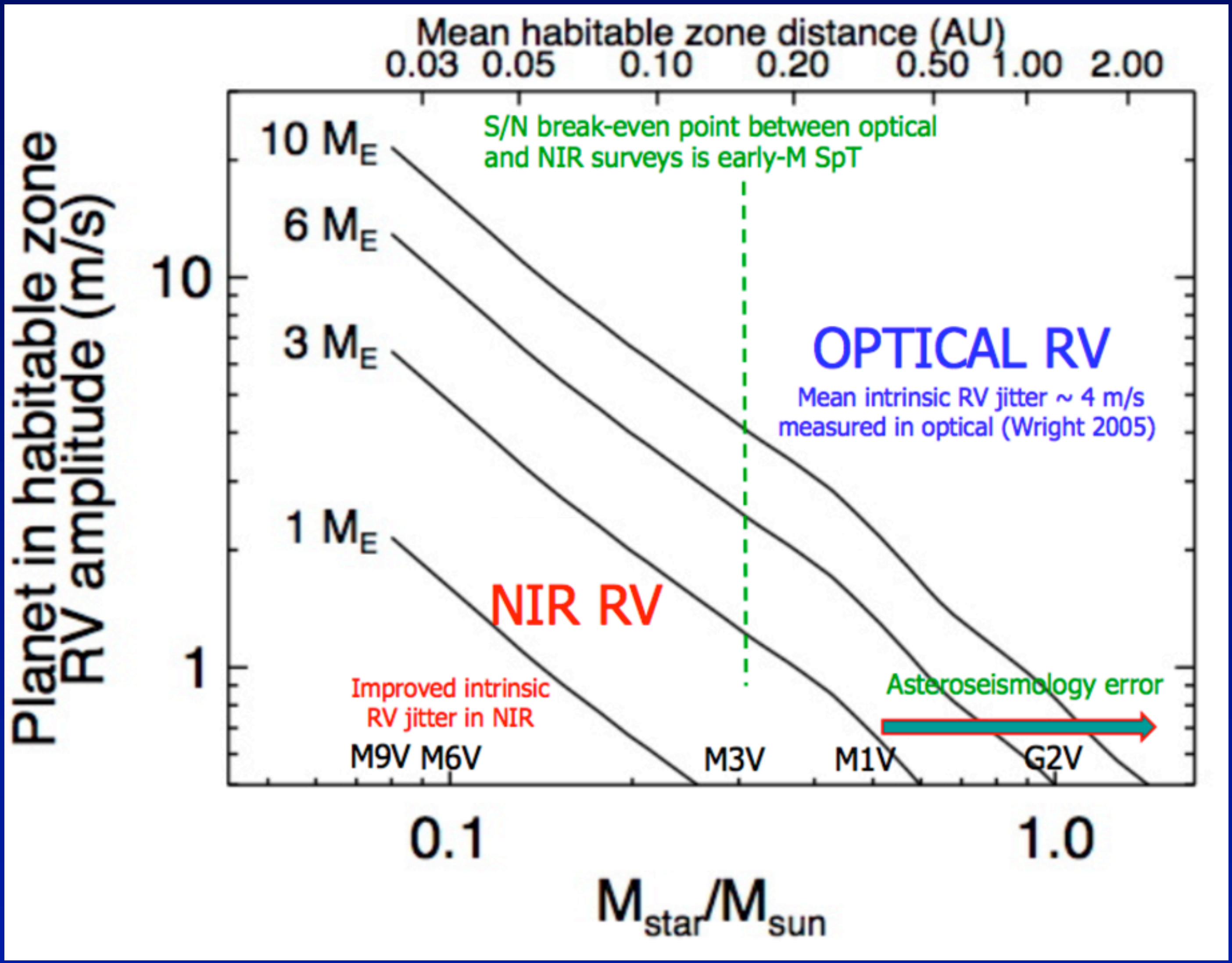
Model
Telluric
OH



Plenty of radial velocity information



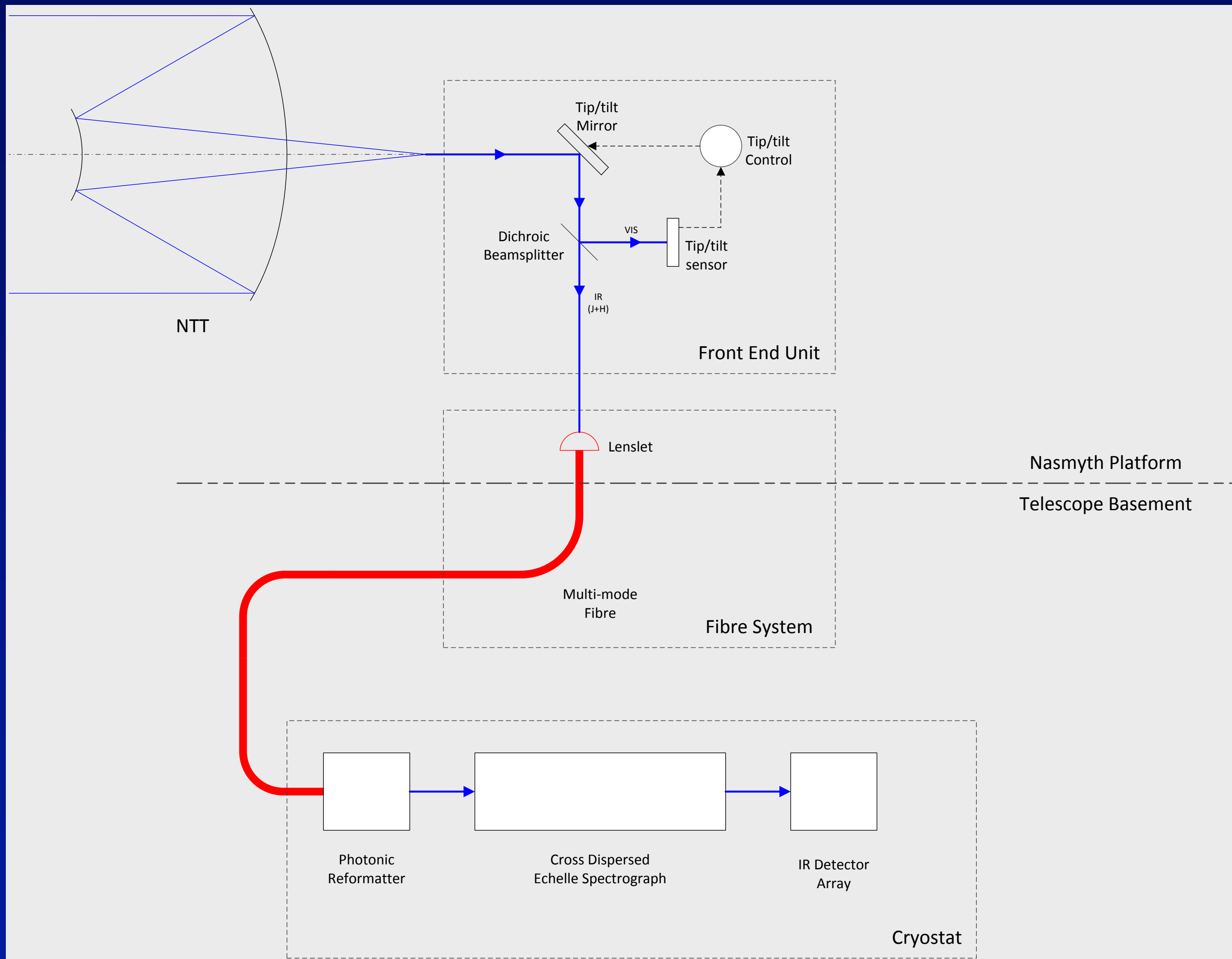
The potential in the infrared



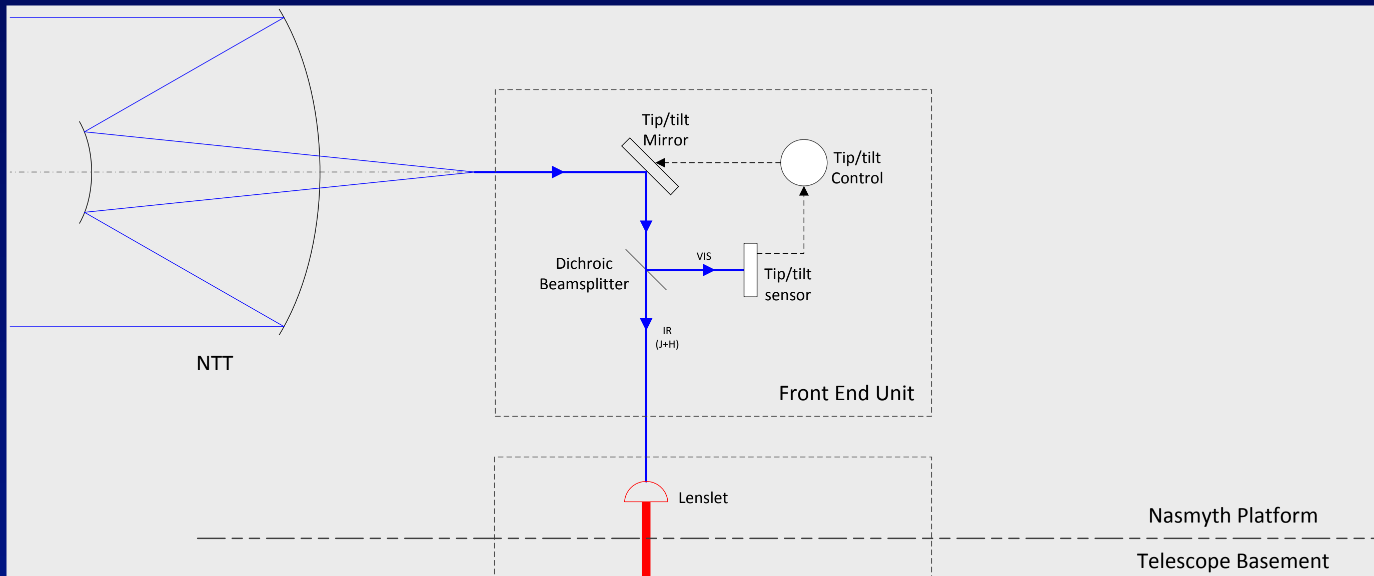
Design Baseline Concept

- Fed by photonic lantern
- Cross dispersed at fibre output in echelle spectrograph
- 4k IR detector
- Reflective camera
- Fixed echelle, cross disperser, camera
  - No mechanisms (in main optical path)

Photonic Spectrograph Layout (1)

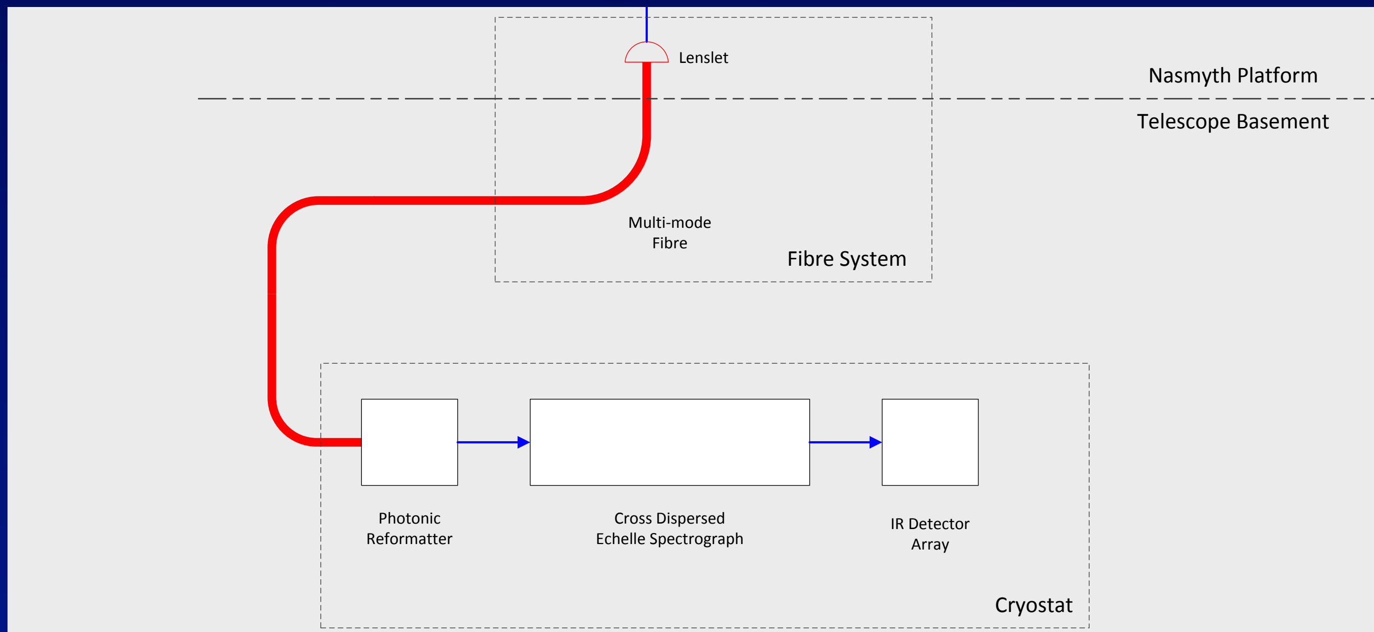


Photonic Spectrograph Layout (2)



- Light from telescope fed into Front End Unit (FEU) mounted on Nasmyth platform
- Visible light from target is split off onto a tip/tilt sensor via a dichroic beamsplitter
- This is used to control a tip/tilt mirror which stabilises the target image on the input to the fibre system
- IR light (J+H) passes though into the fibre system

Photonic Spectrograph Layout (3)



- **Beam enters multi-mode fibre via a lenslet - matches number of modes in fibre to number of modes in telescope PSF**
- **Fibre carries light to spectrograph located in telescope basement**
- **Photonic reformatter converts multi-mode fibre into linear array of single mode outputs**
- **Reformatted output forms entrance slit for spectrograph**
- **Slit is ~10 μm wide by 10.N μm high (N=number of modes)**
- **Narrow slit means smaller spectrograph for same spectral resolution compared to seeing limit or traditional image slicer spectrographs**
- **Efficiency ~5% (HARPS) -> >20%**

Mock survey – 100 nights/yr for 5 years assuming std overheads

Y=11.75 J=11.25 H=10.75, S/N=150 in 1hr

~Sp Type:	Mass	No. of stars
M2.5 V	0.3	200
M3.0 V	0.24	200
M4.0 V	0.19	200
M5.0 V	0.15	200
M6.0 V	0.12	114
M6.5 V	0.1	37
M8.0 V	0.09	14
M9.0 V	0.08	5
Total		970

Survey size of 1000 recommended by NASA exoplanet community report

Other Science

- Ionisation history of the Universe from rapid follow-up of z>7 GRBs
- Studies of weather, temperature, gravity and abundance for cool stars, particularly, brown dwarfs, protostars and M giants
- Zeeman Doppler Imaging
- Characterization of extrasolar planets
- Abundance analysis of comets
- Planetary weather and circulation patterns
- Asterioseismology
- Nuclear activity in nearby galaxies

Synergy

- **Optical transit surveys – many other ground-based transit search surveys .. coming K2, JWST, CHEOPS, TESS, PLATO**
- **Astrometric … GAIA**

Conclusion

- **Modelling indicates <1 m/s is achievable, >20% efficiency**
- **Limits probably driven by stability of stars**
- **Method to detect sub Earth-mass planets in habitable zones of *closest* stars**
- **Conservative design can achieve science goals**