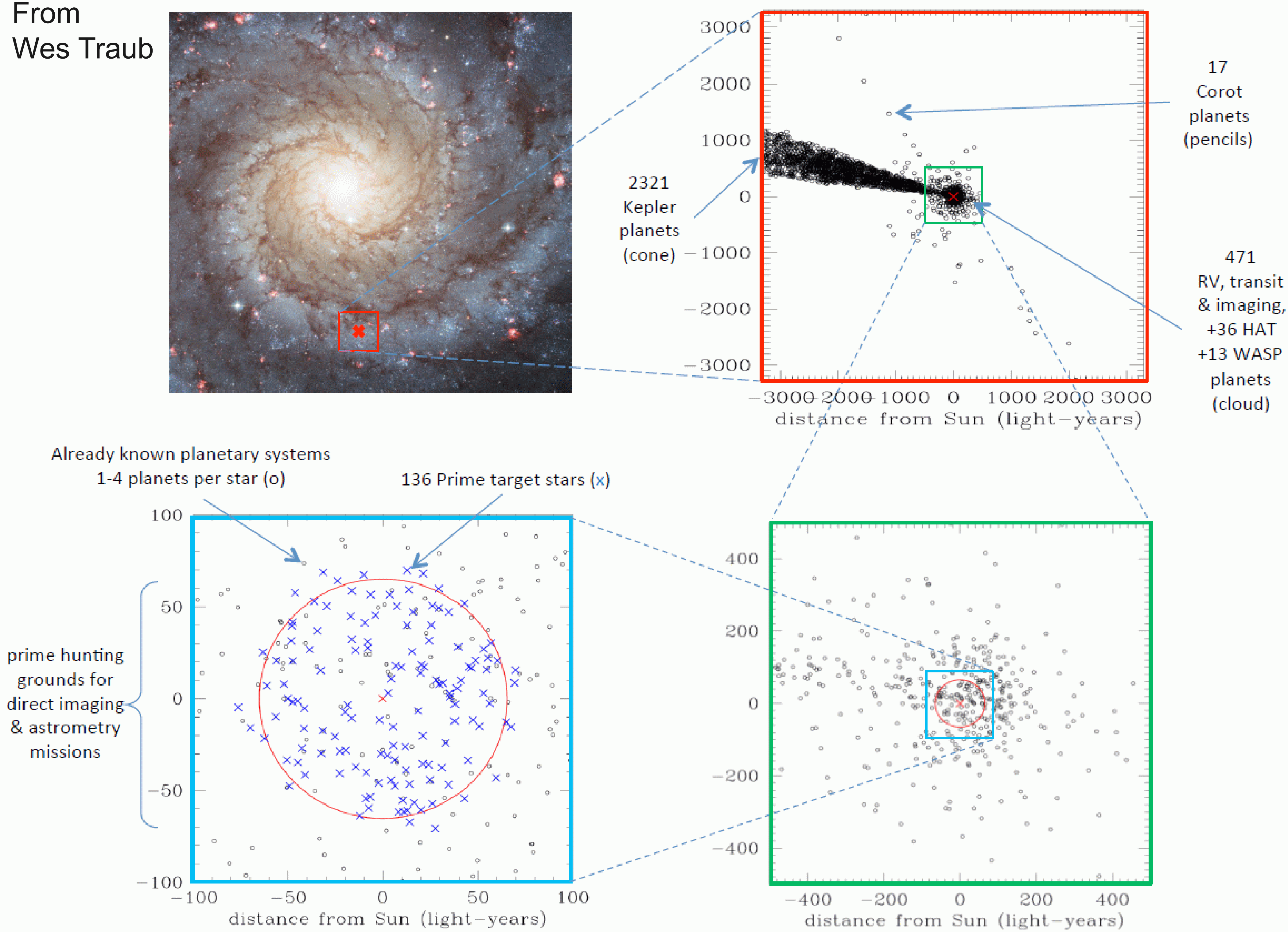
Topics from the recent Leiden workshop

Karl Stapelfeldt
NASA/GSFC

From
Wes Traub



Available information from selected exoplanet samples

Sample	Planet Radius	Planet Mass	Planet Orbit	Characterize Atmosphere	System
RV	No	Lower limit	Yes	No	Short periods & larger masses
Transit	Yes	Yes if RV, or if TT varies	Yes if RV	Yes for large Rp/R*	Short periods and coplanar
µLensing	No	Yes	partially	No	Mostly no
Ground AO imaging	Estimate from radiometry	Estimate from theory tracks	Yes	Yes	Larger masses
Nearby stars direct imaging & astrometry	Eventually estimate from radiometry	Yes	Yes	Yes	Yes except for shorter periods

47 Attendees: 20 from Holland, 15 from U.S.,
11 from other Europe, 1 from Japan. Several here today.
Guest speakers from European industry.

Workshop Goals

Reaffirm that nearby stars are the ultimate destination for what we want to do in exoplanet science

Take stock of what is being done and should be done for the nearby star sample

Keep common cause internationally and seek ways to revive it between space agencies

Conference Program
30 talks in the following areas:

- Observables and Measurements
- Frequency of Terrestrial Planets
- Dust and Debris Disks
- The potential of Groundbased Techniques: RV, transit, and high contrast imaging
- Current and Planned Space Missions
- Limitations from Stellar Variability
- Characterization of Nearby Stellar Hosts
- Mission Concepts for Terrestrial Planet Characterization
- Talks online at http://www.lorentzcenter.nl/lc/web/2012/507/info.php3?wsid=507

Workshop topics I'll side-step

Many topics redundant to ExoPAG 7:
alpha Cen Bb, present & future of RV,
Exoplanets & JWST, AFTA / WFIRST,
EXCEDE. GAIA.

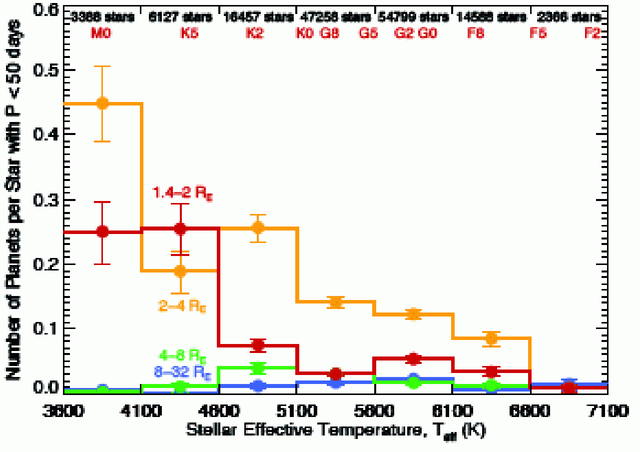
Imaging mission architectures :
discussed with all the diversity &
complexity we are familiar with

Planet Occurrence From Kepler

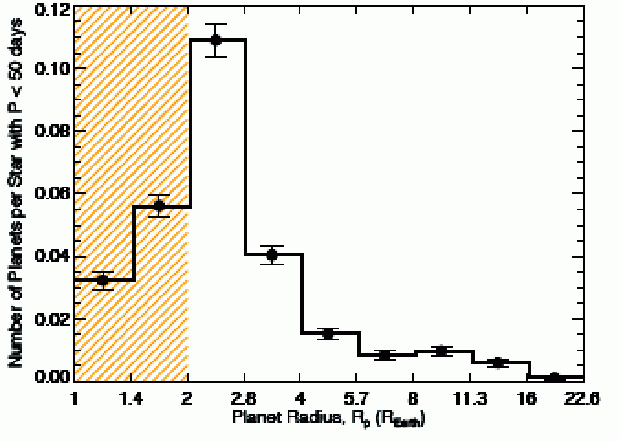
Andrew Howard

Conclusions:

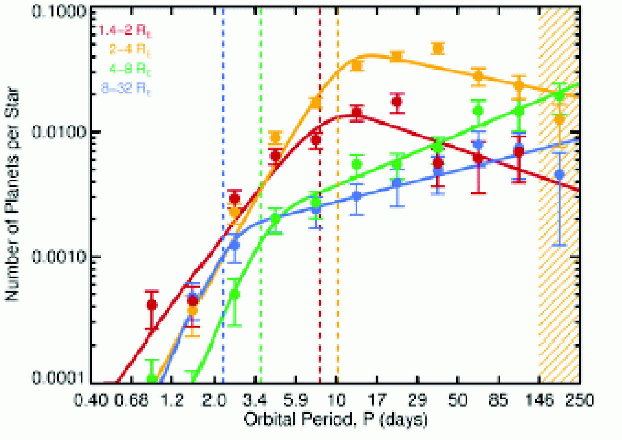
Small planets prefer small stars



Small planets are common

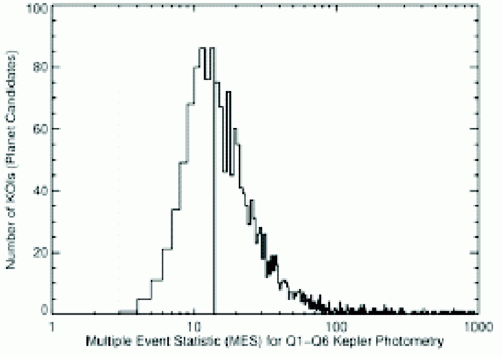


Orbital period distributions: truncated power law?

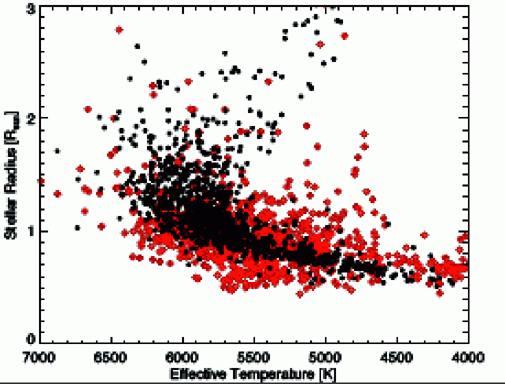


What's Needed?

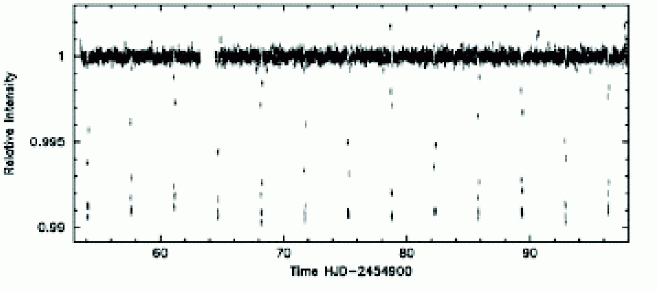
Completeness studies



Better stellar properties



Extended mission photometry



•Super Earths are puffy

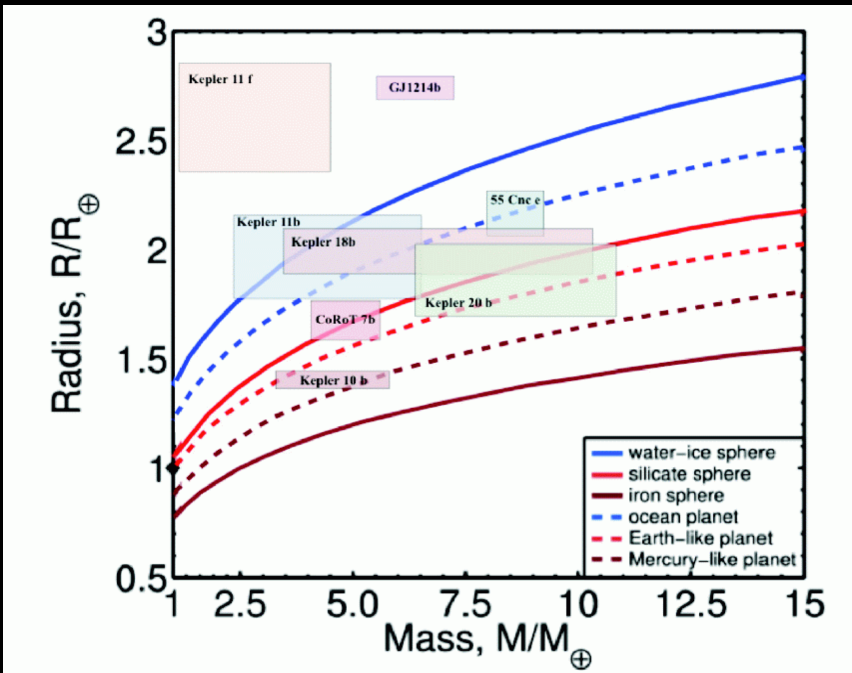
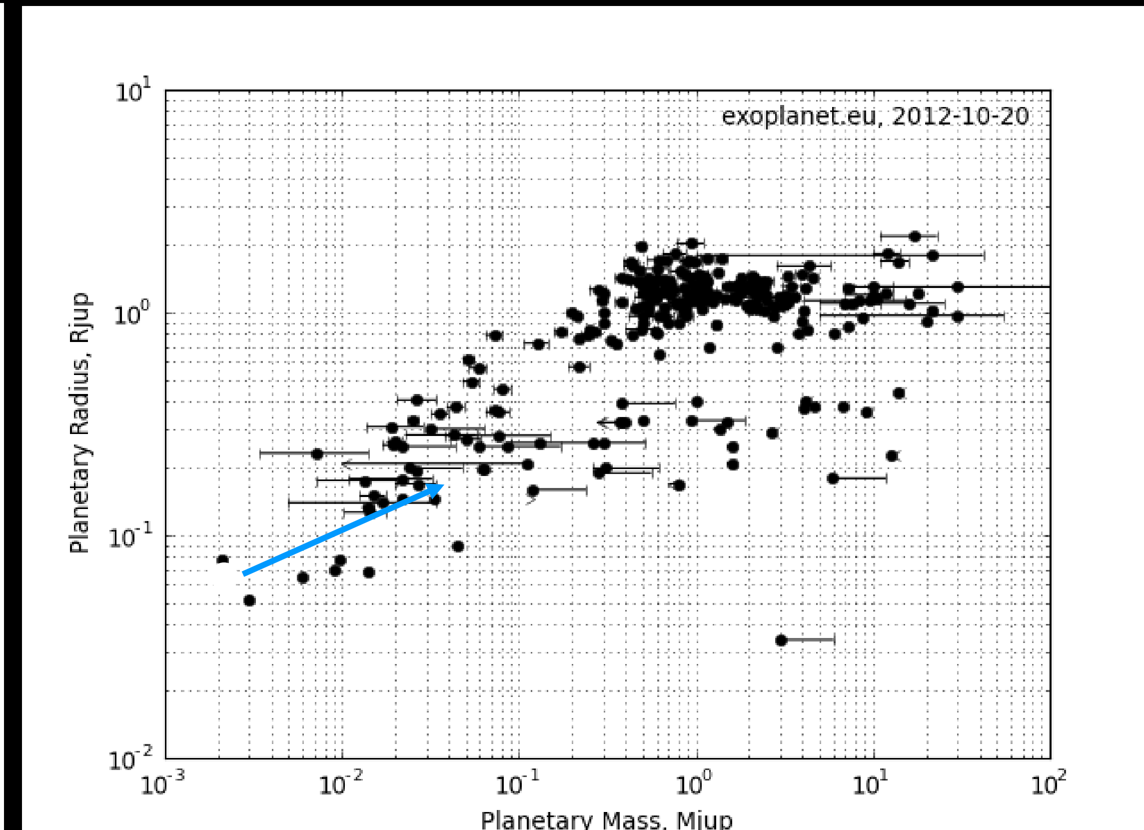


Figure 1: Mass-radius relationship for different bulk composition of the planet (Adapted from Wagner et al. 2011) with superimposed known transiting planets where both the mass and the radius of the planet have been measured. The size of the boxes indicates the 1-sigma error on these parameters. So far, in most cases the error bars

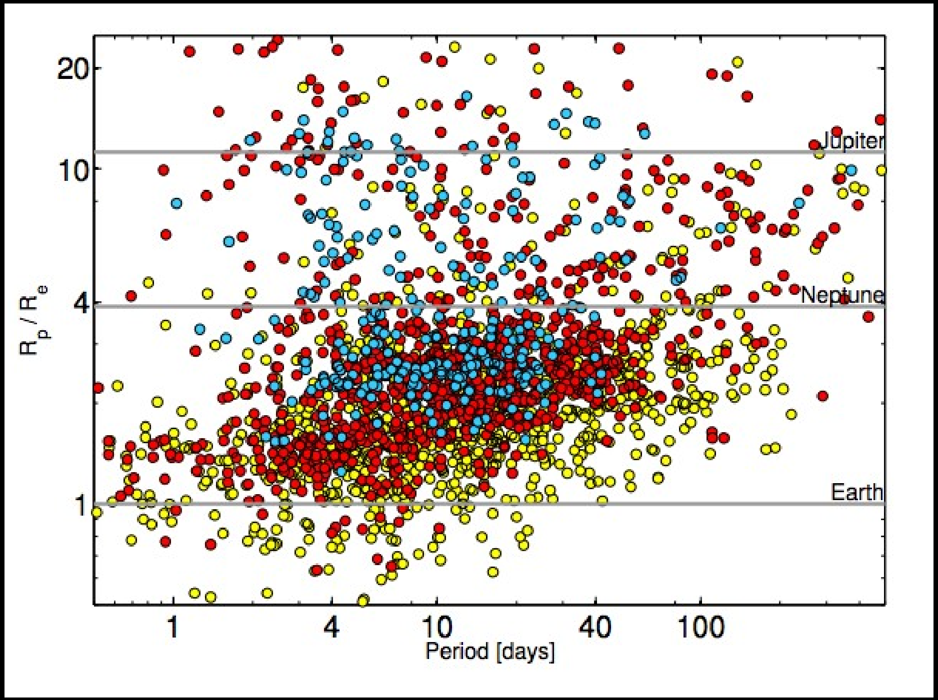


- Valencia et al. 2010 and Wagner 2011

- GJ 1214b density is 1.8 g cm-3 (2.7 Rearth)
- Neptune core mass is ~1.2 Mearth
- At 2.0 Rearth, already indications of volatiles

• Need ηrocky ; will Kepler provide it ?

- TPF goal is to find Earthlike planets. Super-Earths may not qualify.
- Massive atmospheres are unlikely to have large O2 mixing ratio:
- 1. Timescale may be too long for biological activity to effect conversion from CO2
- 2. O2 unstable in excess of H2

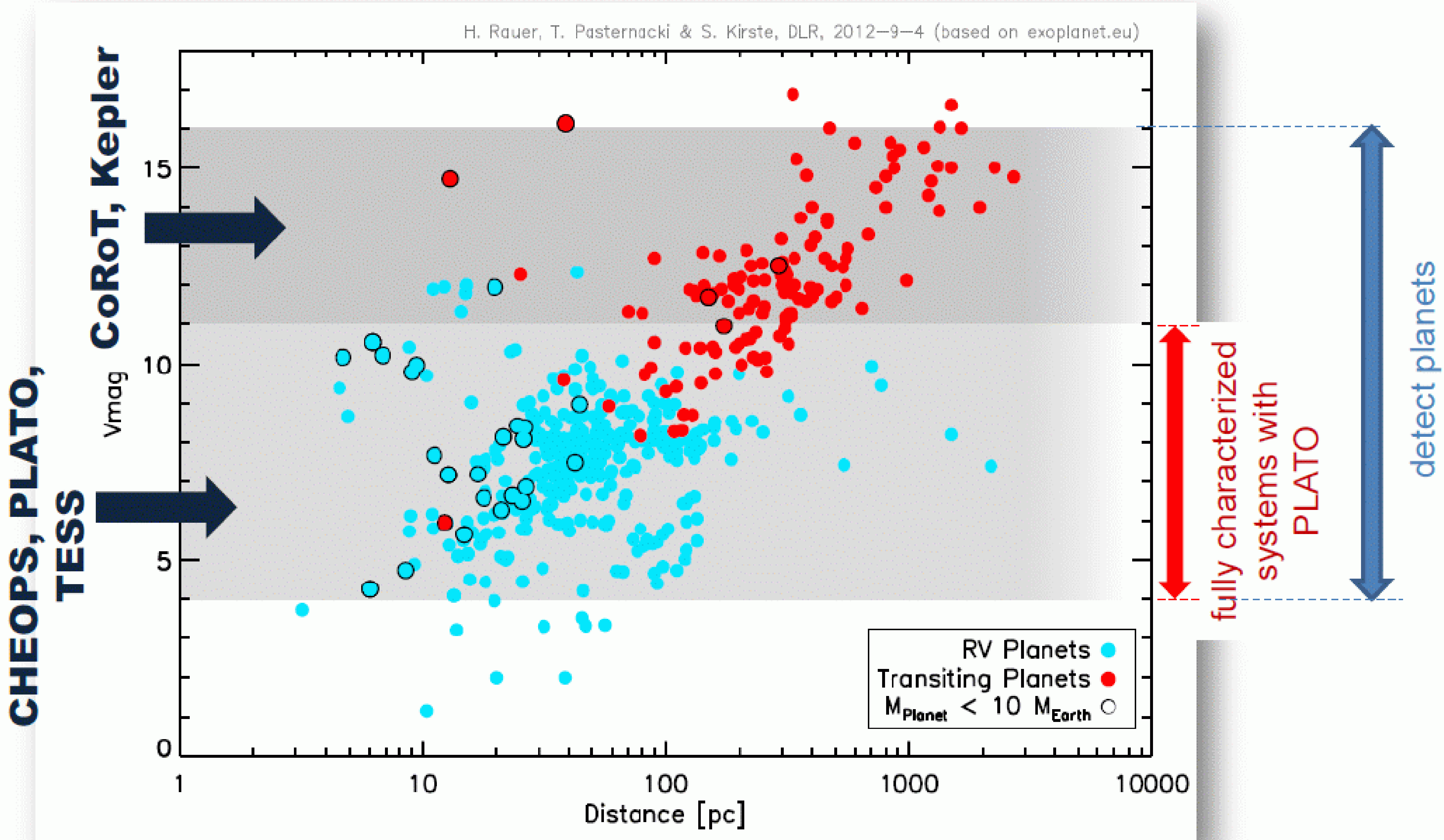


- Batalha et al. 2012

- Need more RV detections of small transiting planets: what is the largest radius consistent with a rocky planet ?

Heike Rauer

Future Transit Survey Magnitude Range



Luminosity function for cold dust

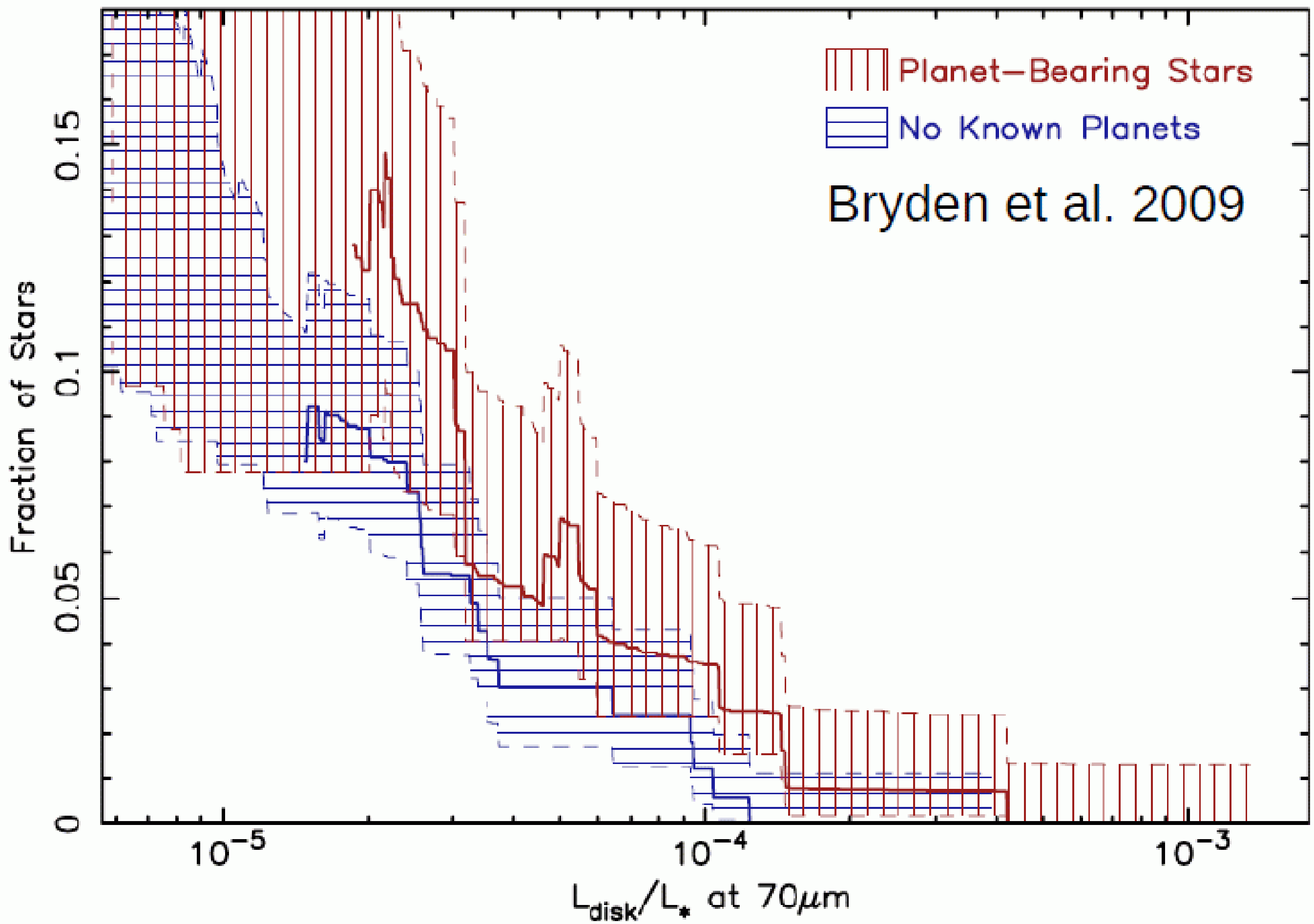


Figure 3. Cumulative fraction of stars with 70 μm excess as a function of disk luminosity for the planet and non-planet samples. As in Figure 1, the

N.B. planet-bearing stars show more dust !

•ExoPAG SAG 1 Report

PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, **124**:799–808, 2012 August

The Exozodiacal Dust Problem for Direct Observations of Exo-Earths

AKI ROBERGE,[1] CHRISTINE H. CHEN,[2] RAFAEL MILLAN-GABET,[3] ALYCIA J. WEINBERGER,[4] PHILIP M. HINZ,[5]
KARL R. STAPELFELDT,[1] OLIVIER ABSIL,[6] MARC J. KUCHNER,[1] AND GEOFFREY BRYDEN[7]

Received 2012 March 30; accepted 2012 June 7; published 2012 August 17

ABSTRACT. Debris dust in the habitable zones of stars—otherwise known as exozodiacal dust—comes from extrasolar asteroids and comets and is thus an expected part of a planetary system. Background flux from the solar system's zodiacal dust and the exozodiacal dust in the target system is likely to be the largest source of astrophysical noise in direct observations of terrestrial planets in the habitable zones of nearby stars. Furthermore, dust structures like clumps, thought to be produced by dynamical interactions with exoplanets, are a possible source of confusion. In this article, we qualitatively assess the primary impact of exozodiacal dust on high-contrast direct imaging at optical wavelengths, such as would be performed with a coronagraph. Then we present the sensitivity of previous, current, and near-term facilities to thermal emission from debris dust at all distances from nearby solar-type stars, as well as our current knowledge of dust levels from recent surveys. Finally, we address the other method of detecting debris dust, through high-contrast imaging in scattered light. This method is currently far less sensitive than thermal emission observations, but provides high spatial resolution for studying dust structures. This article represents the first report of NASA's Exoplanet Exploration Program Analysis Group (ExoPAG).

1. INTRODUCTION

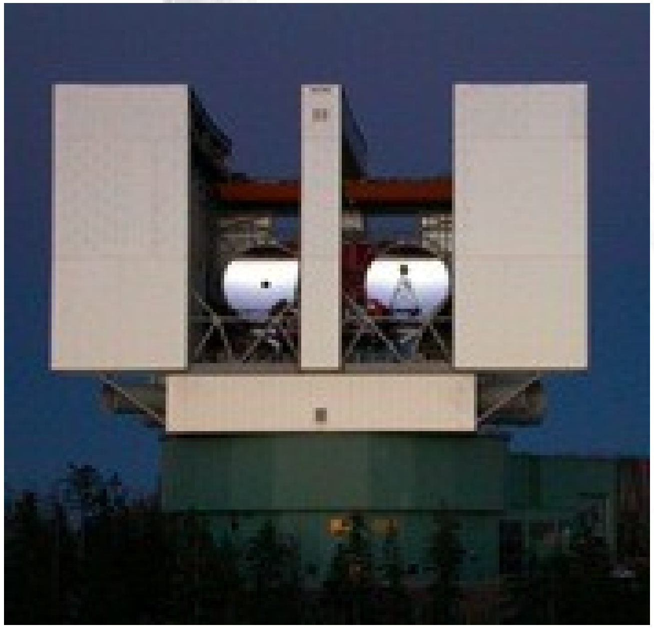
Interplanetary dust interior to the solar system's asteroid belt is called the zodiacal dust, which comes from comet comae and

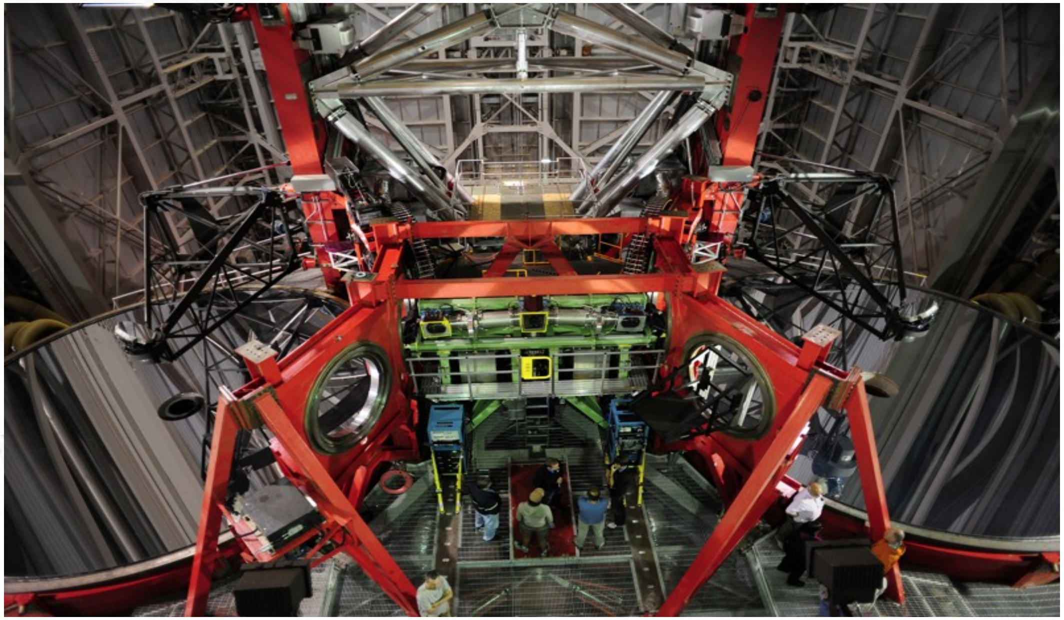
2009). However, a more sensitive survey for exozodiacal dust around a smaller set of nearby stars with the Keck Nulling Interferometer (KIN) found mostly nondetections (discussed further below; Millan-Gabet et al. 2011). As will be shown,

Large Binocular Telescope Interferometer

NASA-funded instrument to measure HZ exozodi in nearby stars, design performance to 10 zodi level. PI: Phil Hinz, Univ. Of Arizona

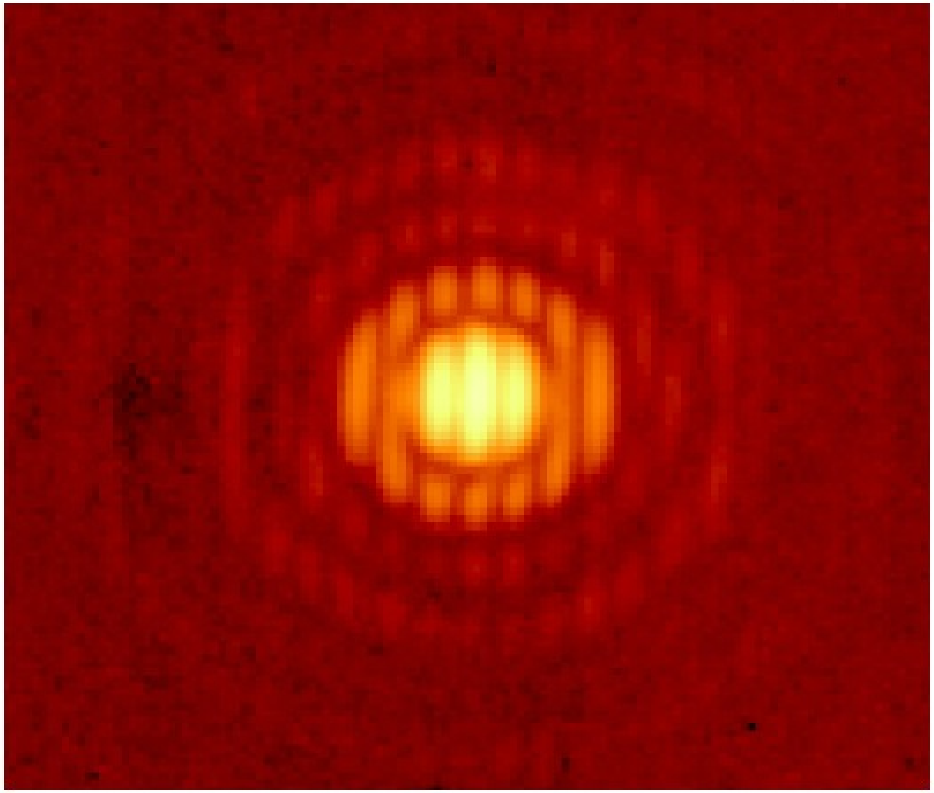
- 3 – 5 μm camera (LMIRCam) and 8 – 13 μm nulling interferometer (NOMIC)
- Science team selected, commissioning to complete in early 2013. Operational sensitivities pending





LBTI L' Interferometric Image

LMIRCam Imaging



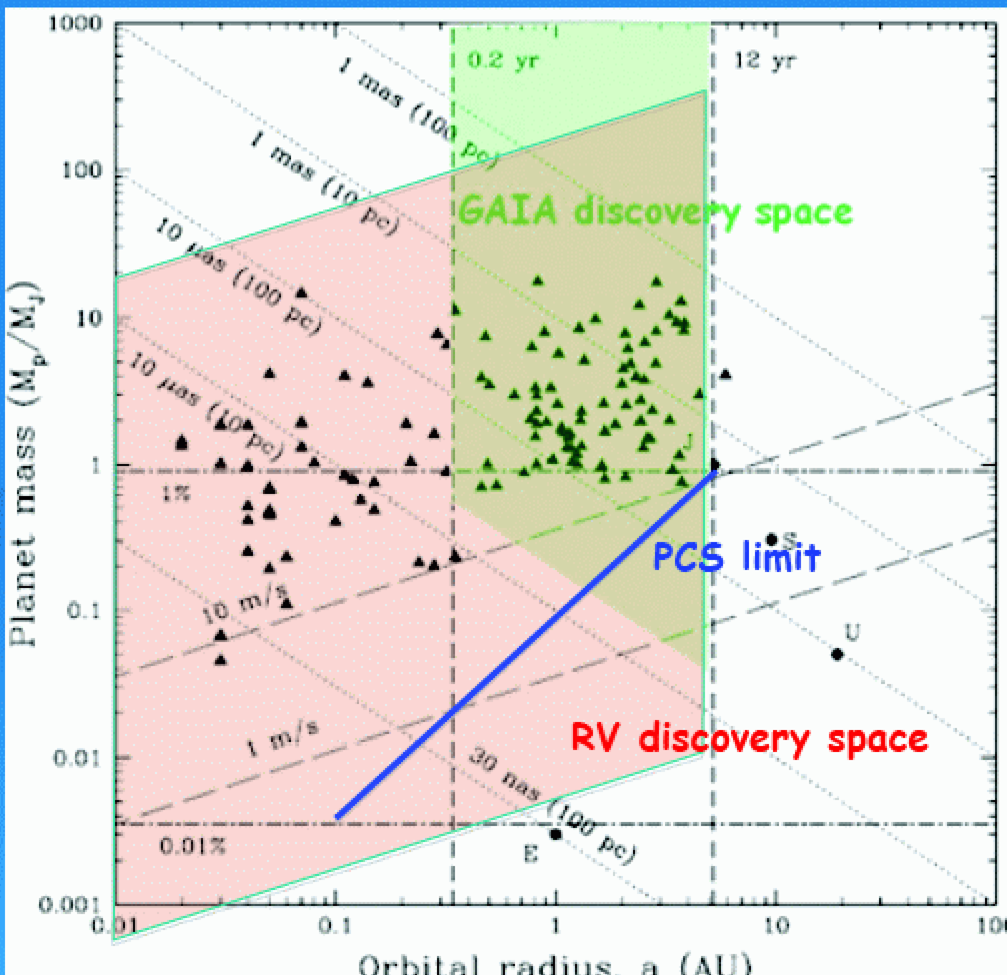
V=0.65

Best 5% of LMIRCam images in a sequence.

M. Kasper
ELT

Scientific context in 2025+

GAIA: Know orbits all Giant Exoplanets out to 5 AU within 50 pc
RV: Know orbits (but not orientation on-sky) of most rocky planets in the solar neighborhood out to ~0.5-1 AU, even in HZ for M-stars



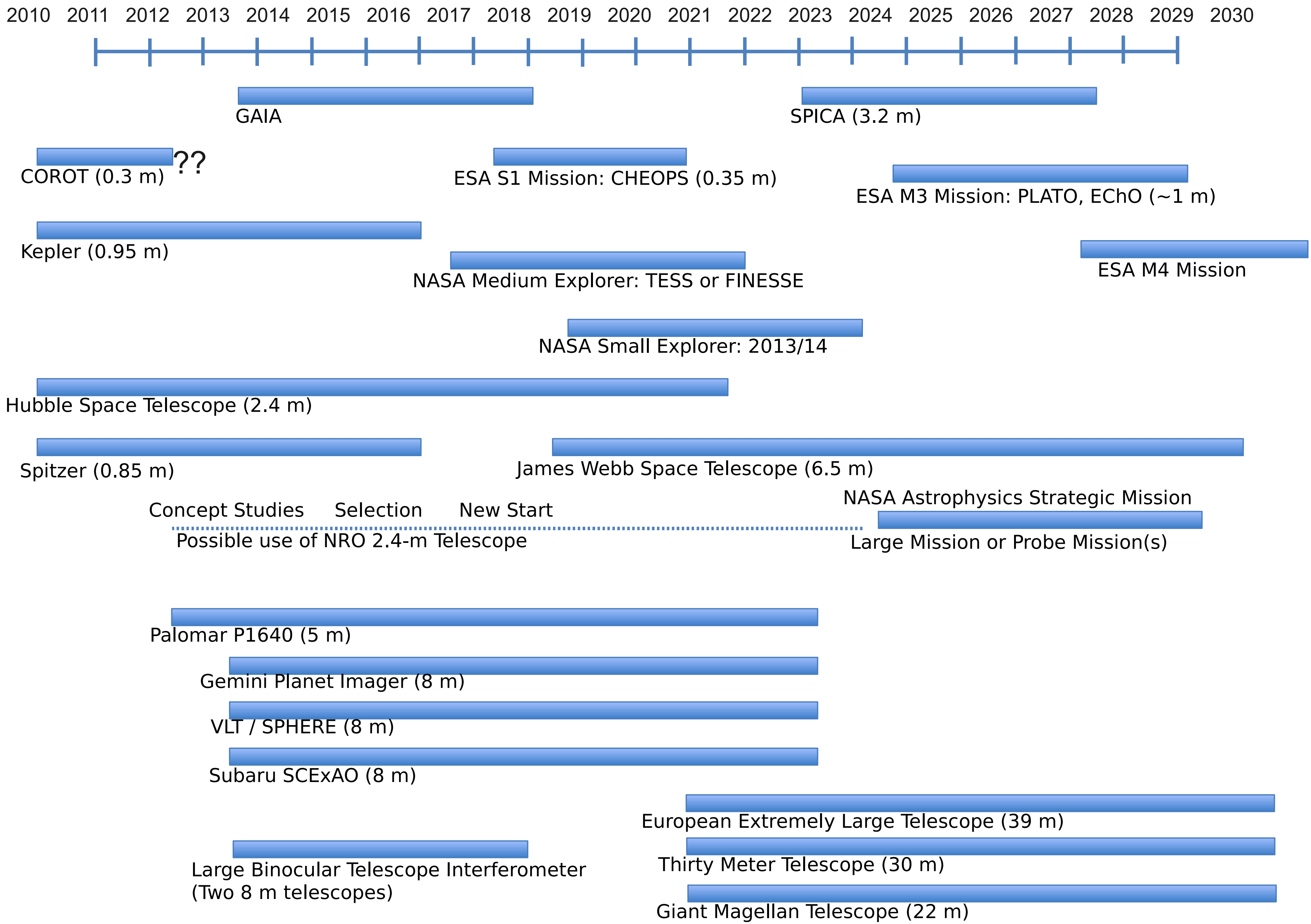
PCS

Jupiter @ 5 AU is 10^{-9},
Earth @ 0.1 AU is 10^{-8}
≈ PCS photon noise limit for stars J~4-6 in some hrs observing time

In reflected light, hard to go
a)further out or
b)lower mass at 5 AU

Science objectives:
1.Characterization of irradiated planets.
2.Survey of self-luminous Exoplanets (forming beyond snow-line SFR)

Large Project Planning Horizon: Peter Lawson



CHEOPS: New ESA S-class Transit mission selected

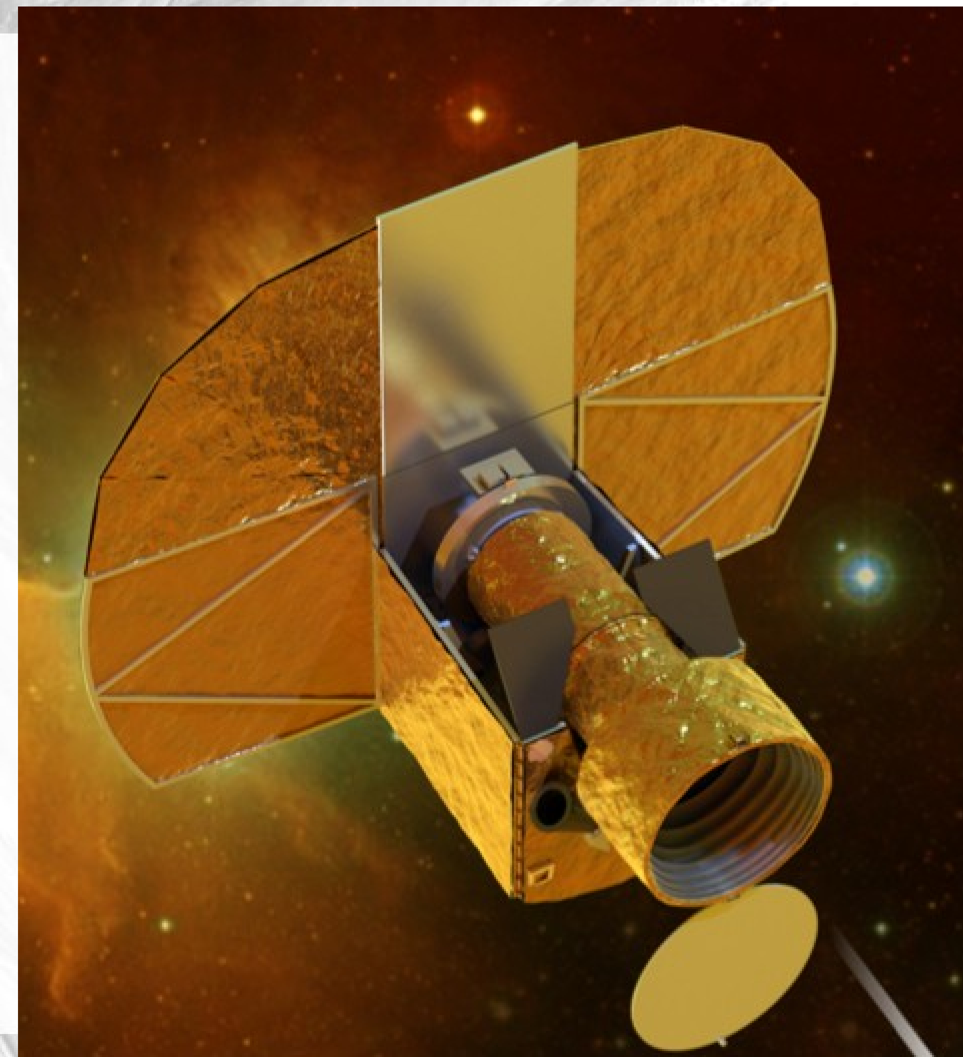
100 ppm per minute photometry of bright stars, one at a time

Targets stars with known or suspected planets

Prime science is investigation of planetary mass/radius relation

50 M Euros, 2017 launch
3.5 year mission

PI Willy Benz (Bern)



Chas Beichman

Do We Need A Target Finder?

No! Extrapolate from Kepler, precision RV, TESS, microlensing, that $\eta_{\oplus} > 10\%$ and just get on with building an imaging flagship to study 100 best stars.

"Requirement" that we find targets will delay spectroscopic mission by decades

BUT WE DO NEED ASTROMETRY: Overview by F. Malbet

Performance / Mission scale

Type of astrometry mission	Ground-based large telescope large field imaging	Ground-based optical interferometry differential narrow-angle astrometry	Space-borne wide-angle astrometry survey	Space-borne narrow angle astrometry
Project	LCO/CAPSCam, VLT/PALTA,...	VLTI/PRIMA (ESO)	Gaia (ESA)	NEAT-like
Status	in operation	commissioning	launch date: 2013	proposal
Availability	now	2014?	2015-2016	>2020?
Accuracy	**0.1-1mas**	**10-50 μas**	**25 μas**	**0.2 μas**
Exoplanet targets	Giant planets around M stars	Giant planets around solar-type stars	Giant planets around several 10^5s of stars of different types	70 Earths in HZ of F-G stars
		Neptunes around M stars		survey of systems around different stars
	Neptunes around brown dwarfs	Young planetary systems		Young planetary systems
Mission scale	**Existing**	**Existing**	**M-type mission**	**M-type mission**

Next Steps

Complete first draft of workshop summary report, iterate with the SOC and workshop attendees. Consensus-based report.

Provide report to astronomy community and space agency management to inform future programmatic decisions

Promote international formulation of missions to study our nearest neighbors