XPIDER

Exoplanet Interferometer

Detecting Earth Relatives

Big-picture

Past and Present: HST, Spitzer, Kepler, Ground-based

The Next Decade: Ground-based, Kepler, JWST, TPF-Darwin

What has been done: physical properties, atmospheres of hot Jupiters

What can be done: Atmospheres of transiting super-Earths (JWST)

What cannot be done ?

The Question to ask:

What will humanity look forward to in 10 years ?

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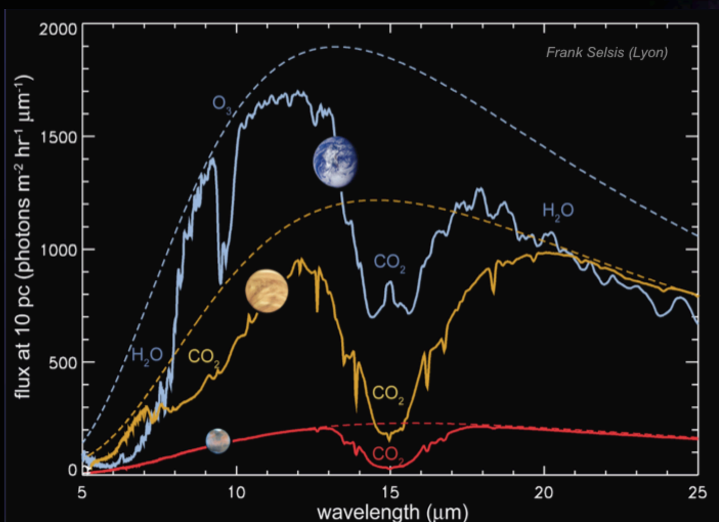
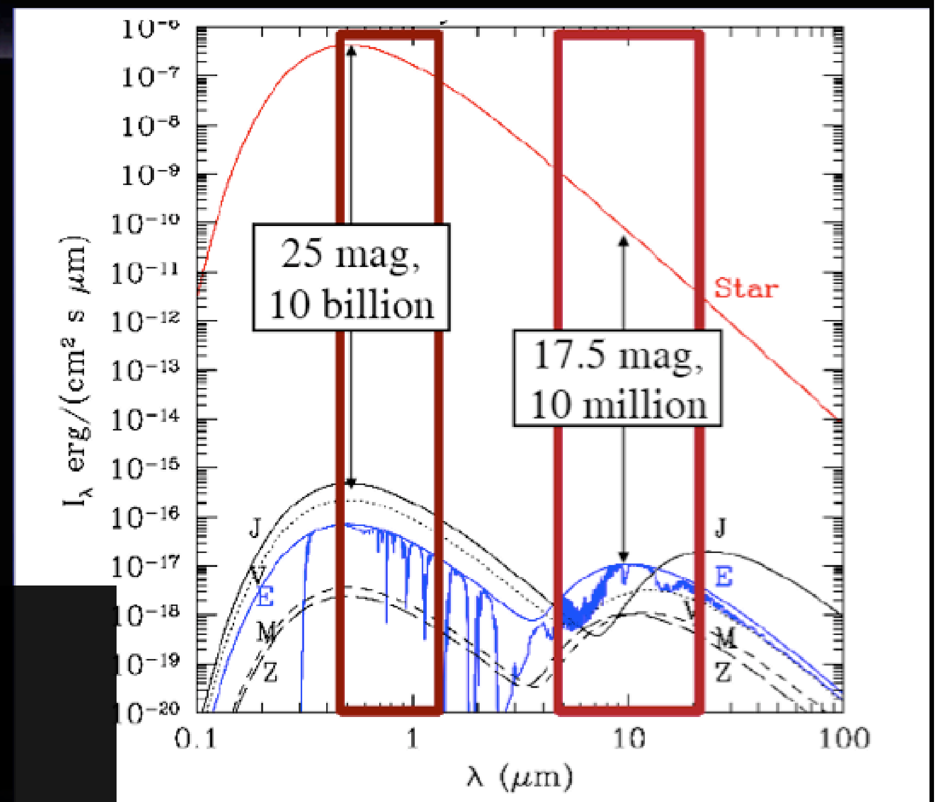
The exo-Earth argument





For detection HZ (SNR~5):
- M stars, 32 hours, 26 targets, = 35 days total integration
- K stars, 64 hours, 25 targets, = 67 days total integration
- G stars, 128 hours, 38 targets, = 203 days total integration

~ 300 days of integration needed for detection phase, assume 50% integration time = 600 days total for detection phase

For characterization H20 (SNR~10)
- M stars, 2.5 days integration
- K stars, 25 days integration
- G stars, 250 days integration

- Follow-up characterization of candidates from RV and transits (90 candidates)
- M,G,K stars within 17 pc
- Bio signatures: H2O, CO2, CH4, O3

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Primary Science Matrix

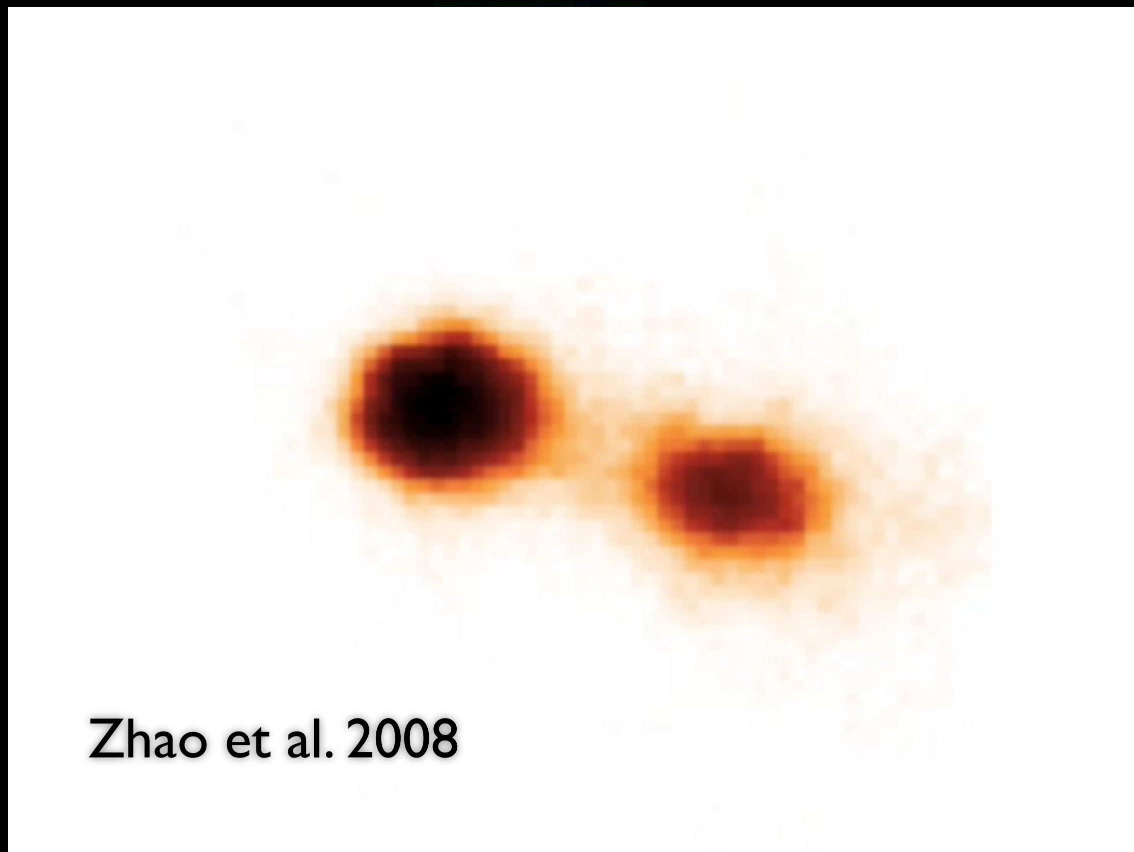
Science Objectives	Measurement Objectives	Measurement Requirements	Instruments	Mission Requirements
Detection and characterization of Habitable planets	• Direct imaging • Mid-IR Spectroscopy • Detection	• Nulling interferometry • 10 mas ang res • 6-20 micron spectroscopy	• 4 x 1m telescopes • 500 m base line • mid-IR spectrograph	• Pointing stability • Thermal stability • Multi-year time span
Comparative exoplanetary science	• Direct imaging of multiple-planet systems • Direct imaging of range of planets	• Nulling interferometry • 10 mas ang res • 6-20 micron spectroscopy	• 4 x 1m telescopes • Variable base line • mid-IR spectrograph	• Pointing stability • Thermal stability • Multi-year time span
Study of formation and evolution of planetary systems	• Direct imaging of debris disks • Direct imaging of young stars	• Imaging interferometry • 10 mas ang res • 6-20 micron spectroscopy	• 4 x 1m telescopes • Variable base line • mid-IR spectrograph	• Pointing stability • Thermal stability
Microlensing	• Gravitational lensing images • post-event follow-up	• Imaging interferometry • 10 mas ang res	• 4 x 1m telescopes • Variable base line	• Pointing stability • Thermal stability

Additional Science Matrix

Science Objectives	Measurement Objectives	Measurement Requirements	Instruments	Mission Requirements
Direct Imaging of circumstellar disks	• Direct imaging • Mid-IR Spectroscopy • Density and T profiles	• Interferometry •10 mas ang res • 6-20 micron spectroscopy	• 4 x 1m telescopes • 500 m base line • mid-IR spectrograph	• Pointing stability • Thermal stability
Interacting Binaries	• Roche Lobe imaging • Orbits, mass-transfer • Interacting magnetic fiellds	• Interferometry •10 mas ang res • 6-20 micron spectroscopy	• 4 x 1m telescopes • 500 m base line • mid-IR spectrograph	• Pointing stability • Thermal stability
Star spots	•Interferometric imaging of stellar surfaces • Differential T measurements	• Interferometry •10 mas ang res • 6-20 micron spectroscopy	• 4 x 1m telescopes • 500 m base line • mid-IR spectrograph	• Pointing stability • Thermal stability
AGNs	• Direct imaging of dusty torus	• Interferometry •10 mas ang res • 6-20 micron spectroscopy	• 4 x 1m telescopes • 500 m base line • mid-IR spectrograph	• Pointing stability • Thermal stability

Guest Observer Programs

Imaging Roche Lobes



Zhao et al. 2008

Telescope and Instruments

Telescope : 4 x 1m aperture in formation flight
Instruments : Long baseline interferometer + mid-IR spectrometer
Baseline : 500 m
Wavelength :

- Imaging - 10 micron
- Spectroscopy: 6 - 20 micron

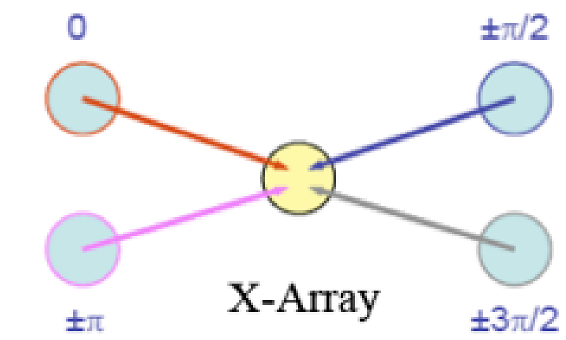
Resolution :

- Angular - 2 mas
- Spectral - 25

Sensitivity : 4.8 microJy, 10 microns, 15 hours

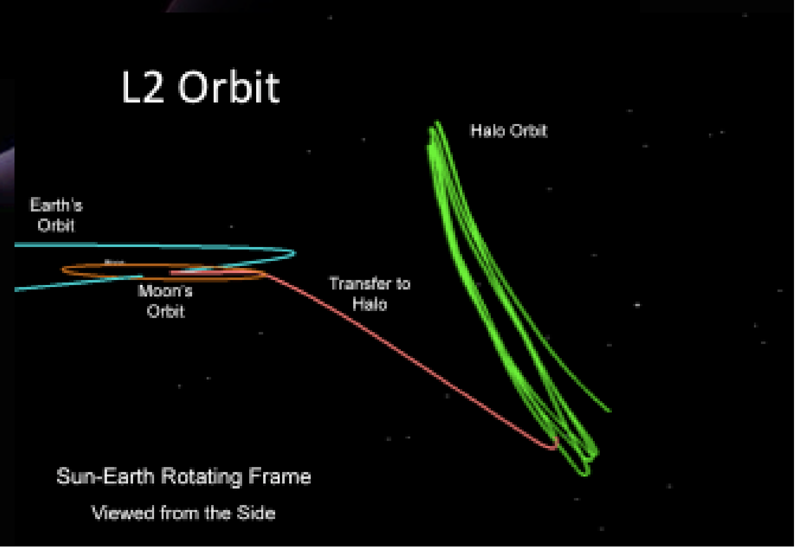
Duration :

- Mission life-time - 5 years
- Extendable life-time - 3 years



L2 Orbit

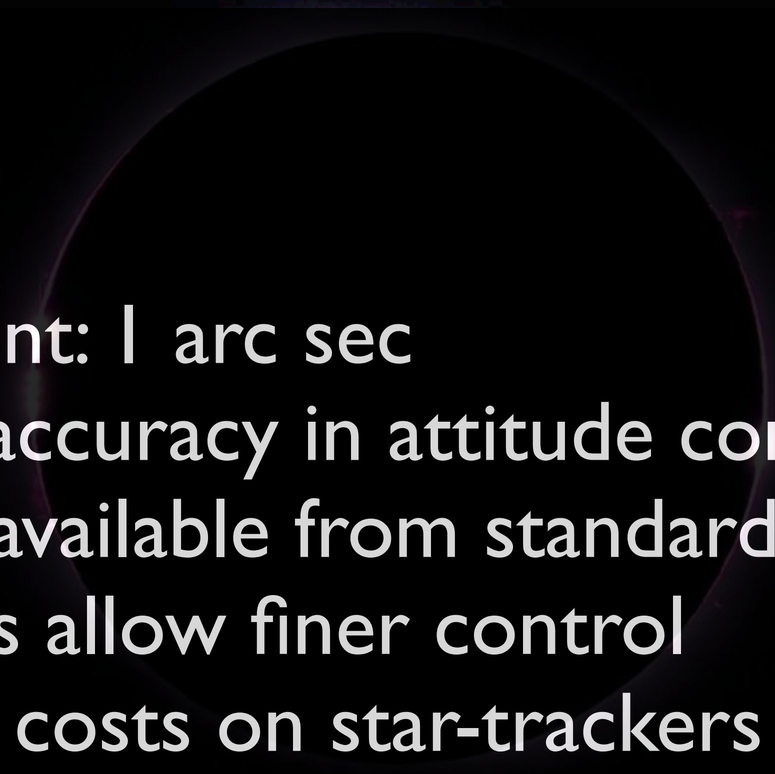
- Requirement of low thermal background : L2
- Requirement of better communication bandwidth for control of formation flight



Data volume and rate

- Data volume requirements : 5 kbps x 25 (easy to meet requirements)
- Standard telecom hardware (X-band, for L2)

Pointing requirements



- Requirement: 1 arc sec
- 1 arc sec accuracy in attitude control of the spacecraft is available from standard star-trackers
- Delay lines allow finer control
- Minimizes costs on star-trackers

Spacecraft Buses

- Need 5 spacecraft on a single Launch vehicle: 4 x 1m + beam combiner.
- Each spacecraft = $ 250M (Custom made bus) x 5 = $ 1250M
- Mass: 5 x 300kg = 1500 kg

Launch Mass

26 % margin on launch mass

SYSTEMS WORKSHEET:				***FY08Q2 Templates Spacecraft***	
	Mass Fraction	**Mass (kg)**	**Subsys Cont. %**	**CBE+ Cont. (kg)**	**Mode 1 Power (W) Launch**
Power Mode Duration (hours)					
Payload on this Element					
Instrument 1	26%	600.0	35%	810.0	0
Instrument 2	5%	120.0	43%	171.6	
Instrument 3	1%	20.0	43%	28.6	
Instrument 4	2%	40.0	43%	57.2	
Instrument 5	0%		43%	0.0	
Instrument 6	0%		43%	0.0	
Instrument 7	0%		43%	0.0	
Payload Total	34%	**780.0**	37%	**1067.4**	**0**
Spacecraft Bus			do not edit formulas below this line, use the c		
Spacecraft	65%	1500.0	30%	1950.0	
S/C-Side Adapter	1%	25.0	5%	26.3	
Bus Total		1525.0	30%	1976.3	
Thermally Controlled Mass				1976.3	
Spacecraft Total (Dry)		2305.0	32%	3043.7	0
Subsystem Heritage Contingency		738.7	32%	32%	
System Contingency		252.5	11%	11%	0
Spacecraft with Contingency		**3296**	of total	w/o addl pld	**0**
Propellant & Pressurant1	7%	250.0			
Spacecraft Total (Wet)		**3546**			
L/V-Side Adapter		100.0			
Launch Mass		**3646**			
Launch Vehicle Capability		**3495**			
Launch Vehicle Margin		**-151.2**			
JPL Design Principles Margin		**26%**	**30% required**		

Major Risks

- Novel mission type: Lack of precursor missions
- Formation flight not demonstrated at this level
  - Navigation
  - Propulsion
- Challenges in interferometry
  - laser metrology
  - long term performance of nulling
- Cooling : Need to design details, but Spitzer is proof in action

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Total Mission Cost

COST SUMMARY (FY2009 $M)

WBS Elements	Total		
Project Cost ($ FY09)	$2948.3 M		
Development Cost (Phases A - D)	$2639.8 M		
01.0 Project Management	$101.5 M	5% of development	
02.0 Project Systems Engineering	$101.5 M	5% of development	
03.0 Mission Assurance	$81.2 M	4% of development	
04.0 Science	$30.0 M		
05.0 Payload System	$310.0 M		
Instrument 1 (4 x 1m telescopes)	$200.0 M		
Instrument 2 (Interferometer)	$70.0 M		
Instrument 3 (Laser telemetry)	$20.0 M		
Instrument 4 (Spectrometer)	$20.0 M		
Instrument 5			
06.0 Flight System	$1250.0 M		
07.0 Mission Operations Preparation	$15.0 M	$15M	
09.0 Ground Data Systems	$15.0 M	$15M	
10.0 ATLO	$109.2 M	7% of Payload and Fligh	
11.0 Education and Public Outreach	$10.2 M	0.5% of development	
12.0 Mission and Navigation Design	$7.0 M	$7M	
Development Reserves	$609.2 M	30%	
Operations Cost (Phases E - F)	$172.5 M		
Operations	$150.0 M	$30M/yr	5
Operations Reserves	$22.5 M	15%	
8.0 Launch Vehicle (L/V B)	$136.0 M		

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This is what humanity will look forward to in 10 years.

Team Xpider

- Nikku Madhusudhan
- Yamina Touhami
- Jessie Christiansen
- David Bernat
- Andrew Fittingoff
- Krista Soderlund
- Padma Yanamandra-Fisher

Scientific Advisors

- Rachel Akeson
- Keith Wafield