Spitzer Status

Presented to COPAG and ExoPAG
June 5, 2014
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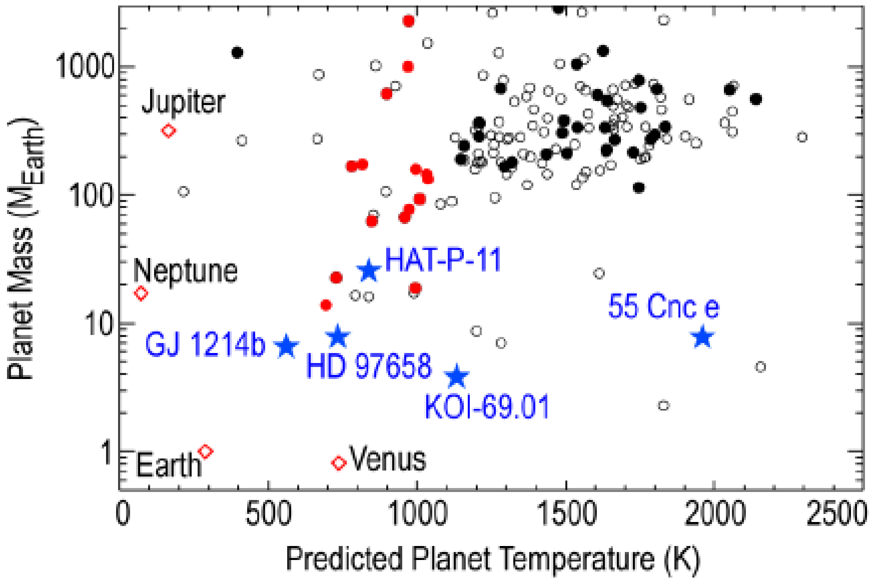
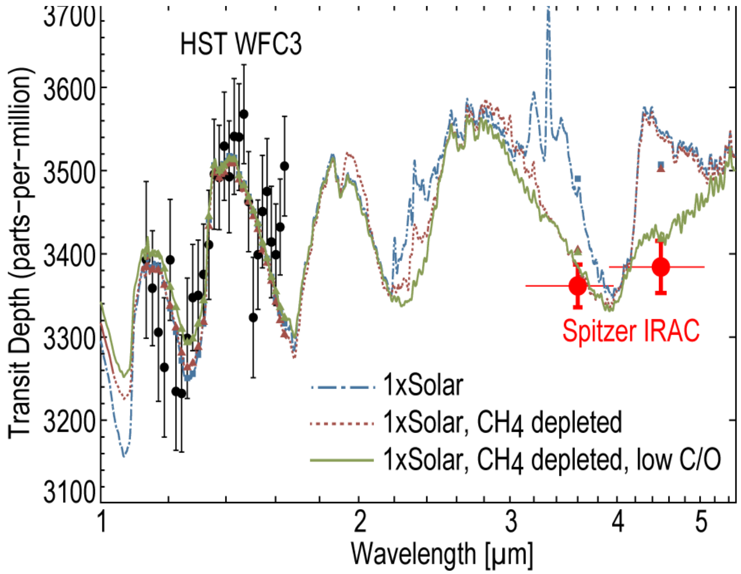
Motivation

- Spitzer very important for both Cosmic Origins and Exoplanet Science
- Spitzer is threatened with cancellation as a result of the recently concluded Astrophysics Senior Review
- We seek support for a discussion or presentation to the ASC in August advocating increased support for the entire Senior Review portfolio, with Spitzer as an example of lost science

Spitzer Exoplanet Science



• Targets for *Knutson et al.* study of metallicity versus mass for eclipsing exoplanets.



Spitzer & HST measurements of Exo-Neptune HAT P-11-b in transit

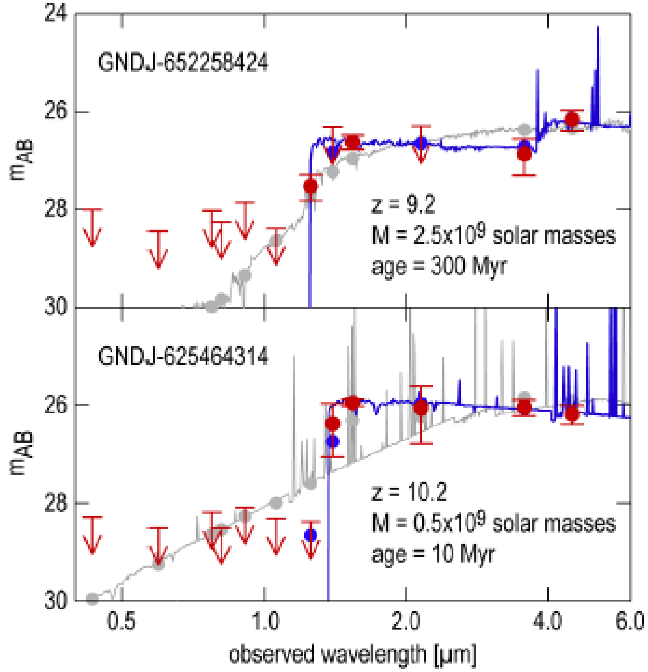
- Only Spitzer provides information about exoplanet temperatures
- Improved control of systematics allows Spitzer exoplanet studies to achieve precision <30 ppm, supporting push to smaller, colder planets
- Spitzer measurements probe carbon content of exoplanet atmospheres
- Spitzer [often in tandem with HST] identifies most important exoplanet targets for study with JWST.

Spitzer: Maintaining Exoplanet Science Momentum into JWST Era

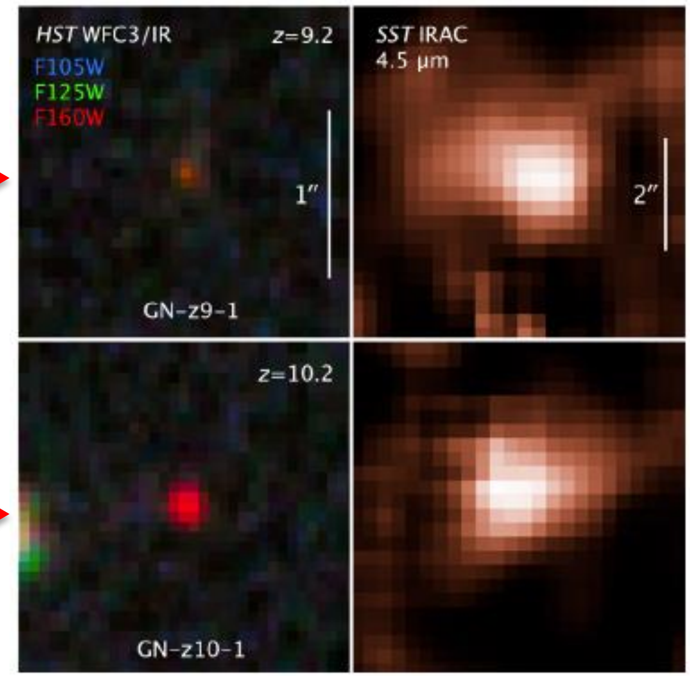
- **New techniques for exoplanet studies**
  - Transit timing variations
  - Microlensing parallax
  - Eclipse mapping
- **Improved methodology enables studies of cooler and smaller exoplanets - down to < $2R_{earth}$ in size.**
- **Follow-up of discoveries from ground-based transit searches, (including MEarth-South and NGTS) and K2.**
- **Synergistic measurements with HST/WFC3 – pointing the way for JWST. Identify planets with atmospheric haze requiring eclipse measurements**
- **Large samples will continue to address focused questions**
- **High sensitivity data will continue to drive atmospheric modeling.**

Witnessing Cosmic Dawn – Cosmic Origins Science with Spitzer

<u>Direct detection</u> of z ≈10 galaxies with Spitzer and HST



HST WFC3/near-IR Spitzer IRAC 4.5 μm



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Neither Great Observatory can do this alone.

These will be challenging but important targets for early mission JWST spectroscopy, before JWST surveys complete

← **JWST spectroscopy, R=100, S/N = 10 in 10,000s**

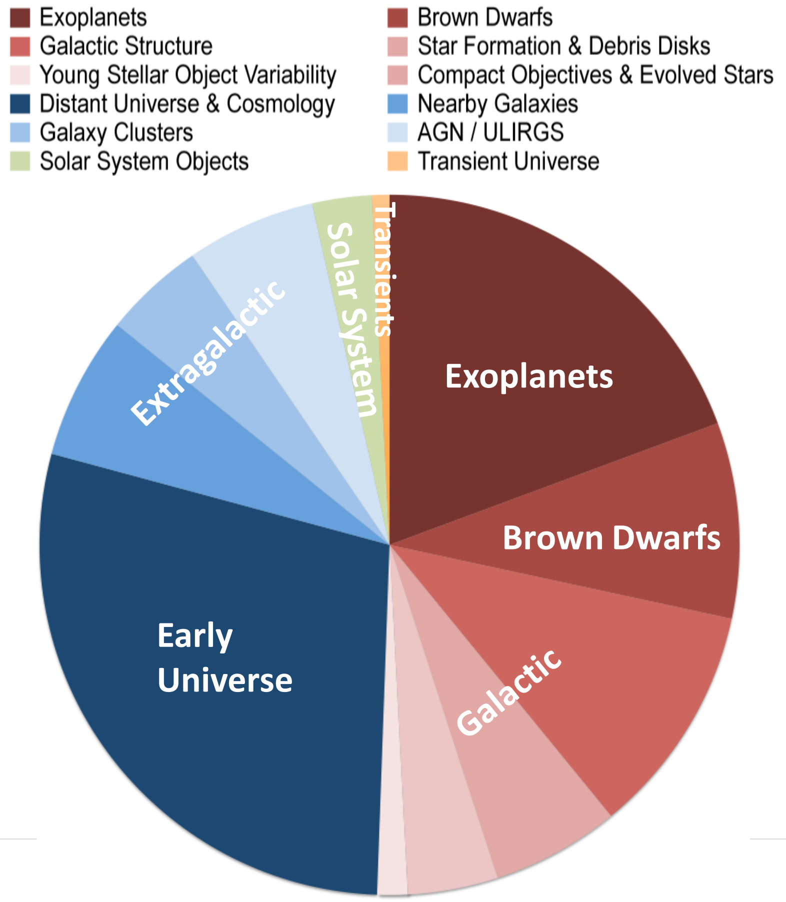
Spitzer Extragalactic Origins Science in 2015 – 2018

- **Determine galaxy ages and masses at z > 9. Defines the z > 12-15 galaxy landscape that JWST will explore.**
  - Complete Frontier Fields [currently only 4 of 6 scheduled]
  - Establish targets for early mission spectroscopy from JWST
- **Constrain stellar populations in 5 < z < 8 galaxies**
- **Confirm and measure high-z cluster candidates from Planck, WISE, SPT-pol, e-ROSITA, etc.**
- **Continue expanding role in time-domain extragalactic science (RR-Lyrae, Novae, and SNe in nearby galaxies).**
  - 197 variables and transients discovered in first ~30 hours of a systematic search for such phenomena.

Breadth of Science

- **100% of time available to the community (GO & DDT)**
  - All science is peer reviewed
- **Observatory supports 55 - 70 GO programs/cycle plus ~ dozen DDTs**
- **Cycle-10 Highlights:**
  - 7x oversubscription is highest ever
  - 40% of successful programs are led by first-time Spitzer PIs

Warm Mission:
Distribution of time by science category.



Spitzer Reclama

- **NASA Astrophysics invited Spitzer to reclama against the possibility of shutdown**

- **We propose to operate as a community observatory for $17.2M/yr, [including $3M in user community funding], in 2016 and beyond.**
  - Reclama request is $4.3M less than FY2014 budget, which, in turn was $4.5M less than FY2010 – the initial year of the Warm Mission
  - Reclama request is $2M less than proposed to Sr. Review for this observatory mode

- **$14.2M currently budgeted for Spitzer in FY2015; however, $6M of that is GO funding for earlier cycles. We feel we must honor this commitment. Thus we requested $7.5M of new funds to permit operations in 2015 as well.**

- **We are seeking near term relief to get Spitzer through 2015**
  - Cycle 11 Call for Proposals currently on hold

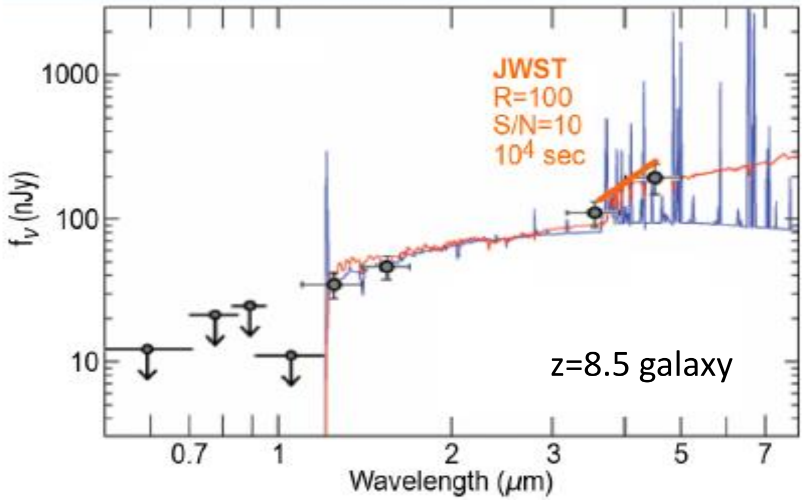
The Bigger Picture – Focus on 2016 Budget is Important

- **From the Senior Review Report:**
  - "The operation of the nation's space borne observatories is so severely impacted by the current funding climate....that the SRP feels that American pre-eminence in the study of the Universe from space is threatened to the point of irreparable damage if additional funds cannot be found to fill the projected funding gaps"
- **Other missions than Spitzer have also been adversely affected by results of the Senior Review process**
- **We seek support for a discussion or presentation to the ASC in August advocating increased support for the entire Senior Review portfolio, not just Spitzer**
  - ExoPAG and CoPAG might comment specifically on loss of Spitzer capabilities, perhaps using examples above and beyond those cited here

BACKUP SLIDES

Spitzer is Highly Synergistic with Other NASA Missions

- **HST and JWST**
  - Spitzer + HST together set the stage for detailed studies with JWST, e.g. metallicity at high-z
  - Spitzer transit and eclipse photometry identify [with HST] best exoplanets for JWST study



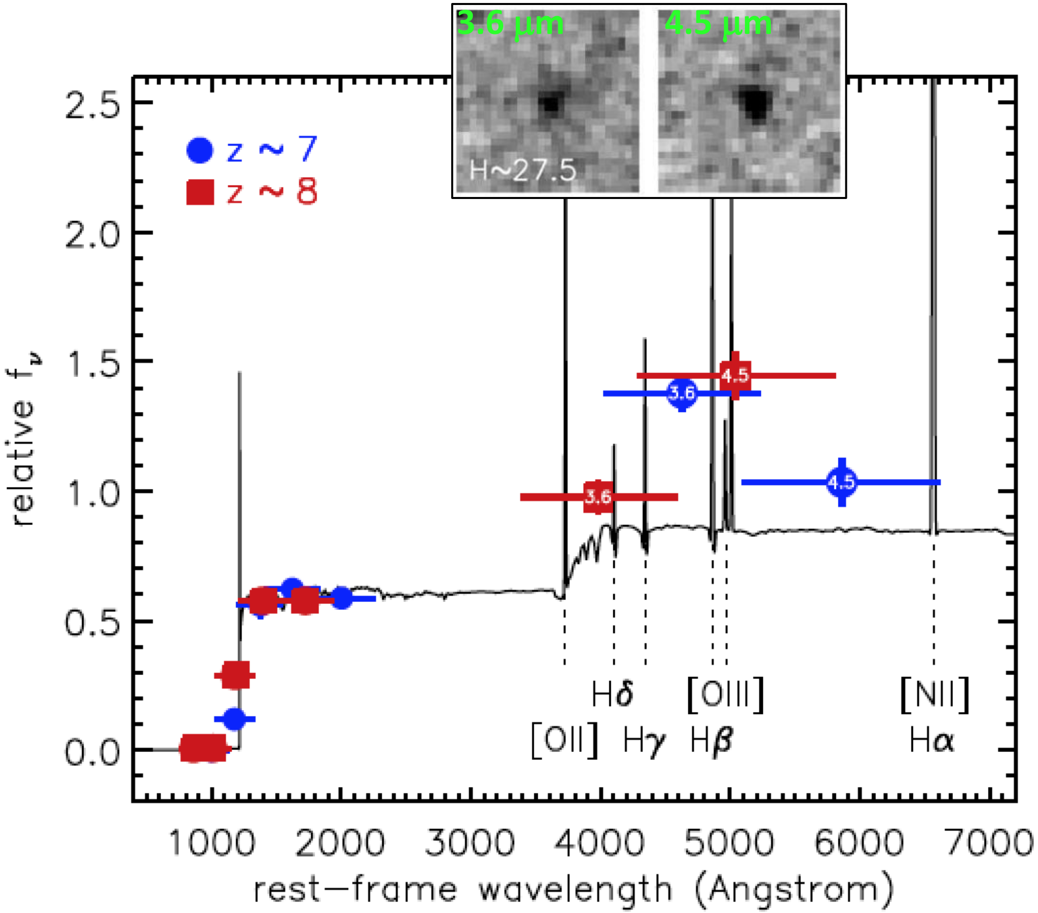
- **Kepler**
  - Spitzer measurements showing transit achromaticity have validated dozens of Kepler exoplanet candidates
  - Spitzer could characterize the atmospheres of many exoplanets identified by K2

- **NuSTAR**
  - Primary survey areas chosen to have existing IRAC data
  - Approved Cycle-10 program is imaging ALL other NuSTAR fields

Live Fast and Die Young: Hot Stars at z > 5

- **IRAC data have been instrumental in identifying large numbers of rapidly star-forming galaxies at 5 < z < 8.**
- **By stacking z ~ 7,8 galaxies, Spitzer can detect old and young stars**

  → mass, age, IMF



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Spitzer, JWST, and Other Infrared Facilities

The James Webb Space Telescope (JWST), scheduled for launch in 2018, will be NASA's next major space observatory. JWST covers wavelengths studied both by Spitzer and by HST, including the 3-to-5 μm region currently accessible to Spitzer. Spitzer's studies of distant galaxies and exoplanets (and other areas) will raise new and important questions and provide compelling targets for JWST. For example, faint galaxies detected by Spitzer photometrically (see **Figure A**) will allow JWST's important spectroscopic investigations to begin immediately after observatory commissioning.

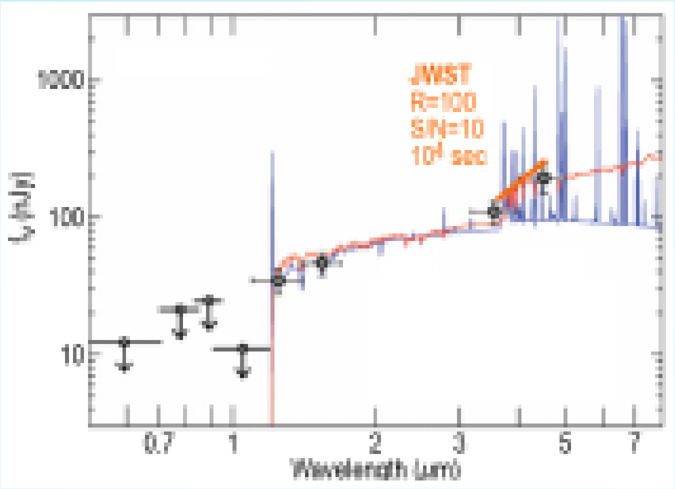


Figure A. *Spitzer measurements of faint galaxies, as shown above, identify early mission targets for spectroscopic follow-up with JWST. The Spitzer measurements at 3.6 and 4.5 μm and the shorter wavelength HST data are compared with two models and with the projected low resolution spectroscopic sensitivity of JWST.*

Spitzer's sensitivity* far outstrips that of any other currently operating infrared facility, allowing Spitzer routinely to execute observations that would literally be impossible otherwise. This sensitivity advantage is portrayed in **Table A**, below.

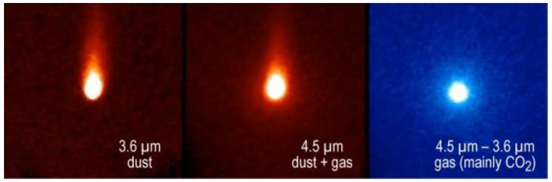
Table A. Sensitivities of Infrared Facilities. (10-σ in 10000 sec for Spitzer, Gemini, and SOFIA. 10-σ in All-Sky Survey for WISE.) *All fluxes are in μJy.*

WAVELENGTH BAND	3.6 μm	4.5 μm
Spitzer*	1.0 μJy	1.5 μJy
Gemini	44	348
SOFIA	315	2040
AllWISE**	108	142
MaxWISE [proposed]	86	80

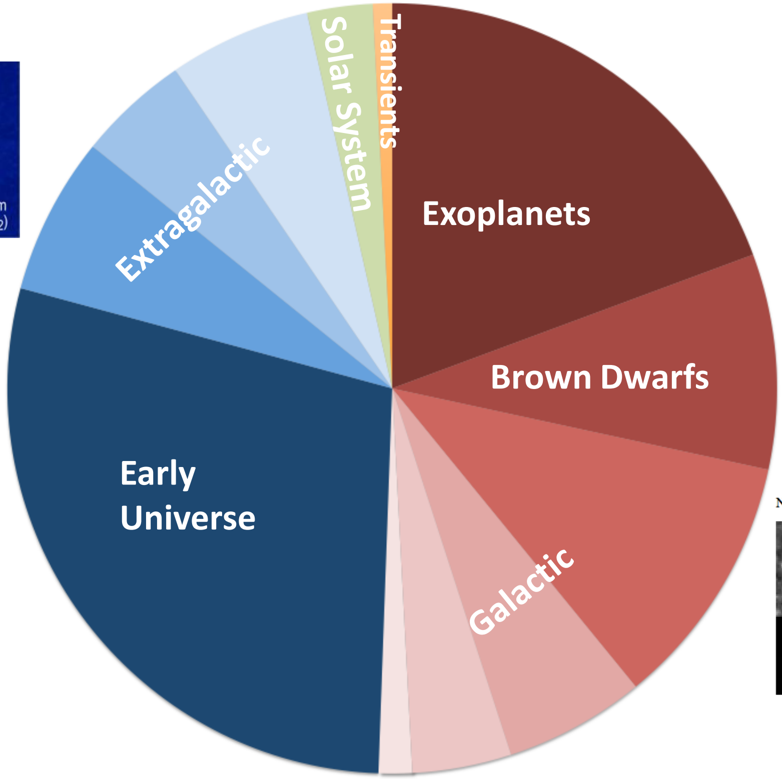
* In addition to sensitivity, Spitzer's measurement functionality is: 1) Adjacent 5×5 arcmin fields of view observed simultaneously at 3.6 and 4.5 μm. 2) Array format 256^2, yielding 1.2 arcsec/pixel. 3) Image FWHM 1.5 arcsec.

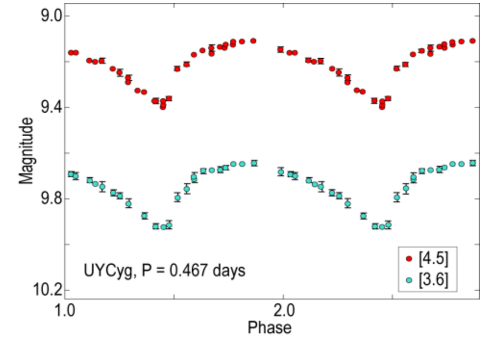
**WISE bands are at 3.4 and 4.6 μm.

Why Spitzer?

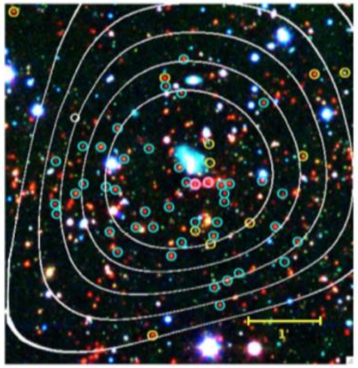


Comet CO2 production rate.

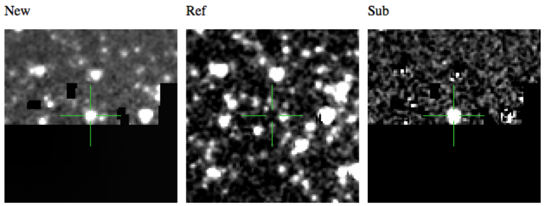




New mid-IR P-L relation for RR Lyraes.



Stellar mass for high-z clusters.

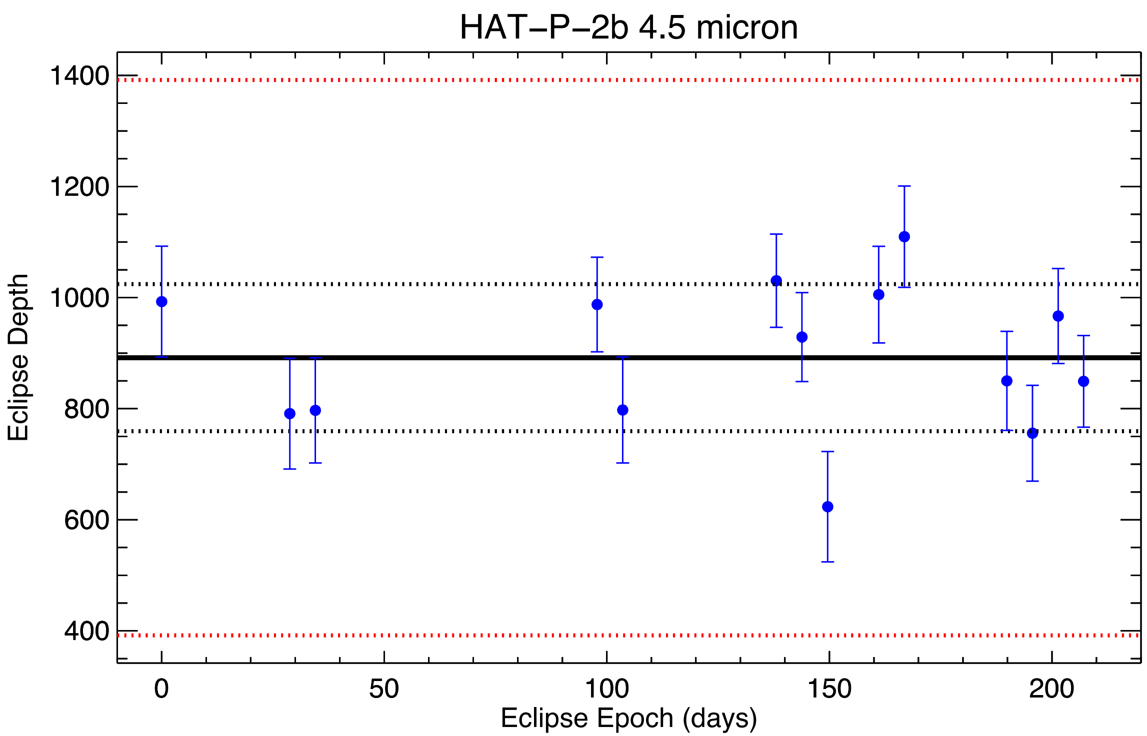


Novel infrared transient in NGC6822.

- The user community executes an astonishing variety of exciting science with Spitzer.
- Users continue to envision compelling new science.

Achieving High Precision

- **Multiple transit/eclipse measurements from Spitzer have been used to reliably measure depths to ~30 ppm with scatter of individual depths of order 100 ppm**
- **Hansen et al. have incorrectly argued that systematic uncertainties set a floor of 500 ppm on the precision of Spitzer eclipse measurements.**



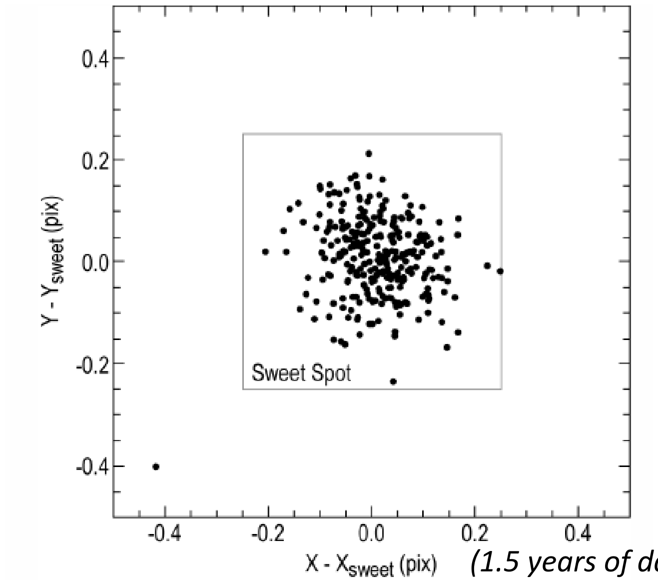
500 ppm

<u>14 eclipses</u>
- Dispersion is 132 ppm
- Final achieved precision is ~ 30 ppm

(Data from deWit, Lewis, & Knutson.)

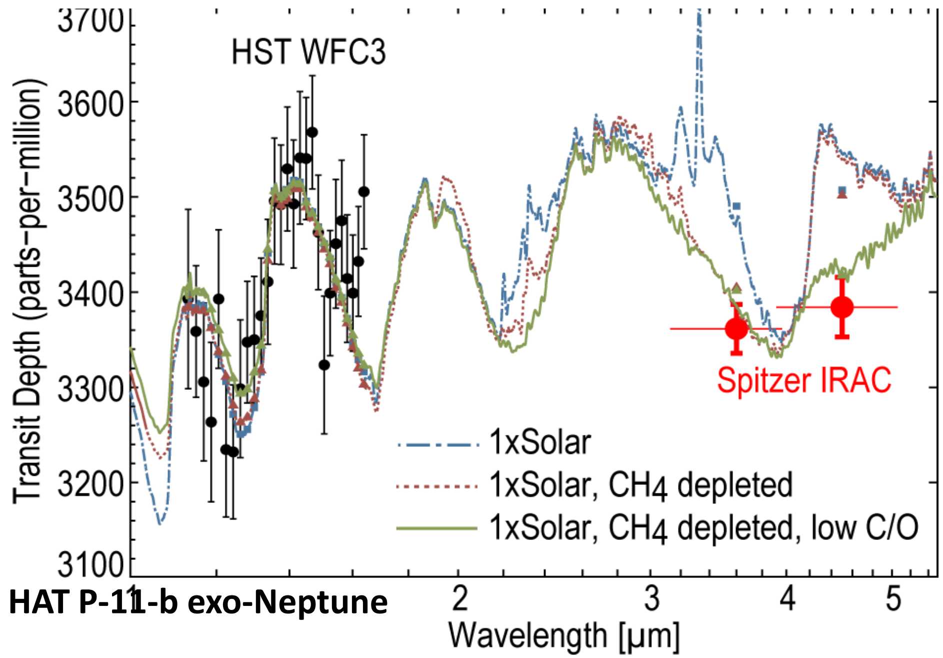
Onward to Smaller Exoplanets

One IRAC pixel 1.2"



(1.5 years of data)

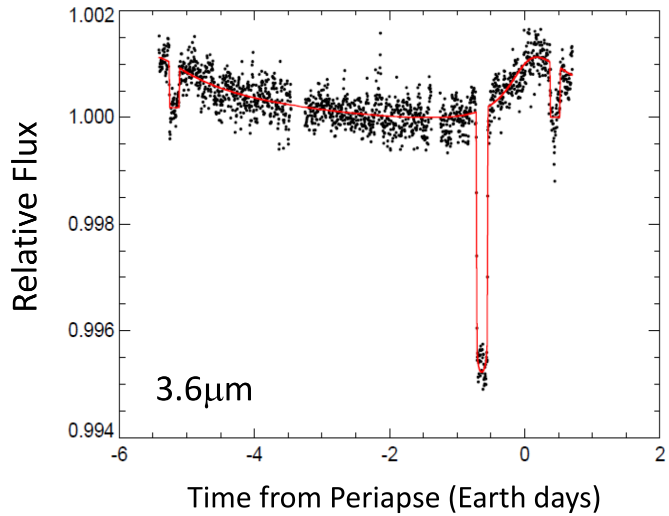
Precise placement of host star on IRAC pixel contributed to a > 2x reduction in systematic uncertainties in exoplanet measurements. Spitzer can characterize planets ~< $2R_{earth}$ in size.



HAT P-11-b exo-Neptune

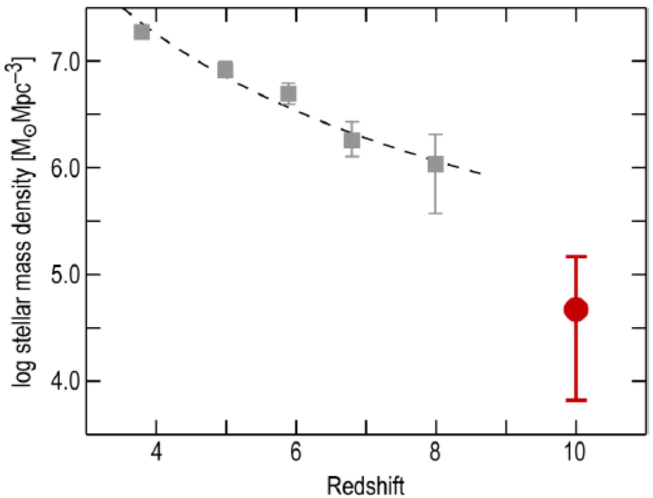
Spitzer [+ HST] measurements of radii of exoplanets at transit provide important constraints on composition of exoplanet atmospheres and set the stage for JWST.

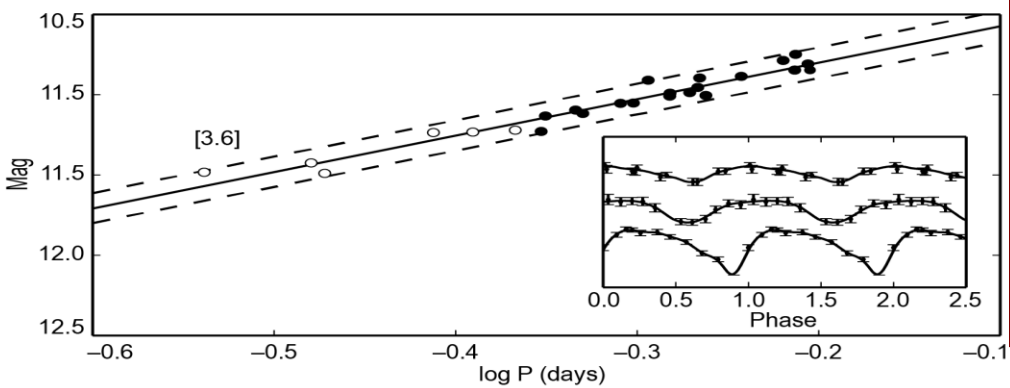
Spitzer Delivers Astro2010 Science



New Worlds: Phase curve of HAT-P-2b.

Cosmic Dawn: The assembly of stellar mass in the early Universe.

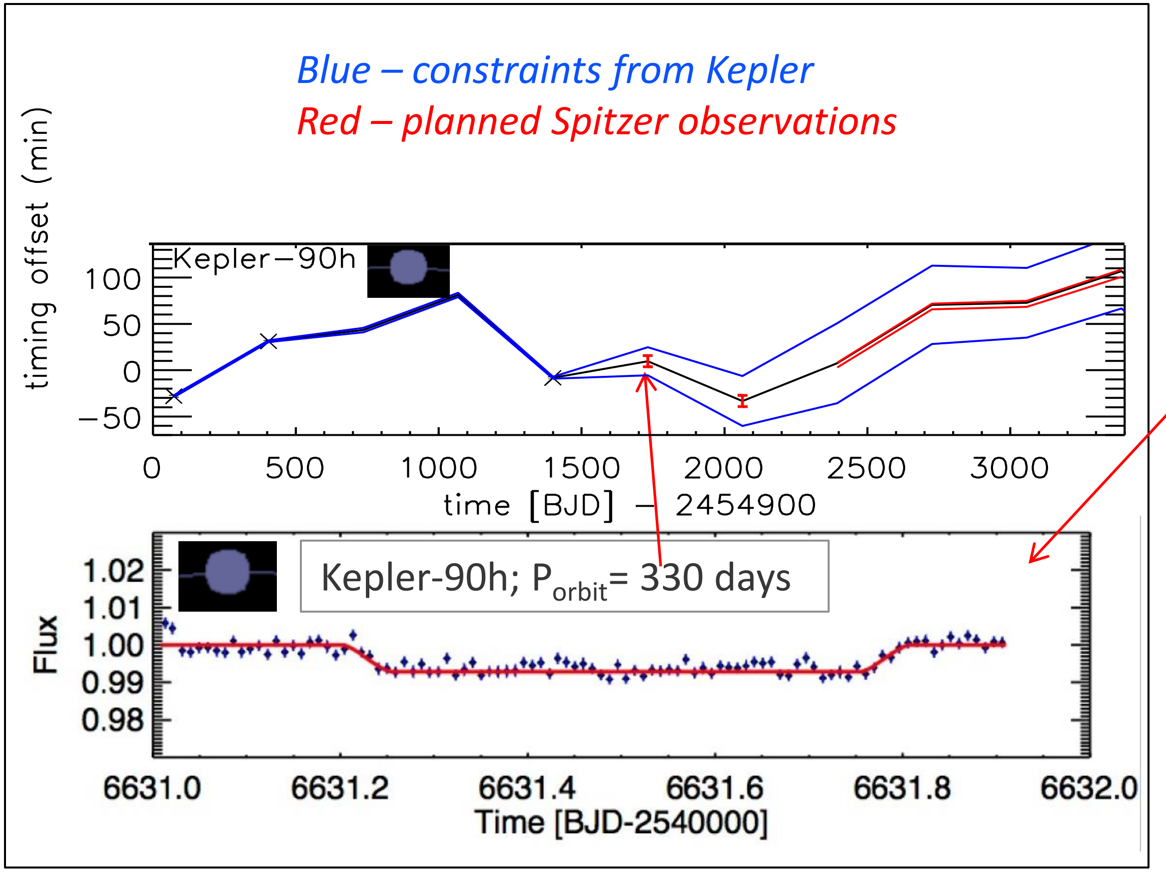


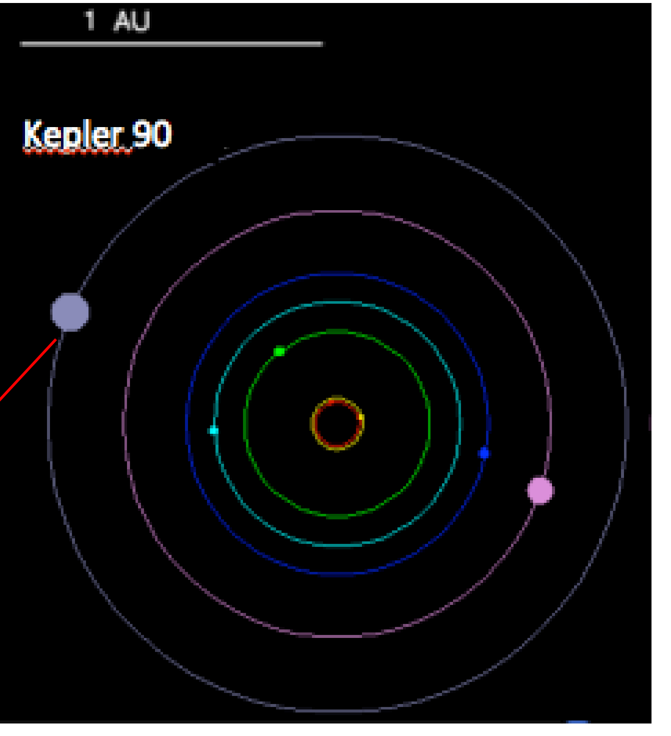


Physics of the Cosmos: P-L relation for RR Lyrae stars in M4 – First rung on a new cosmic distance ladder.

Studying Complex Planetary Systems via Transit Timing

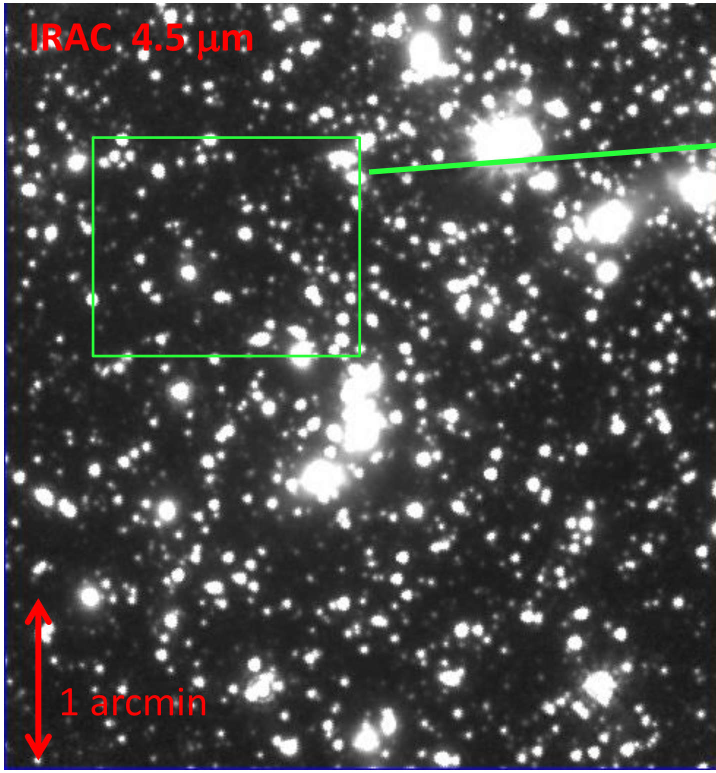
- **Observing transit times for the outer 2 planets in the Kepler-90 system.**
  - This is the only way to measure masses of these planets to a few percent.
  - Can study ~one dozen systems with long period planets identified by Kepler.

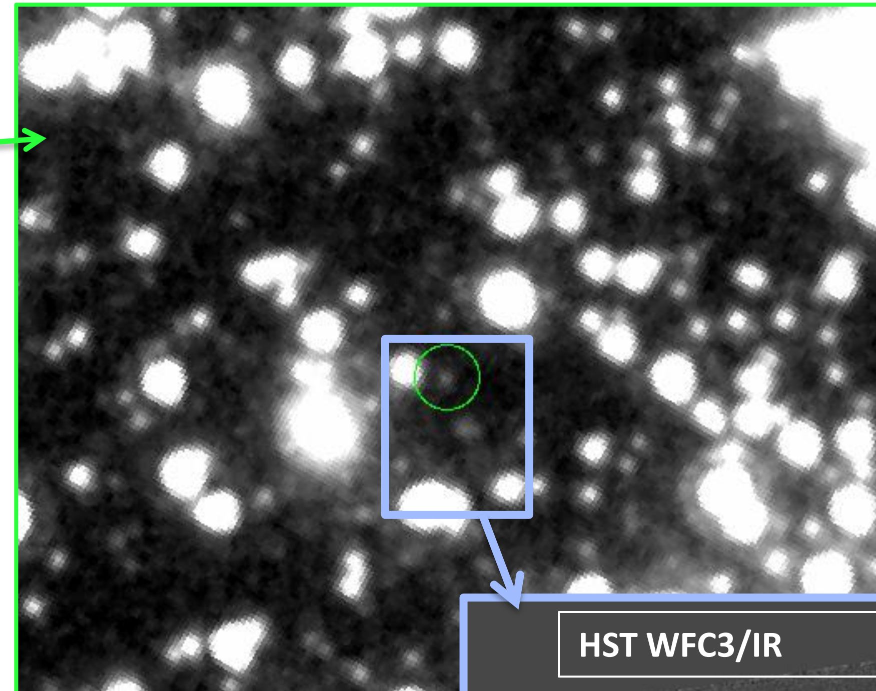


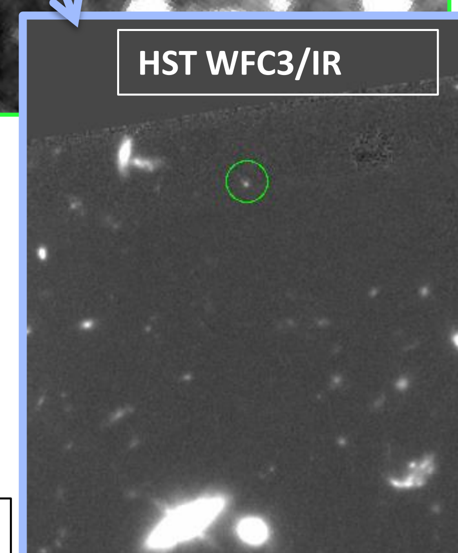


Kepler-90: 7 transiting planets

High Redshift Galaxies in Frontier Field Abell 2744







- Frontier Fields initiative: HST & Spitzer use galaxy clusters as powerful gravitational lenses to explore early Universe.

- Lensed z=8 SF galaxies in A2744 – 1st Frontier Field cluster observed with Spitzer

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