Status of the Spitzer Space Telescope and of Selected Other IPAC Projects

John R. Stauffer

*IPAC, Head of Science Staff*
What is IPAC?

- IPAC is NASA’s Infrared Science center
- It includes:
  - The Spitzer Science Center
  - The NASA Herschel Science Center
  - IRSA (Infrared Science Archive - serves IRAS, 2MASS, SWAS, etc.)
  - NED (NASA Extragalactic Database)
  - NStED (NASA Stellar and Exoplanet Database - New)
  - WISE science center
What will I be talking about?

- The past, present and future of Spitzer
- Status and expectations for WISE
- Status of NStED
Completion of the Cryogenic Mission and Preparation for the Beginning of the Warm Mission
Based on extrapolation of past measurements and future operational plans, predicted cryogen depletion date is 4/16/09 ± 9 days*.

Depletion date uses a linear extrapolation of mass measurements since January 2005, then adjusts the end date by comparing future operational plans to the past operations.

*Depletion date uncertainty ±9 days based on 2-sigma linearity of data. Historically, this method has errors as large as ±5% (3 months).
Scheduling Summary
Through Week 266 (2009 January 1)

<table>
<thead>
<tr>
<th>Category</th>
<th>Hours Scheduled (Week)</th>
<th>Hours Scheduled to Date</th>
<th>Hours Total</th>
<th>Hours Remaining</th>
<th>Percent Complete</th>
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<td>GTO</td>
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<td>GO5 - GTO/Rieke</td>
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<td>GO5 - GTO Total</td>
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<td>GO5 - GO/Legacy</td>
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<td>TOTAL</td>
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<td>33793.2</td>
<td>37160.6</td>
<td>3367.4</td>
<td>90.9</td>
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Issues and Comments

• When Cycle-5 began, unexecuted AORs from previous cycles were elevated one group in scheduling priority
  – e.g. Low priority AORs from Cycle-4 become medium priority in Cycle-5
    WE DON’T GUARANTEE CYCLE-4 PROGRAMS WILL BE COMPLETED

• Goal remains to ensure that the highest ranked science programs are scheduled before the end of the cryogenic mission while maintaining high efficiency
  – All Cycle 3 AORs have been executed
  – Expect to complete nearly all Cycle 4 and Cycle 5 priorities 1 and 2
    • Are working with observers to satisfactorily schedule AORs causing difficulty (e.g. difficult constraints, large data volumes, bright source latents)
  – Assuming no major anomalies and with cryogen lasting until April 2009, we should accommodate much of the Cycle 5 priority 3
    • Approximately 1500 hours
    • Began executing priority 3 observations in IRAC 56 (end of October 2008)
Operating Environment
Assumptions for IWIC

• Spitzer will be passively cooled after cryogen runs out
  – Telescope ~ 24-25 K
  – Multiple Instrument chamber (IRAC) ~ 25-29 K
  – IRAC will be ~0.2-0.6 K above the MIC through self-heating
  – Plan to operate IRAC at >1K above MIC for thermal control ⇒ 31 K
  – Telescope temperature equilibrium occurs within 5 weeks

• Observatory operations remain identical to cryogenic mission
  – No change in S/C fault protection

• OPZ (operational pointing zone) remains the same

• Downlink system supports 1.65 Mb/s
  – One downlink / 12 hours
  – Downlinks are 2 hours in duration

• Pointing system exhibits same stability and accuracy
  – Will perform pointing calibrations with same cadence as cryogenic mission

• Variations in optical properties of Spitzer will be small
  – Dramatic changes in focus, boresight-instrument alignment, PSF will be considered anomalies
Predicted IRAC Performance

- Observations with 3.6 and 4.5 μm (InSb) arrays only
  - 5.8 and 8.0 μm arrays will be powered on, but zero biased
- Temperature of arrays actively controlled
  - Arrays heated to operating temperature of 31 K
- Limited testing of similar arrays at 30 K by University of Rochester (McMurty et al. 2008 SPIE 6265, 626508)
- No significant increase in dark current (~ 0.2 electrons/s)
- Slight increase in read noise
  - Possibly 50%
  - May be mitigated with higher Fowler sampling
- Most observations should still be background / photon dominated
  - Anticipate frametimes >30 seconds background limited for all backgrounds
- Residual images are more significant but possibly decay faster
  - Behavior of channel 1 long term residuals to be determined (estimated to be half current strength from 30 K ground test)
  - Redundancy will be important
  - Thermal annealing is expected mitigation method
  - ΔT ~ 8 K effective in cryogenic mission, plan anneals to 40 K (ΔT = 9 K) for warm mission
State of IRAC after IWIC

- IRAC is on and arrays are stabilized at operating temperature
- Array biases are set and fowler number/wait tick combinations for frametimes defined
- AOT has been checked-out and ready for science
- If necessary, anneal strategy has been developed, final anneal IER tested and demonstrated effective
- Detectors linearized to better than 1% up to 90% full well
- Bias Uncertainty 1-2%
- Gain Map uncertainties 1.2% and 0.5% at 3.6 and 4.5 μm
- Relative photometric calibration < 5% (probably much better)
- Absolute photometric calibration < 10% (probably better than 5%)
- Data taken for first-frame correction
- Data taken for pixel-phase effect, array location dependent photometric correction
- Data taken for point response function generation
Results of Cycle 6 “Exploration Science”
Call for Proposals
Proposals Received

- 35 proposals received -- 38,050 hours requested
  - 46 letters of intent received

<table>
<thead>
<tr>
<th>Proposals</th>
<th>Science Category</th>
<th>Hours</th>
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<tbody>
<tr>
<td>13</td>
<td>Distant Universe</td>
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<td>3</td>
<td>Nearby Universe</td>
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<td>7</td>
<td>Exoplanets</td>
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<td>10</td>
<td>Galactic</td>
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<tr>
<td>2</td>
<td>Solar System</td>
<td>1,829.8</td>
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</table>

- Oversubscription ~ 4

- Original Legacy Science Program
  - 34 letters of intent, 28 proposals received, requested ~16,800 hours
Cycle-6 Selection

- 10 programs selected - 10,345 hours
  - Extragalactic 5377 hrs  Galactic/Planetary 4968 hrs

<table>
<thead>
<tr>
<th>PID</th>
<th>Science Category</th>
<th>PI Institution</th>
<th>Title</th>
<th>Co-Is</th>
<th>Hours</th>
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<td>60010</td>
<td>cosmology</td>
<td>Wendy Freedman Carnegie Observatories</td>
<td>The Hubble Constant</td>
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<td>705</td>
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<td>60022</td>
<td>high-z galaxies</td>
<td>Giovanni Fazio Smithsonian Astrophysical Obs.</td>
<td>SEDS: The Spitzer Extended Deep Survey</td>
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<td>2108</td>
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<td>60024</td>
<td>high-z galaxies</td>
<td>Mark Lacy Spitzer Science Center</td>
<td>SERVS: the Spitzer Extragalactic Representative Volume Survey</td>
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<td>60034</td>
<td>high-z galaxies</td>
<td>Eiichi Egami University of Arizona</td>
<td>The IRAC Lensing Survey: Achieving JWST depth with Spitzer</td>
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<td>60007</td>
<td>nearby galaxies</td>
<td>Kartik Sheth Spitzer Science Center</td>
<td>The Spitzer Survey of Stellar Structure in Galaxies (S4G)</td>
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<td>60021</td>
<td>exoplanets</td>
<td>Heather Knutson Harvard University</td>
<td>Dynamic Studies of Exoplanet Atmospheres: From Global Properties to Local Physics</td>
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<td>60028</td>
<td>exoplanets</td>
<td>David Charbonneau Harvard University</td>
<td>Confirmation and Characterization of Kepler Mission Exoplanets: The Era of Rock and Ice Exoplanets</td>
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<td>800</td>
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<td>60020</td>
<td>galactic structure</td>
<td>Barbara Whitney, SSI Space Science Institute</td>
<td>GLIMPSE360: Completing the Spitzer Galactic Plane Survey</td>
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<td>John Stauffer Spitzer Science Center</td>
<td>Young Stellar Object Variability: Mid Infrared Clues to Accretion Disk Physics &amp; Protostar Rotational Evolution</td>
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<td>60012</td>
<td>near-earth objects</td>
<td>David Trilling Northern Arizona University</td>
<td>The Warm Spitzer NEO Survey: Exploring the history of the inner Solar System and near Earth space</td>
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Cycle-6 Selection (2)

- 2 exoplanet programs recommended for DDT

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<th>Co-Is</th>
<th>Hours</th>
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<td>exoplanets</td>
<td>Joseph Harrington</td>
<td>The Spitzer Exoplanetary Atmosphere Survey</td>
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<td>University of Central Florida</td>
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<td>60027</td>
<td>exoplanets</td>
<td>Michael Gillon</td>
<td>Detecting the Transits of Nearby Super-Earths</td>
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<td></td>
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<td>Geneva University</td>
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</table>

- Harrington - ToO program for new planets
  - Requested 1400 hours (500 hrs known planets, 900 hrs ToO)
  - Awarded 200 hours DDT

- Gillon - Detecting a super-Earth transit
  - Requested 500 hours
  - Awarded 100 hours DDT
Cycle-6 & 7 Small GO program

- Proposals due 6 February 2009
  - 1500 hours available (one-year)
  - Proposals < 500 hours
  - Simplified TAC process

- Data Analysis Funding
  - Estimate ~ $1.5 million small GO program support

- Cycle-7: expect to solicit another 1500 hours of small programs
After Cycle 7

• We will propose for a continuation of the Spitzer warm mission in early 2010.

• If our proposal is approved, there will be a 2nd call for two more years of Exploration Science proposals, with proposals due in the Fall of 2010.

• Orbital geometry requires that the Warm Mission end around January 2014.
Creation of the Final Spitzer Archive
Why a “Heritage” Archive?

- Leopard was optimized for identification & retrieval of data from specific observations
  - *The HA will have additional functionality and an improved interface to facilitate deeper and more complex mining of the archival data*
    - Support for searches based on astronomical criteria
    - Maintain support for Spitzer-specific search criteria
    - Significant capability for interaction with the result set

- The current archive, served through Leopard is part of the SSC Operations system
  - *Leopard is a Java Application*
  - *Built to support uplink and pipeline operations as well as data access*
  - *Not built with an emphasis on long term maintenance and ease of migration*

- The Heritage Archive is to be built by SSC and maintained long-term by IRSA
The Spitzer Heritage Archive will contain ~25 TB (DBMS <1TB) at handover, including:

- **Spitzer pipeline data:**
  - Raw data products
  - BCD and post-BCD data and ancillary products
- **Calibration products**
- **Data Quality Analysis Information**
- **Observation design information**
  - Program abstract, title, observational constraints.
- **Enhanced Spitzer data and other legacy data**
  - Data from the Legacy teams
  - SSC-produced enhanced data
    - **Supermosiacs from IRAC and MIPS-24** (if available and validated)
    - **Enhanced IRS products** (if available and validated)
    - **Source lists** (if available and validated)

- The HA will also eventually contain the IRAC data from the “warm” mission (Added incrementally)
Source Lists for the Archive

• **Description:**
  - *list of fluxes/colors of compact sources in Spitzer imaging data*
    • Excluding 16/70/160 microns (which are more labor intensive)
    • Excluding known moving objects
  - *Goal is to have a lights-out pipeline for processing*
    • Except for generating input assignment of namelists to programs
  - *Final product needs to be an easily searchable, highly documented, list for archive users*

• **Post-BCD team is working towards a Source List for the Spitzer Heritage Archive**
  - *Held Internal Review 10/08*
    • The overall approach was deemed sensible
    • But many details remain to be understood

• **Go/No-Go decision Pending external review in 3/09**
WISE Mission Status and Planned Science
**Science**

- **Sensitive all sky survey with 8X redundancy**
  - Find the most luminous galaxies
  - Find the closest stars to the sun
  - Provides input catalog for JWST
  - Provide lasting research legacy

**Salient Features**

- **4 imaging channels covering 3 - 25 microns wavelength**
- **40 cm telescope operating at <17K**
- **Two stage solid hydrogen cryostat**
- **Delta launch from WTR in November, 2009**
- **Sun-synchronous 6am/6pm 500km orbit**
- **Scan mirror provides efficient mapping**
- **Operational life: 7 months (124% margin)**
- **4 TDRSS tracks per day**
Simple Mission Design

- Delta 7320 launch – WTR
- 523 km, circular, polar sun-synchronous orbit
  - Nodal crossing time 6:00 PM
  - One month of checkout
  - 6 months of survey operations
- One simple observing mode
  - Half orbit scan
- Scan mirror “freezes” orbital motion - enabling efficient mapping
  - 8.8-s exposure/11-s duty cycle
  - 10% frame to frame overlap
  - 90% orbit to orbit overlap
- Expect to achieve at least 8 exposures/position after losses to Moon and SAA
- Uplink, downlink, calibrations at poles
  - 4 TDRSS tracks per day
WISE Flight System

Payload (Space Dynamics Lab, USU)
- 2-Stage Solid H₂ cryostat
  - 13.5 months life time (7 required)
- All aluminum reflective optics: <17K
  - 40-cm telescope
- Dichroic beamsplitters separate wavelengths onto four 1024² pixel arrays
- 2 HgCdTe detectors: 3.3, 4.7 microns (32K)
- 2 Si:As detectors: 12, 23 microns (7.8K)
- 3 electronics boxes (mounted in spacecraft)

Spacecraft (Ball Aerospace Tech. Corp.)
- Orbital Express architecture
- Augmented single string
- No mechanisms, no deployables, no propulsion
- 3-axis stabilized
- Pointing stability/accuracy: ~ 1”/ ~1’
- Ku band science data link: 100Mbps
- 3.5 days (96 GB) of science data storage
WISE Data Products

• WISE Image Atlas
  – Formed by combining all image frames covering each point on the sky ($\geq 8x$ at $|\beta|\sim 0$; $\sim 1500x$ at $|\beta|\sim 90$)
  – FITS format, 4 bands registered, approx. 4kx4k pix @ 1.375″/pix.
  – Depth-of-coverage and noise maps corresponding to each Atlas Image
  – Metadata describing each Atlas Image
  – Approx. 140,000 images covering entire sky in four WISE bands (depends on final footprint)

• WISE Source Catalog
  – Basic attributes of each object detected on combined (i.e. Atlas) images
    • J2000 positions accurate to 500 mas with respect to 2MASS All-Sky PSC
    • Photometry in four WISE bands with SNR$\geq 5$ at 120, 160, 650, 2600 $\mu$Jy at 3.3, 4.7, 12, 23 $\mu$m
    • $\geq 95\%$ completeness and $\geq 99.9\%$ reliability at SNR=20 (in unconfused regions)
  – ~300 million entries (Working Database will contain $\sim 10^9$ entries)

• WISE Explanatory Supplement
  – Mission and data product description and characteristics
  – User’s guide (e.g. data formats, access modes)
  – Cautionary notes
Brown Dwarfs (BDs): stars with too little mass to fuse H into He.

WISE 3.3 & 4.7 μm filters tuned to methane dominated BD spectra.

WISE could identify Gliese 229B ($10^{-5} L_{\odot}$) to 150 light years, a free floating planet (FFP) like Jupiter ($10^{-9} L_{\odot}$) to 1 light year, BDs with $T > 200$ K ($10^{-8} L_{\odot}$) if closer than α Centauri.
The First Field Brown Dwarf Discovered by Spitzer

- The brown dwarf found in the 8 square degree Spitzer/IRAC Shallow Survey would be a 6σ detection with WISE.
- WISE will survey 5000 times more sky.
- WISE should discover several hundred brown dwarfs cooler than any currently known, and double or triple the density of known star systems in the solar neighborhood.
How many BDs will WISE see?

<table>
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<tr>
<th>Mass Function</th>
<th>$T_{\text{eff}} &lt; 300$</th>
<th>$T_{\text{eff}} &lt; 500$</th>
<th>$T_{\text{eff}} &lt; 750$</th>
<th>$d &lt; 1.3$ pc</th>
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<td>1340</td>
<td>0.88</td>
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<tr>
<td>Reid etal $M^{-0.7}$</td>
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<td>671</td>
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<tr>
<td>Reid etal $M^{-1.0}$</td>
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<td>197</td>
<td>921</td>
<td>0.93</td>
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<tr>
<td>Reid etal $M^{-1.3}$</td>
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<td>330</td>
<td>1310</td>
<td>1.74</td>
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</table>

Assuming uniform star formation rate over the past 10 billion years and that WISE just meets its 4.6 µm sensitivity requirement.

At present, only 1 Brown Dwarf with $T < 750$ K has been found, even using Spitzer data.
WISE will find about one thousand such objects, including perhaps the nearest planetary system to our own.
WISE Status and Schedule

- Passed mission Critical Design Review in June 2007
- Passed System Integration Review in November 2008
- Payload is assembled and has completed first round of cryogenic performance testing
- Spacecraft integration is nearing completion
- System integration begins in April 2009
- Launch scheduled for November 2009
- On-orbit operations December 2009 - May 2010
- Preliminary Data Release November 2010
- Final Data Release December 2011
NASA Star and Exoplanet Database (NStED) Status and Plans
The NStED Charter

• Curate scientific data related to exoplanets and potential host stars
• Facilitate scientific exploitation of these data sets
• Support target selection and science planning for future observations
The NStED Services

• Stellar Services
  – Data related to relatively bright nearby stars
    • All known planet-hosting stars
  – Query for individual stars or by stellar/planetary parameters
  – Images and spectra

• Exoplanet Services
  – Data related to known exoplanets
  – Photometric light curves of transiting exoplanets
  – Dedicated interface related to exo-planet transit surveys
Stellar Content for NStED

- Approximately 140,000 stars
- Associated data include:
  - Next 2000 (N2K) Stars template spectra
  - Coronographic images from Palomar
  - 2MASS image mosaics

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<th>Published Parameters</th>
<th>Derived Parameters</th>
<th>Associated Data</th>
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<td>Images</td>
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<tr>
<td>Kinematics</td>
<td>Rotation</td>
<td>Spectra</td>
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<tr>
<td>Photometry, Colors</td>
<td>Activity Indicators</td>
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<tr>
<td>Spectral type</td>
<td>Variability</td>
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<td>Luminosity Class</td>
<td>Multiplicity</td>
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<td>Temperature</td>
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<td>Luminosity</td>
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<td>Radius</td>
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<td>Mass</td>
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<tr>
<td></td>
<td>LSR Space Motion</td>
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</table>
Stellar Data - Published Parameters

- **Current data types**
  - Position & Distances
  - Kinematics
  - Photometry and Colors
  - Spectral types
  - Luminosity class
  - Metallicity
  - Rotation
  - Activity Indicators
  - Variability
  - Multiplicity

<table>
<thead>
<tr>
<th>Object and Aliases</th>
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<tbody>
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<td>HIP 54035</td>
<td>GJ 411</td>
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<tr>
<td>HD 95735</td>
<td>BD+36 2147</td>
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</table>

### Multiplicity
- Number of components listed in the WDS catalog: 0
- Number of known planets: 0
- Link to Planet Encyclopedia: 0

### Variables [E]
- **Type**: Amplitude (mag) - Period (days)

### Coordinates [E]
- **System**: Equatorial J2000
  - Right Ascension / Longitude: 11h 3m 20.19s
  - Declination / Latitude: 35d 55m 11.56s
- **Ecliptic**: 152.107126 - 27.39345
- **Galactic**: 184.925199 - 65.423979
- Proper Motion (mas/year): -577.000 - 4761.800

### Physical Properties
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<th>Value</th>
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<th>Number of measurements</th>
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<td>Parallax (mas)</td>
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<td>Spectral Type (&quot;HD&quot;)</td>
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### Photometry
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<th>Number of measurements</th>
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### Colors
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Exoplanet Data - Published Parameters

- Maintaining up to date list of stars known to host exoplanets
  - Updated weekly
- Time Series Data
  - Photometry
  - Radial Velocity

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<td>Link to Exoplanet Encyclopedia Entry</td>
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![Graph of HIP 108859](image1.png)

Object Name: HIP 108859

![Graph of HIP 16537](image2.png)

Object Name: HIP 16537

Relative Time (days)

Relative Flux ratio

Radial Vel (m/s)

BJD (days) \(= x \times 10^4 + 2400000\)
Transit Survey Data

- Dedicated service for transit survey data
- Initial service based upon
  - *TrES Observations of Kepler Field*
  - *KELT survey data*
  - *Donated surveys of four clusters*

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</table>
Transit Survey Query Interface

- All of the parameters in the data master files are searchable
- Cross-dataset searches enabled
- Grouped by category
- Selectable output
Transit Survey Table Output

- HTML table output
- ASCII version of whole table
  - Self documenting header for columns
- Scripts for bulk downloading light curves resulting from query
- Unique ID links to detail page

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Download all results: IPAC ASCII format table
Download all lightcurves: scripts
Row: 1 - 100 of 112509
101 - 200
Display Maximum 100 rows per page

References = refereed publication referring to technical details of survey
Public = T/F indicating if lightcurve data available to public
Region = identifier for part of sky observed in survey

Result Table

Download all results: IPAC ASCII format table
Download all lightcurves: scripts
Row: 1 - 100 of 112509
101 - 200
Display Maximum 100 rows per page
NStED-CoRoT Collaboration

• NStED is the U.S. portal to CoRoT mission data
• CoRoT: COnvection, ROtation & planetary Transits
  – NASA/CNES/ESA Collaboration
• NStED will serve CoRoT mission and ground-based data
• NStED and CoRoT is collaborating with CoRoT to build light curve characterization and manipulation tools
• First CoRoT public data expected early 2009
Website and Contacts

• NStED Version 2.0 is now publicly available
  http://nsted.ipac.caltech.edu

• To contribute data, contact
  Stephen Kane (skane@ipac.caltech.edu)
  Kaspar von Braun (kaspar@ipac.caltech.edu)