National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Use of the Deep Impact HRI Instrument to Observe Exoplanets Via Microlensing

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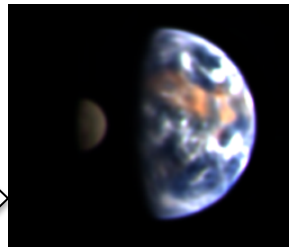
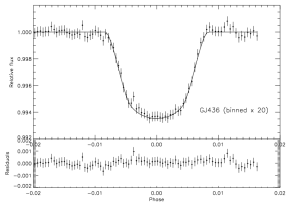
Deep Impact/EPOXI

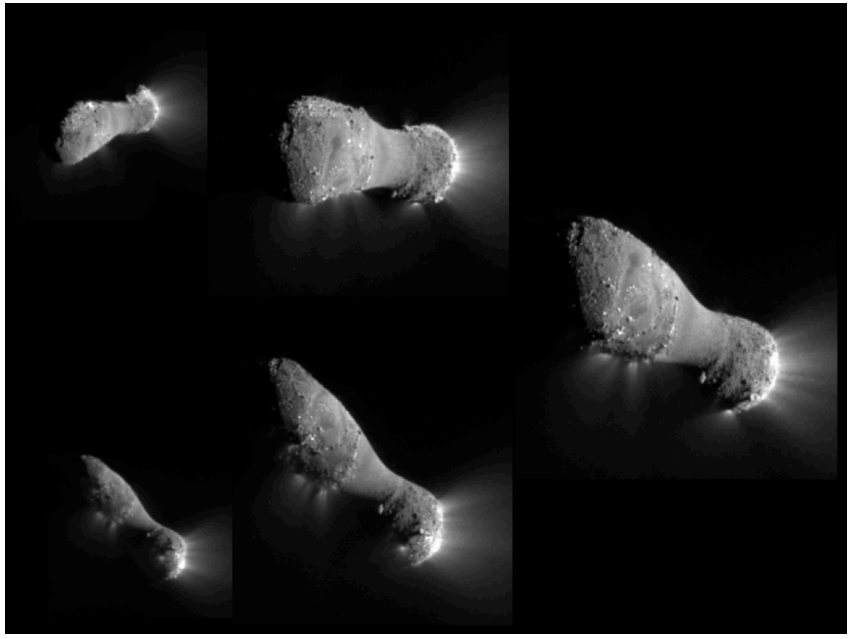
EPOCh Observations- 2008





9P/Tempel 1
July 2005

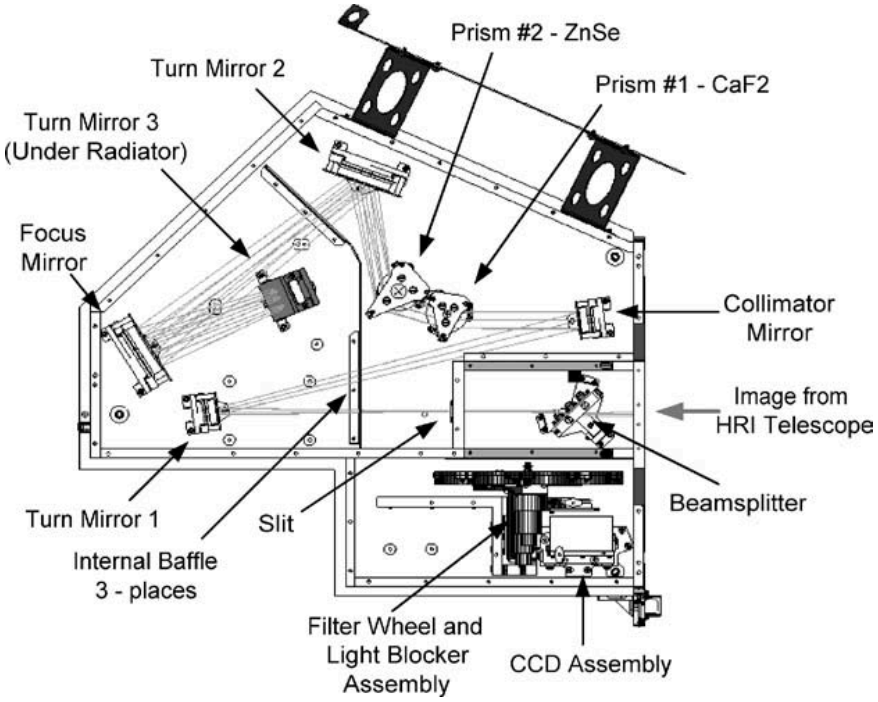
103P/Hartley 2
November 2010



Spacecraft

- Deep Impact Flyby Spacecraft
  - Launched in Jan 2005 to carry Impactor to comet Tempel-1 and observe results of impact.
  - Attitude Control
    - 3-Axis stabilized, 4 reaction wheels and 1 inertial reference unit
    - Pointing stability +/- 150 micro-radians (75 HRI pixels)
  - Image Data Storage
    - 2 RAD 750 Spacecraft Control Units, prime and backup
    - 339 Mbytes per SCU (total of 678 Mbytes), up to 7000 image files per SCU
  - Telecom System
    - 1 meter parabolic high gain antenna, 35.6-dBic gain and 2.36-degree beam-width
    - 18.6 Watt Traveling Wave Tube Amplifier
    - Data rates between 8000 to 16000 bits/sec using 34-meter antennas for 2012 and 2013

Deep Impact Spacecraft



HRI Spectral Imaging Module

Instrument

- HRI
  - 30 cm aperture, f/35 optical system
    - Visible light detector
      - 1024x1024 CCD
        - » 21 μm^2 pixel size (2 micro-radians)
        - » .118 Deg FOV
        - » 14 bits/pixel (stored as 16 bits/pixel)
        - » Full-well of 400,000 electrons
        - » Quantum efficiency of 0.7 at 600 nm
        - » System readout noise <28 electrons (~1 DN)
        - » Operating temperature -110 Deg C.
      - 1024x1024, 512x512, 256x256, 128x128 and 64x64 sub-frame modes
      - Integration time from 0 to 1048575 ms (17.5 minutes) .
      - 9 Position filter wheel
        - » 350, 450, 550, 650, 750, 850 and 950 nm centers with 100 nm bandwidth
        - » 2 650 nm center filters with >700 nm bandwidth
    - Defocus 4 arcsec / 10 pixel FWHM
      - De-focused PSF and deep CCD well-capacity allow high photon-limited S/N.

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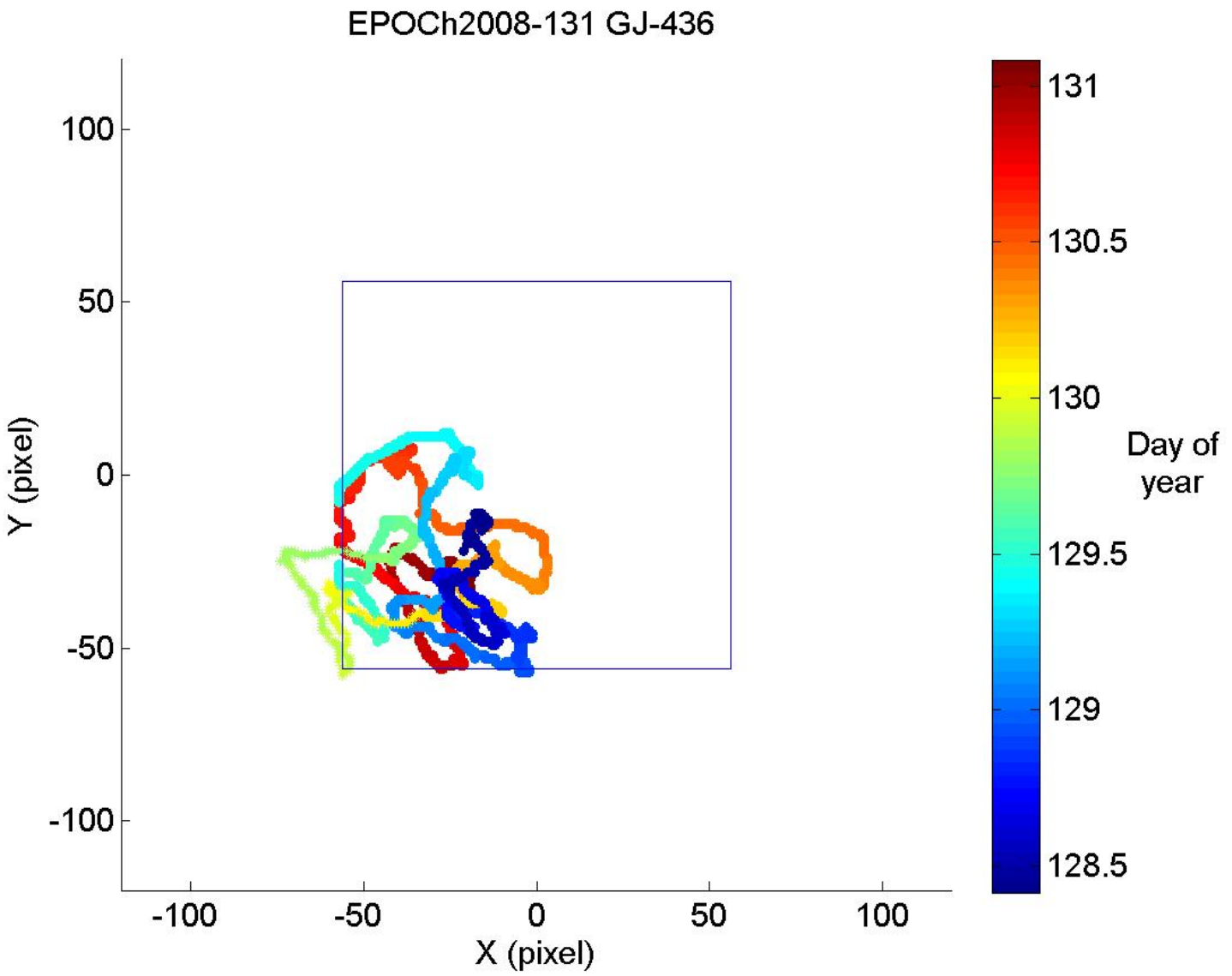
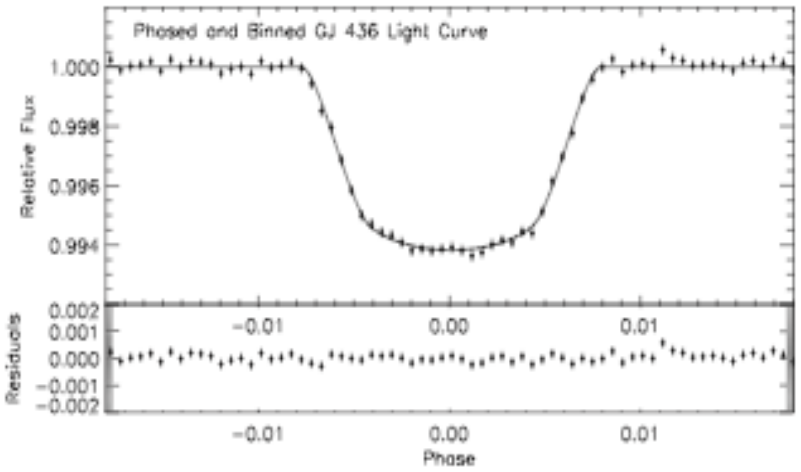
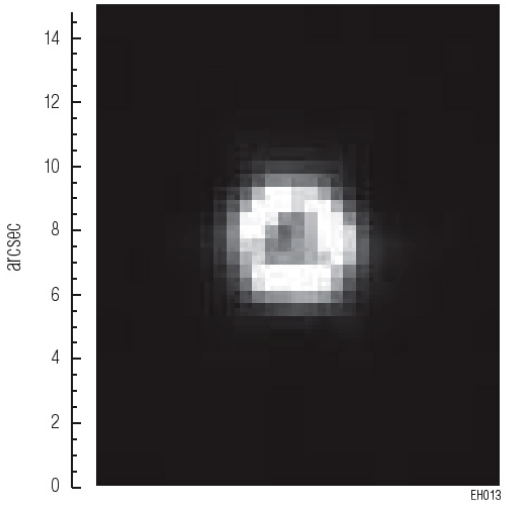
Typical EPOCh Pointing Performance



Typical EPOCh Results



Typical light curve for GJ436 Transit



HRI Vis instrument PSF

Observing Strategy

- Use modified EPOCh observing strategy and sequences.
- EPOCh strategy
  - Run imaging sequence between DSN tracks, accumulating a maximum of 7000 images.
    - 128x128 sub-frames during most of cycle.
    - 256x256 sub-frames around known occultations to improve chance of target in the instrument FOV.
  - Terminate imaging sequence and slew to HGA communications attitude prior to each DSN track.
  - Run playback sequence during DSN track, play back all images acquired since the last DSN track and terminate at end of track, slew back to target and resume imaging.
  - Pointing updates for target implemented during DSN tracks.

Observing Strategy for Gravity Micro-Lensing

- Observation times limited to when HRI bore-sight to Sun angle is between 60 and 120 degrees.
  - 2 observation periods per year, each period 80 days in length, additional constraint of overlapping Earth observatory visibility.
  - First S/C opportunity is June - August 2012.
  - Second opportunity is January - March 2013
- Lower downlink rates of 16000 bps in 2012, 8000 bps in 2013, instead of 200000 bps used for EPOCh
  - Use 128x128 sub-frame mode, may lose up to 15% of images. Star Tracker software patches since EPOCh may improve this number.
  - 7000 128x128 pixel images took 3.3 hours to downlink at 200000 bps during EPOCh. This would take 47 hours at 16000 bps.
  - Given nominal 2x 6 hour 34 meter pass/week, and an imaging rate of 1/ minute, we are limited to about 800 minutes of imaging twice a week.
- Mitigation strategies
  - Try to get 70 meter antenna passes, 4x increase in downlink rate.
  - Use higher data rates with less margin, increased risk, but potentially 2x data return.

Upgrades between EPOCh and EPOXI Hartley-2 Encounter

- Star Tracker Patch for Improved Pointing Stability
  - Fixed incorrectly flagged persistent bad stars
  - Circular mask on square FOV to avoid using corner stars
- Reduced some large excursions, overall pointing accuracy/stability largely unchanged

Spacecraft Flight Software Enhancements

- On-board gzip compression of image and stored telemetry files
  - Increase downlink throughput by a factor of 2-3.
- Use of MRI as fine-guidance sensor
  - Decrease image size to 64x64 pixel sub-frame
  - Increase downlink throughput by a factor of 4
- Total image throughput increase of 8-12x
- Updates available in fall 2012

References

- **"An Overview of the Instrument Suite for the Deep Impact Mission",** Donald L. Hampton*, James W. Baer, Martin A. Huisjen,* Chris C. Varner, Alan Delamere, Dennis D. Wellnitz, Michael F. A'Hearn and Kenneth P. Klaasen, 3 December 2004
- **"The Contingency of Success: Operations for Deep Impact's Planet Hunt",** Richard R. Rieber and Robert F. Sharrow, IEEE, 2009
- Ballard, S., et al. 2010, ApJ, 716, 1051