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

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• 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

- Turn Mirror 2
- Prism #2 - ZnSe
- Turn Mirror 3 (Under Radiator)
- Prism #1 - CaF2
- Focus Mirror
- Collimator Mirror
- Image from HRI Telescope
- Beam splitter
- Slit
- Filter Wheel and Light Blocker Assembly
- CCD Assembly
- Internal Baffle 3 - places
• HRI
  – 30 cm aperture, f/35 optical system
  • Visible light detector
    – 1024x1024 CCD
      » 21 $\mu m^2$ 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.
Typical EPOCh Pointing Performance

EPOCh2008-131 GJ-436

Day of year

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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