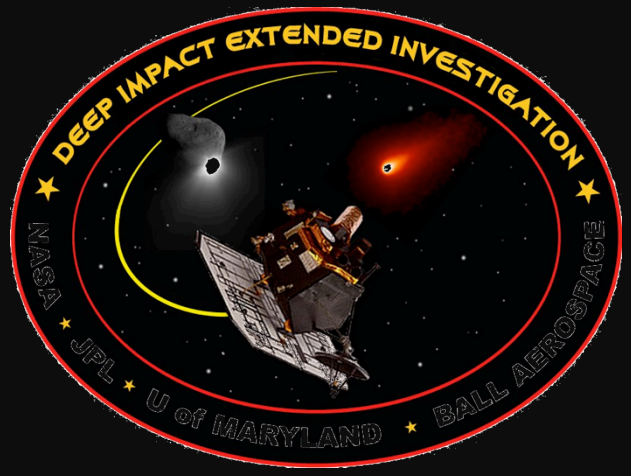
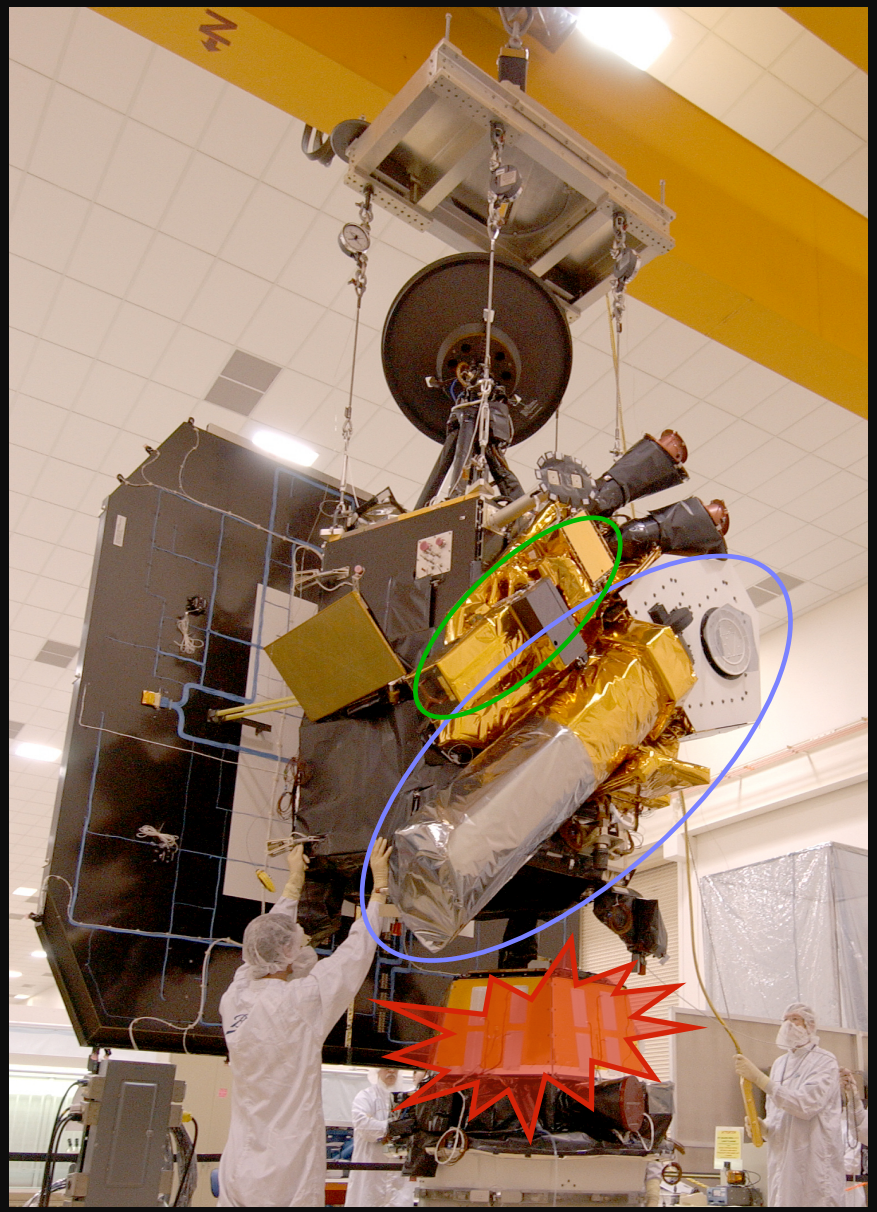
Deep Impact Continued Investigations (DI3)

Tony Farnham

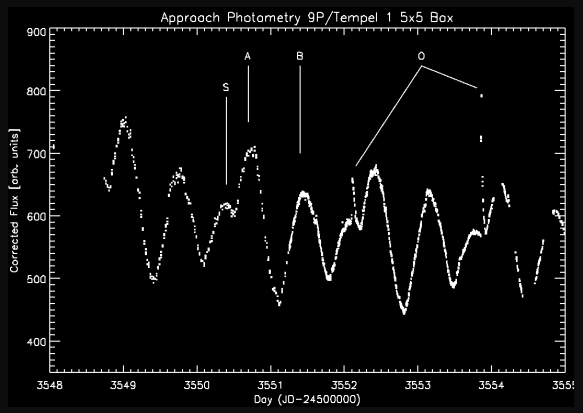


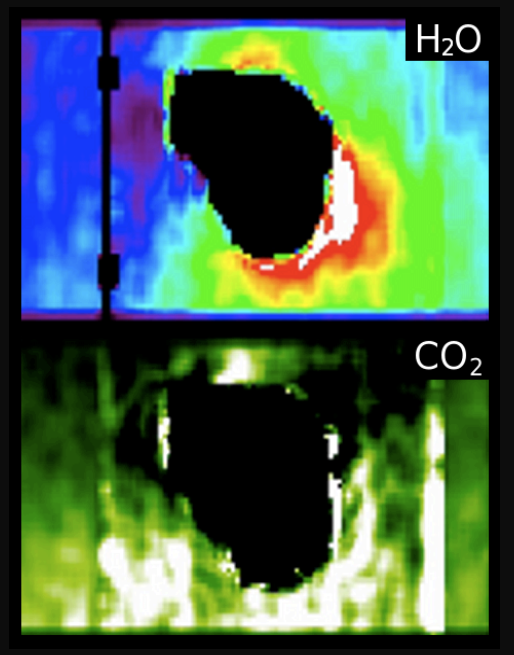
Deep Impact Spacecraft

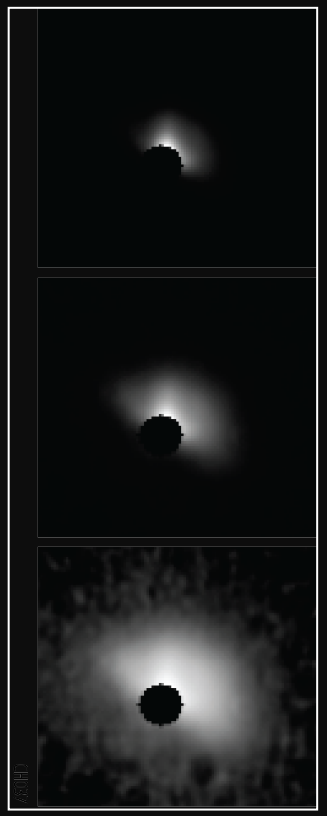


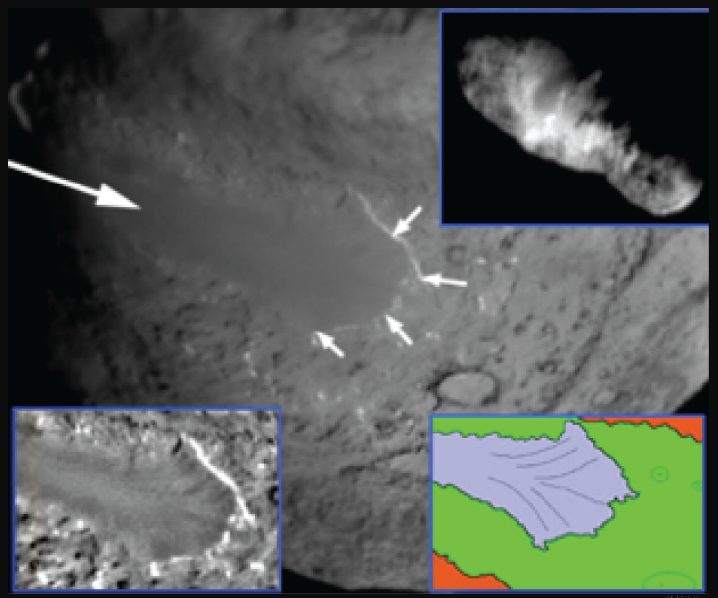
- Medium Resolution Imager (MRI)
  - 8 broad and narrowband filters
    - OH, CN, C_2 and continuum
  - 10 μrad/pix
- High Resolution Imager (HRIVIS)
  - 8 filters (colors)
  - 2 μrad/pix
- Near-IR Spectrometer (HRIIR)
  - λ ~ 1.05 - 4.8 μm
  - R = δλ/λ ~ 250 to 700
  - Capture H_2O, CO_2 and CO
- Impactor Targeting System (ITS)
  - ~MRI (destroyed at Tempel 1)

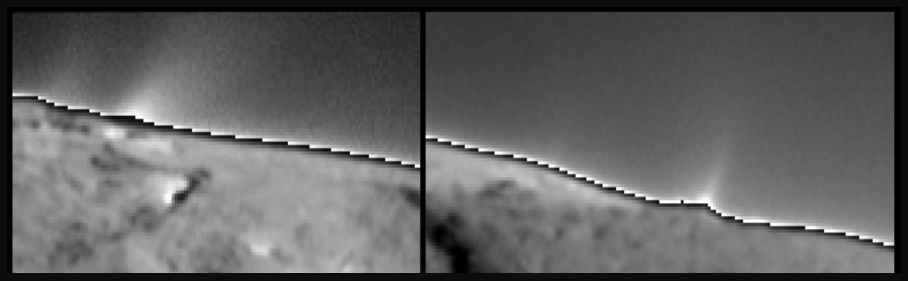
Deep Impact Primary mission
Comet Tempel 1 – July 4, 2005



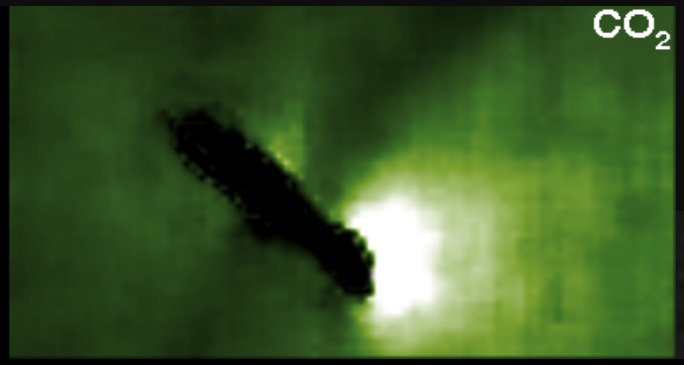


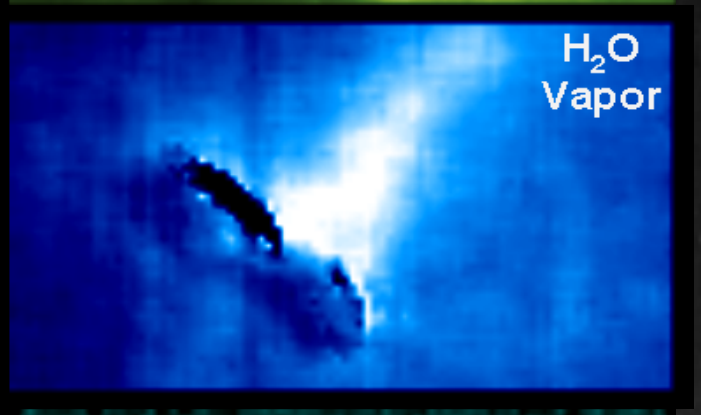


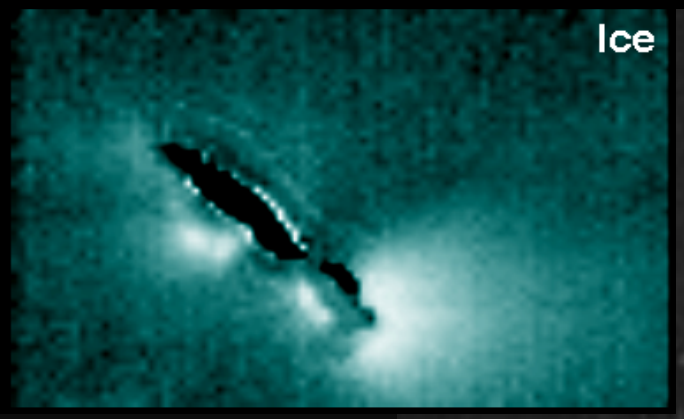


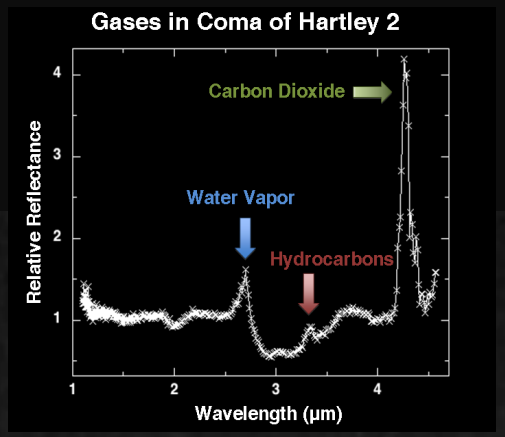


Deep Impact eXtended Investigation
Comet Hartley 2 – Nov 4, 2010









Post-Hartley 2 Activities

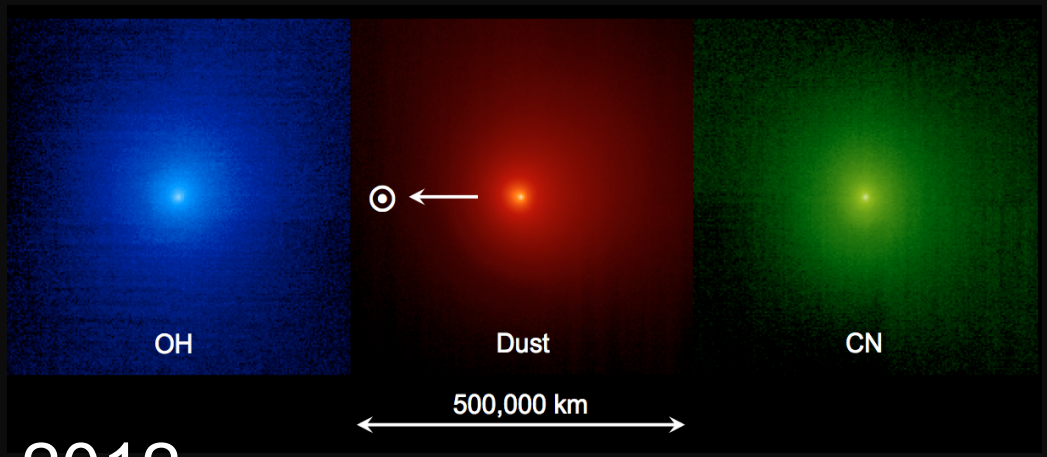
- Spacecraft and all (non-vaporized) instruments are healthy
- Retargeted for third flyby in 2020
  - Near-Earth asteroid 2002 GT
  - Potentially hazardous object
  - Not enough fuel to reach another comet
- Cruise science
  - Use as a remote observatory for bright comets
  - Plenty of interesting candidates in the next few years
- Low-cost science
  - Developed sequences that are reused for every comet
  - Minimal staffing
  - Low priority for DSN time (limits amount of data obtained)

Spacecraft is a Unique Asset

- Proven high-quality instruments
  - Optimized for cometary science
  - New IR calibrations completed in 2012
- Only facility that can directly observe CO_2
  - Also measure H_2O and CO at the same time
  - Direct comparison of three major comet species
- Atmosphere is not a factor (weather, telluric lines, etc)
- During windows, can continuously observe
  - High cadence observations, long-term monitoring
    - 15 min sampling for ~1 week with MRI imaging
    - 15 min sampling for ~2 days with IR scans
- Different viewing geometry from Earth- or space-based
  - Complementary data
  - Fill in gaps when Earth can't observe (e.g., ISON)

Comet C/2009 P1 Garradd

- Served as proof of concept for remote observations
- Bright Oort cloud comet



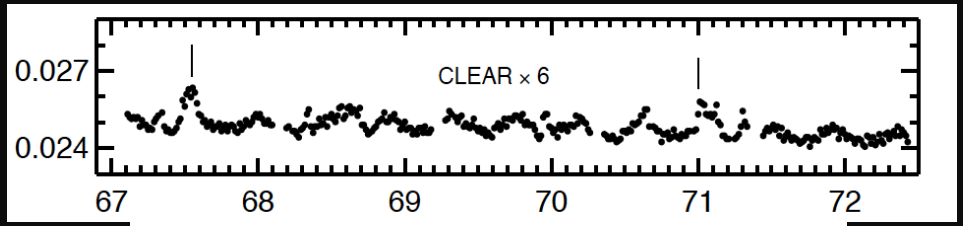
- Observed Feb 20 – Apr 10, 2012

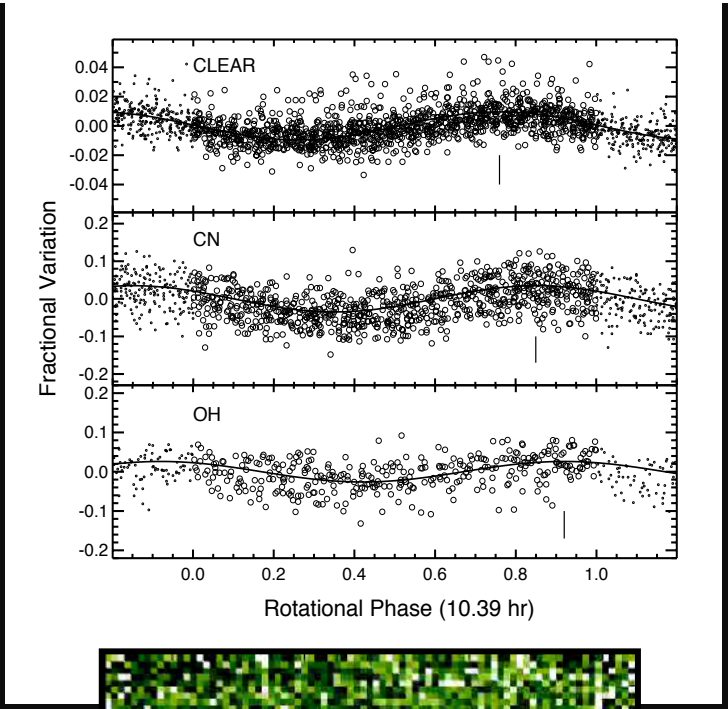
  r = 1.74 to 2.11 AU, Δ = 1.88 to 1.30 AU

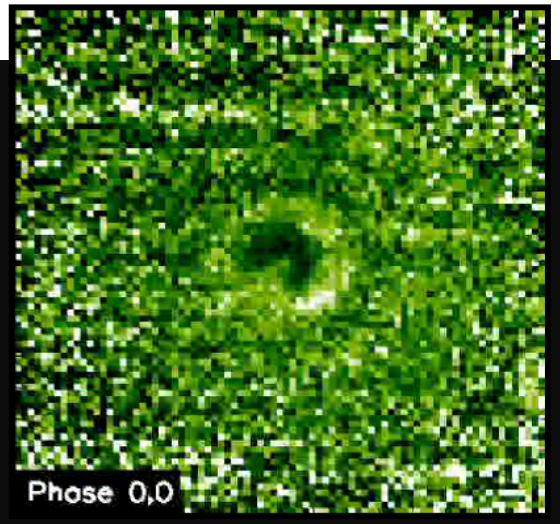
- Highlights:
  - Measured Afρ and OH, CN production rates (in progress)
  - Measured rotational properties undetected from Earth
  - First simultaneous detection of H_2O, CO_2 and CO
  - In conjunction with ground-based data, showed uncorrelated behavior between H_2O and CO
    - Abundance ratios depend on when it is observed!

Garradd Results - Rotation

- Lightcurve variability
  - 10.39 hr period (single peak)
  - 1% in cont., 4% in CN
  - Sensitive because of monitoring
  - Peaks for different species are offset
    - Different sources
  - Two small outbursts
- Spiral arcs constrain pole direction (points away from DI)
  - RA ~ 227° Dec ~ +27°
  - Obliquity ~60°
  - Gas velocity ~700 m/sec







CN

Garradd Results – IR Spectra

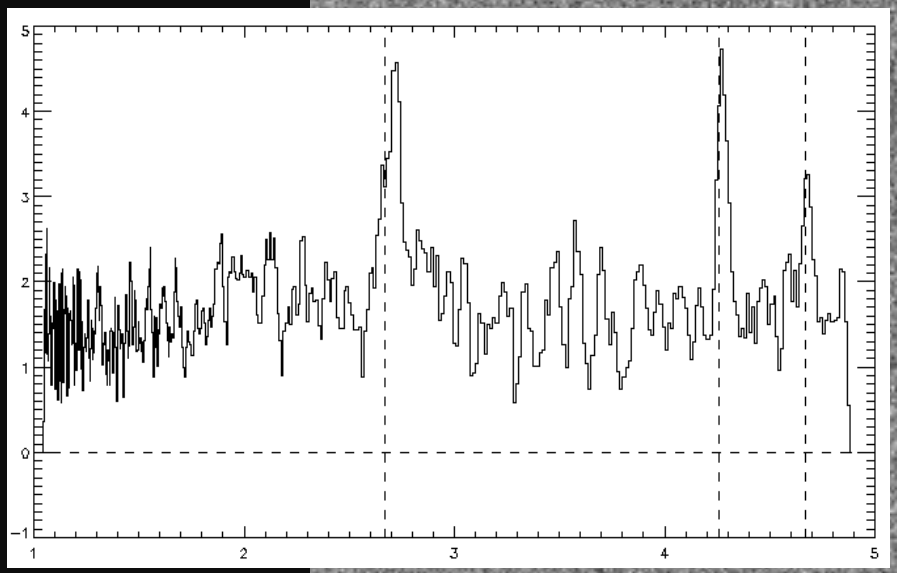
- Observed Mar 26-27 and Apr 2-3, 2012
- Detected H_2O, CO_2 and CO for the first time

  Q_{H2O} = 4.9 x 10^{28} mol/sec

  Q_{CO2} = 4.1 x 10^{27} mol/sec

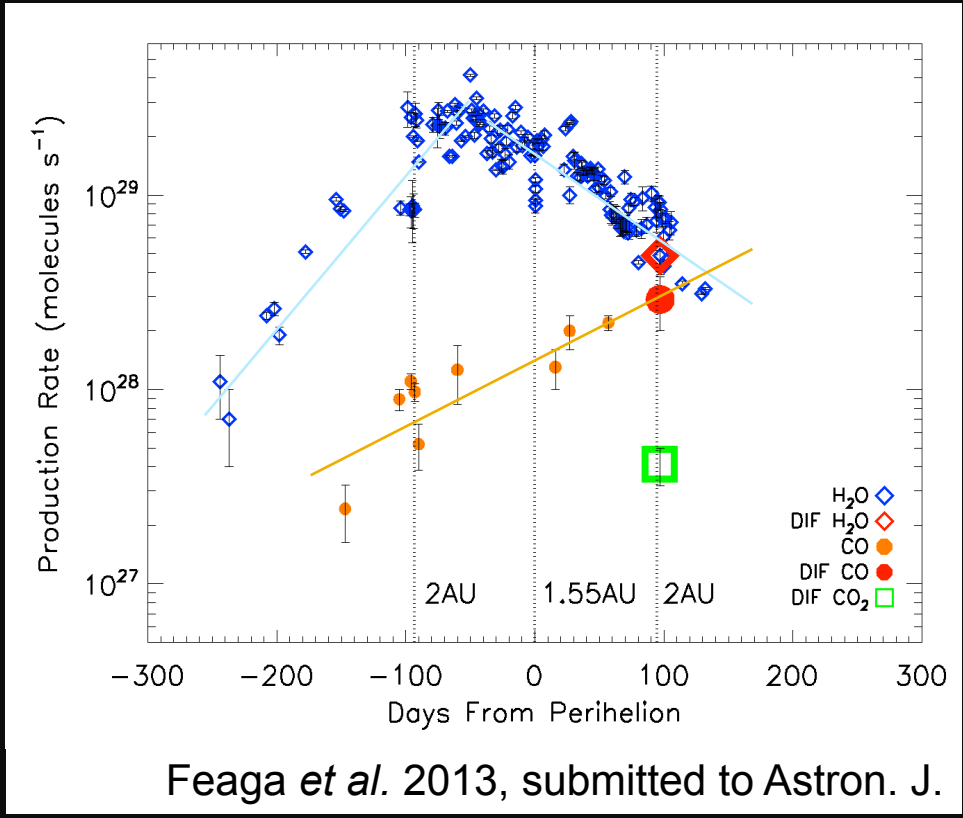
  Q_{CO} = 2.9 x 10^{28} mol/sec

  – Highest CO/H_2O ever observed inside the snow line (60%)



Garradd Results – IR Spectra

- CO/H_2O from DI differed from ground-based measurements
- Follow-up with ground-based data showed H_2O and CO differ temporally
  - H_2O peaks 2-3 months before perihelion
  - CO increases monotonically
    - Never seen before
  - CO_2 measured by DI, but trend is unknown
- Interpretation: A heterogeneous nucleus experiencing a seasonal effect OR rapid pre-perihelion water loss globally exposed less altered material containing CO
- Need frequent monitoring of relative abundances to truly understand behavior



Feaga *et al.* 2013, submitted to Astron. J.

Comet C/2011 L4 PanSTARRS

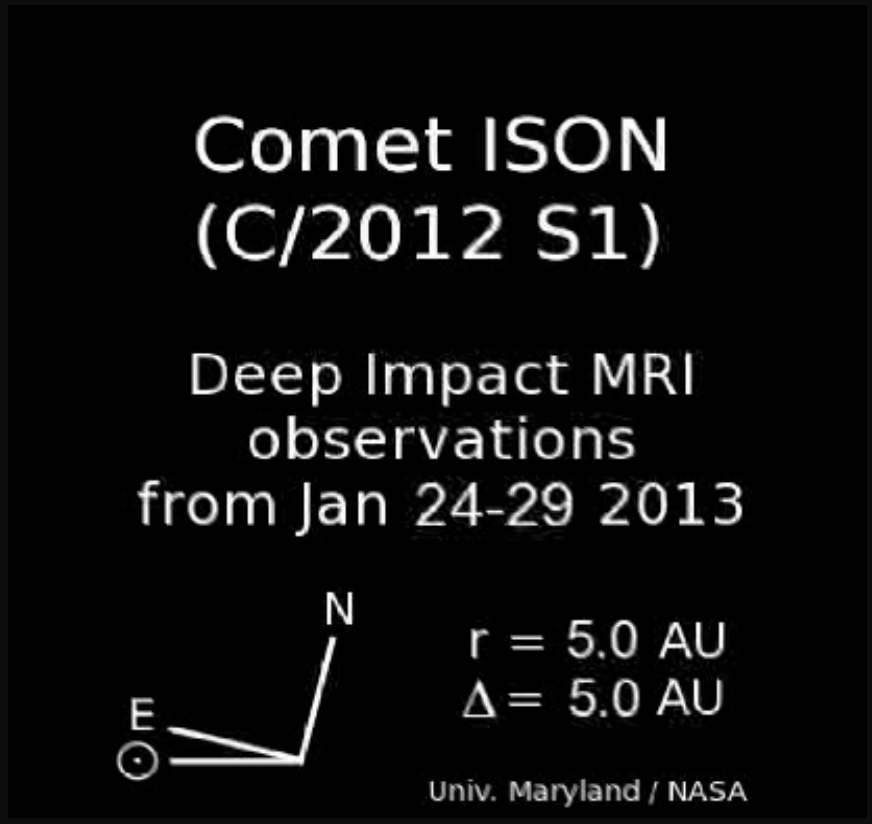
- Bright, well observed long-period comet
- Were scheduled to observe October – December 2012
  - Inbound, shortly after crossing ice line
  - Cancelled due to request from NASA HQ to shut down the spacecraft
  - Survived, but with very minimal support
- Scheduled to get observations in September 2013
  - Outbound, near the ice line

Comet C/2012 S1 ISON

- Unique sungrazing comet discovered at large distance
- Priority for NASA
- Observed Jan 17 – Mar 10, 2013

  r = 5.2 to 4.5 AU

  Δ = 5.7 to 3.9 AU
- Faint, but shows activity
  - No gas detected in narrowband filters or in IR spectra
- Current observations
  - Observing now with MRI (July 6 – 11, 2013)
  - IR spectra scheduled for July 19-20 and ~Aug 11-16, 2013
- Filling in gap where ISON is not observable from Earth



Future Comet Observations

Planned/desired observations, pending funding and DSN time

- Comet 2P/Encke
  - Stable, short period orbit
    - Should be thermally evolved
    - Good comparison to the Oort cloud comets
  - Would be valuable to obtain measurements of dominant species
  - Window available Dec 2013 – Feb 2014
- C/2013 A1 Siding Spring
  - Makes a close approach to Mars in Oct 2014
  - NASA may be interested in the dust hazard
  - Windows Jan – Jun 2014, Nov 2014 – Feb 2015

Future Comet Observations

- C/2012 K1 PanSTARRS
  - Bright long period comet
  - Makes a close approach (0.12 AU) to DI in Aug 2014
  - Multiple observing windows straddle the snow line
  - Windows Nov 2014 – Feb 2015, June – Aug 2014
    Jan – Mar 2015, May – Jul 2015
- 67P/Churyumov-Gerasimenko
  - Support for the Rosetta mission
  - Windows Nov 2014 – Feb 2015, May 2015 – Mar 2016
- 19P/Borrelly
  - Deep Space 1 target
  - Extended window Jan – Sept 2015

Final Considerations

- We've shown that DI observations combined with ground-based observations are very powerful
  - We are putting together a web page outlining our observation windows and goals
  - We invite ground-based observers to provide input regarding their observations, for setting up collaborations and comparative studies
  - Dennis Bodewits is coordinating this
- Although HQ is looking more favorably on DI (thanks Lindley Johnson), it still has low priority
  - We request that SBAG recognize DI as a unique low-cost asset that contributes to the NASA mission, to minimize the risk of the spacecraft being shut down while it is still providing high-quality science.