DI, EPOXI, NExT
and Various Tirades

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Today in History

NASA

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DI Results - 1

- Impact Flash
  - Nuclear surface layer porosity >75%
  - All input KE (19GJ, and maybe more?) in KE of hot puff
- Excavated ejecta
  - Ice within 2m of surface (excavated ejecta are cold except for first 1-2 seconds); ice grains are long-lived, thus pure (not mantles on dark cores)
  - Excavated material $\geq 3\times10^4$ impactors
  - Momentum transfer efficiency ~ 2-3 (high porosity)
  - Excavated grains smaller than ambient --> grains are fragile aggregates
  - Fallback allows measurement of effective g ~ 0.34 mm s^{-1}
    - Implies ρ ~ 0.4 g cm^{-3} for bulk nucleus (porosity ≥ 65%); v_{esc} ~ 1.4 m s^{-1}; Y < 10 kPa and probably < 1 kPa
  - Excavated volatiles same as ambient (except C_2H_6)
  - Organics (dark ejecta) excess near surface

DI Results - 2

- Ambient comet
  - Ice is on surface but!
    - Only a trace in very isolated areas
    - Unrelated to bulk of outgassing
  - Negligible thermal inertia (but see Davidsson *et al*.)
  - Surface morphological structures vary dramatically among cometary nuclei
  - Layering is ubiquitous - from 10m scale to km scale
  - Water must be very near surface (10s of cm)
  - Outgassing is heterogeneous (CO_2 and H_2O come from different parts of nucleus)
  - Dust jets not well correlated with H_2O -
    - Not excess outgassing above exposed ice as widely thought
  - Natural outbursts are frequent (~ 1-2 wk^{-1})
    - Correlated with rotational phase?
  - Lots of circular depressions, some with raised rims, and all with a size distribution like that of craters on asteroids

New Questions

- How do we make the layers in comets?
  - Are we seeing primordial cometesimals?
- How do we preserve the porosity during accretion of comets?
  - Are accretion velocities lower than models suggest?
- Is the heterogeneity of outgassing primordial?
  - How do seasonal changes affect the outgassing?
  - If primordial, this means radial mixing of cometesimals
- How are jets made?
- What drives natural outbursts?
- Why is morphology so different in the absence of apparent causes?
- Erosion must keep surface fresh at every apparition - so how can there be so many craters?
- Are outbursts ubiquitous?

EPOXI

- Deep Impact flyby spacecraft will fly past 103P/Hartley 2 on 4 Nov 2010
- R~800m, much smaller than 9P/Tempel 1 (or any other comet imaged *in situ*), but more active in total, thus much more active per unit area
  - A different kind of comet that should help sort out the reasons behind the morphological differences seen among comets
- Encounter at r~1.05 AU, Δ ~ 0.14 AU
- Surface brightness relative to Tempel 1
  - Gas 20x, dust 4x, nucleus 2x
  - Much better signals for all aspects
- Encounter geometry improved (approach phase ~ 90°)
  - Spectrometer colder, much less background signal
- Orbital history and phasing different from Tempel 1
  - Perihelion reduced since 1890 in steps to 1940
  - Statistically expect different season than for Tempel 1
  - Helps separate evolutionary from primordial effects
- Higher frequency sampling to understand outbursts
- Expect Surprises!!!

Target Comparison

	Tempel 1	Hartley 2
Nuclear Radius [km]	3.0±0.05	0.8±0.15
Nuclear Albedo	0.04	0.04
Dust Production = log(Afρ) [cm]	2.2	2.6
Water Production = log(Q(OH)) [s^{-1}]	27.6	28.5
$r_{\odot}$ [AU]	1.49	1.06
Δ [AU]	0.9	0.16
Encounter Speed [km/s]	10.3	12.3
Approach Phase [°]	63	86

Earth Flybys

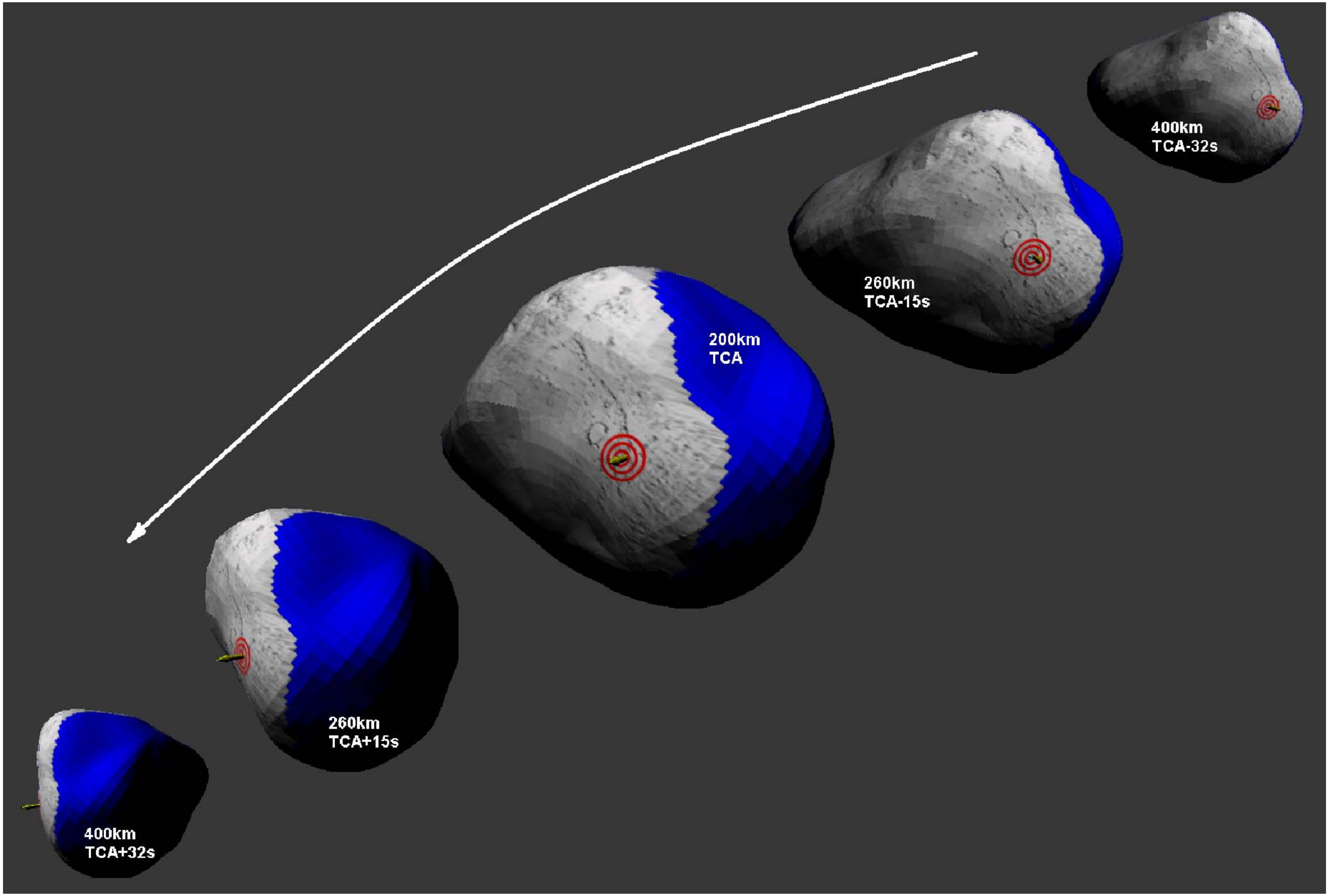
- 29 Dec 2008 - completed successfully, transfer to higher inclination orbit
- 29 Jun 2009 - approach from north, CA~1.35E6 km
- 28 Dec 2009 - approach from south, CA~1.34E6 km
- 27 Jun 2010 - approach from north, CA~3.04E4 km

- 4 Nov 2010 - Encounter Hartley 2, CA~750km
- Observations for 60 days on approach & 30 days on departure
- At CA, nuclear diameter ~ 1000 pixels in HRI, ~200 pixels in MRI

Stardust NExT

- Stardust spacecraft (minus sample canister) to fly past 9P/Tempel 1, 14 Feb 2011
  - Roughly 1 orbit + 1 month after Deep Impact
- Key Goals
  - View the DI crater
    - dust was too fine and too numerous for DI to see through
    - Size of crater places more constraints on the yield (shear) strength of the surface layers
  - View more of the surface
    - Trace layering across the nucleus
  - Study the erosion of the surface over an orbital period
    - Is it uniform?
    - Which terrains evolve the most?

NExT Encounter



What Next?

- Follow the water!!! We can discover water in comets as well as on Mars
  - Comets are still the most nearly pristine bodies that we can reach and thus most likely to tell us about solar system origins if we can make the right measurements
- ESA will place Philae on surface of 67P/Churyumov-Gerasimenko and follow it from > 3AU through perihelion
  - Dramatic increase in understanding of top 10s of cm of one location
  - Dramatic increase in understanding of evolution around an orbit
- Next big step is a bulk sample return
  - Get enough rare grains to do real isotopic studies and thus get proper ages
  - Return the organics unmodified
  - Try to return the volatiles as ice, but at least a complete inventory of them
- Should be New Frontiers but!
  - If cost caps don't rise appropriately it won't fit
  - If NF allows over-budget Discovery proposals, then strategic/flagship missions should be opened up to NF missions that don't fit NF if the science is compelling
  - bulk sample return is as important as, and most likely cheaper than, Europa or Titan for a flagship mission
  - Even CRYOGENIC sample return from a comet is easy compared to Mars sample return and will almost certainly lead to greater breakthroughs in understanding the solar system and its origin

General Rants

- Must keep PI-led missions to ensure enough flight opportunities
  - Will some Discovery missions be allowed to fail? What is the risk-reward trade?
- Must not let MSL eat the entire planetary exploration budget
- Flight opportunities for technology are crucial
  - How do new technologies fly on science missions?
  - ASRGs are one of several technologies that need to become flight qualified, also new comm systems
- NASA is capable of leading
  - Don't follow the herd trying to do better what ESA, JAXA, ISRO, etc. are doing (unless they are clearly going to do an inadequate job)
    - BUT! Ensure US scientists are involved in those missions
    - Make sure the data become available to US scientists promptly
  - Dare to do the breakthrough missions that others don't do
    - Allow or invite scientists from other countries as needed but take the lead
  - Measurements in totally new regimes are the key to breakthroughs
- Fix ITAR so that foreign collaborations are practical
  - Get the community to work with congress