Cometary Science

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Major Cometary Goals: Last Decadal Survey

Building Blocks of the Solar System

- Where in the solar system are the comets found, and what range of sizes, compositions, and other physical characteristics do they represent?
- What processes led to the formation of these objects?
- Since formation, what processes have altered comets?
- How are comets involved in the formation of planets?
- How have they affected the planets since formation?

None have been "answered"

Last Decadal Survey: Organics *(Don Brownlee)*

The Origins of Organic Matter that Led to Life

- *What is the composition, origin, and primordial distribution of solid organic matter in the solar system?*
- *What is its present-day distribution?*
- *What processes can be identified that create, destroy, and modify solid organic matter in the solar nebula, in the epoch of the faint early Sun, and in the current solar system?*
- *How did organic matter influence the origin of life on Earth and other planets?*
- *Is organic matter similarly distributed among primitive bodies in other planetary systems?*

Physical Characteristics

Where in the solar system are the comets found, and what range of sizes, compositions, and other physical characteristics do they represent?

Progress:

- Comets among the NEOs (based on orbital characteristics)
- Possibility of "Main Belt Comets" (MBC) based on dust activity for 3 objects near perihelion (Elst-Pizarro, etc.)
- Spitzer IR + ground-based visible survey (SEPPCoN)*
  - size, albedo, thermal inertia (many: porous, fluffy, poorly-conducting)
- Compositional surveys. For example, IR survey of volatiles (NIRSPEC) show significant variations
- Deep Impact *in situ* observations: high porosity, sub-μm particles, and low surface and bulk strength

*Survey of Ensemble Physical Properties of Cometary Nuclei

Physical Characteristics

Where in the solar system are the comets found, and what range of sizes, compositions, and other physical characteristics do they represent?

Current Questions:

- Are the NEO and MB comets actually comets? If so how did they get there?
- Are the physical characteristics measured to date representative of comets as a whole?
- Are their physical and compositional differences among the various potential cometary populations (Oort Cloud, Kuiper Belt, MB, NEO, Centaurs, Trojans?) ?
  - *More comprehensive surveys with larger statistics*
  - *In situ studies of candidate comets (re-activate them?)*
  - *Continued dynamical modeling to explain observations*

Cometary Formation

What processes led to the formation of comets?

Progress:

- Modeling (NICE) and Stardust: radial mixing in early solar system
- Compositional heterogeneity within and among comets, for example:
  - Deep Impact asymmetries in distribution of H_2O vs CO_2 in coma
  - NIRSPEC volatiles differences among comets and within comet Tuttle
- Comets maybe layered piles from low-velocity collisions of 10-200 m planetesimals (TALPS model)
- IR studies of Deep Impact ejecta show ice and non-ice are not intimately mixed (did not co-accrete)

Current Questions:

- What is the degree, scale, and origin of heterogeneity in and among comets?
- How are comets put together?
  - *Continued remote sensing surveys (compositional)*
  - *Detailed spacecraft studies of multiple comet morphology*
  - *In situ study of cometary materials (particle level)*

Cometary Evolution

Since their formation, what processes have altered comets?

Progress:

Observed morphology of Temple 1 (Borelly, Wild2)

- Large scale cryovolcanic (fluid) or glacial (solid) flows
- Pervasive layering
- Preservation of multiple impact craters
- Compositional heterogeneity (CO_2 vs H_2O)

• Current Questions:

- At what time scale do these processes operate? *(Stardust NExT)*
- How do the observed evolutionary processes related to bulk erosion and alteration of comets?
- Are cometary surface pristine or have they undergone significant physical and chemical alteration?
  - *Detailed spacecraft studies of multiple comets*
  - *In situ study of one comet at multiple times*

Planetary Formation

How are comets involved in the formation of planets?

Progress:

- Possibly cores of gas giants:
  - Juno Mission nearing launch will determine if Jupiter has core
- Delivery of H_2O and other volatiles to planets:
  - Remote D/H measurements in IR and particularly mm now possible

Current Questions:

- Are cores of giant planets comets, or because of early mixing in the solar system, could they be asteroids?
- What are the D/H ratios of various comets and how does that vary among the different comet populations?
  - *Continued remote surveys of D/H with increased sensitivity*
  - *In situ measurements of D/H for several comets*
  - *Continued dynamical modeling*

Post-Accretional Cometary Effects

How have comets affected the planets since formation?

Progress:

- In addition to K/T, possibility of more impact related extinctions
- Recognition of present day impact hazard
- Potential for comets to re-supply volatiles

Current Questions:

- What is the distribution of comets among NEOs?
- What is the isotopic composition of NEOs?
  - *Remote sensing studies + in situ physical and isotopic studies of candidate comets in NEO population*

Key Issues in Cometary Science

- What are the elemental, isotopic, molecular composition and physical interrelationships of cometary volatiles, organics, and minerals?
  - Comet Sample Return (TBD: Surface, Deep Core, Cryogenic?)
- How do comets work? What are the evolutionary processes active on comets and what drives them?
  Does (primordial?) heterogeneity drive evolution or is the heterogeneity the result of differential evolution?
  - Rendezvous with and study multiple comets in detail
- Where are comets located, how did they get there, and are there differences among populations?
  - More extensive remote surveys with larger statistics
  - Continued dynamic modeling
- How did comets form? How did particles aggregate into planetesmals and how did they aggregate into comets?
  - All of the above