Icy Bodies and the Outer Solar System:

New Scientific Explorations in the Visible and Ultraviolet

Hubble Science Legacy Workshop

April 3, 2002

Space Astronomy Laboratory
University of Wisconsin
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Comets, Centaurs, and Kuiper Belt Objects (KBOs):

RELEVANCE: **Comets and KBOs are the planetesimal remnants of planet formation in the outer solar system.**

Dynamical: **Comet, Centaur, and KBOs provide information on the orbital evolution of the solar system from *number/spatial distribution, apparition frequency, inclination, and eccentricity.***

Compositional: **Comet, Centaur, and KBOs provide information on the density, temperature, composition, and radial distribution (with heliocentric distance) from *volatile ratios (CO:OH), Isotopic ratios (e.g. D:H, OD:OH, C^{12}:C^{13}, albedo, and gas to dust ratios.***

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- *Co*

Popula

- *Co*

Long P

(Oort C

Short P

(Kuiper

- *Shorter Periods*

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Comet S Decade:

- What is the (c position of cometary nuclei *In situ* measur *Deep Impact, Rosetta*).
- How does the O vs. Oort vs. Extra solar?)?
- Remote sensi
  - Categ
- How do variat n, evolution, heliocentric diste distances.
  - Explori
- What aspects bound) planetary system formation?
  - Study c
  - Coordination with probes.
- What is the relationship between comet nuclei and KBOs/Centaurs?

Indirect Scientific Relevance and Goals:

RELEVANCE: **Comets are natural astrophysical laboratories. photochemistry, fluorescence, gas kinetics, and plasma processes.**

- Photochemistry (rates and branching ratios)
- Fluorescence (g-factors, detailed balance)
- Gas kinetics (collisional mixing to exospheric vectorial flow)
- Plasma Interactions (charge exchange, ion-pickup, MHD)

RELEVANCE: **Comets interact with the Sun and Solar Wind.**

- Comet ion interactions with magnetized solar wind
- Charge exchange with highly ionized solar wind component
- Photochemical sensitivity to solar FUV-EUV flux
- Variable sampling of solar latitudes (low cost *Ulysses*)

Comet Science Targets in the Ultraviolet:

Advantages:

- Low background continuum.
- Ground states.
- Higher energy interactions.
- Photochemical end states.

Detailed distribution, isotope ratios, and production rates of:

- Primary molecules (H, C, O, S, CS, $CO_{EUV-NUV}$, OH)
- Trace species (H_2, S_2, Ar)
- Ions (CO^+, CO_2^+, CN^+, O^+ - Response vs. solar wind activity and EUV flux)

Spectral lines of interest:

- O V at 525Å
- C III at 1084Å
- O III at 374Å
- Ne VIII at 448Å

430/442-38/539-617Å

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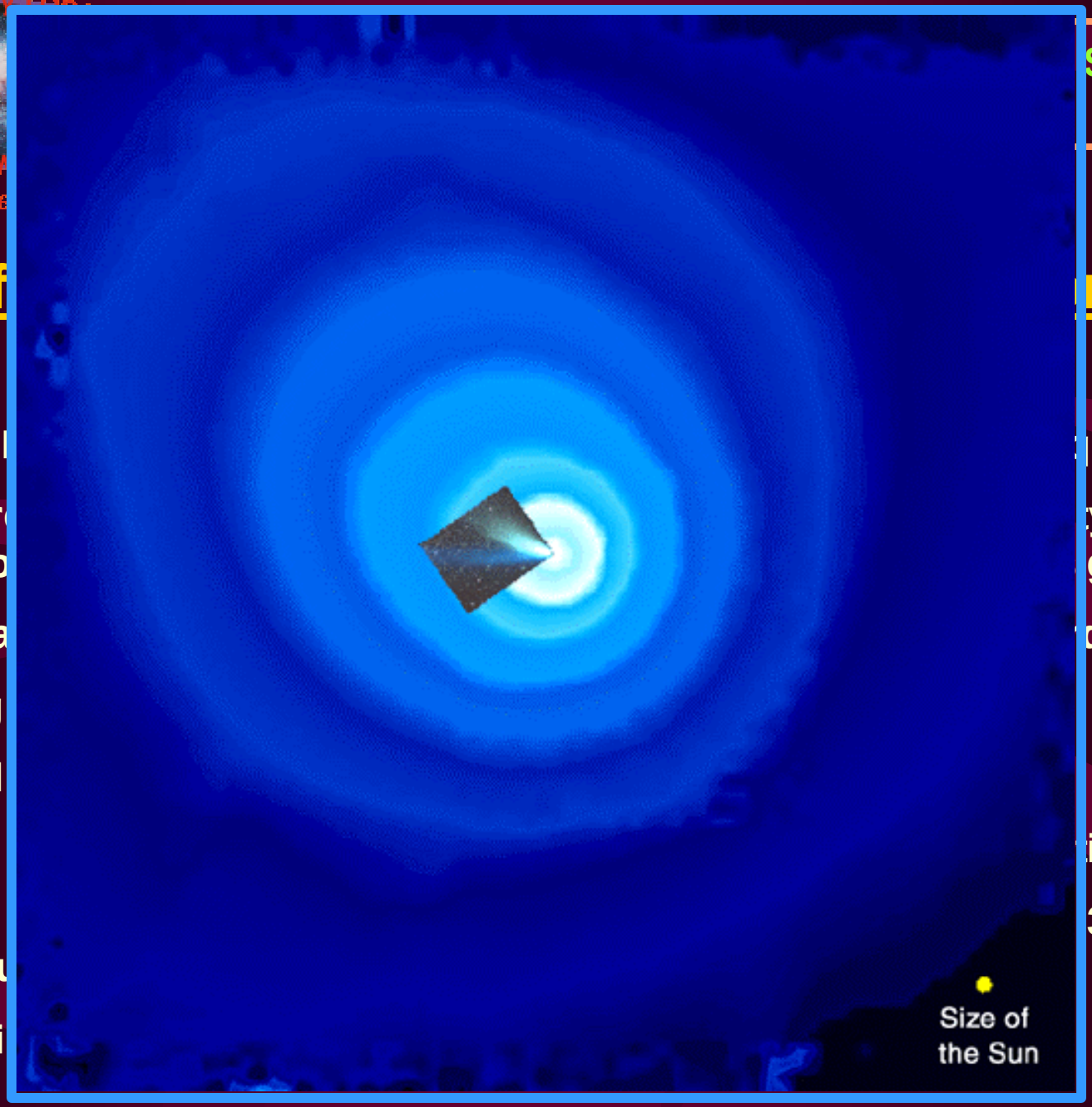
Scientific

Usef ry:

- Spatial l uate.
- Apertur y detecto gns.
- Bandpa der).
- Moving
- Several
- Echelle ion)
- Field of 30 arcminu
- Wide-Fi



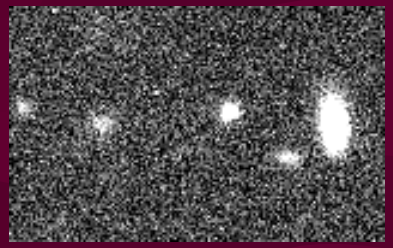
Programmatic Requirements:

The Comet Mission: We have had the capability to observe comets in the inner solar system where they are most active.

- Observe short and long term changes in individual object properties
  - Follow for entire orbits
  - Solar wind variations with cycle and solar latitude
  - Statistical samples of composition
- Scale lengths decrease
- Solar wind interaction more pronounced
- Rapid changes in temperature and activity levels
- Outbursts and disruptions (Deep Impact)

Centaurs and the Kuiper Belt:

- *KBOs and Centaurs preferentially sample of the high end of the Planetesimal population:*



- *KBOs and short period comets are thought to be parts of the same population:*

- *KBOs are relatively numerous (50,000-100,000 over 100 km in diameter):*

- *Centaurs represent bridging bodies, some comet-sized and all close enough to the Sun to have significant gas production.*

Populations and Dimensions:

Classical Belt:

Plutinos:

- Occupies the region between 40-49 AU
  - Clustered in the region near 40 AU
- Stable orbits with low eccentricity and inclination scatter
  - Stable orbits with a 3:2 orbital resonance with Neptune
- Remnant of protoplanetary disk
  - Pluto/Charon are members

Scattered Belt:

Centaurs:

- Aphelia out to 100 AU
  - Aphelia of 5-40 AU
- High inclination scatter
  - Wide size distribution
- Not consistent with planetary dynamical interaction
  - Unstable orbits require recent injection to the solar system

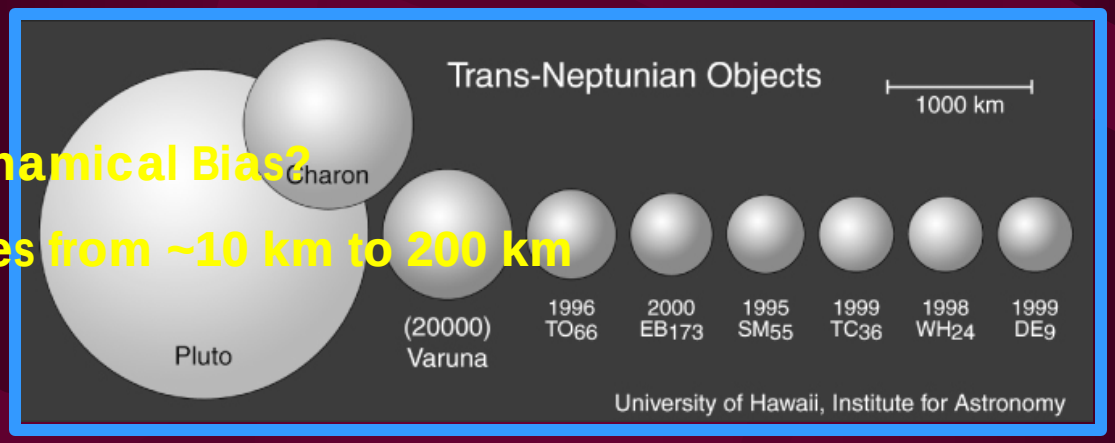
Size Distributions:

KBOs:

- Substantial Observational Bias
- Sizes from ~100 km up to Pluto

Centaurs:

- Dynamical Bias?
- Sizes from ~10 km to 200 km



Observational Limitations:

Centaurs:

- Gas production more easily studied in the radio
- Dust coma observable in the visible

KBO Surveys:

- Still in reconnaissance phase where all-sky searches are used
- Available field of view trumps from ground telescopes is greater

Spatial Scales in the Outer Solar System:

- No space telescope conceivable in the next 10-20 years will be able to resolve detailed surface features on *Pluto,* let alone the rest of the Kuiper Belt.

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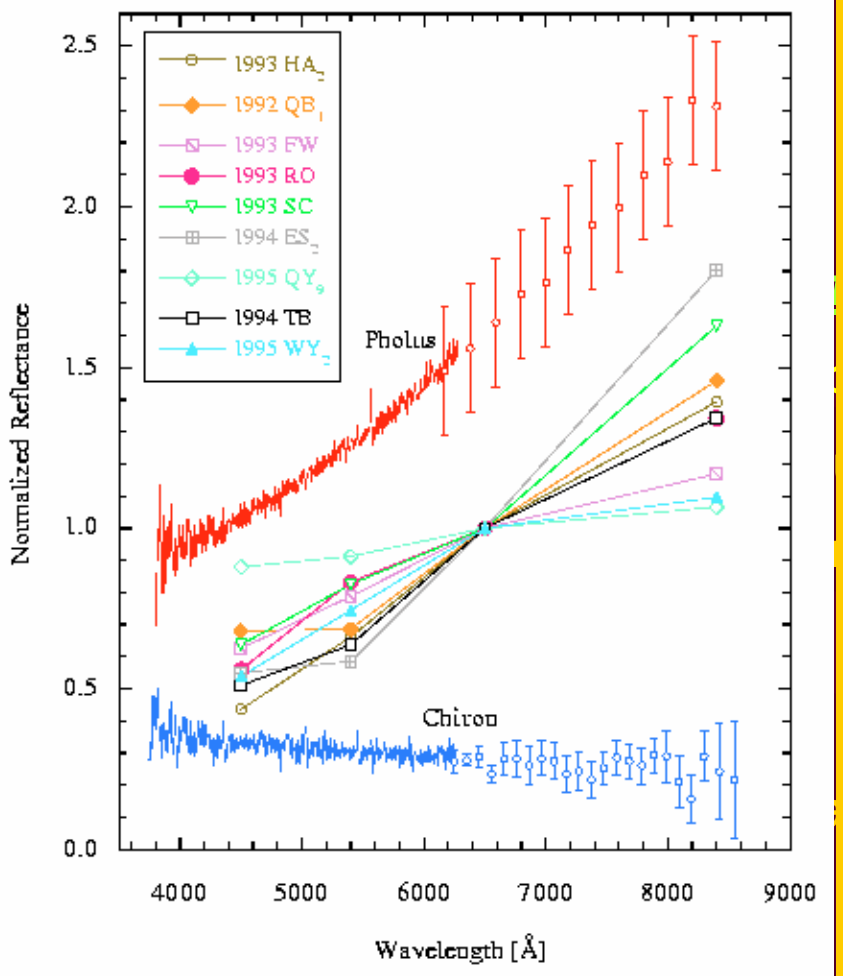


Fig 3: Luu & Jewitt, AJ Nov 1996

Take advantage of r ***f seeing:***

- Contrast increa based apertures
- AO systems lim udies and wide-field

Program: Inc operties including:

- Rotatio
- Satellit
- Size/Al -9%)

NUV Photometry/Sp

- Search for signa ic emissions
- Stellar occultations

Useful Capabilities for the HSL Observatory:

Precision Sensitivity:

- Maximize Aperture for Resolution and Effective Area
- Diffraction Limited Image Quality

Broad Bandpass:

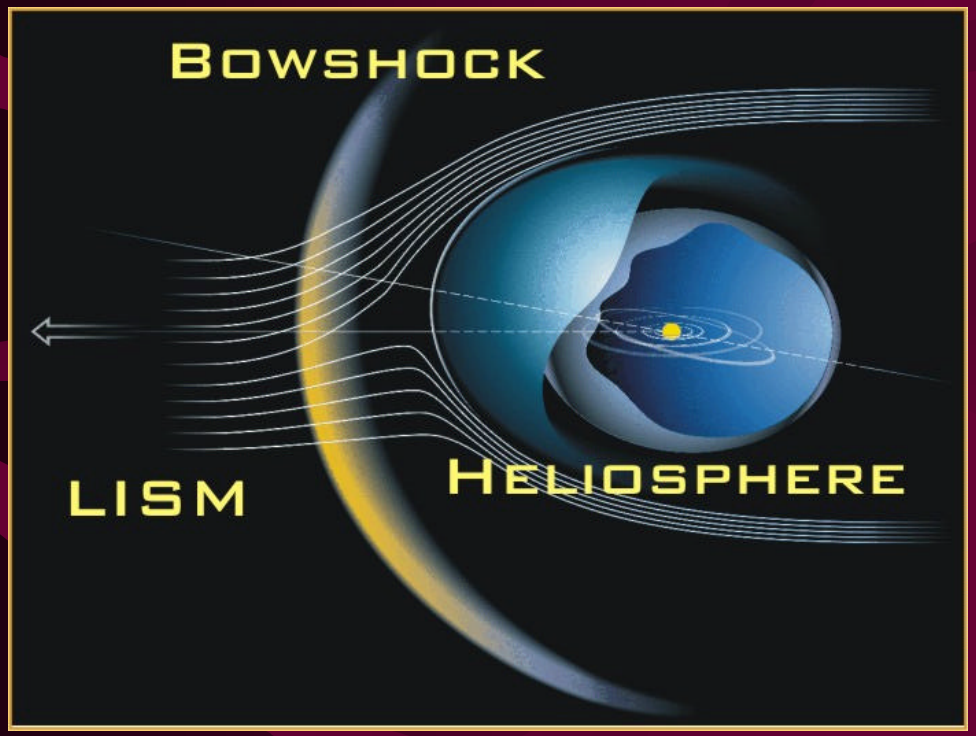
- Seeing and Background Advantages Extend to Visible
- Overlap and Direct Comparison with Ground

Filtering and Spectroscopy:

- 5-10Å Broadband Spectroscopy
- Broadband NUV-Visible Filters; Targeted Narrowband in NUV

Campaign Commitment for Characterization Surveys:

The Interplanetary Medium and Heliosphere:



- The Heliosphere is carved out of the Local Interstellar Medium by the solar wind.
- The Ionized component of the LISM interacts with the solar wind at a boundary, the Heliopause
- The neutral component of the LISM penetrates the solar system, where it scatters H Ly-a , is ionized by solar EUV, and charge exchanges with the solar wind.

Studies:

The IPM Ly-α emission line contains information about:

- The Temperature and Density of the LISM
- The Properties of the solar wind/LISM plasma interaction
- The Intensity of the solar ionizing radiation field
- The Density of the solar wind.

History:

- The Brightness and All-Sky distribution of the IPM has been mapped
- Existing facilities have not done as well with line shape studies

Useful Capabilities for the HSL Observatory:

Precision Sensitivity for Diffuse Targets:

- Wide-Field Aperture Summation Photometry (also good for certain comet lines)
- Very High (>10^5) Spectral Resolution (both wide and narrow field)

  -New Technology for wide field:

  - UV FPI?
  - Reflective SHS?