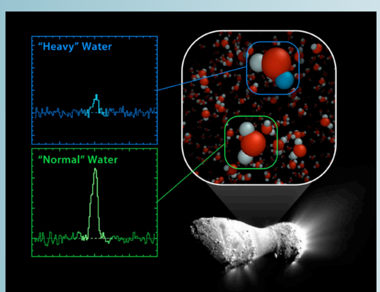
Solar System Studies with CCAT

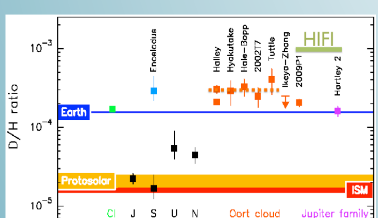
D.C. Lis (California Institute of Technology)
and
D. Bockelée-Morvan (LESIA, Observatoire de Paris)

COMETS

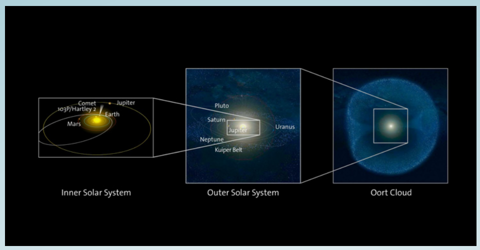
Comets as remnants of the protosolar nebula: Comets are among the most primitive bodies left over from the planetesimal-building stage of the solar nebula, and so their physical and chemical composition provides an important link between nebular and interstellar (or outer disk) processes. Recent dynamical models suggest significant mixing between the two main reservoirs of comets: the Oort Cloud and the Kuiper Belt. Consequently, we see increasing emphasis on classifying comets based on their composition and isotopic ratios, rather than orbital dynamics (e.g., Mumma & Charnley 2011).



Herschel/HIFI observations of water and HDO in comet Hartley 2. Picture: NASA-JPL/Caltech



D/H ratios in the Solar System. The orange squares show values measured for water in the Oort-cloud comets 1P/Halley, C/1996 B2 (Hyakutake), C/1995 O1 (Hale- Bopp), C/2002 T7 (LINEAR), 8P/Tuttle, and C/2009 P1 (Garradd). The arrow for 153P/Ikeya-Zhang indicates an upper limit. The recent Herschel/HIFI measurements in the water of comets 103P/Hartley 2 and C/2009 P1 are shown. Error bars are 1σ. From Bockelée-Morvan et al. (2012).



Comet reservoirs in the outer Solar System. Picture: NASA-JPL/Caltech

D/H ratio and the origin of the Earth oceans: Volatile-depleted primitive materials similar to current chondritic meteorites have long been considered the building blocks of terrestrial planets. In the prevailing model, the temperature in the terrestrial planet zone of the protosolar disk was too high for water ice to survive, therefore, the Earth accreted "dry", and water, and probably also organics, had to be delivered by external sources. Late-stage cometary impacts have long been suggested as a possible source of terrestrial water and understanding the D/H isotopic ratio in different solar system reservoirs provides key constraints.

D/H ratios measured in long-period, Oort-cloud comets, ~3×10^{-4}, correspond to a factor of 12 enrichment with respect to the proto-solar value in H_2, but are significantly lower than the values measured in heavy molecules in dense interstellar clouds. This suggests that comets incorporated material reprocessed in the inner solar nebula that was subsequently transported outward by turbulent diffusion. The high cometary D/H ratios, twice the Standard Mean Ocean Water (SMOW) value, measured in Oort cloud comets appeared to have ruled out the delivery of the majority of terrestrial water from cometary sources. However, recent HIFI observations of comets 103P/Hartley 2 (Hartogh et al. 2011) and C/2009 P1 (Garradd; Bockelée-Morvan et al. 2012) demonstrate that the earlier high D/H values are not representative for all comets. Consequently, a much higher fraction of Earth's ocean water could have been delivered by icy bodies like those currently residing in the Kuiper Belt or Oort Cloud, which also might have seeded the early Earth with organics.

The CCAT science objective is to significantly increase the sample of comets with accurate D/H measurements, by observing of the 509 GHz HDO line (inaccessible to ALMA), to allow statistical studies of the diversity of the isotopic ratio in the Oort Cloud and Jupiter Family comets, as well as possible correlations between the D/H ratio and chemical composition.

Comets like Hartley 2 could have been a source of ocean water. Picture: NASA-JPL/Caltech

TNOs

CCAT studies of the thermal continuum emission of TNOs using the short-wavelength camera will allow the determination of their physical properties (i.e., size, albedo, density, as well as the thermal properties). With a 350 μm confusion limit of 0.25 Jy, CCAT can detect a 100 km diameter TNO out to 20 AU or a 1,000 km diameter TNO out to 100 AU. A statistically significant sample of 200 TNOs can thus be observed in 400 hours, spread over 3–4 years.

CHAI INSTRUMENT

The CCAT Heterodyne Array Instrument (CHAI) is a modular, dual-frequency band array high-spectral resolution receiver, which in the first-light configuration covers the scientifically most important parts of the 460 GHz and 830 GHz atmospheric windows for simultaneous observations with 64-pixel (baseline) and 128-pixel (goal) arrays each. This is substantially larger than any of the few heterodyne array instruments currently in operation. The design emphasizes modularity and the pixel count is a compromise between best sensitivity on the one hand and simplicity on the other.

The baseline design matches major parts of the CCAT science goals for high-resolution, i.e. heterodyne, instrumentation at first light, with future improvements reachable within the goal specification and through upgrades at modest effort due to the modularity of the design.

The CHAI consortium combines groups from Universitat zu Koln, JPL/Caltech, Cornell, and Canada, which have a extensive heritage of successful collaborations from previous large projects, such as Herschel/HIFI.

CHAI will have an instantaneous field of view of about 2x2', beam size of 6.6'' , and pixel spacing of 14'' in the 460 GHz band, and 1x1' FOV, 3.5'' FWHM, and 8'' pixels spacing at 830 GHz. Covering transitions of CI, CO and isotopologues as well as other molecules, CHAI is an important component of the CCAT Observatory, enabling it to address key science questions in the area of ISM/star formation in Milky Way and nearby galaxies.

CHAI Goal Specifications

Number of pixels	2 times 128
Frequency coverage	430–510 GHz (L)
	800–835 GHz (H)
Front End IF	2–6/4–8 GHz
Spectral Resolution	100 kHz
Beam Size	6.3″/3.6″
Field of View	2′×2′/1′×1′
Trx (DSB)	<80/<150 K

References:
Mumma, M.J., & Charnley, S.B. 2011, ARAA, 49, 471
Hartogh, P., Lis, D.C., Bockelée-Morvan, D., et al. 2011, Nature, 478, 218
Bockelée-Morvan, D., Biver, N., et al. 2012, A&A, 544, L15

CCAT Engineering Design Phase is partially supported by funding by the National Science Foundation's Division of Astronomical Sciences

Canadian Consortium