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Results from the SEPPCoN Survey of Jupiter-Family Comets

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Introduction

Jupiter-family comets (JFCs) are a dynamically distinct group. One of the prime motivations behind studies of JFCs, is that their main source of origin has been shown computationally to be the Kuiper belt region beyond Neptune. Therefore studying the nuclei of these comets, as well as their coma species, can provide valuable insights into the nature of the km-sized KBOs. These include their size distribution and internal structure. With surface colour measurements one can study how their surfaces evolve from their journey towards the inner solar system. See [1] for a detailed review of this topic.

Unfortunately, most cometary nuclei tend to be both small (radii $\sim$ 1-3 km) and dark (albedo $\simeq$ 4%), and masked by the presence of gas and dust comae at small heliocentric distances. Although the database of physical parameters of asteroids continues to grow, there exist only 8 JFC nuclei that have acceptable constraints on their albedos and physical properties [2]. JFC nuclei can be characterized either by observing them when they are far enough from the Sun (typically $\geq$ 3 AU) that the sublimation levels are small or negligible, or from high spatial resolution images obtained from space-based telescopes.

A primary goal is to accumulate a large comprehensive set of high quality physical data on cometary nuclei in order to make accurate statistical comparisons with other minor-body populations such as near-Earth asteroids, Centaurs, and Kuiper-belt objects (KBOs). Information on the size, shape, spin-rate, albedo and colour distributions is critical for understanding their origins and evolutionary processes affecting them.

We present our latest analysis and results from SEPPCoN, our Survey of Ensemble Physical Properties of Cometary Nuclei. This on-going survey involves studying 100 JFCs – about 30% of the known population – at both mid-infrared and visible wavelengths. We have used the Spitzer Space Telescope to study the comets' thermal emission, and many large ground-based telescopes for extensive optical monitoring.

Ground-Based Optical Campaign

As the Cycle 3 Spitzer observations were being taken a large coordinated campaign was launched to observe the Spitzer sample of JFCs using large ground based telescopes in order to characterize, as much as possible, the physical properties of their nuclei at optical wavelengths. This is important not only for constraining the albedo distribution of this population of comets by linking with the Spitzer data, but also for deriving more robust measurements of their size and rotation-period distributions. In many cases time-series photometry was obtained thus reducing the uncertainties in mean size due to unknown rotational phase inherent to 'snapshot' measurements, while also allowing an assessment to be made on the comets' rotational period. Others were monitored over several observing runs, important for measuring phase-darkening curves.

So far we have been awarded $\sim$40 nights of observing on the following facilities for this programme: European Southern Observatory 3.58-m NTT and 8.2-m VLT (Chile); Apache Point ARC 3.5-m (New Mexico); 4.2-m William Herschel Telescope (La Palma, Spain); Univ. of Hawaii 2.2-m and Keck 10-m on Mauna Kea (Hawaii); Palomar 200-inch and 60 inch telescopes (California); 2.6-m Nordic Optical Telescope (La Palma, Spain); 2-m Liverpool Telescope (La Palma, Spain); and the SOAR 4.1-m at Cerro Pachón (Chile). To date we have attempted observations of 91% of our sample of 100 JFCs, at least 64 of those were successfully detected. Of those 64 detected comets just 16 showed signs of outgassing. In most cases the comets were at heliocentric distances between 3.0 and 6.5 AU. This data set is further augmented by archival data from the NEAT programme [3]. The analysis of the optical data sets is on-going and we will present an progress update on this and on the analysis of the Spitzer data.

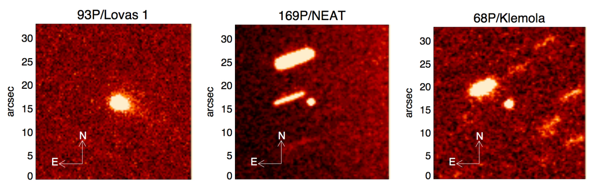

Figure 1: Examples of processed optical R-band imaging of three comets successfully detected at the ESO 3.6-m NTT telescope in May 2007. Comet Lovas 1 shows clear signs of activity, whereas comets NEAT and Klemola appear unresolved.

Spitzer Large Programme

The Spitzer observations (imaging with IRS PU and MIPS: 16 and 22 μm) are complete [4] [5]. Almost all our targets were imaged while farther than 4 AU from the Sun, to minimize (and often eliminate) confusion caused by dust from cometary activity. The Spitzer data constrain the effective radii of the nuclei and we find, preliminarily, that the cumulative size distribution's power-law slope is similar to what has been found by others using visible wavelength studies, suggesting that there is no strong trend of albedo with size. The Spitzer data also tell us about the thermal inertia, and we find that many – though not all – cometary nuclei seem to have low values, consistent with a porous, fluffy, poorly-conducting, dusty surface layer. The Spitzer images show that about one-third of our sample appeared with extended dust emission despite being close to aphelion. We find that JFCs are more likely to be active post-perihelion, than pre-perihelion, at least at these heliocentric distances ($R_h \geq 3$ AU). We have used dynamical analysis to constrain the dust grain sizes and thereby distinguish dust tails from dust trails. The dust temperatures are in most cases consistent with isothermal, low-albedo grains in LTE. Results from Spitzer observations of two of our targets were presented in [6] and [7].

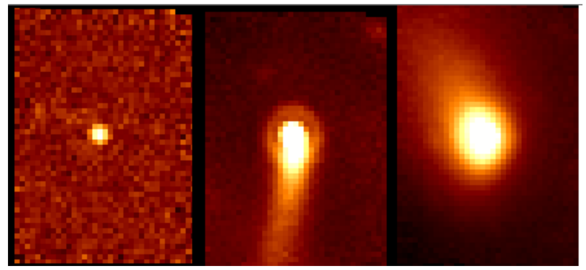

Figure 2: Selected images from the Spitzer programme (22-μm). *Left (68P/Klemola):* Comet appears as a sharp point source indicating that the nucleus dominates the observed flux and that good constraints can be placed on its size. *Centre (173P/Mueller 5):* Here the comet displays some activity but good constraints can be placed on its size with further detailed analysis. The Airy ring is clearly visible here, further emphasizing the point-like nature of the central part of the comet. *Right (32P/Comas Sola):* This comet's vigorous activity severely limits what can be ascertained about its nucleus properties.

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