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"Observational Search for Cometary Aging Processes"

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OBSERVATIONAL SEARCH FOR COMETARY AGING PROCESSES
FINAL REPORT — NAGW-1897

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Program Goals & Overview

The scientific objectives of this study were (*i*) to search for physical differences in the behavior of the dynamically new comets (those which are entering the solar system for the first time from the Oort cloud) and the periodic comets, and (*ii*) to interpret these differences, if any, in terms of the physical and chemical nature of the comets and the evolutionary histories of the two comet groups.

Because outer solar system comets may be direct remnants of the planetary formation processes, it is clear that the understanding of both the physical characteristics of these bodies at the edge of the planet forming zone and of their activity at large heliocentric distances, r, will ultimately provide constraints on the planetary formation process both in our Solar System and in extra–solar planetary systems. A combination of new solar system models which suggest that the protoplanetary disk was relatively massive and as a consequence comets could form at large distances from the sun (*e.g.* from the Uranus-Neptune region to the vicinity of the Kuiper belt), observations of activity in comets at large r, and laboratory experiments on low temperature volatile condensation, are dramatically changing our understanding of the chemical and physical conditions in the early solar nebula.

In order to understand the physical processes driving the apparent large r activity, and to address the question of possible physical and chemical differences between periodic, non-periodic and Oort comets, the PI has been undertaking a long–term study of the behavior of a significant sample of these comets ($\approx$50) over a wide range of r to watch the development, disappearance and changing morphology of the dust coma. The ultimate goal is to search for systematic physical differences between the comet classes by modelling the coma growth in terms of volatile-driven activity. The systematic observations for this have been ongoing since 1986, and have been obtained over the course of $\approx$300 nights using the telescopes on Mauna Kea, Kitt Peak, Cerro Tololo, the European Southern Observatory, and several other large aperture facilities. A > 2 TB database of broad band comet images has been obtained which follows the systematic development and fading of the cometary coma for the comets in the database. The results to date, indicate that there is a *substantial* difference in the brightness and the amount of dust as a function of r between the two comet classes. In addition to this major finding, the program has been responsible for several exciting discoveries, including: the P/Halley outburst at r = 14.3 AU, the discovery of Chiron's coma and modelling and observations of the gravitationally bound component, observational evidence that activity continues out beyond r = 17 AU for many dynamically new comets

Program Highlights

- There is a dramatic difference in the level of activity on the outbound light curves of the short–period comets and the Oort cloud comets (dynamically new) comets. Between distances of 12-22 AU the dynamically new comets are as much as a factor of 100 brighter than the most active of the SP comets in the sample (P/Halley).

- A database of comet nucleus sizes is being built up which shows that the SP comets and the Oort Cloud comets both have surprisingly small nuclei. The difference in the activity levels therefore has to be due to the type of volatiles present. Since the SP comets evolved dynamically inward from the Kuiper Belt population which formed farther from the sun and should have been intrinsically *more* active, this is clear evidence for aging.

- Several observations of the dynamically new comets have shown them to be active at extremely large distances: C/1987 H1 Shoemaker at r = 18.8 and 23.7 AU and C/1983 O1 Cernis at r = 21 and 23 AU.

- A database of comet nucleus colors has also been built up, and comparison with the Kuiper belt objects shows a similar diversity of nucleus colors, which may be indicative of surface processing.

- Discovery of cometary activity on 2060 Chiron at 11.8 AU, and development of a gravitationally bound dust atmosphere model. Subsequent observations with the Hubble Space Telescope confirmed the presence of the coma close to the nucleus. This project has instigated a long-term monitoring of the activity levels of Chiron as it approached its 1996 perihelion. Observations of Chiron on up to 200 nights continue to be analysed to look at both the long-term and short term brightness fluctuations.

- Determination of a new size for the nucleus of P/Schwassmann-Wachmann 1, indicating that it is not an extraordinarily large comet as previously believed. Determination that the comet is in a complex state of rotation.

- Co-Discovery of the outburst of P/Halley at 14.3 AU during February 1991. The comet was a factor of 100 brighter within a 5 arcsec aperture than the expected nucleus, and it possessed a coma extending greater than 300,000 km. By June 1991, at a distance of 14.88 AU, the coma had faded.

- An extensive set of data was obtained on the dynamically new comet C/1986 P1 Wilson (which was observed to have split in 1988. The entire set of observations has been analysed using Finson–Probstein dynamical dust models, an analysis of the light curve, and orbital dynamics to determine the possible time of splitting, the characteristics of the dust and the onset and cessation of activity.

- Supporting observations for space missions to comets have been carried out during the grant period. For example, an extensive data set has been obtained for P/Wild 2 (Stardust mission), from which the engineering models for the encounter have been developed (with R. Newburn at the Jet Propulsion Laboratory). In addition a rotation period was determined for P/Wirtanen (Rosetta mission), and other observations of future possible space targets have been undertaken.

- Development of a full Finson-Probstein modelling software package with improvements to take into account the light-scattering properties of the grains. Software was used to analyse ground-based and space-based observations of P/Halley to investigate the structure of the grains in the coma. (Thesis project of T. Farnham).

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