THE CHEMICAL AND PHYSICAL PROPERTIES OF COMETS: UNIFORM ANALYSES OF NARROWBAND PHOTOMETRY. D. G. Schleicher1, T. L. Farnham2, and A. N. Bair1, 1Lowell Observatory (1400 W. Mars Hill Rd., Flagstaff, AZ 86001), 2Univ. of Maryland (Dept. of Astronomy, College Park, MD 20742).

Brief Abstract: Comets are widely believed to be the most pristine objects available for detailed study remaining from the epoch of solar system formation. As such, comets can be used as probes of the proto-planetary material which was incorporated into our Solar System. We are now in the process of performing a new uniform reduction and set of analyses of 31 years of narrow-band photometry of 150 comets which form the Lowell comet database. We will present first-look results regarding the chemical compositions of comets for 62 comets measured since our first database analysis (A’Hearn et al. 1995), including evidence for as many as 10 compositional groupings, at least some of which appear to be associated with the comets’ place of origin rather than due to subsequent evolution. This research is supported by NASA's Planetary Atmospheres Program.

Full Abstract: Investigations of the chemical composition and physical properties of comets are important for a variety of reasons. In addition to revealing the characteristics of comets themselves, the composition and structure of comets hold unique clues to conditions in the early solar nebula and the solar system's formation processes, since comets are the most pristine objects available for detailed study. Differences in chemical composition or physical attributes among comets can indicate either differences in primordial conditions or evolutionary effects. Many comets exhibit significant seasonal variations in gas and dust production rates, and a sub-set show variations in coma composition with season, implying probable compositional inhomogeneities across their surfaces. The actual cause of a specific difference in properties can be determined by statistical analyses of the chemical, physical, and orbital properties of a large number of objects. Indeed, our original compositional study of the ensemble properties of comets [1] revealed that some properties were clearly associated with physical evolution induced by repeated close passages to the Sun, while other properties appear to reflect differences in conditions at the time of each comet's formation.

We are currently conducting a new compositional study, incorporating improved filter calibrations which effectively decontaminate the ultraviolet continuum filter of C3 emission, resulting in greatly improved NH flux measurements and associated ammonia abundances, and for the first time yielding meaningful colors of the dust grains. Including all of our narrowband comet photometry obtained since 1976 — over 770 nights of observations on a total of 150 comets — the sample size available for compositional taxonomic studies has also more than doubled from the original investigation [1]. In addition, numerous short-period comets have been reoberved, resulting in much smaller uncertainties. These uniform taxonomic and dust analyses for the database as a whole will tightly constrain the chemical and physical properties of comet nuclei and the dust grains released from these nuclei. Each of these properties will be examined for correlations with age, evolution, and site of the comet's origin. The results of these investigations, particularly from the improved ammonia measurements, will place additional strong constraints on the conditions present and the processes which took place during comet formation in the outer proto-solar nebula.

Figure 1. New compositional tree diagram for cluster analysis. The 62 comets are linked according to the degree of similarity of chemical composition; the longer the “branch,” the more diverse the composition. Newly measured Machholz 1 [2] is the bottom-most branch of the tree.
With the completion of the reductions of all data obtained since 1993 (i.e. since the original database), we have performed a first-look investigation of a compositional taxonomy for these data. In lieu of computing relative abundances by averaging production rate ratios for each comet (a task reserved for after the database is frozen), this first-look simply uses a single, representative data point for each comet. The results are shown in the figures, in the form of a dendogram based on a basic cluster analysis for 62 well-determined comets (Figure 1), along with principle component plots based on a separate principle component analysis (Figure 2). Even this first-look confirms several of the sub-groups seen in the original database analysis, and NH abundance is a clear discriminant which often differs from the abundances of the carbon-bearing species.

![Graph showing principle components](image)

Figure 2. Plots of the first 3 principle components are shown. Symbols are based on major branches from the cluster analysis. The first principle component (U1) consists primarily of near-equal parts of CN, C2, and C3 with respect to OH. The 2nd p.c. (U2) is dominated by NH with respect to OH, while the 3rd p.c. (U3) consists of near-equal parts of CN and C2 with respect to OH.

References: