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CORRELATED GROUND-BASED AND IUE OBSERVATIONS

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In this talk I will not really be discussing a new observational technique but rather something which deals primarily with the psychology of cometary observers and of those who schedule telescope time for cometary observers. My goal is to point out the great value of coordination among different observers, particularly those working in different wavelength regions. This coordination, which has already been mentioned yesterday, is more important among observers of comets than among observers of almost any other class of astronomical object. The basic reason for this is that comets are highly time-variable, often erratically so, and observations of a particular comet usually cannot be repeated. As a result, some uncoordinated observations cannot be interpreted at all while others are susceptible to misinterpretation. I will discuss several specific examples of coordinated observations based on recent experience. In some of these the coordination was deliberate while in others the coordination was a fortunate, accidental circumstance. Although I was involved to some extent in many of these observations, it should be obvious from the nature of the talk that many other people were also involved, some of them to an even greater degree than I was.

OH Production Rates in Comets

A first example was discussed yesterday by Millis when he compared the OH production rates derived from ground-based, filter photometry with those derived from IUE Spectrophotometry. The ground-based results could easily have been criticized either on the grounds of inadequate treatment of atmospheric extinction or on the grounds of inadequate absolute calibration. The IUE results, on the other hand, could have been criticized because they are based on observations of only a very small fraction of the comet and are thus quite model sensitive. The fact that the two methods are subject to unrelated sources of error and still yield results in reasonably good agreement gives much greater confidence that both methods are reliable.

In one sense, this is a relatively trivial example since one can carry out the relevant science using either technique alone. The second technique merely corroborates the first. In other cases, the science simply cannot be done without the coordination of observations.

HCN and CN Production Rates

A much more critical need for coordinated observations exists in the area of radio spectroscopy of comets. The only universally accepted observations of radio lines are those of OH and even here there appear to be discrepancies between the results derived from radio observations and those derived from optical and ultraviolet observations. More important, however, are the many negative searches for other spectral lines and the tentative detections of a few species (HCN, CH_3CN, H_2O). How should one interpret the many negative results? It seems that the only sensible approach is to compare the upper limits to abundances obtained from optical observations of chemically related species.

When Comet Bradfield (1979l) was first discovered, we were able to use the experience of previous ground-based photometry of comets and the apparent magnitude to estimate the production rate of CN that we would observe for this comet (c.f., A'Hearn and Millis, 1980). Since the comet would make an unusually close approach to Earth, it would also significantly alleviate the problem of beam dilution that plagues most radio observations. We then estimated that if the comet behaved normally and if HCN were really the parent of CN, then the HCN should be observable because of the favorable geometry. Zuckerman obtained observing time with the 36-foot telescope at Kitt Peak and searched for HCN as well as several other species. All searches were negative. Using the inner coma rotational temperature (kinetic temperature) determined for CS by Jackson et al. (1980) and using a Gaussian to approximate the spatial distribution of HCN, we were able to set an upper limit (5σ) on the production rate of HCN at a few times 10^{26} sec^{-1} and on the peak column density at 8 x 10^{12} cm^{-2}. These numbers are an order of magnitude lower than those found for Comet Kohoutek (Huebner, Snyder, and Buhl, 1974) and the molecular production rate is less than the expected CN production rate. In the absence of any other information we would have concluded that HCN could not be the parent of CN. Fortunately, we did have other information because Millis was carrying out filter photometry of the comet from Hawaii within 6 hours of the radio observations as well as on numerous other nights. It subsequently turned out that the CN production rate in Comet Bradfield had varied approximately as r^{-4} rather than the r^{-2} that we had observed in some previous comets (A'Hearn, Millis, and Birch, 1980). The upper limit for HCN production then turned out to be somewhat larger than the observed CN production rate rather than smaller. Although we might ultimately have recognized this variation in CN production from the visual magnitude light curve of the comet, it is quite possible that we would have drawn a totally invalid conclusion if we had not had nearly simultaneous radio and optical observations.

Although this was a relatively straightforward case, because there are several pieces of indirect evidence suggesting that HCN might be the parent of CN, it was also a particularly significant one because of the rather low upper limit achieved. There have been numerous other searches for radio spectral lines both of species observed in other spectral ranges and of species not previously observed in comets. Even negative results in some of these searches might have significance if properly related to optical results.

Triplet/Singlet Ratio of C_2

A third example will show that purely serendipitous results can be achieved if different observers happen to make relevant observations nearly simultaneously. When ananlyzing the CO^+ bands in the IUE spectra of Comet Bradfield, we discovered that the bands were not due to CO^+ at all and that the strongest of these bands was the $\Delta v = 0$ sequence of the Mulliken bands of C_2 (A'Hearn and Feldman, 1980). Although C_2 triplets have long been observed in the optical (the well known Swan bands), this was the first unambiguous observation of C_2 singlets from which convincing fluxes could be derived. Fortunately Birch in Australia and later Millis in Hawaii had been observing the Swan bands and, by coincidence, some of their observations were on precisely the same dates as the IUE observations. This enabled us to derive the triplet-to-singlet ratio for C_2 and, using the theory of Krishna-Swamy and O'Dell (1979), to derive the absolute transition moment for the forbidden transition $a\,^3\Pi_u - X\,^1\Sigma_g^+$.

Observations of "Bare" Nuclei.

Recently there has been much interest in attempting to observe the nuclei of comets, particularly to determine whether they bear any similarity to the asteroids. Comet Arend-Rigaux, at two previous apparitions, had appeared to exhibit a purely asteroidal behavior and at the 1977 apparition Paul Weissman stimulated a number of observers to attempt observations with the filter systems used successfully on asteroids. Fortunately, other observers were also stimulated to carry out the more usual cometary observations in the same time period. Degewij (1978) obtained a spectrum showing the typical cometary emission bands of CN and C_3 while I (1978) obtained Schmidt photographs indicating the presence of both a gaseous coma and a short, dusty tail. These observations showed quite clearly that the photometry of the asteroid filter sets could not be related in any simple way to the true nuclear properties.

More recently Ray Newburn has stimulated efforts to observe the nucleus of Comet Tempel 2 when it is relatively far from the sun. In this case a number of different observers carried out filter photometry (much of it not yet published) which should have led to a determination of the color of the nucleus. Other observers obtained spectral scans which should have described the nucleus. Most of these observers had carried out their observations on a simple, one-shot basis. When the observations of the photometrists were compared with each other (Zellner et al. 1979; Millis, private communication), it was clear that this comet had undergone unexpected outbursts. This makes it rather difficult to be sure, for example, that the spectrophotometry carried out by Spinrad et al. (1979) refers to the nucleus rather than to a halo of grains.

Although these various observers were not explicitly coordinated in the usual sense of the word, they were all stimulated to obtain data in the same general time period. If there had not been several observers active at this time, the outburst phenomena of Tempel 2 might have been suspected depending on which observers happened to get data, but might also have entirely escaped detection. It seems clear that somewhat greater coordination, perhaps involving UBV photometry in the week preceding and the week following the spectrophotometry, would have gone far to *determining whether the spectrophotometry was relevant to the nucleus itself.*

Infrared and Optical Albedo

We have already heard in this meeting about the attempts to determine the albedo of the grains in the cometary coma during the discussions by Gradie and Campins. Determination of the albedo involves comparison of the reflected solar continuum with the thermal emission, both of these quantities being measured by broad-band photometry. Although there is some evidence that the broad-band photometry in the infrared is dominated by true thermal, continuum radiation, it is certain that the broad-band photometry in the optical includes a large contribution from fluorescent emission lines. It appears to me that a significant improvement in these albedo estimates might result if the infrared photometrists were in closer coordination with the optical photometrists who use narrow-band filters specifically to isolate the reflected continuum.

Interpretation of Continuum/Emission Ratios

As a final example in which coordination might lead to improvements in understanding, I would mention the case of continuum/emission ratios measured to estimate the dust/gas ratio. The standard programs of narrow-band filter photometry of comets, such as that discussed yesterday by Millis but also including programs by a number of other observers, usually include a method for determining the continuum/emission ratio in whatever diaphragm is being used for observation. In some cases these measurements are made in a variety of different diaphragms but in general this is not the case. Direct interpretations of the continuum/emission ratio as a measure of the dust/gas ratio can be very misleading. For some comets, the continuum might be predominantly from a strong, nuclear condensation while for other comets the continuum might be spread out over the entire diaphragm (as is usually observed for new, dusty comets). It seems clear that the usual photometric results could be very profitably combined with contemporaneous spectra of the type described just a few minutes ago by Larson. The photometry would provide the absolute calibration while the long-slit spectra would provide the information on spatial variation of the continuum/emission ratio. This should considerably enhance our ability to interpret both sets of data.

In summary, I think we have a large number of different examples in which coordinated observing has led or could lead to significant, scientific gains. In the past, such coordination has been largely hit-or-miss although a few observers have made specific attempts for special projects. Coordination of this type has been discussed in the context of the International Halley Watch, which will be described tomorrow by Newburn, but the coordination is not a widely accepted procedure for cometary observing. I strongly urge that this coordination be more widespread than it is at present.

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