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INFRARED OBSERVATIONS OF COMETS

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The history of observations of comets in the infrared is quite short, the first observations of a comet in the infrared being made only 15 years ago (Ikeya-Seki (1965f) by Becklin and Westphal (1965)). Despite this short history infrared observations turn out to be very important for deducing a great deal about properties of the cometary dust surrounding the cometary nucleus; however, all observations in the infrared have been limited to long period comets. Observations of all comets to date seem to be typified by Figure 1 which is a plot of post-perihelion observations of Comet Kohoutek made by Ney (1974a). There are three features of the spectrum which seem to be present in nearly all of the comets observed: First, there is a peak in the spectrum in the near infrared and visible wavelengths, which can be attributed to scattered sunlight. This feature, as expected, gets fainter as a comet recedes from the sun. The second dominant feature in the spectrum is a broad peak in the infrared which is attributed to the thermal emission of the dust in the coma. This part of the spectrum also gets dimmer as the comet gets further from the sun, but at the same time the peak of the spectrum shifts to longer wavelengths, indicating that the dust from which this radiation arises is cooling as the comets recedes. The other feature in the spectrum which should be noted is the emission feature at about 10 microns attributed to emission from metallic silicates. This feature was first observed by Maas et al (1970) in comet Bennett 1969i.

The broad feature in the infrared which is attributed to the emission of dust grains has a peak which is determined by the temperature of the dust. In several comets it has been observed that the dust temperatures derived in this way are higher than the equilibrium black body temperature for a body at the comet's position in the solar system (Comet Ikeya-Seki, Becklin and Westphal, 1966; Comet Kohoutek, Ney, 1974a; Comet West, Ney and Merrill, 1976; Comet Bennett, Maas et al. 1970). This is so because the grains are not effective radiators of their heat at infrared wavelengths. This would be the case for example, if the grains were smaller than the wavelength of the infrared radiation they are emitting. This interpretation allows an upper limit of a few microns to be set on the size of the grain. The faithful reproduction of the solar spectrum in the near infrared and visible, however, indicates that the size of the grains must be larger than the wavelength of this radiation. From that one may deduce that the size of the grain must be larger than a few tenths of a micron. This broad generalization then sets the size of the dust grains in the coma at larger than a few tenths of a micron but smaller than a few microns.

A great deal of more specific information can be derived from detailed observations. For example, in the case of Comet Kohoutek, observations made by Ney (1974b) show no silicate feature in the anti-tail whereas the feature appears in the coma (Figure 2). This would indicate that the sizes of the particles involved in the anti-tail are larger than in the coma, since this condition would mask the effect of the silicate feature normally seen. Figure 2 also demonstrates the fact that the temperature of the grain in the coma is typically higher than that expected for the comet's position in the solar system. In this case the predicted equilibrium temperature is about 580^{o}, whereas the derived temperature of the coma is about 720^{o}. The fact that there there are larger grains involved in the anti-tail is consistent with the theory Sekanina (1974) that pieces fractured from the comet but which are too large to be blown away by radiation pressure remain in orbit in independant trajectories along with the comet itself. It is interesting to note that there was no silicate feature at all observed for Comet Kobayaski-Berger-Milon (1975b) (Ney, 1976) implying that only large grains were involved in the dust coma of this comet.

Another interesting feature of the infrared emission of comets is its occasional variability. For example, the infrared radiation of Comet West increased at a time consistant with the fragmentation that was observed to occur (Sekanina, 1976). Fragmentation is assumed to increase the total surface area. In Comet Bradfield (1974b) the silicate features at one point disappeared

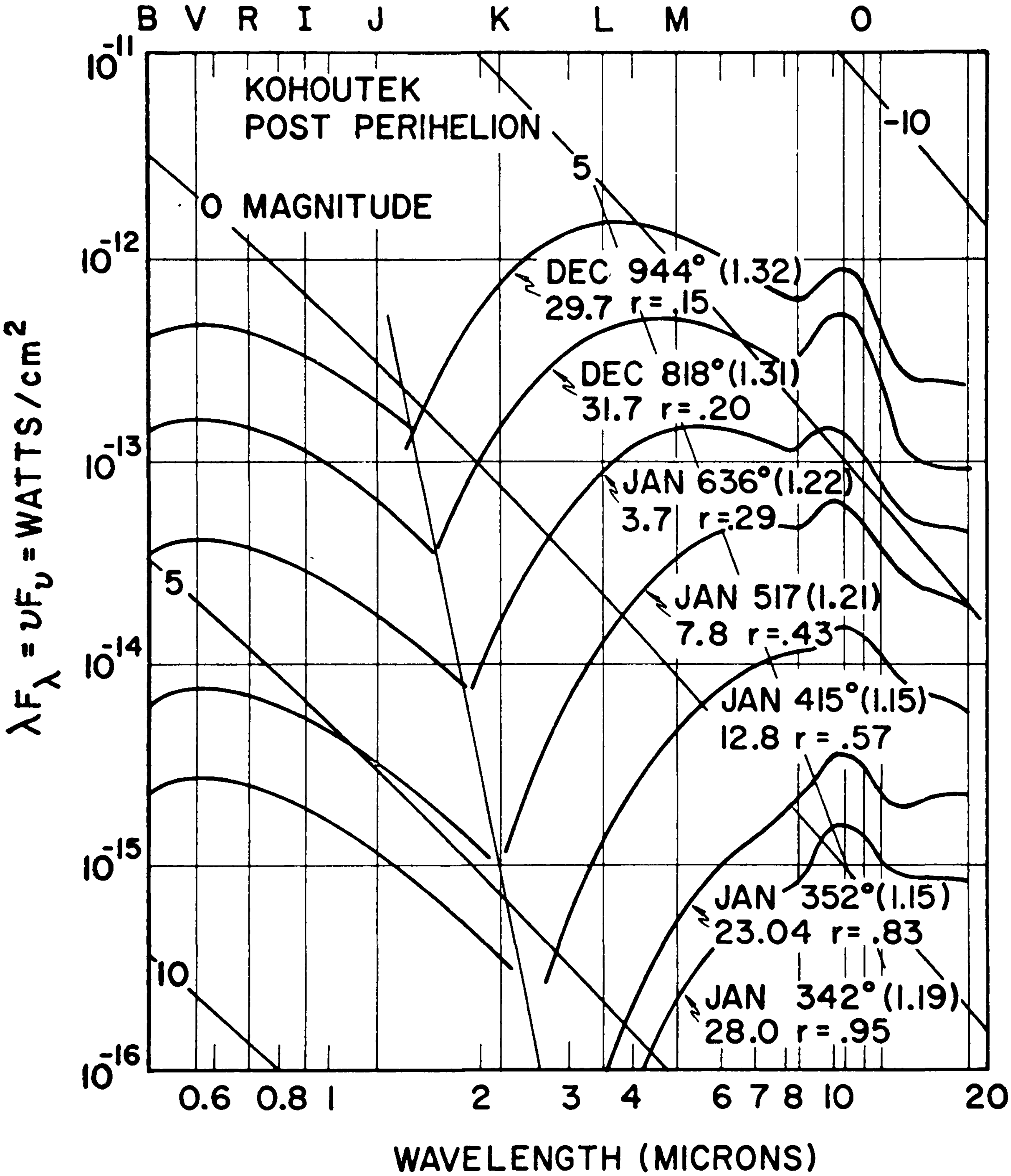

Figure 1. Postperihelion observations of Comet Kohoutek (Ney, 1974a). The three principal spectral components typical of observed comets can be seen: the peak in the visible and near infrared due to scattered sunlight; the infrared peak due to the thermal emission of dust grains; and the 10 micron silicate emission feature.

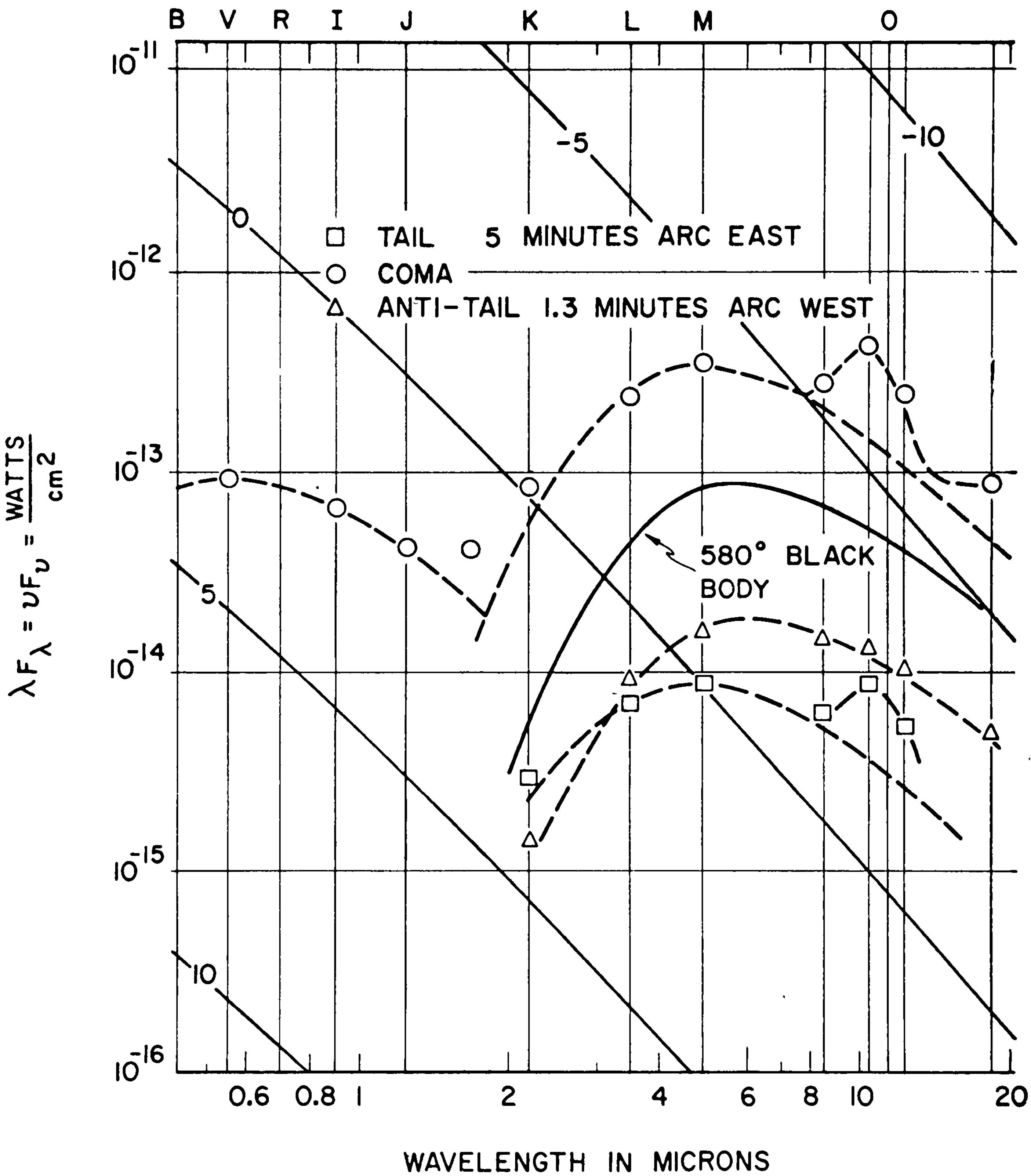

Figure 2. Infrared measurements of Comet Kohoutek (Ney, 1974b). Showing absence of silicate feature in anti-tail, and expected (580 K) blackbody spectrum for the distance of the comet from the sun.

abruptly (Ney 1974). This was accompanied by a large change in magnitude - about three magnitudes in four days. This implies either that the dust size was variable, that the amount of dust was variable or that perhaps a composition change had taken place. It has been suggested that this phenomena might be connected to the layering of the cometary material.

Infrared measurements have been used also to deduce the nuclear size. After the abrupt change in magnitude observed for comet Bradfield, a stellar image appeared to remain in the coma as if all the dust had been blown away. If the albedo of this remaining nucleus is assumed to be one, than a diameter of 5 to 10 km in size would account for the remaining infrared brightness (Ney, 1974). In the same manner an extrapolation of photometry as a function of diaphragm size was used by Rieke and Lee (1974) to derive a size for comet Kohoutek of about 10 km.

Comet West provided the geometry necessary to study the albedo of the dust grains as a function of the illumination angle. The forward scattering phase function so observed was peaked in the forward scattering direction and seemed to be characteristic of a phase function of dielectric grains such as dirty ice or silicates which seem to be good absorbers as compared to "clean" core mantel grains of ices or perfect crystal silicate grains.

Finally it is fascinating to speculate about the similarities between cometary grains and interstellar grains, because infrared signatures of the cometry grains indicate that they are in many aspects similar to grains which are observed in the interstellar medium and in circumstellar shells.

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