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Comet Ikeya-Seki (1965) and the nature of the interplanetary medium during its apparition

M. K. V. Bappu and K. R. Sivaraman

Abstract

The effects of a solar wind on the different parts a comet are discussed in terms of the observations obtained of Comet Ikeya-Seki (1965f). The solar wind contribution to the formation of the scattering agencies in the cometary nucleus is shown to be negligible. Isophotes of the coma in the light of the CN (O,O) emission band and Na 5893 Å derived from slitless spectra are presented. The heliocentric distance of the termination point of Na emission is shown to be dependent on the varying nature of the interplanetary medium properties at different phases of the solar cycle.

It has been recognised from some time (Biermann 1951) that the plasma tails of comets are influenced by solar corpuscular radiation and that comets can be effective space probes for an evaluation of the properties of the interplanetary medium. Indeed, it has been the stimulation by such efforts that has led to the detection of the "solar wind" and its associated properties. That the differing aspects of cometary radiation are solar stimulated is obvious, though the agencies responsible may have different contributions to the emission and continuous spectra observed.

While nearly three hundred comets have been observed in the six and a half decades of the twentieth century, for very few among these have we reliable physical observations, that have contributed towards a better understanding of cometary physics. Observational difficulties are the prime cause and much of our information originates from the few bright comets that have perihelion passages that make them favourable for observation.

Comet Ikeya-Seki is one such object that has provided much new information. Its exceedingly short perihelion distance took it through the outer regions of the solar corona and the rather dramatic outcome of the close encounter made it one of the most spectacular comets ever seen. Its appearance at the minimum phase of the solar cycle provided a good opportunity for the assessment of the threshold characteristics of the interplanetary medium necessary for the well known features of cometary radiation.

We have, at Kodaikanal, observed the polarization of the emission bands and continuum (Bappu *et al.*, 1967a), measured the flux of the CN and C_2 emission bands (Bappu and Sivaraman 1967c) and obtained both slit and slitless spectra of the coma and tail (Bappu and Sivaraman 1967b). The energy distribution in the continuum has been determined by comparison with θ Crt, HD 27836 and HD 28291, which have well determined energy curves. The coma of Comet Ikeya-Seki has an energy distribution that simulates the distribution of a typical G8V star. The polarization of the continuum measured at 5875 Å corresponds to a value of 17·9 per cent at a phase angle of 90°. The corresponding value for 4310Å is 24.7 per cent. The value of polarization in the tail 3′ away from the cometary nucleus is 13.6 per cent at 5550A. The polarization values in the tail can be explained if we assume that Fe particles of diameter 0.6μ are the principal agencies for continuum scattering. We believe, that the continuous spectrum of the head is caused by single scattering predominantly by ice spheres and ice spheres with metallic particles imbedded in them. These particles cause the increase reddening that simulates a G8V spectrum energy distribution instead of that of a G2V star. Also, the magnitude and sign of polarization lead us to explain the scattering agencies as those described above.

An earlier measurement of polarization and reddening in the spectacular comets of 1957, comets Arend-Roland and Mrkos (Bappu and Sinvhal 1960) and of polarization in the tail (Johnson 1960) of Comet Arend-Roland yielded values similar to those we have obtained for Comet Ikeya-Seki. It is interesting to note that despite the differences in the experiences of all three comets when they approached the solar vicinity, by and large the particle sizes that give rise to the continuum are more or less the same. It appears that the efflux of icy and metallic particles from the conglomerate that forms the nucleus is controlled more by the rate of evaporation and evaporation-stimulated fragmentation as a function of corpuscular radiation which may be essentially a second order effect.

A measure of the cometary flux in the emission bands would be useful in evaluating the role of the solar wind in producing the comet plasma. We have from the flux measures of the coma in the light of the C_2 (1,0) and CN (0,0) bands, made an effort to calculate the number of molecules of each constituent that fluoresce by sunlight and which are contained in a cylinder of diameter 121300 km., centered on the cometary nucleus. These work out to 1.554×10^{29} molecules for CN and 1.840×10^{30} molecules for the C_2 (1,0) bands. An "abundance" ratio for C_2/CN is thus 11.84 which may be compared with the value of 9.0 for Comet Ikeya (1964f) (Kovar and Kovar 1965). We have very little data of this kind to enable us to draw conclusions of real abundance differences between comets of different ages.

Abundance ratios of the kind derived above for cometary heliocentric distances of 1.0 A.U. would show up differences if solar wind contributions at different times are a strong controlling factor on the dissociation of parent molecules from which CN and C_2 originate. We choose the value of $r=1.0$ A.U. as a convenient heliocentric distance for cometary observations to be possible, and where excitation in the coma would be near optimum.

The apparent shape of the coma is one possible means of estimating the velocities of ejection of the molecules and their mean life times. These shapes can be derived from isophotes using the techniques of photographic photometry. We have in figures 1 and 2, indicated the isophote structure of the CN (0,0) coma and sodium coma of Comet Ikeya-Seki on October 29.9. These isophotes are derived from slitless spectrograms obtained at a dispersion of 250A /mm in the yellow and 125Å /mm in the blue-violet regions. The image scale in the spectrograph camera focal plane was 75″/mm. The exposures were of the order of a minute in order to keep fogging by moonlight to a minimum. While the isophotes do not extend to very large distances from the centre they nevertheless show up the nature of the equal intensity contours closer to the nucleus. In particular the isophotes of the Na-coma are of considerable interest, since we are not aware of any instance in the past where it has been possible to present such a system of

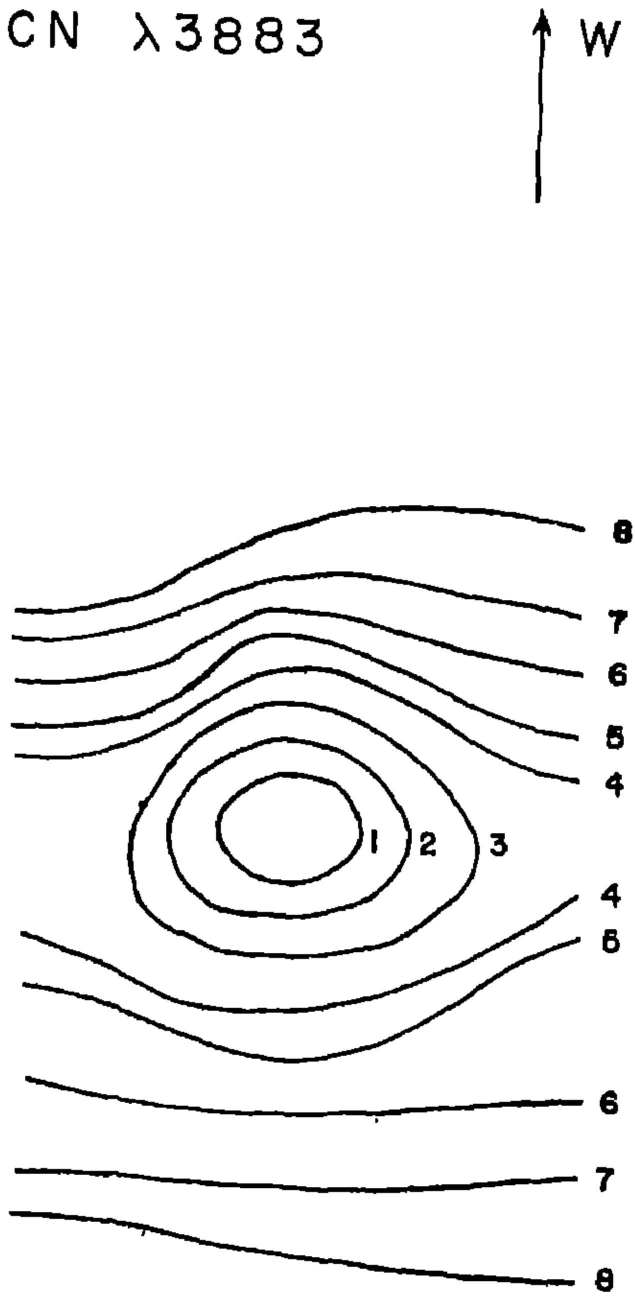

Fig. 1. Isophotes of the CN (o, o) coma of Comet Ikeya-Seki (1965f). The tail is westward of the Sun.

10 mm = 4.9 seconds of arc.

Number on Isophote	Intensity	Number on Isophote	Intensity
1	18.5	5	14.2
2	17.8	6	13.1
3	16.4	7	12.1
4	15.3	8	11.0

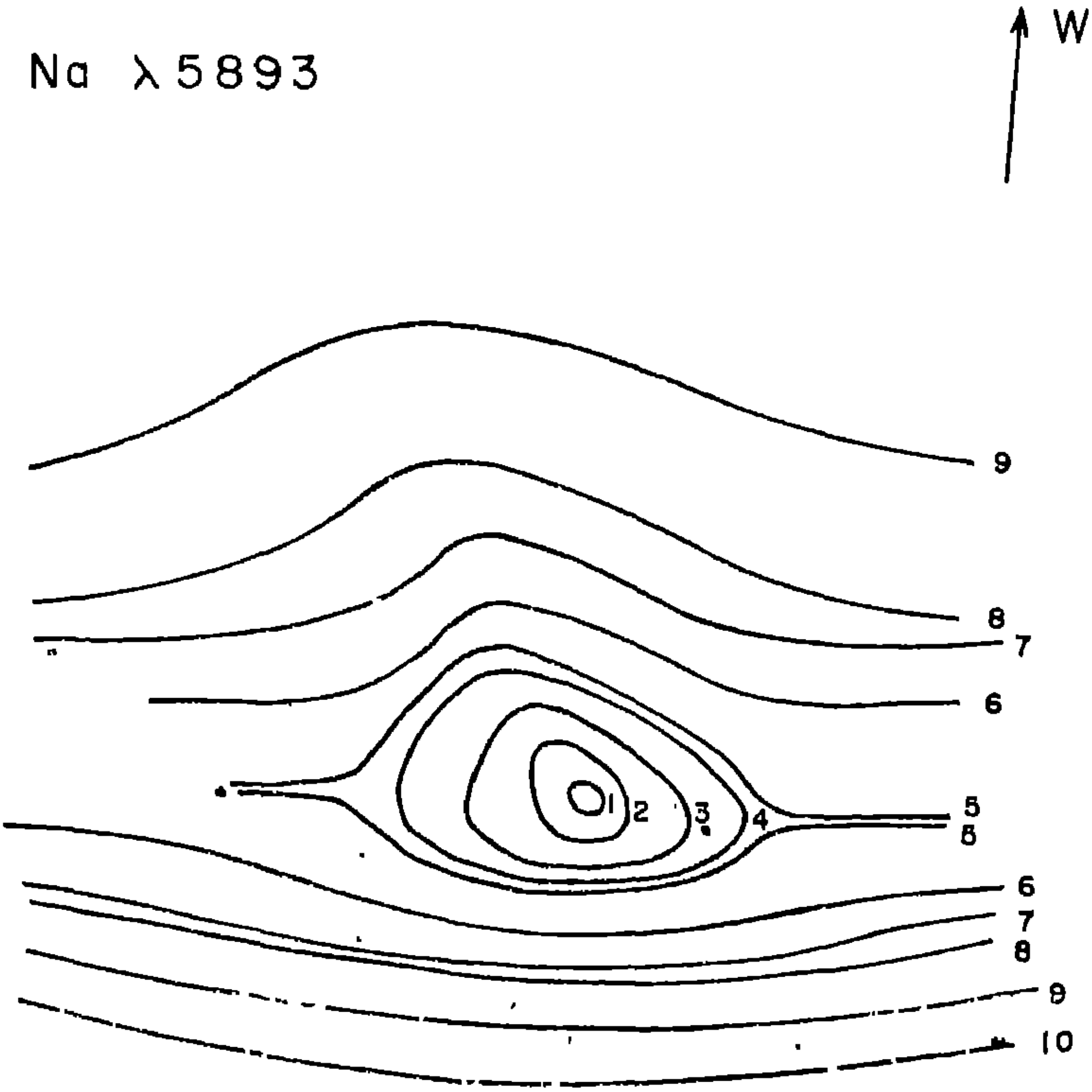

Fig. 2. Isophotes of the Na-coma of Comet Ikeya-Seki (1965f). The tail is westward of the Sun.

10 mm = 5.2 seconds of arc.

Number on Isophote	Intensity	Number on Isophote	Intensity
1	38.0	6	18.6
2	34.4	7	16.0
3	28.1	8	14.9
4	24.8	9	12.6
5	22.3	10	11.6

isophotes. The most striking feature is the flattening of the contours in the direction of the sun, caused by the high f-value of the Na-atoms. These sunward contours are further affected by the differing radial velocity components for those Na-atoms ejected at an angle to the line of sight. This is so, since, the solar D-line absorption is wide and the velocity effects in the coma can, by virtue of the wide line-contour of the solar D-lines, simulate a varying excitation source.

On the tailward side the Na tail emanating from the coma is obvious. However, the contours indicate a slight bulge in the direction of the radius vector that points almost west, with a more intense portion of the tail twenty degrees away. A visual examination of the spectrum indicates that both "tails" are part of the same tail starting off in the direction of the radius vector. An apparent shadowing in the centre makes the single tail look double near its source. The effect, however, is marginal.

The CN coma, is very much more circular than Na. The contours on the sunward side are very slightly flattened. The contours follow the 1/R trend of intensity variation along the radius vector. The isophotes are narrower on the tailward side which may be an indication of the existence of a dispersion in ejection velocities.

The behaviour of Na emission in coma and tail of Comet Ikeya-Seki has been specially noteworthy. We have slit spectra of the cometary head obtained on October 30.985 and November 3.975 when the heliocentric distances of the comet were 0.497 A.U. and 0.626 A.U. respectively. The D-line is the strongest feature in the spectrum of October 30.985 while it is non-existent in the spectrum of November 3.975. Prismatic camera exposures on November 2.967 and November 3.971 (Bappu and Sivaraman 1967b) fail to show the Na emission that was a striking characteristic of earlier days. Hence, the Na emission in the coma ceased to exist when the comet was at a heliocentric distance of only 0.593 A.U. Na emission in comets have commonly been observed in cometary spectra when their heliocentric distances were less than 0.8 A.U. In some cases, Comet Mrkos (1957d) for example, sodium emission was seen even at a heliocentric distance of 1.1 A.U. This difference in nature of sodium excitation can probably be accounted for in terms of the general effects of solar activity. A more energetic solar wind near solar maximum makes the Na display of a comet more striking than it can be at a minimum level of solar activity.

There are very few instances in the literature of systematic observations of Na emission in comets. However, about a dozen cases are available which indicate the validity of our conjecture, *viz.*, the Na emission display is seen to greater heliocentric distances near solar maximum than at solar minimum. This characteristic also seems to manifest itself in the excitation of the Na tail. Comet Mrkos (1957d) had a sodium tail of 5° extent (Bigay *et al.*, 1957) when the dust tail was about 14°. Comet Ikeya-Seki (1965f) had a dust tail of nearly 20° with only a 2° Na tail which we have observed on prismatic spectra of October 29, 30 and 31.

We believe that such a behaviour indicates the appreciable role of solar corpuscular radiation since polarization measures (Bappu and Sinvhal 1960) show convincingly that resonance fluorescence by sunlight causes the Na emission in the coma. The solar wind perhaps enables the release of the Na atoms from the parent molecules by the ionization processes effective in producing the cometary plasma.

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ERRATA

KODAIKANAL OBSERVATORY BULLETIN NO. 18d

Location	Error	Read.
Page A 155 - First line under "The Observational material"	Spectogram	Spectrogram
-do- 4th line of same para	Spectgram	Spectrogram
First line of Second para	Spectogram	Spectrogram
Page A 158 - Equation under figure I	Curved bracket within square bracket incomplete	The curved bracket should be closed.
Page A 160 - Last line of first para	amounts	amounts
Page A 162 - Seventh line of third para	$A'A_2B_2B$	$A'A_2B_2B$
Page A 163 - Second line of last para	$d' AB + EF$	$d' > AB + EF$