Table 1. Occulted source elongations for different events

Date	Frequency (MHz)	Comet	Occulted source (R.A. & Dec. 1950)	ϵ (deg.)	Result
05/01/74	327	Kohoutek	2025–150	20·0	Positive
18/12/85	103	Halley	2314+038	86·5	Positive
11/02/86	327	Halley	2052–106	11·2	Negative
29/03/86	408	Halley	1827–360	86·0	Positive
01/05/87	408	Wilson	0606–795	92·8	Positive
02/05/87	408	Wilson	0637–752	93·0	Positive
13/05/90	103	Austin	2204+292	70·3	Positive

Table 2. Comet parameters

Date at 1400 UT	N. coord.[A] (R.A. & Dec.)	Distance (A.U.) T. centric	H. centric	ϵ (deg.)	PA of tail[B] (deg.)
12 May	22 42·2+30 00·44	0·3597	0·9020	62·4	268·3
13 May	22 32·4+28 57·38	0·3443	0·9221	65·4	266·0
14 May	22 22·0+27 45·74	0·3296	0·9420	68·6	263·7

[A] Coordinates are those of the comet nucleus.
[B] Position angles of the tail are given at 0200 UT. The transit time of the source was 0152 UT.

Table 3. Occulted and control source parameters

Source	Approx. coord. (1950)	Date (1990)	ϵ (deg.)	Scintillation index Observations	RKH model	Source diam.[A] (arcsec)
3C441[B]	2204+29	13/05	70·3	0·43	0·14	1·0
3C19	0038+33	12/05	37·0	0·16	0·18	0·8
		14/05	38·0	0·17	0·18	0·8
3C42	0126+30	12/05	26·0	0·16	0·14	1·2
3C123	0434+30	12/05	24·0	0·18	0·22	0·8

[A] Equivalent gaussian diameter (Readhead and Hewish 1974).
[B] Occulted source.

The geomagnetic planetary index, another indicator of fine ionisation structure in the ionosphere, was very low to moderate throughout 13 May. Finally, solar activity which influences both the ionosphere and solar wind velocity and structure was low to moderate during the week preceding and including the occultation date.

For making a quantitative estimate of the electron content in the plasma turbules contained in the tail, the power spectrum of intensity variations of the source was taken using the data around the transit time. Fig. 4 shows the spectrum of 3C441, where the values have been normalised to the highest spectral density. On the assumption that the thin screen scattering theory of Salpeter (1967) is valid for these observations, the scale sizes of the turbulence can be calculated. The scale size is given by $a = v/2\pi f_2$, where v is the velocity of the diffraction pattern across the observer and f_2 is the width of the scintillating power spectrum at the exp(−0·5) points. The width f_2 was found to be 0·923 Hz, as can be seen from Fig. 4. Assuming that the plasma at this point in the tail has not yet been accelerated to typical solar-wind velocities, we can assign a velocity of $v = 100\ \mathrm{km\,s^{-1}}$ (Jockers 1981). Thus,

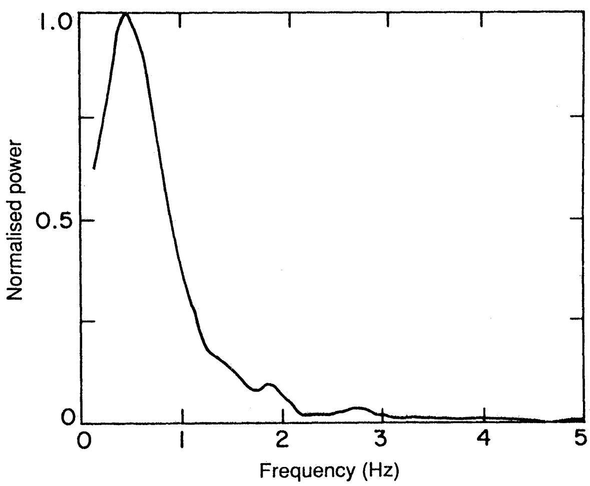

Fig. 4. Normalised power spectrum of enhanced scintillations of 3C441 caused by the ion tail of Comet Austin on 13 May 1990.

the scale size is $a = 17$ km, a much finer scale of turbulence than the typical values of 100–1000 km for IPS in the normal solar wind. If the occultation were to take place at the edge of the tail, where the tail plasma merges with the solar wind, then one can expect the velocities to approach that of the normal solar wind, i.e. around 400 km s^{-1}. This would give a scale size $a = 68$ km, which is also a much finer scale than expected.

Table 4. Estimated scale sizes and ΔN in the tail of Comet Austin

Velocity (km s^{-1})	Scale size (km)	ΔN (cm^{-3})	References
25	4	11	Scherb *et al.* (1990)
100	17	6	Jockers (1981)
400	68	3	Av. solar wind velocity

For a gaussian electron density correlation function, the r.m.s. phase deviation imposed across a wavefront emerging from a thin screen containing plasma turbulence is given by

$$\phi = (2\pi)^{1/4} r_e \lambda (aL)^{1/2} \Delta N,$$

where $r_e = 2\cdot82\times10^{-13}$ cm is the classical electron radius, $\lambda = 291$ cm is the operating wavelength, $a = 17\times10^5$ cm is the scale size, $L = 10^{11}$ cm is the thickness of the screen assumed (Jockers 1981) and ΔN is the r.m.s. electron density deviation. For weak scattering, the scintillation index is given by $m = \sqrt{2}\,\phi$. In the present case $m = 0\cdot43$, so $\phi = 0\cdot304$ rad, and thus we get $\Delta N \approx 6$ cm^{-3}. If the mean density in the tail is taken to be 100 ions cm^{-3} (Schmidt and Wegmann 1982), then this value corresponds to a 6% modulation in the ion density at a distance of about 1 A.U., while the normal solar wind shows about 4% modulation around 0·1 A.U. Table 4 shows the scale sizes and r.m.s. electron density deviations obtained assuming different velocities for the diffraction pattern. All scale sizes obtained lie in the range 4–70 km which are much finer than those of IPS from the solar wind.

3. Discussion and Conclusions

Since the occultation of the source took place only on one day, it was not possible to see if there was a gradient of scale sizes as one moved away from the axis of the comet. Nevertheless, our value of 17 km for the scale sizes 2° from the tail axis is in good agreement with the observations of Comet Wilson by Slee *et al.* (1990). Since no photographs of the comet are available around this period, an accurate estimate of the tail-lag, opening angle and thickness is not possible. It is possible that the actual tail-lag was much larger than the assumed 3°, thus bringing the point of occultation much closer to the axis. A re-analysis of Halley's comet data (Alurker *et al.* 1986), taking into account the tail-lag, is being carried out in view of the new results obtained during the observations of Comet Wilson (Slee *et al.* 1990) and the present observations of Comet Austin.

With regard to the accuracies of the values of a and ΔN, it is apparent from Table 4 that the velocity of the plasma is not known to better than a factor of 4, causing scale sizes to have the same inaccuracy. This would in turn lead to a variation in ΔN by a factor of 2. This may become worse when the error in L is also taken into consideration.

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References

Alurkar, S. K., Bhonsle, R. V., and Sharma, A. K. (1986). *Nature* **322**, 439–41.
Alurkar, S. K., Sharma, A. K., Janardhan, P., and Bhonsle, R. V. (1989*a*). *Nature* **388**, 211–12.
Alurkar, S. K., Bobra, A. D., Nirman, N. S., Venat, P., and Janardhan, P. (1989*b*). *Ind. J. Pure Appl. Phys.* **27**, 322–30.
Ananthakrishnan, S., Bhandari, S. M., and Rao, A. P. (1975). *Astrophys. Space Sci.* **37**, 275–82.
Ananthakrishnan, S., Manoharan, P. K., and Venugopal, V. R. (1987). *Nature* **329**, 698–700.
Ananthakrishnan, S., Manoharan, P. K., and Venugopal, V. R. (1989). *Nature* **338**, 212.
Duffett-Smith, P. J. (1976). Ph.D. Thesis, Univ. of Cambridge.
Hajivassiliou, C. A., and Duffett-Smith, P. J. (1987). *Mon. Not. R. Astron. Soc.* **229**, 485–93.
Hewish, A., Tappin, S. J., and Gapper, G. R. (1985). *Nature* **314**, 137–40.
Jockers, K. (1981). *Icarus* **47**, 397–411.
Readhead, A. C. S., and Hewish, A. (1974). *Mem. R. Astron. Soc.* **78**, 1–49.
Readhead, A. C. S., Kemp, M. C., and Hewish, A. (1978). *Mon. Not. R. Astron. Soc.* **185**, 207–25.
Salpeter, E. E. (1967). *Astrophys. J.* **147**, 433–48.
Scherb, F., Magee-Sauer, K., Roesler, F. L., and Harlander, J. (1990). *Icarus* **86**, 172–88.
Schmidt, H. U., and Wegmann, R. (1982). *In* 'Comets' (Ed. L. L. Wilkening), pp. 538–60 (Univ. Arizona Press).
Slee, O. B., McConnel, D., Lim, J., and Bobra, A. D. (1986). *Nature* **325**, 699–701.
Slee, O. B., Bobra, A. D., Waldron, D., and Lim, J. (1990). *Aust. J. Phys.* **43**, 801–11.

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