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P/Halley: Spatial distribution and scale lengths for C_2, CN, NH_2, and H_2O

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From P/Halley long slit spectroscopic exposures on 12 dates, extending form 1985 Oct. to 1986 May, spatial profiles were obtained for emissions by C_2, CN, NH_2, and OI (^{1}D). Examples of our derived spatial profiles are given in Fig. 1. The qualitative trend of the scale lengths for the different species is nicely exemplified in this figure. C_2 has the longest parent scale length followed by CN and NH_2. OI which tracks the parent H_2O distribution is quite narrow but slightly wider than the continuum profile which has a center essentially indistinguishable from the stellar seeing disk. Comparison of C_2 and CN also shows that C_2 is falling off faster in the wings so that daughter scale length of CN must be larger than that of C_2.
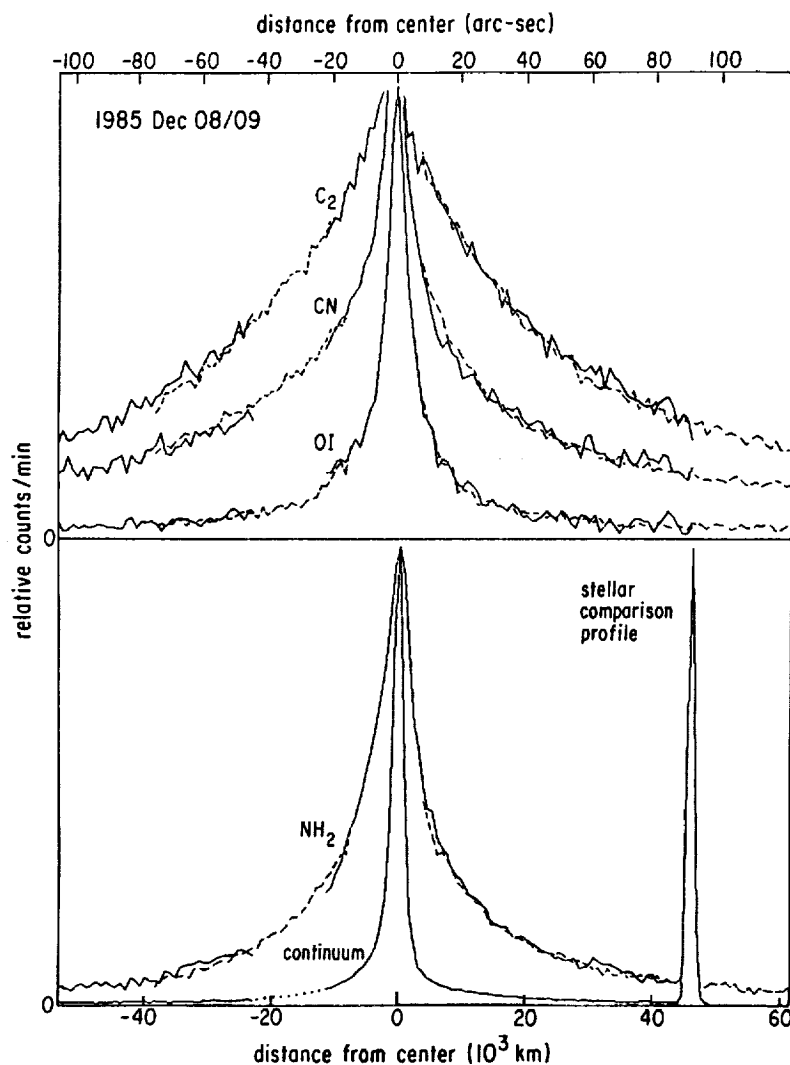

Fig.1. Spatial profiles for 1985 December 8 and 9. Solid curves are the sums of four 5 minute exposures from December 8 and 9. Dashed curve is from a 20 minute exposure on December 9 in which the nucleus was placed behind an occulting mask. All profiles are shown with their correct signal levels at the ends of the slit. The core of the continuum distributions is essentially equal to the stellar seeing profile as illustrated by the solar-type comparison star BS 8931 taken within a few minutes of the P/Halley data. The two data sets of masked and unmasked profiles show excellent agreement.
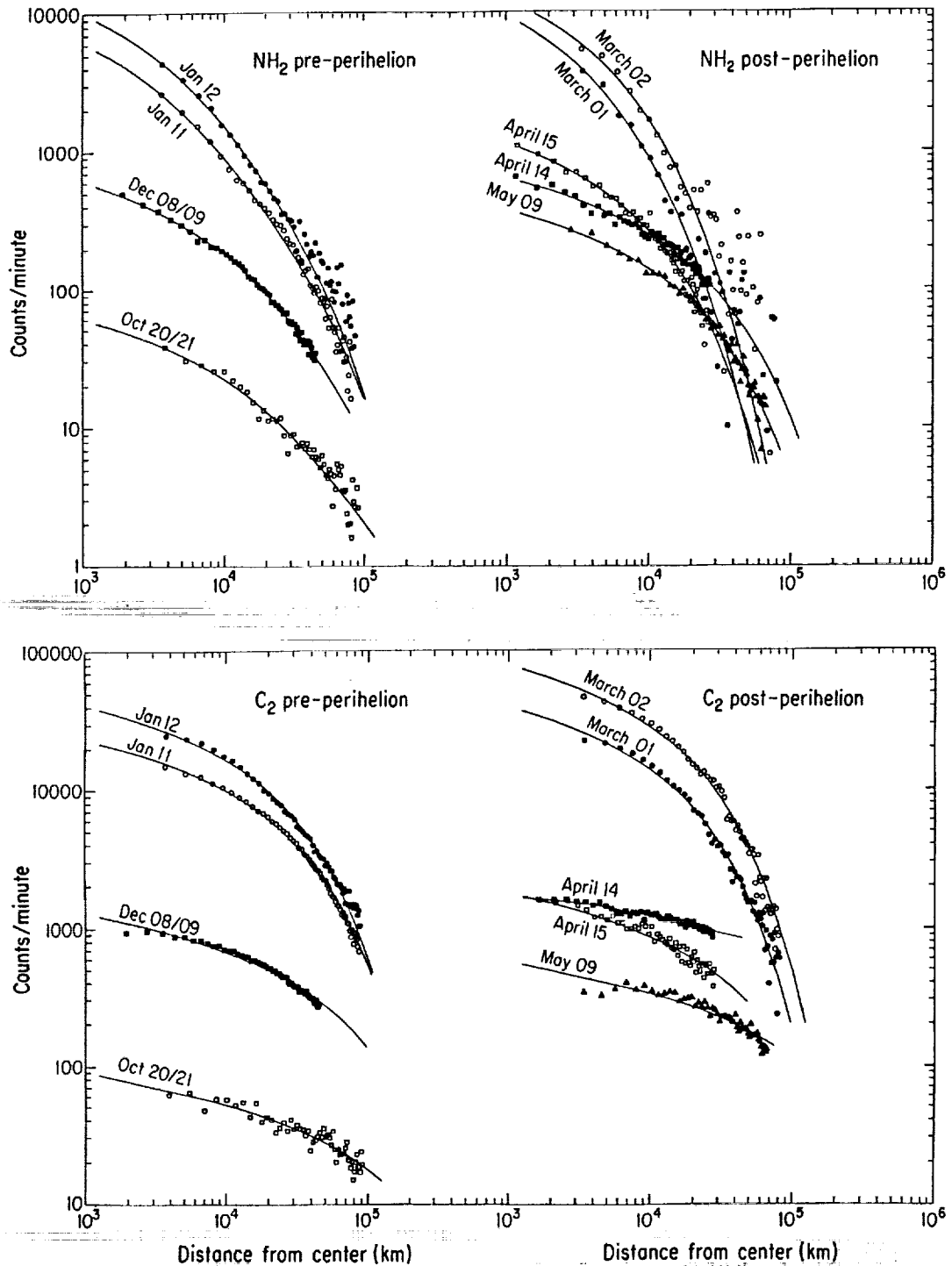
Fig. 2. Summary plot of pre- and post-perihelion NH_2 and C_2 profiles and Haser model fits. April 14 is shown by solid squares, and April 15 is shown by open squares; symbols for other profiles are unambiguous. The change in scale length (curvature of profiles) for various heliocentric distances is well demonstrated. The profiles for April 14 and April 15 which are strongly perturbed by P/Halley's varying production rate stand out clearly.

Our data and Haser model fits are plotted on a log/log scale in Fig. 2 for NH_2 with its relatively narrow profile and for C_2 with its longer parent scale length. The fitting to the observed radial profiles was accomplished using a differential correction least-squares fitting routine (Combi 1979). The figure illustrates that the comparatively simple Haser model can provide an excellent fit to the observed radial intensity distributions. The resulting pre-perihelion scale lengths demonstrate good consistency and can be used for production rate determinations whenever it is necessary to extrapolate from observed column densities within finite observing apertures.

However, the data also show that the time-varying production rate of P/Halley, especially severe after perihelion, can strongly affect the profiles. The worst case is exemplified by April 14.3/15.3. The former was taken during a period of rapidly decreasing activity, while the April 15.3 data were observed on a rising slope of the lightcurve (Millis and Schleicher 1986). Thus for the latter date we are seeing a substantial enhancement in the center of the profile which has not yet had time to spread outward. The effect is stronger for NH_2 since its short parent lifetime allows it to respond quickly. On the other hand for April 14.3, the wings of the profiles are enhanced since the increased species production rate some time before has now had time to propagate outward. In order to interpret these profiles correctly, a time-dependent production rate model was developed and presented as a separate paper at this conference (Combi and Fink 1991).

Excluding the data set of April 14.3/15.3, which was clearly affected by P/Halley's time dependent production rate we obtained the following results for our scale lengths.

	parent (10^3 km)	daughter (10^3 km)
C_2	58 ± 20	58 ± 20
CN	28 ± 15	$320 + 200/-100$
NH_2	4.9 ± 1.5	62 ± 20
H_2O	74 ± 60	--

For C_2 a slight flattening of the profile close to the nucleus could not be fitted with a two step Haser model but can be accommodated with a CHON halo model (Combi and Fink 1991). If the inner region is excluded from the fit, the daughter/parent scale length ratio changes from near one to about 6. However, when production rates are sought using a two step Haser algorithm, only an equal scale length model comes close to providing an acceptable fit. Only three observations yielded CN daughter scale lengths because our profiles did not extend sufficiently far. The long daughter of CN also makes this emission very sensitive to production rate variations causing greater scatter in the parent values. A curios asymmetry of the scale lengths for NH_2 was found with the post-perihelion parent being about twice the pre-perihelion value, but the daughter being about half the pre-perihelion number. Since a line spectrum from pre-dissociation dominates the UV photo-absorption cross section for both NH_3 and NH_2 the Swings effect is the most likely explanation for this pre-/post-perihelion difference. Most of the OI ^1D profiles, which effectively map out the comet's H_2O distribution, deviated very little from a $^1/r$ fall off so that it was not possible to obtain a reliable H_2O parent scale length, although consistency with the nominal lifetime of $80x10^3$ seconds is demonstrated. A considerably more detailed description of our data analysis, reduction procedure and scale length determination has been accepted for publication (Fink, Combi and DiSanti 1991).

References
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