CES+CCD OBSERVATIONS OF INTERSTELLAR LINES TOWARDS SN 1987A

Pierre Magain
European Southern Observatory
Casilla 19001
Santiago 19
Chile

High resolution, high S/N spectra of SN 1987a were obtained with the ESO Coude Echelle Spectrometer fed by the 1.4 m Coude Auxiliary Telescope. The short camera was used in combination with a high resolution RCA CCD (640 x 1024 pixels, 15 x 15 μm each). The resolving power of this combination (R $\approx$ 70000) is slightly lower than the maximum attainable with the long camera, but the higher efficiency allows to reach higher S/N ratios.

Spectra were obtained around the D lines of Na I, the resonance line of Li I (Baade and Magain, 1987) and the H and K lines of Ca II. However, the emphasis was put on obtaining high S/N spectra in the 423 nm region, which contains the resonance lines of CH^+ and Ca I. Since these data are presented in other papers (Magain, 1987; Magain and Gillet, 1987), only a short summary will be given here.

This region was observed on 3 different nights, and the spectra were subsequently co-added, allowing to reach a S/N of 550. The CH^+ spectrum, in a heliocentic velocity scale, is presented in Fig. 1. A CH^+ line, with an equivalent width of 0.4 mÅ is detected at a velocity of 280 km/s, which corresponds to material inside the LMC and coincides with the strongest component detected in most species, including CH (Magain and Gillet, 1987).

The calcium spectra are shown in Fig. 2, which is reproduced from Magain (1987). At least 7 components are detected in Ca I, some of them clearly multiple. The comparison of the Ca I and Ca II column densities allows to derive the ionization degree and, hence, to estimate the electron (and gas) density in the corresponding clouds (Fig. 3). Most of the clouds exhibit fairly low densities, typical of clouds in the solar neighbourhood, with two outstanding exceptions: the clouds with velocities between 150 and 200 km/s have much higher densities, which may be interpreted as resulting from recent compression of the gas by shock waves. Such shocks may be associated with remnants of former supernovae, or with stellar winds (maybe from the progenitor of SN 1987a itself).

CH^+ is also generally believed to be a tracer of shocks (see, e.g., Elitzur and Watson, 1980). This would indicate that a shock has also compressed the LMC component at 280 km/s. This is not incompatible with the Ca data, which show that this component also exhibits a relatively high density. On the other hand, if the shocks associated with the 150 - 200 km/s components have originated inside the LMC, their velocities are ≥ 100 kms, which is too high for any CH^+ to be produced (CH^+ - forming shocks have velocities of the order of 10 km/s, Elitzur and Watson, 1980).

To conclude this short summary, let us point out an important consequence of our results. The calcium data clearly indicate that the so-called "intermediate velocity clouds" (50 km/s < V < 200 km/s) can be separated in two different classes:
- the clouds with V < 150 km/s have low to very low densities and may be located in the halo of our galaxy, or in the intergalactic space;
- the clouds with V > 150 km/s exhibit high densities and are most likely composed of shocked LMC gas.

REFERENCES

Baade, D., Magain, P.: 1987, Astron. Astrophys., in press
Elitzur, M., Watson, W.D.: 1980, Astrophys. J. 236, 172
Magain, P.: 1987, Nature, in press
Magain, P., Gillet, D.: 1987, Astron. Astrophys., in press

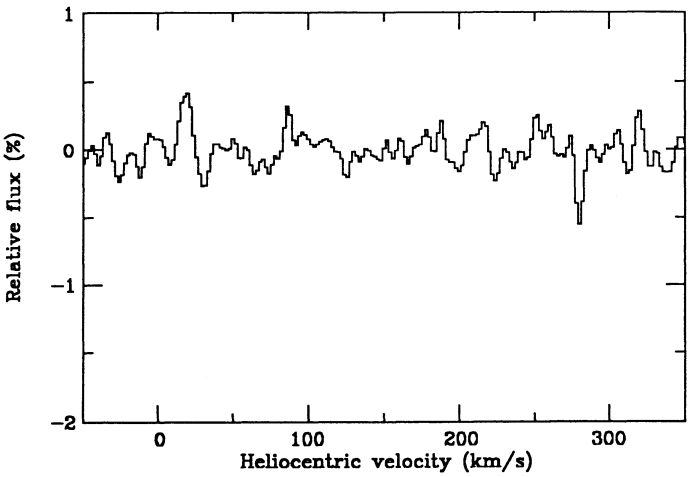

Fig. 1. Spectrum of interstellar CH^+ towards SN 1987a, in a heliocentric velocity scale.

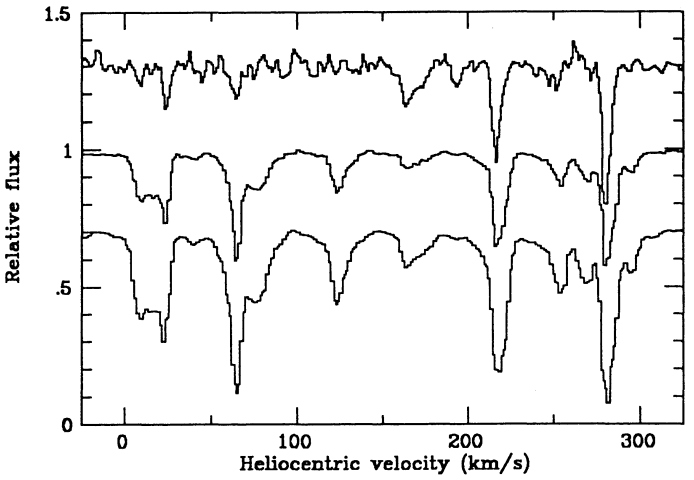

Fig. 2. Spectra of Ca I (top), Ca II-H (middle) and Ca II-K (bottom) in a common heliocentric velocity scale. The ordinate refers to the middle spectrum, while the others are displaced by 0.3 units. Moreover, the Ca I spectrum is expanded 20 times.

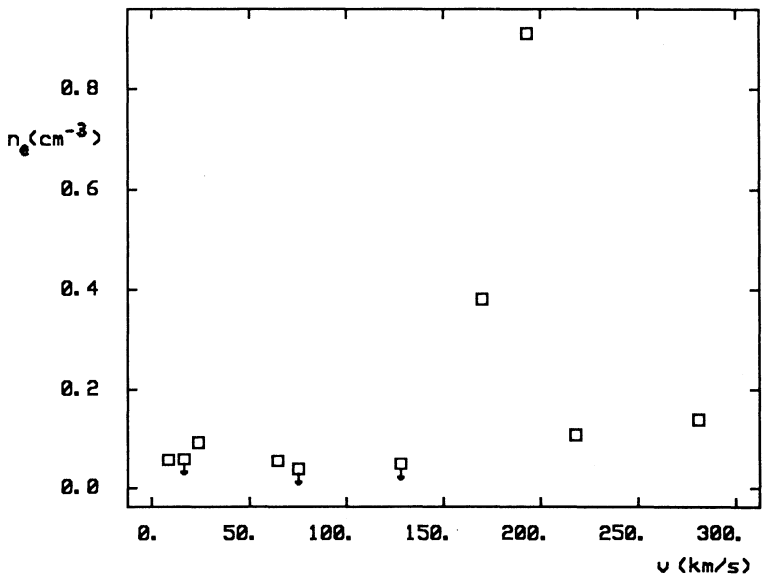

Fig. 3. The electron density in the interstellar clouds as a function of heliocentric velocity. Squares with arrows indicate upper limits.

DISCUSSION

G. VLADILO: Just a technical question: how many spectra have you averaged to obtain the spectrum in the CH^+ region? Which was the typical exposure time?

P. MAGAIN: Nine spectra were averaged, with three different settings of the instrument. Exposure times ranged from 30 to 45 minutes.