# Clouds in the Halo

*J.-C. Pecker*

*Well, what can be done with ten nights on a future 25 metre telescope (the VLT)? The first to send in his article was Professor Jean-Claude Pecker from Collège de France and Institut d'Astrophysique in Paris. He feels that most of the time should be used to study the stars and the gas in the halo of the Milky Way. Join him on the magic carpet . . . but remember to fasten the seatbelts!*

*"Experience, till now, gives us hope that human resourcefulness and imagination, combined with enough photons, will find solutions . . ."* J.-L. Greenstein.
*. . . Yes! . . . But what is more difficult is to find problems!*

Evoking the fairy-tales of the Orient, as did Jesse Greenstein (ESO Conference on Optical Telescopes of the Future, December 1977), I feel that my Ten Nights at the VLT have, like the Thousand and One Nights of Scheherazade, a completely imaginary character! When the VLT goes into operation, I am sure that my doctor will not allow me to walk without crutches . . . The magic carpet that brings me there travels more in time than across the oceans, which is not bad at all because the adaptation will be rather difficult.

I have therefore been forced to think a lot before establishing my "dream" programme. A telescope with a diameter of 25 m implies a greatly improved light-gathering capacity and a much better resolution. I admit that the temptation to try to observe "the limits of the Universe" is very large, and also to count the faintest objects somewhere in the sky: but the atmosphere is still there; and I prefer to await a satellite "out of the ecliptic", which is equipped with a telescope of reasonable size, in order to really get rid of the background light from the dust and the interplanetary gas (zodiacal light), or at least most of it.

I think it would be interesting to use the VLT to improve the knowledge of the energy distribution on stellar surfaces. But I am afraid that the VLT in the end will not be better than an array of cleverly arranged smaller telescopes.

On the contrary, the following argument appears reasonable: *at the same spectral resolution, the space volume which can be explored by the VLT is eleven times larger than what can be studied with the Palomar 200" telescope* (remember that the relation between *limiting* magnitude and instrument diameter is given by $m_0 = -2.5 \log D +$ constant because the limit is given by the signal-to-noise ratio, cf. the article by W. A. Baum in *Astronomical Techniques, Stars and Stellar Systems,* II, 1962, p. 5, ff.). It is the study of the spectra of stars and galaxies which has, in general, left me hungry. Some major problems in present-day astronomy are still unsolved because of the lack of statistical significance. The examples are obvious: one can count on one hand (or at least on a few hands) the stars for which the chemical composition has been determined from spectral line measurements; even more rare are the normal stars for which the line profiles have been well measured; and I know only of one star, the Sun, for which the line profiles have well-determined asymmetries (with the exception of some monstrosities, however interesting they may be, like for instance P Cygni). For how many galaxies do we really know the chemical composition in 1978? At the most a dozen. We shall get at least a hundred with the VLT. For how many quasars do we know the spectrum in great detail? Improving the number by a factor of 10 will allow us to avoid risky speculations.

This factor of 10 can, at the same dispersion, be a gain in the *time*-resolving power. The variable stars of type $\delta$ Scu or $\beta$ CMa; the eruptive stars of type T Tau or UV Cet are really not very well known . . . What a harvest we would get from a time resolution of the order of one second in the study of, for instance, the changes of the Ca II (K) or the H$\alpha$ line profile! Stationary or progressive waves, various oscillations, mass outflow . . . these important evolutionary processes will undoubtedly come within reach.

However, at this point in my thought chain the choice becomes painful! Surely the VLT is situated at a perfect site . . . I therefore really have ten full nights at my disposal—and I have of course chosen the dark, new-moon period! Moreover, from the VLT mountain I can easily observe the galactic centre during my nights.

It is consequently our Galaxy, the Milky Way, that is the subject of my programme. "Our" Earth: the first celestial body to study—the geophysicists have taken care of that. "Our" Sun (or rather "our" solar system): Long live the space probes! (But there is also a lesson to which I return after my tenth night). So now, *"Our Galaxy"*—and we reserve, for the future, "our" local group, "our" super-galaxy, "our" . . . I stop here without prejudice to the extrapolation of this hierarchical playing with Russian dolls! (Cf. the front-page figure, freely after G. de Vaucouleurs, 1970).

## The Centre of the Galaxy

The Galaxy, like the Sun and like a cluster of galaxies, is a *condensation of matter immersed in a dilute medium.* As for the Sun, it is the transitional region between condensation and dilution (the atmosphere—in a very general sense) which to a large extent determines the physics. And it is the *physics* of the Galaxy to which I have decided to devote my nights—to its physics and its evolution.

Objective-prism spectra of stars in a fairly large field towards the centre of the Galaxy could be obtained in order to determine the radial velocities of stars very close to the nucleus (a difficult operation in 1978?). The magnitude which is presently reached with the Fehrenbach objective-prism method is about $13^m$–$14^m$ with a 60 cm objective: a gain of $6^m$ may therefore be possible; but the overlapping of the spectra will be a problem. Is it possible to compensate the necessary increase in the plate scale in the focal plane by a sufficient exposure time to reach a reasonable number of stars close to the galactic centre? Will it not be necessary to restrict the study to the near infrared region (1 $\mu$m)? And will the techniques for measuring radial velocities be sufficiently accurate? Maybe . . . Too many uncertainties about the possibilities of electronic photon counting in this region of the spectrum do not allow me, now in 1978, to know if I shall be able to use the VLT in such a mode in the year 2000.

## The Galactic Halo

But if I cannot be sure to determine accurately the kinematics at the centre of the Galaxy I can at least study that of the halo.

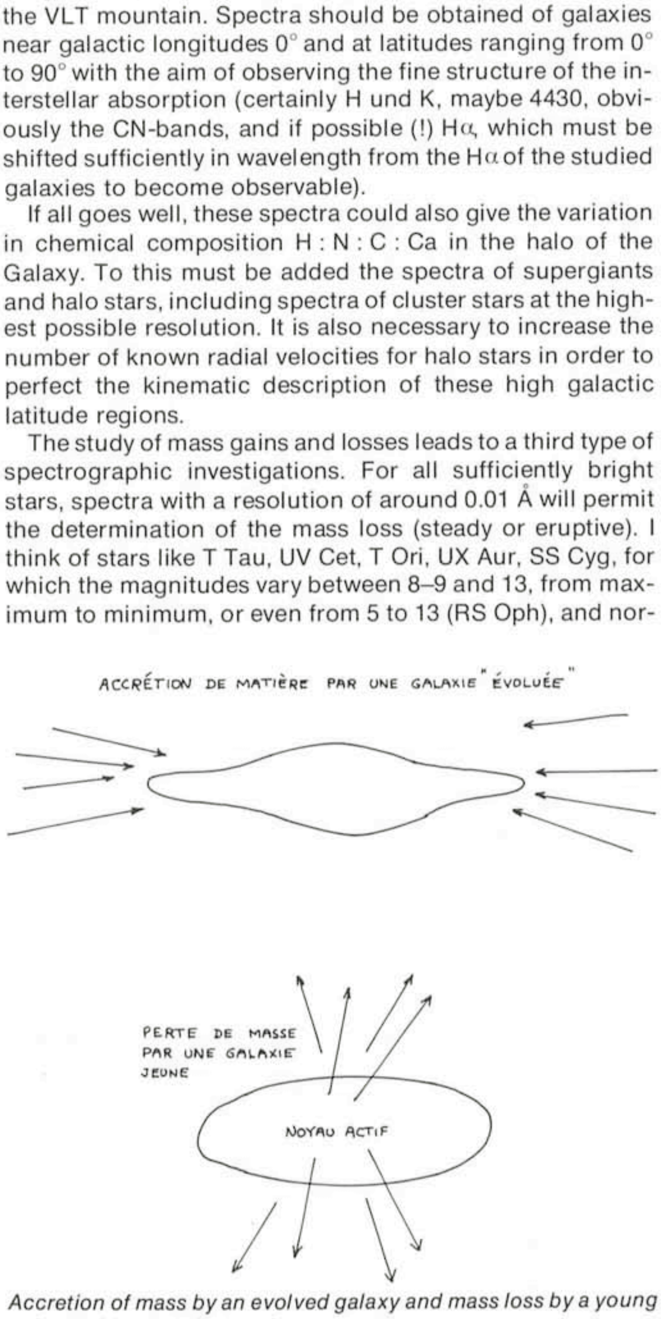
I therefore devote my programme to the very fundamental study of the *mass gains and losses of the Galaxy* (see the figure on this page) after ideas by Pecker (1972, 1974, 1978) and Pecker and Vigier (1976)).

The first, obvious question: to study the Oort clouds and the Dieter ring—neutral hydrogen which has apparently been collected by the *galactic equator.* This neutral hydrogen (which has been observed in the 21 cm line) ought to be connected with other, visible components (dust emitting in the infrared, calcium absorbing in the K-line, H II regions and emission in Hα). These regions must be investigated with great care; in particular the galaxies which are seen behind the clouds should be observed spectroscopically in order to detect absorption structures.

The same programme should also be carried out towards the *galactic poles* ... One of these will be observable from the VLT mountain. Spectra should be obtained of galaxies near galactic longitudes 0° and at latitudes ranging from 0° to 90° with the aim of observing the fine structure of the interstellar absorption (certainly H und K, maybe 4430, obviously the CN-bands, and if possible (!) Hα, which must be shifted sufficiently in wavelength from the Hα of the studied galaxies to become observable).

If all goes well, these spectra could also give the variation in chemical composition H : N : C : Ca in the halo of the Galaxy. To this must be added the spectra of supergiants and halo stars, including spectra of cluster stars at the highest possible resolution. It is also necessary to increase the number of known radial velocities for halo stars in order to perfect the kinematic description of these high galactic latitude regions.

The study of mass gains and losses leads to a third type of spectrographic investigations. For all sufficiently bright stars, spectra with a resolution of around 0.01 Å will permit the determination of the mass loss (steady or eruptive). I think of stars like T Tau, UV Cet, T Ori, UX Aur, SS Cyg, for which the magnitudes vary between 8–9 and 13, from maximum to minimum, or even from 5 to 13 (RS Oph), and normal stars—those which serve to calibrate stellar classification schemes. The best possible time resolution should obviously be obtained at the given spectral resolution and some long time-sequences will be observed.




*Accretion of mass by an evolved galaxy and mass loss by a young galaxy with an active nucleus.*

## The VLT Programme

Did I use my ten nights? A thousand and one more likely!

So therefore a limited programme: one night with very highly resolved Hα profiles of the brightest stars in the sky; one night on T Tauri (which has many sisters); three nights to explore, as a function of galactic latitude, bright galaxies in order to detect interstellar lines from the gas in the halo of our Galaxy; three nights on similar research in the direction of the Oort clouds, the positions of which are well known from 21 cm observations; and finally two nights with spectra of various stars at high galactic latitudes at distances of 20 to 60,000 pc from the Sun.

And that is the end of the observing run ... But will we have the necessary computers to support this exploration? And shall we have—with the present situation in European astronomy—a sufficient force of young astronomers for the reductions? It is not enough to get the spectra and to ask the questions: time and equipment are necessary to get through. The case of the Sun is, unfortunately, typical in this and many other respects: there are ancient observations, even very ancient ones, which have never received a satisfactory interpretation! The eleven-year cycle, for instance... And, besides, what a flood of high-precision, modern observations which could undoubtedly result in an improved knowledge of the physics of the Sun, but which overwhelms the computers and even the physicists (magnetic structures in solar eruptions, oscillations in the supergranularity).

In other words, I am afraid that it will sometimes be necessary to postpone the interpretation of certain new data from the VLT and to limit the immediate effort to the explanation of outstanding discoveries.

As in numerous other chapters in astronomy, the use of the VLT will therefore give rise to much bitterness! That of the observer, who after having made a step forward, soon encounters new borders. That of the theoretician (but has the distinction really a meaning? We are all more or less both) who will find himself unable to carry through unambiguously the analysis of a very high dispersion spectrum or who, in order to study what he believes is the most important, has to postpone something else, which a more detailed study subsequently reveals as being even more important.

Likewise, the use of the VLT will also give rise to many interesting surprises. A spectrum of a galaxy obtained for the study of galactic interstellar lines may reveal new properties of this galaxy ... Looking for mushrooms in the forest, one discovers a treasure!

If the magic carpet of my astronomer's dream has carried me to such a distant extrapolation, the time has now come to ask for absolution! It is the rule of the game. But the study of the evolution of our Galaxy is certainly worth a moment of joyous distraction ...

### *References*

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