V.

ASTRONOMICAL PROGRAMS FOR A VERY LARGE TELESCOPE

INTERSTELLAR MATTER WITH VERY LARGE TELESCOPES

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Interstellar matter is certainly one of the fields where a very large telescope (VLT) will prove to be most fruitful. This includes (somewhat paradoxically, but this will be explained later) the study of extended emissions. I will now examine in turn the different domains of interest for a VLT.

I. Neutral diffuse matter

Optical and near IR observations will mainly contribute to this domain through high-resolution spectroscopy of interstellar absorption lines in the spectra of stars. These lines are resonant lines of atoms (NaI, KI, etc.) or ions (CaII, TiII, etc.) as well as of some molecules (CH, CH^+, CN, CS^+, C_2 in the near IR). Clearly this kind of study is always photon - limited; a VLT will collect more photons than present telescopes, thus increase the possibilities considerably.

1. For galactic structure, and cloud kinematics, fainter (more distant or more reddened) stars will be reached: up to now, very high resolution studies ($R \;\bar{\sim}\; 10^6$) have been limited to $V \;\bar{\sim}\; 6$ (Hobbs, 1969 and subsequent papers by Hobbs), and lower resolution ones ($R \;\bar{\sim}\; 3\ 10^4$) to $V \;\bar{\sim}\; 12$.
2. The physics, composition and chemistry of the interstellar medium (ISM) will be studied on more reddened stars, and the faint lines, which are unfortunately often the most interesting, will be observed more easily. For example the isotopic lines of neutral ^7Li and ^6Li should be well resolved (the high present $^7Li/^6Li$ as determined by Ferlet and Dennefeld, 1983, on one star, would have if confirmed far - reaching implications), and the chemistry of CH, CH^+, CN and C_2 better studied (see e.g. Federman et al., 1984). There is reasonable hope of detecting absorption lines from more upper fine structure levels of the ground state of CH, CH^+ and CN; this would yield the temperature of the universal blackbody radiation at several millimeter and submillimeter wavelengths (see Thaddeus, 1972).

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3. The galactic halo gas will be studied in many more directions by observing interstellar lines in the spectra of faint halo stars and extragalactic objects; the amount of relevant data is still very modest (York, 1982).
4. Neutral diffuse matter will be for the first time studied extensively in nearby external galaxies more distant than the Magellanic Clouds, for which absorption line observations already exist (see e.g. Blades and Meaburn, 1980). Observations of individual stars in M33, M31, etc. will yield kinematics and some interstellar abundance information, while observation of quasars behind galaxies will probe the extent and physics of their disks and possible halos (York, 1982).

The instrumental requirements for such studies are :

- A high spectral resolution : $3\ 10^4 \lesssim R \lesssim 10^6$ (grating or interference spectrographs); resolutions lower than $3\ 10^4$ are useless.
- A good image quality.

II. Ionized interstellar mater

This is the realm of emission-line imaging and / or spectroscopy from the visible to the far - IR. The use of a VLT in this field has been discussed by Lequeux (1983) mainly from the technical point of view. The main purposes of such studies are :

1. Physics and chemical composition of individual HII regions, planetary nebulae, supernova remnants, bubbles. I would like to stress the interest of faint lines like [OIII] 4363 (the main temperature indicator for HII regions) or [FeX] 6375, [FeXIV] 5303 which are emitted at very high temperatures. A VLT will do much in this direction. Clearly a high spatial resolution is desirable for studies of shocks, ionization fronts, and in general small-scale structure which is quite general in these objects.
2. Infrared studies of obscured HII regions, Herbig-haro objects, etc. This is a relatively new field which is very promising since emission lines are numerous in the IR (Paschen, Brackett, Pfund lines of hydrogen, fine-structure lines like [NeII] 12.8 μm): see Kessler and Phillips (1983). Ideally one requires both spectroscopy and imaging in those lines.
3. Kinematics of gas in galaxies. This is an old but recently much revived domain which requires observations of complete velocity fields in Hα or other lines. This is best done with sweeping Fabry-Pérot interferometers (TAURUS in the UK, CIGALE at the CFH and Marseille Observatories): see e.g. Marcelin et al., 1983 and Atherton et al., 1982. A high spatial resolution - the main advantage of optical observations with respect

to 21 cm observations - is a must.

4. Cooling flows in clusters of galaxies. This new field of research has technical requirements very similar to the previous one: sweeping Fabry-Pérot interferometers have already been used for this purpose (see e.g. Hu et al., 1983). Mapping and velocity field observations in lines fainter than Hα (e.g. [OIII], [SII], [FeX]) are very desirable. Here too a high spatial resolution is needed in particular for studying shocks.

Instrumental requirements

Spectrophotometry covers in part item 1.
Nebular (long-slit) spectroscopy is useful for items 1, 3 and 4.
Monochromatic imaging and Fabry-Pérot interferometry covers items 3 and 4 and to some extent item 1. An almost ideal combination offering optimum sensitivity and angular resolution is a 10 m VLT at f/2 or f/1.5 (directly or with a focal reducer) and a photon-counting detector with pixels matched to the image size (15-25 μm): see Lequeux, 1983.
Infrared spectroscopy and imaging is required for item 2.

III. Molecular clouds and dust

This is the domain of infrared spectroscopy and imaging. The main scientific goals are, apart from star formation and related topics which are covered by A. Moorwood in another part of this volume:

1. Shocks inside molecular clouds. These are detected by H_2 and CO emission lines (mapping and velocity field): see the review by D. Hall in Kessler and Phillips (1983), p. 267. Imaging is presently very lengthy for lack of sensitivity and of mosaic detectors.

2. Study of molecules. No other interstellar molecules than C_2, H_2 and CO have yet been detected in the IR. Under normal excitation conditions molecules will show up in absorption in front of strong IR sources. There is a chance that powerful instrumentation will detect presumably abundant symmetrical molecules like CH_4 or C_2H_2 in spite of the fact that they have no permitted rotation-vibration transitions.

3. Nature and thermal emission of dust. The problem of the nature of interstellar dust is best attacked through IR low-resolution spectroscopy H_2O and silicate bands are well observed, mainly in absorption (Allamandola, L.J.; Willner, S.P. in Kessler and Phillips, 1983, p. 5 and 37). Many emission bands seen in dust submitted to UV radiation are

still mysterious, although a recent study (Léger and Puget, 1984) proposes that extremely small graphite grains can produce them. Anyhow, this is a very promising field for a VLT, especially if high-resolution mapping is combined with spectroscopy.

Instrumental requirements

Items 1 and 2 ask for high resolution IR spectroscopy, while low resolution spectroscopy is sufficient for item 3. Imaging - still very underdeveloped for lack of IR mosaics - will certainly develop fast in the future and, especially if combined with spectroscopy, will become an extremely powerful tool. It should be remembered that the resolution can be close to the diffraction limit of the telescope, emphasizing the use of a VLT.

IV. Conclusion

It seems clear that a VLT will allow significant progresses in all aspects of the interstellar matter for which optical and IR observations are relevant. This includes wide-field imaging since only a VLT can provide simultaneously high sensitivity and high angular resolution.

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