of the Baade-Plaut field is combined with similar studies of other Bulge fields, such as Baade's window (Terndrup, 1988; Rich, 1989), and the central region (Catchpole et al., 1990). This is important also for the understanding of the stellar composition of the bulges of other galaxies.

In summary, this Key Project aims at improving our understanding of stellar evolution on the AGB by a comprehensive study of the Baade-Plaut field in the Galactic Bulge. Thise will provide information on the history of the Bulge.

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PROFILE OF A KEY PROGRAMME

Kinematics of the Local Universe

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Introduction

How matter is organized in the Universe is a fascinating problem to solve because it imposes severe constraints on the scenarios describing how matter was created and how it has evolved. Unfortunately, the way is hard because of our necessarily subjective point of view and the subtle biases which affect this description. Historical evidence shows that understanding the determination of the velocity field is of fundamental significance. For instance, the discovery of the location of the centre of our Galaxy is one of the most typical examples: the location, first discovered by H. Shapley (1) from the asymmetry of the distribution of globular clusters, was accepted only when dynamical arguments were given by J.H. Oort (2).

Later some astronomers (3, 4) pointed out that the galaxies are arranged in a kind of belt almost perpendicular to

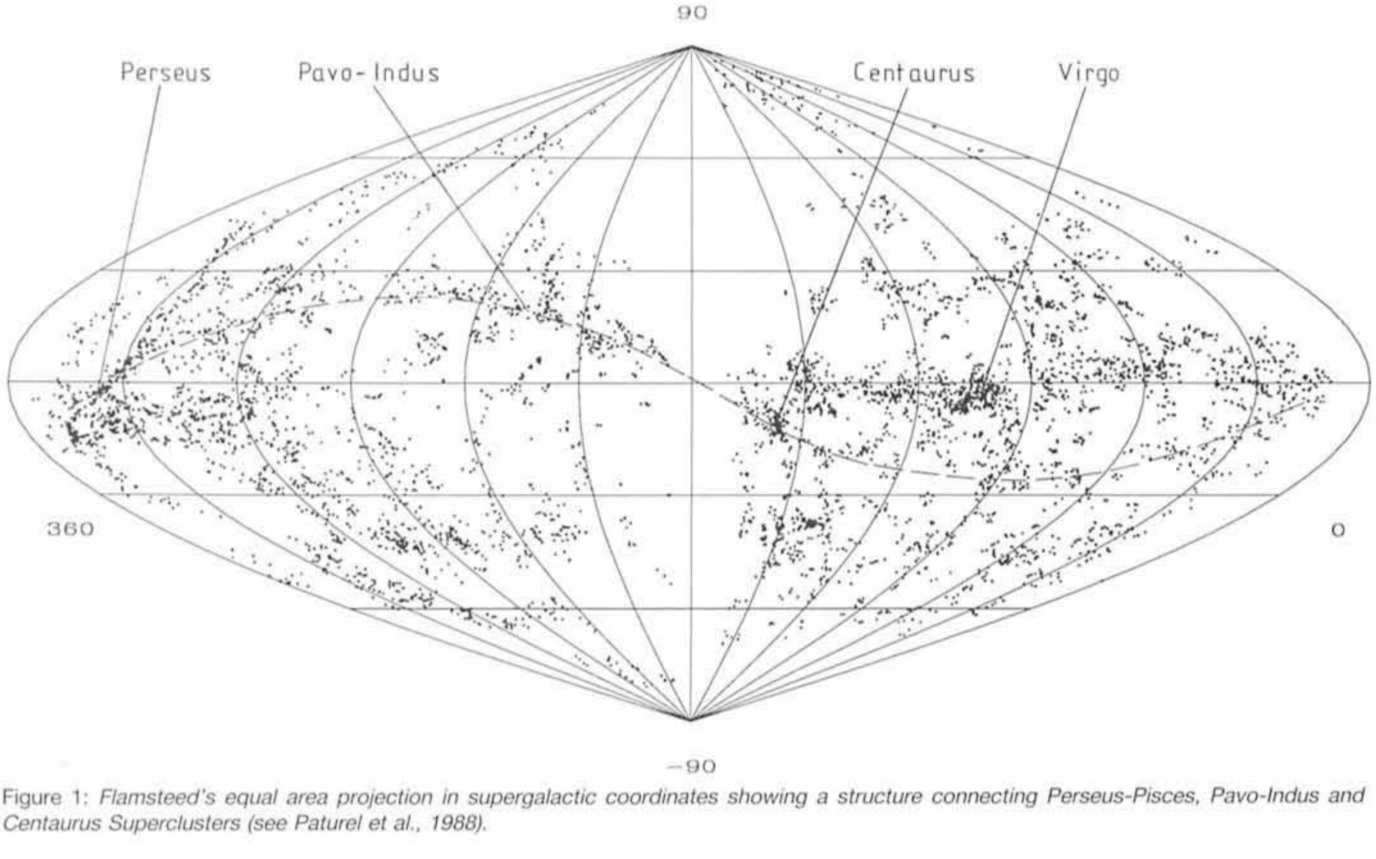

Figure 1: *Flamsteed's equal area projection in supergalactic coordinates showing a structure connecting Perseus-Pisces, Pavo-Indus and Centaurus Superclusters (see Paturel et al., 1988).*

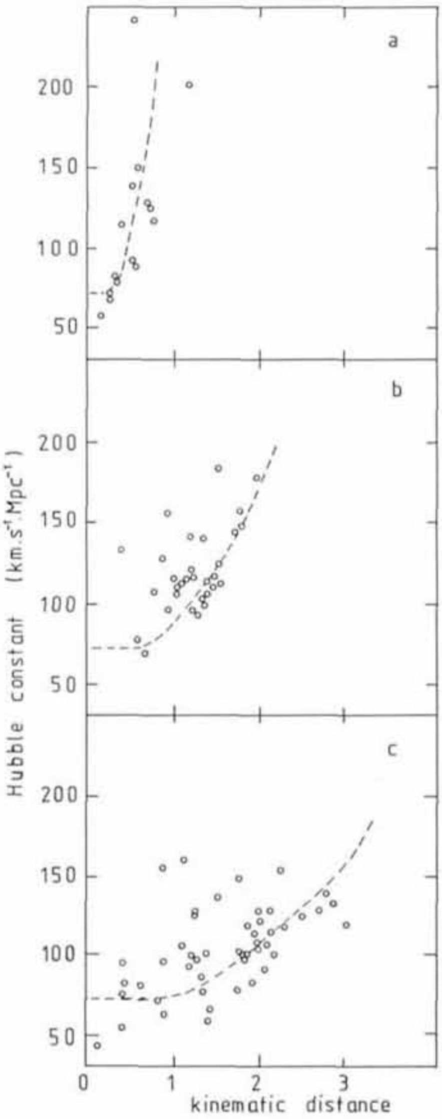

Figure 2: *A given sample affected by the Malmquist bias: Theory and observation. The Hubble constant H_o is plotted versus the kinematic distance (expressed in units of the Virgo cluster distance) for three luminosity classes: Figure 2a Low luminosity galaxies; Figure 2b Medium luminosity galaxies: Figure 2c High luminosity galaxies. At a given distance, the higher the luminosity, the lower the bias (see Bottinelli et al., 1988).*

the plane of our Galaxy. In 1953 de Vaucouleurs (5) described this kind of Milky Way of galaxies as the Local Super Galaxy (now called the Local Super Cluster). Again the existence of such a large system was accepted only when dynamical evidence appeared (6, 7).

Today, astronomers are in an almost similar situation. The existence of a very large structure has been suspected (8, 9, 10, 11). Figure 1 shows Flamsteed's equal area projection in supergalactic coordinates. An S-shape connecting Perseus-Pisces, Pavo-Indus and Centaurus Superclusters is visible. The search for dynamical arguments is thus highly suitable to test the reality of such a large system.

For this purpose, essentially two different approaches operate:

– The first one consists in measuring the distance d and the radial velocity V_r of a sample of galaxies and deriving the peculiar velocity $V_p = V_r - H_o d$, where H_o is the Hubble constant. It has been used by Lynden-Bell et al. (12) to infer a rather complex peculiar velocity field implying the existence of an important mass concentration (5.4×10^{16} $M_\odot$) – the so-called "Great Attractor" (hereafter GA) – located in the direction of the Hydra-Centaurus supercluster but lying beyond it (at 4350 km·s^{-1} instead of 3000 km·s^{-1})

– The second one relies on the observation of the distribution of galaxies and provides the peculiar velocity field from the gravitational acceleration through the linear perturbation theory (13). The use of an IRAS galaxies sample (14, 15, 16, 17) and of an optical sample (18) confirm the anisotropy of the velocity field but do not support the idea of a GA lying beyond the Hydra-Centaurus supercluster.

Why do both ways not lead to the same conclusion? We may suspect that the disagreement arises from distortions induced by erroneous determinations of distance.

Distance Determination and Malmquist Bias

Both methods need accurate relative distances. A zero-point error may affect the determination of the Hubble constant H_o but not the study of the velocity field, which requires only a good linearity of the distance scale. Unfortunately, it is not easy to be sure of the linearity because of biases.

In a series of papers started in 1975, Sandage and Tammann claimed that distance determinations are biased; many astronomers were reluctant to accept this idea with its implications probably because of the lack of clear proof. In 1975 and 1984, Teerikorpi (19, 20) studied from a theoretical point of view the bias arising when determining distances from a magnitude limited sample (the so-called Malmquist bias). This analysis has been confirmed with actual data (21, 22, 23). Let us explain how it works:

If a class of galaxies is characterized by a symmetrical luminosity function (for example a Gaussian function of mean absolute magnitude M_o and dispersion σ), any sample of these galaxies, limited to an apparent magnitude m_{lim}, will not contain the less luminous galaxies, due to this cut-off. The limiting absolute magnitude M_{lim} at distance r is simply given by $m_{lim} - M_{lim} = 5 \log r + 25$, if r is in Mpc. Therefore, at any distance r, the mean absolute magnitude of the galaxies belonging to this sample is brighter than M_o. Then, if one measures the apparent magnitude of a galaxy in this sample and assumes that its absolute magnitude is M_o, the derived distance will be, on the mean, underestimated and this underestimation increases with increasing distances. However, if the sample is deep enough (faint m_{lim}), at small distances the underestimation becomes negligible. Figure 2 shows how a given sample is affected by the bias according to the theory (assuming a gaussian luminosity function) and to observations. The agreement between theoretical prediction and observation is satisfactory.

To overcome these pernicious effects, it is essential to work with complete samples limited by an apparent magnitude (or an angular diameter) as faint as possible. The problem is thus to build an adequate sample.

The Sample

Since 1983 we have been building an extragalactic database (24) in which the most important, available measurements are collected for 73,000 galaxies. The Catalogue of Principal Galaxies (25, 26) constitutes the frame of this work. This database has been used to homogenize the relevant data; special care was paid to HI data (27, 28) and to apparent diameters (29). Besides, our participation in the Third Reference Catalogue of Bright Galaxies (30) provided us with accurate apparent magnitudes and morphological types.

The apparent diameters are available for 72 per cent of the galaxies. When they are reduced to the standard system D_{25} (diameter defined up to the limiting surface brightness of 25 mag.arcsec^{-2}) they constitute a good substitute to magnitudes. The conclusion is that it is feasible to derive the distance from the Tully-Fisher relation (hereafter TF, 31) expressed in diameter:

$$\mu = -5 \log D_{25} + a \log V_m + b.$$

In this relation V_m is the maximum velocity rotation deduced from the 21-cm line width corrected for inclination and dispersion effects (32, 33).

Thus, a study of the peculiar velocity field has been undertaken from a complete sample of 3856 spiral galaxies having photometric diametres larger than 1.6 arcmin. For each galaxy it is necessary to know both the radial velocity and the distance estimated from the diameter-TF relation.

When the radial velocity is known, it is easy to derive the distance modulus from 21-cm line observations with the meridian radio telescope in Nançay

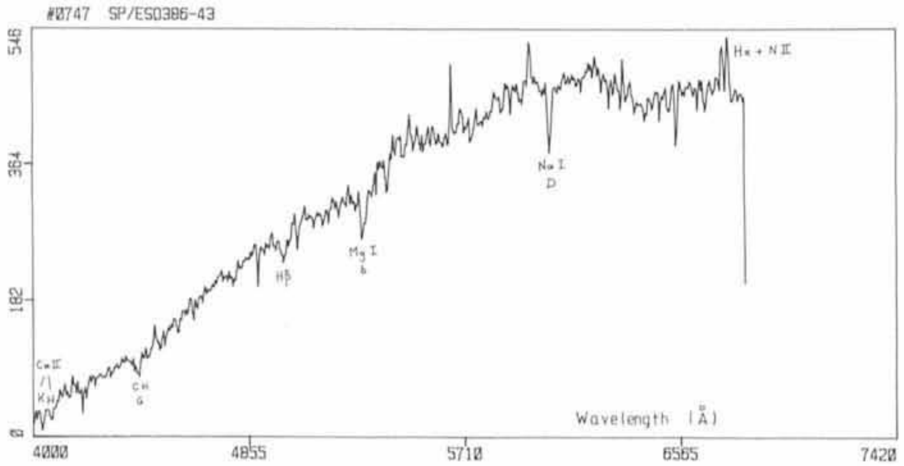

Figure 3: *An example of a calibrated spectrum obtained a few seconds after the end of the exposure.*

(France) which can observe declinations above −38 degrees and where guaranteed observing time has been granted.

Thus, the most important target is to quickly obtain optical radial velocities. Among our sample, more than 600 galaxies still lack this fundamental information. Fortunately, the very efficient modern spectrographs allow us to carry out such a large programme. The main part of these galaxies lies in the southern hemisphere and constitutes the subject of the present ESO Key Programme at La Silla. A joint programme has been undertaken at Observatoire de Haute-Provence (OHP) for the Northern Hemisphere.

Radial Velocity Measurement

The ESO 1.52-m telescope and OHP 1.93-m one are both equipped with very similar spectrographic acquisition systems.

ESO observations are performed with the B&C spectrograph (grating No. 16 with dispersion 187 Å.mm^{-1}) at the 1.52-m ESO telescope. The coverage in wavelength is 3956-6820 Å. At OHP, the CARELEC spectrograph attached to the 1.93-m telescope has more or less comparable characteristics. The dispersion is 260 Å.mm^{-1} and the coverage is 3733–7633 Å.

The same procedures, based on IHAP software, were developed at both observatories. Let us give more details about this efficient method to derive radial velocities.

Four IHAP-BATCH programmes have been written; they work at ESO as well as at OHP.

The first batch (called CALIGULA) is used for the calibration at the beginning of each night: i.e. measurement of the OFFSET, determination of the FLAT-FIELD, and test of the He-Ar calibration lamp (He lamp in OHP).

The second batch (called SPARTACUS) produces a calibrated astronomical spectrum. The automated calibration is made using a spectrum of the calibration lamp measured just before the astronomical spectrum. Such a calibrated spectrum is shown in Figure 3.

Generally, the first spectrum of the night is a spectrum of a standard star. Thus, it is possible to reduce each galaxy spectrum using the cross-correlation batch programme (called CROCO). The operator must first select the spectral region which will be used (in order to avoid some poorly detected regions or some strong emission lines). The programme automatically performs the transformation into a log scale for the wavelength axis and then displays the cross-correlation function (cross-correlation between the galaxy spectrum and the standard star spectrum; see Fig. 4). The radial velocity of the galaxy (more exactly: the difference between the radial velocity of the galaxy and the radial velocity of the reference star) is automatically deduced from the maximum of the correlation function.

The last batch programme (called MELINOS) allows us to determine the radial velocity just by picking out the line on the calibrated spectrum. Giving the rest wavelength of the line to the batch programme will result in printing the corresponding radial velocity. This programme is well adapted to deal with emission lines or spectra with poor S/N ratio (typically when the maximum of the cross-correlation function does not exceed 0.4).

It is highly recommended to derive the velocity from both CROCO and MELINOS in order to take into account all information contained in the spectrum.

Last Step: HI Measurements

When the radial velocity is known and properly corrected to the heliocentric reference system, it is quickly communicated to the Nançay radio telescope for measurement of the HI line width. It has happened that some HI measurements were finished just a few days after the measurement of the radial velocity. Figure 5 shows the HI line profile for an ESO galaxy detected in Nançay.

Obviously, not only the width is derived from the HI line profile: the HI velocity and the HI flux are also valuable by-products.

At the present time, one observing run has been performed at each Observatory (ESO and OHP). Thus, it is too early to draw scientific conclusions; nevertheless, after only 7 nights of effective work, 77 new radial velocities have been obtained. The target of this key programme therefore seems to be quite attainable. Whatever the result may be,

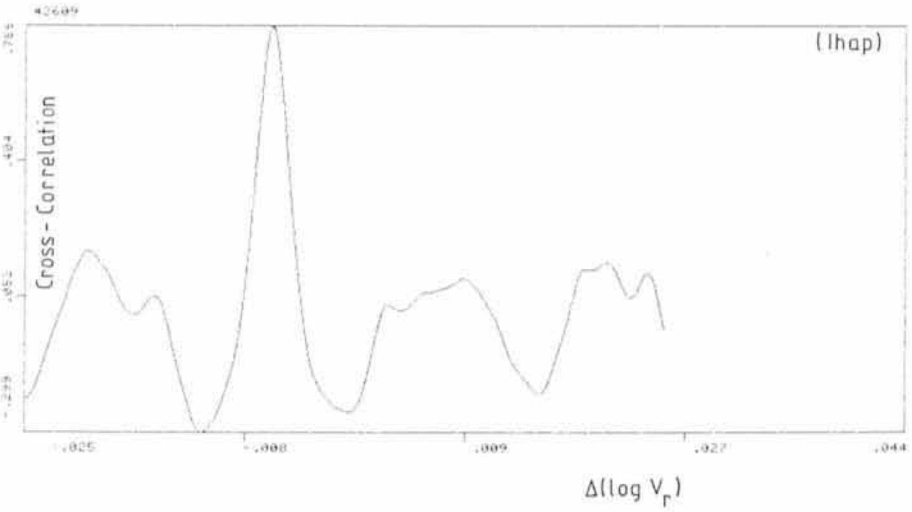

Figure 4: *Cross-correlation between the galaxy spectrum and the standard star spectrum. This method is very fast; the radial velocity can often be obtained before the start of the next exposure.*

our understanding of the kinematics of the local Universe will be improved.

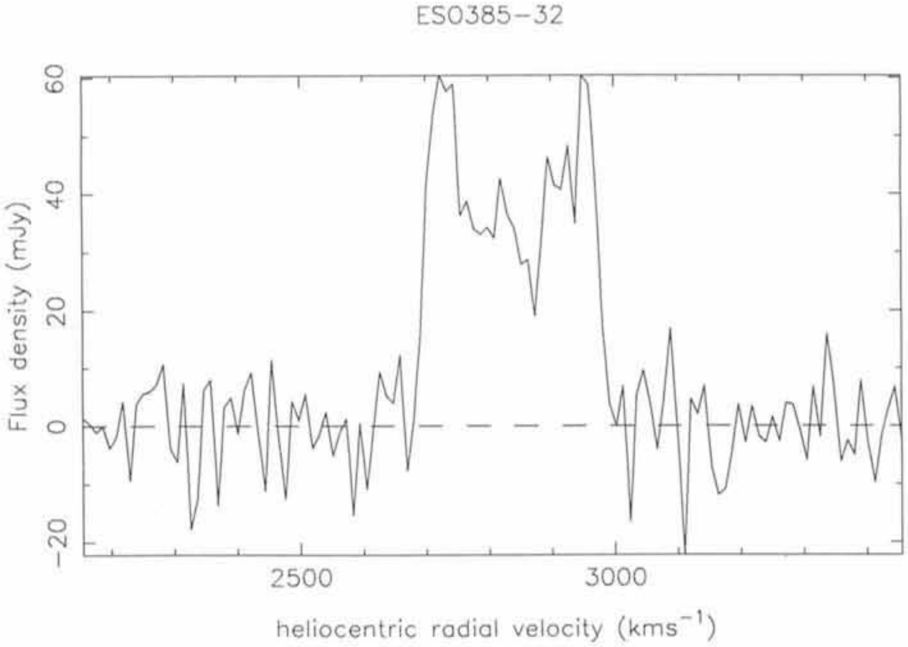

Figure 5: *HI line profile of ESO galaxy ESO 385-G32 detected with the Nançay radio telescope.*

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PROFILE OF A KEY PROGRAMME

Arc Survey in Distant Clusters of Galaxies

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First Steps in the Study of Luminous Arcs

The first luminous arcs were discovered in the centres of rich clusters of galaxies by Soucail et al. (1987) and Lynds and Petrosian (1986). The redshift of the giant arc in Abell 370 ($z = 0.725$) was finally measured with EFOSC/PUMA at the ESO 3.6-m telescope in October 1987 (Soucail et al., 1988). It definitively confirmed that they were gravitationally distorted images of background galaxies by clusters of galaxies (Fig. 1).

During the same period, Tyson (1988) obtained ultra-deep CCD photometry in a sample of empty fields and detected a numerous population of very faint galax-