(such as the reliable study of Zucca et al., 1996) should give hints for the understanding of the processes involved.

To some extent we rediscover, on a quantitative basis however, the old known fact that the cluster core, when compared to the field, is dominated by early-type galaxies.

The core birth scenario could have started in the epoch z ∼ 10–20 involving huge masses and helping the formation of large E/S0 galaxies. Later infall sets in and continues to the present day with galaxy-ICM interaction and subsequent ICM enrichment. Here we begin to form the dwarf spheroids, trigger starbursts in the infalling galaxies via the shocks induced by the interaction galaxy – ICM, and to shape the faint end of the cluster LF. The final shape of the faint end could also be modified by active fragmentation and become steeper than in the field, but such hypothesis needs to be investigated.

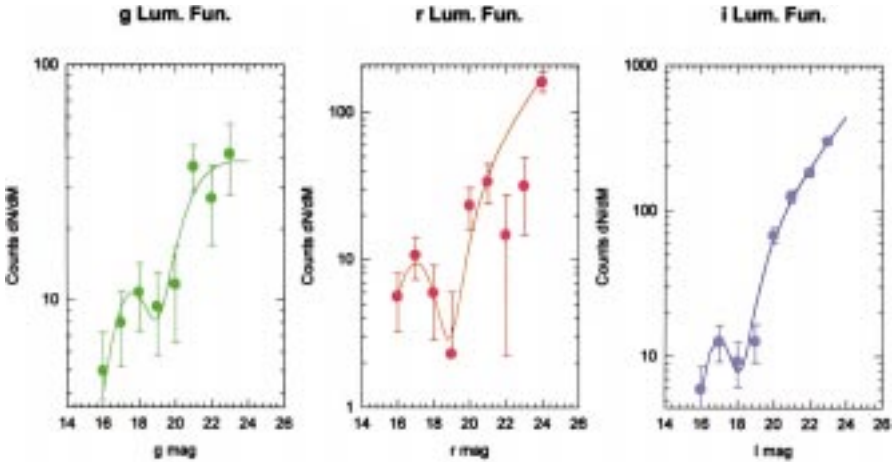

Figure 2. *The Luminosity Function of the cluster A496 (m–M = 35.53, H_0 = 75 km/s/Mpc) as observed in the g, r and i Gunn filters. The Gauss + Schechter functions have been plotted using the parameters estimated from the fit, continued line. The analysis is based on the photometry of 2355 objects of which 2076 have been classified as galaxies.*

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From EROS to DUO, ALADIN, GATT and Others: Wide-Field Astronomy

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The purpose of this report is to illustrate the major role of large-field imaging in all the domains of astrophysics, and to present some recent results. Most of these are based on digitisation and analysis of Schmidt images taken in the course of either sky surveys or specific programmes; however, the experience gained as well as the tools developed for the exploitation of photographic plates, have started benefiting ground-based and space CCD projects. Special emphasis will be put on the crucial importance of computer storage and processing capabilities, as well as efficient analysis and calibration software, for images up to 2 gigabytes. The resources of the Image Analysis Centre of the Observatoire de Paris, including the MAMA facility, used by a wide national and international community of astronomers, will be briefly presented.

1. General Context

The activities of the Image Analysis centre (hereafter: the CAI), started in 1987 with the first operational scans performed by the MAMA microdensitometer. MAMA (Machine Automatique à Mesurer pour l'Astronomie), was designed and built by the Technical Division of INSU (Institut National des Sciences de l'Univers, CNRS). Equipped with a linear RETICON array of 1,024 photodiodes, MAMA digitises a 14 × 14-inch plate in a few hours, providing a positional accuracy of 1 micron and a repeatability of 0.2 micron. In ten years, several thousands plates or films of various origins have been scanned, leading to several terabytes of pixels, and to catalogues with as many as 10 million detected objects per Schmidt field.

The MAMA facility also includes, in addition to the computer system close to the microdensitometer, a set of workstations in charge of image processing and data reduction. More than 100 gigabytes of on-line magnetic disk storage, tape recorders of different types (DAT, Exabytes, DLT), complement the CPU resources. These can be used for the exploitation of images either digitised from plates or produced by CCD devices.

Applications for scanning time, image processing, and assistance to data reduction, are examined by a Committee which meets twice a year. Collaborations with French teams are encouraged when groups from other countries are interested in extensive use of this national facility.

2. Some Scientific Results

2.1 Microlensing

• The some 300 plates taken at the ESO Schmidt in the course of the EROS (Expérience de Recherche d'Objets

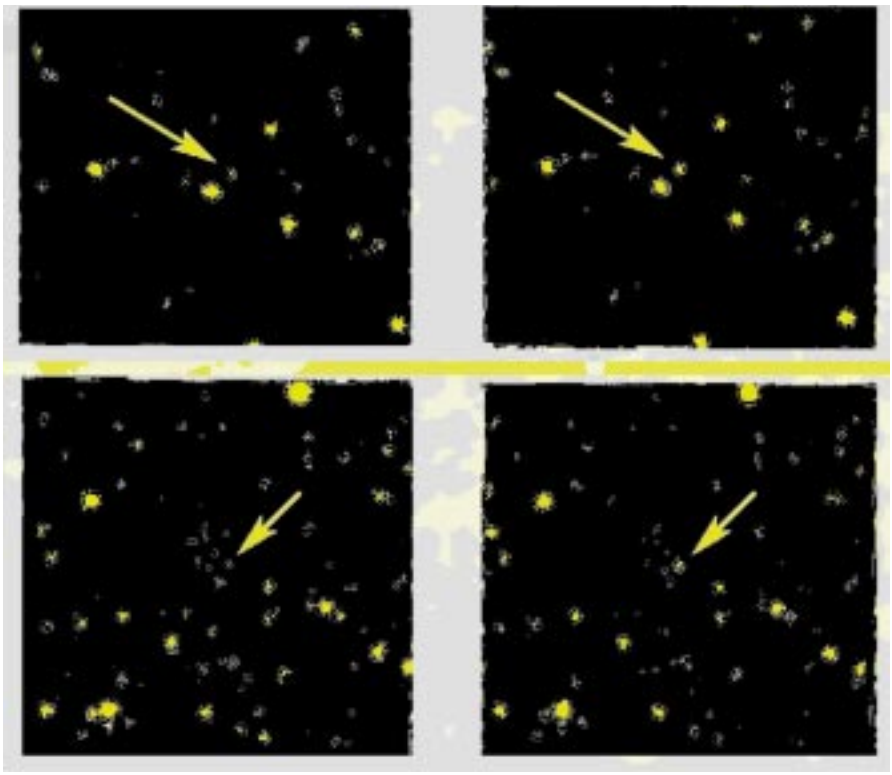

Figure 1: The two EROS microlensing candidates discovered on ESO Schmidt plates towards the LMC. Top: EROS-1, maximum light amplification on 1 February 1992; bottom: EROS-2, maximum on 29 December 1990.

Sombres) programme from 1990 to 1994, were digitised by MAMA and reduced at Centre d'Etudes Nucléaires, Saclay, and Laboratoire de l'Accélérateur Linéaire, Orsay, leading, towards the Large Magellanic Cloud, to the discovery of two microlensing events likely to have been produced in the Galactic Halo (Aubourg, E. et al., 1993, see also Fig. 1 of the present paper).

• About 300 other plates were taken at La Silla in the frame of the DUO (Disk Unseen Objects) project conducted by the Image Analysis Centre during the 1994 and 1995 seasons. Here the surveyed region was close to the Galactic Centre (Fig. 2). After digitisation, the images were reduced with a specific software developed at the CAI by Alard, C. for crowded fields. The monitoring of $\sim$ 13 million stars recorded during the first season lead to the detection of 13 microlensing events: 12 single lenses (Alard et al., 1995; Alard and Guibert, 1997), and a double lens, the less massive component can have the mass of a brown dwarf or a few times that of Jupiter (Alard, Mao and Guibert, 1995; see also Figure 3 of the present paper). Reduction of the 1995 season is in progress.

2.2 Galactic Structure and Dynamics

This domain is the object of many investigations at the CAI. Proper motions accurate to 2 mas/yr down to V $\sim$16–17, as well as magnitudes and colours, are obtained by several groups, either to sound the general stellar populations of the Galaxy, or to investigate specific objects: open and globular clusters, variable stars, etc.

2.2.1 Stellar Populations

• Using plates from Palomar, ESO, OCA (Observatoire de la Côte d'Azur), and Tautenburg (Germany), the Besançon team has conducted a long-term investigation of the galactic populations towards several directions (see, e.g. Robin et al., 1995; Ojha et al., 1996 and references therein. The kinematic and photometric data derived from the analysis of the plates have been widely used to constrain the Besançon Model (see, e.g., Haywood, 1994, Haywood et al., 1997).

• Similar studies have been conducted by Soubiran (1992) in the North Galactic Pole region, or are still in progress along the meridian plane of the Galaxy (MEGA project, Kharchenko and Schilbach, 1996).

2.2.2 Variable Stars

• Blink microscope detections by A. Terzan of more than 4,000 new Long Period Variables on ESO Schmidt plates covering an area of 100 square degrees including the Galactic Centre have been complemented by astrometry as well as photometry, resulting in accurate positions and, for part of them, in light curves (see, e.g. Terzan et al., 1997 and references therein; Alard et al., 1996). A comprehensive atlas of digital finding charts for these 4,400 objects is in preparation.

• The DUO search for microlensing events has also lead to the discovery of thousands of galactic variable objects (Alard et al., 1995, Alard and Guibert, 1997). Among them, contact binaries, dwarf novae, RR Lyrae… Thousands of new Long Period Variables are expected from the combination of the 1994 and 1995 campaigns.

• Reprocessing, with the DUO reduction package, of the EROS photographic images, resulted in the discovery of some 10,000 new RR Lyrae after analysis of 12 million light curves (Alard et al., in preparation).

• Mention should be made of a contribution, using the aforementioned DUO image analysis software, to the investigation of the intrinsic variability of the EROS-2 microlensing candidate (Ansari et al., 1995).

• Other investigations are in progress, e.g., studies of LPVs in the Galactic Centre region using SERC plates (Catchpole et al., in preparation)

2.2.3 Open Clusters

Among the various objects studied in this domain, we will quote here two clusters for which the juxtaposition of several Schmidt fields has allowed investigations of the kinematics and mass function over unsurpassed areas:

• The Pleiades (Schilbach et al., 1995, Meusinger et al., 1996; see also Fig. 4 of the present paper).

• Praesepe (Robichon 1997, in preparation).

Photographic plates are being complemented by HIPPARCOS and TYCHO data in the frame of an extensive investigation of several tens of clusters. A multi-colour atlas of open clusters is in preparation, in collaboration with the Institute of Astronomy, Lausanne.

2.2.4 Tidal Effects in Globular Clusters

An extensive investigation of tidal tails in $\sim$ 60 globular clusters has been undertaken. It is mainly based on "B" and "R" Kodak Tech Pan films exposed at the ESO Schmidt with the BG12 and RG630 filters, and on ESO, SERC and POSS survey plates, which have been digitised by MAMA. Data reduction and interpretation of the observed extensions in terms of tidal effects caused by the galactic Disk and Bulge are in progress. As an example of the most striking examples of the results obtained in the frame of this GATT (Globulars And Tidal Tails) programme, Figure 5 shows the tidal tails extending over $\sim$ 3 degrees displayed by NGC 288) (Léon, Meylan and Combes, in preparation).

2.3 Extragalactic Astronomy

The CAI's services are called on in different domains of extragalactic astrophysics, ranging from individual objects

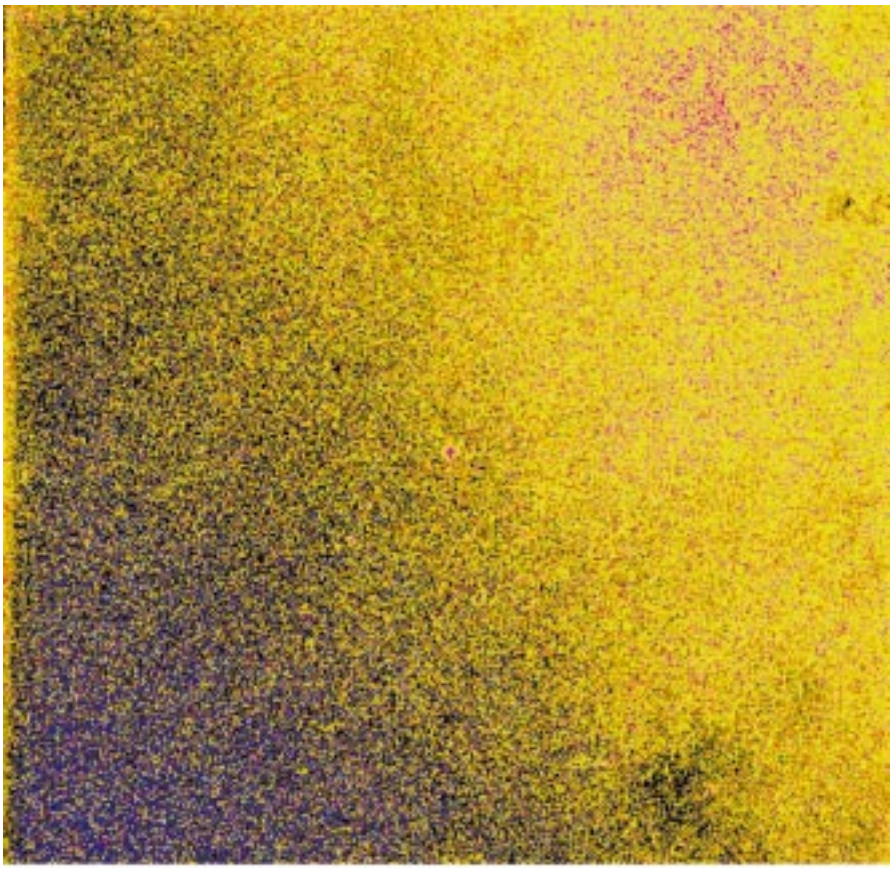

Figure 2: The field monitored in the course of the DUO programme. One of the some 200 IIIa plates taken at the ESO Schmidt at La Silla. North is to the top, east to the left. Up to 200 stars per square arcmin – i.e. per square mm of plate – are detected and deblended, resulting in 13 million stars monitored, and yielding 13 microlenses during the 1994 campaign.

to large-scale structures of the Universe and cosmological problems. Among the results obtained and programmes in progress:

2.3.1 Sagittarius Dwarf Galaxy

Unexpected extensions of this newly-known object were discovered in the course of the DUO programme (Alard, 1996). Figure 6 shows how these extensions have been unveiled by the histogram of distances to 1,500 new RR Lyrae stars towards the Galactic Bulge. Films obtained at the ESO Schmidt in 1996 will probably allow the detection of more variables of this type in additional fields, the objective being to delineate the contours of this galaxy which could be as large as the LMC.

We would like also to mention:

2.3.2 Emission-line galaxies

Automatic detection and detailed studies of emission-line galaxies from digitisation's of Calar Alto and ESO objective prism plates (Alonso, et al., 1995; Surace and Comte 1994).

2.3.3 Quasars

Surveys of ultraviolet-excess quasar candidates in large fields (Moreau and Reboul, 1995; Gosset et al., 1997).

2.3.4 Large Structures

Studies of clusters and superclusters of galaxies: morphology and segregation of galaxies in clusters (Andreon et al., 1995; Andreon, 1996); studies of X-Ray clusters (Durret et al., 1996) and of superclusters of galaxies (e.g. Quintana et al., 1995).

2.3.5 Galaxy Evolution

Luminosity function and evolution of galaxies (Bertin and Dennefeld, 1996). This study suggests that so far claimed needs for evolution of the non-dwarf galaxy population out to z = 0.2 could be due to systematic magnitude scale effects affecting previous investigations.

2.4 Identification and Astrometry of Optical Counterparts

2.4.1 Support to individual programmes

Identifying optical counterparts to determine the equatorial co-ordinates of sources detected at wavelengths ranging from the X-Ray domain to the infrared represents another important activity of the CAI, particularly in view of spectroscopic observations with large telescopes. Here, we will again select a small number of examples:

- IRAS sources (Le Sidaner and Le Bertre, 1993).
- Transient X-Ray sources (Chevalier and Ilovaisky, 1990; Kitamoto et al., 1990; Pakull et al., 1993, Feigelson et al., 1993...).
- Optical sources (eclipsing binary stars in LMC (Grison et al., 1994).

2.4.2 Contribution to the ALADIN Project

ALADIN is a new project currently under development by the CDS, Stras-

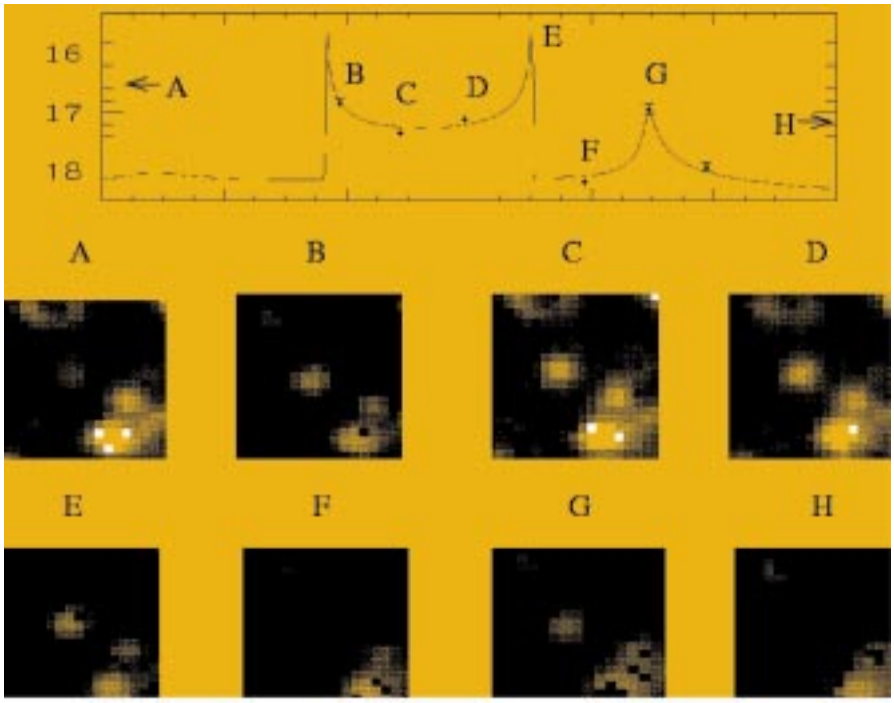

Figure 3: The double-lens DUO-02. Among the series of 8 frames displayed here (each of them extracted from a different ESO Schmidt plate), image G shows the last maximum observed during the event, which appears as an amplification by a double system (see text).

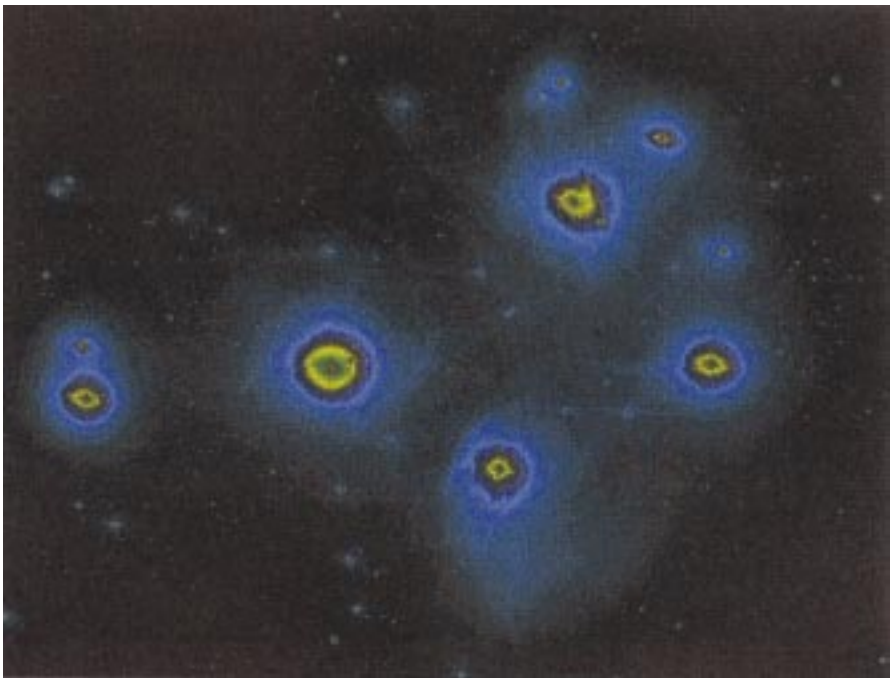

Figure 4: The central region of the Pleiades open cluster. Digitisation of a plate taken with the Tautenburg Schmidt. Proper motions accurate to 2 mas/yr in a large field have been obtained using a stack of such plates taken at different epochs.

bourg, to create an Interactive Deep Sky Mapping Facility, allowing the user to visualise on his/her own workstation digitised images of any part of the sky, to superimpose entries from astronomical catalogues or user data files, and to interactively access the related data and information from the SIMBAD database for all known objects in the field (Bonnarel et al., 1994, and CDS on the WEB). High-resolution images, obtained by digitisation of Sky Surveys, together with the corresponding astrometric calibration based on the PPM catalogue, have been provided to ALADIN by the CAI, essentially for the neighbourhood of the Galactic Plane and selected regions such as the Magellanic Clouds.

3. Image Processing and Data Reduction

Exploitation of large photographic and CCD images at CAI takes advantage of:

• efficient tools for image handling, such as mosaicing thousands of frames into images as large as 2 gigapixels.

• software like SExtractor (Bertin and Arnouts, 1996), or Extractor (developed at CAI by Alard, C.) for detection, deblending, and characterisation of sources from astronomical images in various environments

• optimised tools for astrometric and photometric calibration

• pipelines for concatenation of the aforementioned steps with object selection, pairing, etc. either on individual images or on pairs or series of exposures for colour corrections, and for studies of proper motions and magnitude variations.

Though always insufficient with respect to growing needs, increasing computer power and storage capacity are making possible the success of enterprises like the DUO programme, in which 13 million stars are detected, identified, and monitored on several hundreds of plates, implying handling of nearly 1 terabyte of data.

4. Recent Developments

The exploitation of CCD images of various origins not only is benefiting from skills and tools acquired and developed at the CAI, but motivates new efforts in several domains. This includes:

4.1 Image Processing

In the near and far infrared, the DENIS and ISOCAM images, respectively, are the objects of specific treatments designed by Alard, C. for image improvement and object detection in the cases of peculiar noise distributions or psf characteristics.

4.2 Astrometry: Complementation of Space Data and Developments of Reduction Techniques for Large Fields

This includes, among others:

• Development of astrometric reduction techniques taking advantage of the density and quality of catalogues such as TYCHO, to reach accuracies better

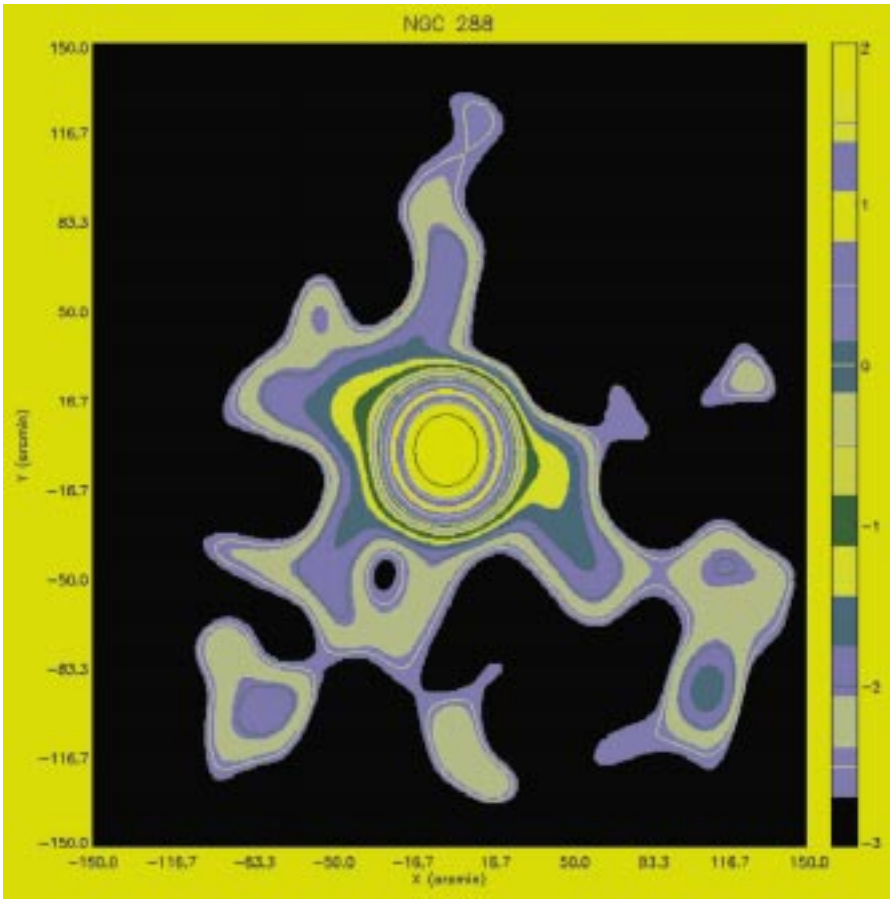

Figure 5: Tidal tails in the NGC 288 Globular Cluster. The figure displays the map of background-subtracted and wavelet-filtered surface density distribution of colour-selected stars in the field of NGC 288 from Tech Pan films taken at La Silla. This work extends the results obtained on a smaller area by Grillmair et al. (1995).

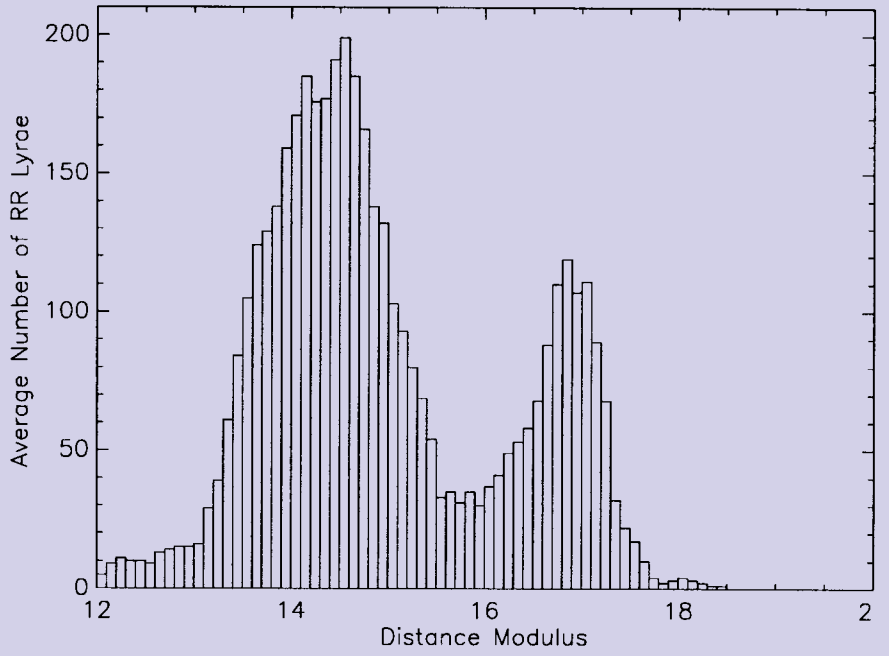

Figure 6: The extension of the Sagittarius Dwarf galaxy unveiled by the histogram of RR Lyrae stars distances.

than 0.1 arcsec in large fields (Robichon et al., 1995).

• Contribution to the link of the HIPPARCOS Catalogue to an extragalactic reference frame (Kovalevsky et al., 1997).

• New tools are under development for exploitation of Carte du Ciel plates. Combined with recent positions provided for instance by the TYCHO mission, such accurate first-epoch data can be used to improve the proper motions of reference catalogues.

• Use of efficient tools built for the retrieval of thousands of reference stars in large images and astrometric reduction algorithms to calibrate CCD images (collaborations with the Côte d'Azur Observatory and the EROS project).

4.3 Spectral Classification

A request, supported by several groups of various origins, has been submitted to the CAI for the realisation of a digital atlas of spectra containing several hundreds of MK standards.

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