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Commission 9

Working group
on
"Wide-field imaging"

Newsletter 6

Contents

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Editor's Note

The Working Group on 'Wide-Field Imaging' has now been running for 3 years, since its conception at the XXIst General Assembly meeting of the IAU in Buenos Aires in 1991. Richard West took on the daunting task of being the very first Chairperson, and managed to organise the Working Group into the highly successful operation it is today. Much has happened in the past 3 year period. We have seen a threat to the continued supply of traditional photographic emulsions, and the discontinuation of some completely. New fine-grain emulsions (in particular Tech Pan 4415) have made an appearance and have provided fresh stimulus to the further potential of photographic emulsions. Techniques of photographic and digital stacking and amplification have been perfected, leading to further possibilities of using photographic materials for performing very deep, wide-field surveys.

Undoubtedly, the high point of the past 3 years (from the WG point of view) was the highly successful IAU Symposium on 'Astronomy from Wide-Field Imaging' held in Potsdam, Germany, during August 1993, at which some 200 participants attended. The Proceedings of the conference (IAU Symposium No. 161, published by Kluwer Academic Publishers) has been produced, and by the time people receive this Newsletter will be appearing on shelves as tangible evidence of the performance of the Working Group over the past 3 years.

It is now time, however, to look forward to the next 3 years, and already a new committee has been elected. The membership of the new committee is published also in this Newsletter. We have also been active in trawling the wide-field astronomy community for membership of the WG for the coming 3 years, and a list of persons who have actively joined the WG or continued their membership accompanies this Newsletter. If your name is not on this list and you wish to be a member, then you should write to me as soon as possible. Only those persons listed will continue to receive future Newsletters and correspondence.

The next 3 years promises to continue with regard to new and exciting developments in our field. In particular, planned large-scale deep CCD surveys of the sky will be beginning to happen, and first results should be expected. Following rapidly on the heels of these will be a mass of wide-field spectroscopic data, produced from advancements in the use of large numbers of fibres (several hundreds at a time) which can be positioned to feed the light from individual objects into highly efficient spectrographs. The sheer quantities of data pose new problems in the areas of mass storage and bulk processing, all of which rely heavily on developments at the forefront of technology. We are truly on the verge of an era which promises to be extremely exciting and richly rewarding.

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The Digitising and Analysis of Astronomical Images

Abstract. Many astronomical research programs depend on the efficient use and analysis of photographic images. In order to fully exploit the ESO/SERC film surveys, to which we have access, we use fast real time video digitising and analysis systems. These systems also have applications in areas beyond pure astronomy.

1. Introduction

Photographic sky surveys, culminating in the ESO/SERC Sky Survey, the deepest photographic survey of the southern skies, have allowed astronomers to carry out a great variety of projects including:

- morphological studies and searches, e.g. supernova remnants;
- photometric studies, e.g. variable stars, nebulosities;
- astrometric measurements.

Quantitative measurement of photographic material has, until recently, required access to comparatively expensive equipment. The major plate digitising projects over the past decade have been carried out using the COSMOS or APM facilities in the UK or the Luytens machine and a variety of PDS machines in the USA and Europe. Access to these is sometimes difficult, and for many applications unnecessary.

The Astronomy research program in the Physics Department of the University of Wollongong has major elements which depend on image digitising and analysis. The Department holds the complete set of the Southern Sky Surveys (ESO R; SERC IIIa-J, I and R surveys). In order to use these in both teaching and research we have established a low cost image digitising and analysis facility based on IBM PC compatibles, commercial video frame grabbers and image analysis software. The real time image enhancement and background subtraction possible with this system allows the full exploitation of archival photographic images. These sophisticated but flexible systems, supported by a CD ROM based image and catalogue database:

- support established research projects, particularly those related to 'Galactic Star Formation';
- support Undergraduate, Honours and Postgraduate programs associated with astronomical image and data processing;
- allow the rapid development of new projects utilising UK Schmidt Telescope plate material.
- allow us to develop wide ranging courses in image analysis e.g. Medical Imaging.

2. Video Digitising Systems

The advent of powerful, low cost computers, frame grabbers and high quality CCD cameras has allowed the development of an image digitising facility which is both state of the art and low cost.

Conceived in its original form in 1988 the system provides for the real time, 8-bit (256 grey scale), video digitising and analysis of photographic plate material.

The image digitising systems are PC/AT based video frame grabbers. The digitising board used is the PCVisionplus board. Computer controlled Look Up Tables (LUTs) allow the stored 512×512 pixel image to be displayed in pseudo colour on a dedicated RGB image monitor. The video digitiser accepts video input from CCD video cameras (National and Phillips) mounted on a Polaroid

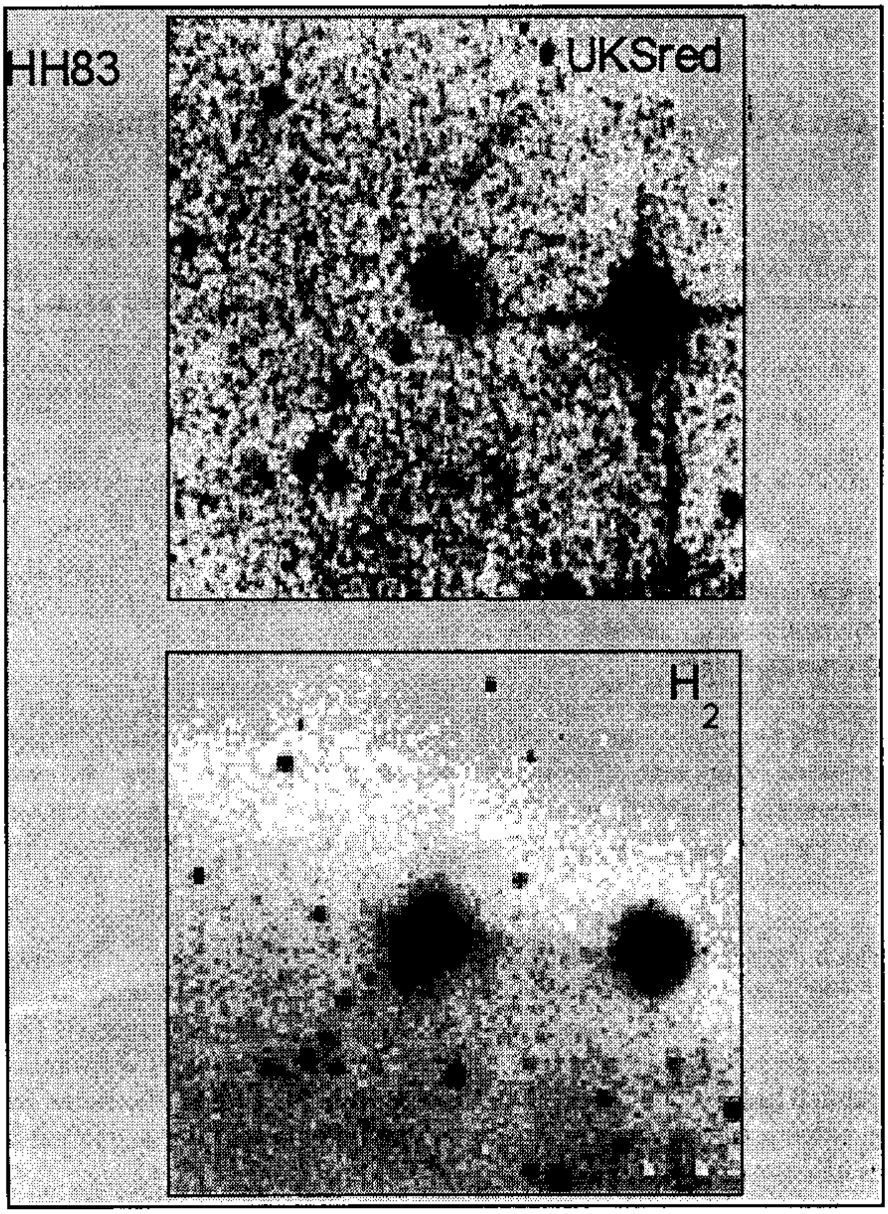

Figure 1. A video image of HH83 from an ESO R plate (top) and an infrared image taken using IRIS (bottom).

Laboratory Camera. A combination of lenses allows both wide-field (300mm square; 6mm pixels) and microscopic (5mm square; 10μm pixels) imaging of sky survey plates. Plate illumination is provided either by a Chromega colour enlarger head for regions up to 5mm square or a light box for larger areas.

Jandell's JAVA software allows real time enhancement and measurement of the digitised images which are displayed on an RGB monitor. This low cost but sophisticated software package supports spatial filtering, contrast enhancement, thresholding, simple backgrounding and source counting as well as photometric analysis. Images are stored as 8 bit TIFF files and as such are compatible with a wide range of software.

The two PC ATs equipped as video digitisers can be networked to the Department's PC, Sun and Macintosh network via Ethernet. Normally however we transfer small numbers of images on floppy disks. Larger amounts of imaging data may be stored on a 6259BPI, 9 track tape unit, a 20 Mbyte tape streamer or a 600 Mb Ricoh Magneto Optical Drive.

We normally carry out off-line analysis and printing using JPL's IMDISP and Alchemy

Mindworks GWS packages. GWS is particularly useful for a first look at images, cropping and scaling and conversion to GIF or other image formats. GWS provides low quality b/w or colour hardcopy using bubblejet printers. High quality output is obtained by using Pizzaz Plus, a screen capture program, to save print files which can then be imported to CORELDRAW for enhancement, addition of text, and printing.

The JAVA software is also flexible enough to allow the import and analysis images from a variety of sources including archival CD ROM images from IRAS, Einstein, and the NASA Voyager and Magellan missions after cropping and reformatting as TIFF files.

3. Astronomical Applications

3.1 MORPHOLOGY

The video systems have provided a platform for the rapid development of expertise in CCD digitising and of software for image processing. One of their main uses has been in scanning plates for selected low brightness sources.

Searches for interesting, but faint, sources often require the rapid measurement and real-time analysis of small areas on a large number of plates. In the past, work of this kind has relied on the use of polaroid cameras or 'wet' photography for plate scanning or large and expensive measuring machines like COSMOS and the APM for photometric measurements. Real time video digitising allows one to display contrast enhanced images while plate scanning.

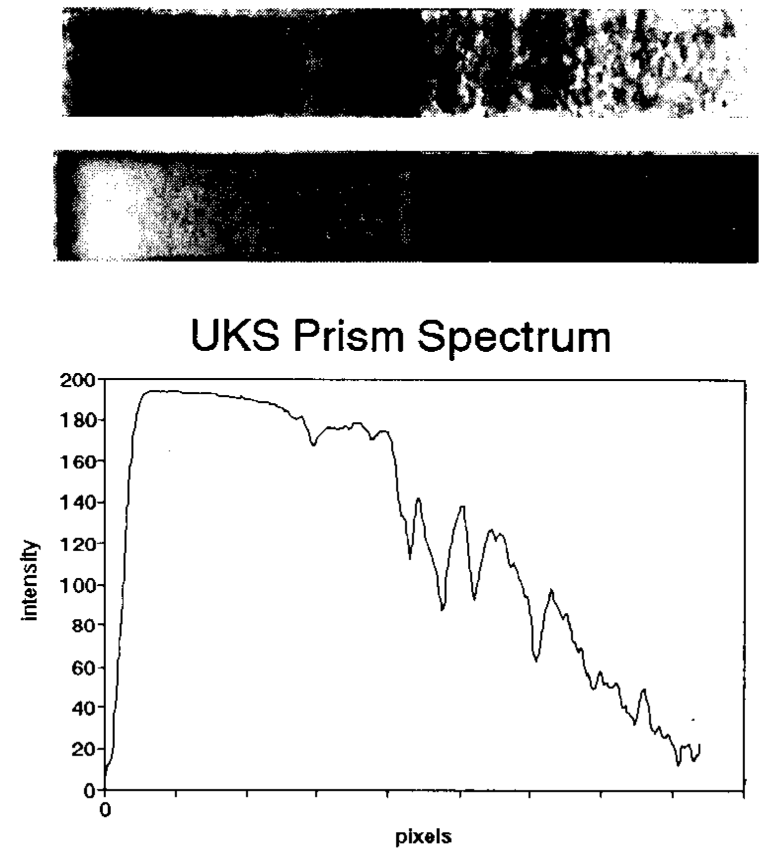

Figure 2. A video image of a stellar objective prism spectrum (top).
The enhanced and reversed image (middle).
A vertically averaged trace through the raw spectrum (bottom).

An example of this kind of search is provided by our programs on Herbig-Haro objects (Fig. 2). In this program we are imaging ESO/SERC J, R and I survey material and infrared K band images obtained with IRIS (the AAO's infrared camera) to identify the driving sources of the outflows. In parallel with this we are searching dark clouds for new Herbig-Haro objects.

3.2 OBJECTIVE PRISM SPECTROSCOPY

Other applications include the digitising UKS objective prism spectra. The ability to enhance spectra, allowing identification of faint features and to output digital spectra in a form suitable for use in spread sheets makes these systems powerful tools both in teaching and research.

3.3 ASTROMETRY AND PHOTOMETRY

The astrometric use of the system is limited by the 512 × 512 pixel field. While positions accurate to better than an arc second can be derived usefully for small 4 arc minute regions, the accuracy degrades as the field size increases.

JAVA supports the measurement of the area, the peak intensity and summed intensity above a designated threshold. The software also allows the user to calibrate the plate using the superimposed spot or wedge calibrations. Subsequent measurements are then directly in intensity units simplifying photometric measurements. This allows users to carry out both surface and integrated photometry of extended sources e.g. galaxies. The added ability to perform automated object counting, can allow low accuracy photometry to be carried out in small, < 4 arcminute, uncrowded fields. This kind of data is most suitable for the analysis of absorption in dark clouds using star counting techniques. Work undertaken by Honours students indicates that, while video digitisers are highly suitable for morphological studies, it is difficult to obtain photometric accuracies of better than 0.2^m using ESO/SERC plates.

4. Other Applications

As part of deliberate policy we have linked the digitising systems closely with our teaching. We have been able to introduce image processing topics into our Honours and Postgraduate programs. The video digitiser has supported hands-on image analysis assignments which form a major part of the Masters subject, 'The Physics of Imaging', introduced in 1991. This has now been included as a core subject in our Bachelor of Medical Physics.

In the push to make at least some of our research more closely related to industry we have evaluated applications in several areas outside astronomy. Such work has included trials of the systems for:

- automatic leaf area analysis;
- analysis of Forest Canopy Dieback (as part of a trial for ALCOA);
- analysis of Gas Explosions using video tape;
- analysis of CAT scans and other medical images.

It has become clear that while video digitising may be used from time to time in such work, expansion of the commercial aspects of this kind of program are not financially viable (though they are instructive).

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The ALADIN Project: Calibrations and Tools

1. Introduction

Automatic plate measuring machines make possible the objective quantification of photographic images of the sky, thereby permitting the extraction of the large amount of astronomical data represented by these images. The data is stored in the form of a catalogue consisting of a list of object positions, magnitudes and classifications (star or galaxy), and which, one hopes, represents the greater part of the useful data stored in the complete image. In essence one exchanges the storage medium of the photographic plate for an electronic list of objects. Unavoidably, such a list is defined by the criteria used to construct the catalogue and one cannot then re-extract a new catalogue based on different criteria, for example criteria based on other detection algorithms or on newer calibration data. To do so a user would be forced to request a rescan of his plates on one of the few and overworked machines.

With this in mind, in 1992 the Centre de Données astronomiques de Strasbourg (CDS) conceived the ALADIN project which aims to provide easy electronic access to digitized images of Schmidt plates. The CDS plans to stock images covering the entire sky by using the Space Telescope Science Institute's (STScI) *Digital Sky Survey* (DDS) (with pixel size = 1.8", or 25 micron sampling, and compressed by a factor of 10), and, in addition, to store images at full resolution (pixel size = 0.7", or 10.0 micron sampling, in an uncompressed format) of important regions such as the Galactic and Ecliptic Poles, the Galactic Plane, and the Magellanic Clouds. Access will be facilitated by a graphical interface (the *client*), resident on the user's local computer, which communicates via the computer network to a *server* at CDS, where the images will be stored in an optical disk juke-box. ALADIN will aid source cross-identifications, with its ability to overlay the positions of sources detected in other wavebands, and the preparation of observations, permitting the visualization of the selected sky region and access to relevant information. In this manner ALADIN will be an indispensable tool for data quality control of the Simbad database. A general description of the ALADIN project is given by Paillou et al. (1994). Presently there exists a prototype with access to 10 Schmidt plates and the ability to plot the Guide Star Catalog positions and overlay objects contained in the Simbad database or in a user-defined data file. The archiving system of 520 Gbytes has been installed and the development of image and catalogue servers is currently underway.

To take advantage of the full image data requires both astrometric and photometric calibrations for each plate and astronomical 'tools' for object extraction and image analysis. Here we present our approach to these calibrations and our design of the ALADIN client's astronomical toolbox. We have adopted a two-tiered approach in which the first level represents ready-made calibrations for immediate use, while the second will permit the *recalibration* of an image with up-to-date standards. In this latter case the user will have the choice of using either his own data or new catalogues of standards (such as Tycho/Hipparcos) stored at CDS.

2. Astrometry

An astrometric calibration is routinely supplied by the measuring machine, based in the case of the MAMA (Machine A Mésurer pour l'Astronomie) at CAI (Centre d'Analyse des Images) (Berger et al. 1991) on the PPM catalogue, and thus will represent the **level 1** calibration. For **level 2** ALADIN will provide the ability to choose a new set of astrometric standards and then to redetermine the plate constants. These new standards may either come from the user himself, or be taken from the CDS archives which will be continually updated with new, large catalogues of standards as they become available. Star positions will be defined as the centre of the best fitting two-dimensional gaussian, while galaxy positions will be given as the object's density weighted barycentre. ALADIN will also supply the actual plate coordinates as these are needed for high precision studies of relative proper motions (Bienaymé & Soubiran 1992).

3. Photometry

The photometry breaks down naturally into two categories: stellar photometry and surface photometry. For the stellar photometry, ALADIN will employ a relation between the angular size of a star and its magnitude. Humphreys et al. (1991) have shown that the form of this relation remains constant from plate to plate, at least for the POSS-I, demonstrating only variations in absolute normalization (zero point variations). For a stellar calibration, one thus requires only a few photometric standards per plate in order to find the zero point. For **level 1** ALADIN will supply this relation, normalized by the Guide Star Photometric Catalog (GSPC) of standards. According to Humphreys et al. this should yield an accuracy of ~ 0.2 magnitudes. However, as their photometric standards and those of the GSPC were chosen to lie near survey plate centres, this estimated accuracy only applies to these regions. The effects of variable plate sensitivity and vignetting will probably increase the photometric error to ~ 0.5 magnitudes over a whole plate. A **level 2** calibration/tool will permit the recalibration of the relation with new standards. This is particularly important for a user who requires a high photometric accuracy, but who is not working near a plate centre. In this case, his calibration will maximise the photometric accuracy in the region of interest.

Surface photometry proves more difficult. In this case one needs the calibrated relation between plate optical density and actual intensity. Once again, the form of the relation appears to be universal (Liu et al. 1992), but the *surface brightness* standards necessary to normalize the relation do not exist for every Schmidt plate. Generally, one uses calibration spots or wedges, when they exist, and in some cases one may have access to CCD images of galaxies. However, to systematically calibrate ALADIN's surface photometry tool, we will attempt to 'create' our own standards by using the GSPC stars and the known PSF of the relevant optical system. This will form the basis of the **level 1** calibration, which should have close to the same accuracy as the stellar calibration, i.e. ~ 0.5 magnitudes over a plate. The **level 2** will once again permit the user to use his own surface brightness standards (CCD frames) to recalibrate the relation. For this, ALADIN will provide a tool to match-up the CCD pixels with those of the plate.

4. Object Detection and Classification

The advantage of ALADIN over a preselected catalogue of objects is the capability to redefine the selection criteria and re-extract a new catalogue from the original image. To this end, the client will provide some detection and classification (star/galaxy separation) routines. The first version of the ALADIN client will be equipped with a standard detection routine which searches for N connected pixels each with an optical density above $t\sigma_{sky}$. At **level 1** the number of pixels N and the threshold t will be preset, while at **level 2** these parameters will be adjustable. We are currently studying the performance of more sophisticated detection routines, drawing on expertise from the field of image analysis, and which in the future we hope to integrate into the ALADIN client.

There are two general approaches to separate stars from galaxies: parametric and non-parametric algorithms. A parametric algorithm describes each object by a set of shape parameters, such as the areas above a set of density thresholds, and then defines a galaxy as an object for which these parameters are sufficiently different from those of a stellar image, whose shape is solely a function of the PSF. This is usually accomplished by defining a 'distance' ψ from the stellar locus in the parameter space. The completeness and stellar contamination level of the resulting galaxy catalogue is then determined by choosing a 'cut' ψ_c. This is the approach we will initially adopt for ALADIN, where **level 1** will have a preset ψ_c and **level 2** will leave this to the choice of the user. For their eventual inclusion into ALADIN, we will evaluate other classification schemes, for example the aforementioned non-parametric approaches which compare each object to a set of image templates created with a library of identified sources (Weir & Picard 1992). Another possibility is to use neural networks to decide the nature of an object, either based on a set of image parameters (Odewahn et al. 1992) or on the entirety of the object's pixels. Here again we are also studying a variety of techniques coming from fields not traditionally aligned with astronomy.

The final product of this tool will be a list of classified objects together with their positions and magnitudes. The catalogue may be extracted over a full plate or plate subregion. This will permit ALADIN to fulfil its rôle as a new form of 'adaptive' astronomical catalogue.

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Large-Scale Schmidt Plate Errors and Guide Star Catalog Analysis

1. Introduction

Although it is well known that large-scale Schmidt telescopes are not suitable for wide-field coordinate determination, they are used sometimes for such kind of work.

An example is the Hubble Space Telescope Guide Star Catalog (GSC). Its authors (Lasker et al. 1990) do not pretend to consider it as a true reference catalogue and this list of star coordinates was designed only to support the operational requirement of the Hubble Space Telescope for off-axis guide stars.

Astrometrical properties of the GSC were investigated by its authors (Russel et al. 1990) and by other astronomers (Taff et al. 1990) and all of them conclude that systematic errors of GSC positions are rather large. Nevertheless, nobody proposes any algorithm or correction tables which could improve GSC in the astrometrical sense.

2. GSC versus PPM

Besides such properties, the deepness of GSC and the absence of good reference catalogues needed for the reduction of faint object observations made with narrow field telescopes or CCD receptors make GSC very attractive for this kind of work.

Trying to investigate the GSC properties we have found that, due to the perfect GSC CD-ROM data organisation, it is possible to fulfil the plate analysis of the GSC systematic errors by the comparison of GSC with other independent catalogues.

Our aim is to use these estimations afterwards to correct GSC star coordinates in faint objects observation reduction procedure. As an external standard we use the PPM catalogue (Bastian et al. 1991, 1992) which contains about 400,000 stars over the whole sky with high-quality positions and proper motions in the FK5 system. The mean PPM precision is about 0.2" for positions and 0.003"/year for proper motions. Thus, results of GSC and PPM comparison for the GSC observation epochs can be considered as the GSC systematic errors estimation.

2. GSC Plate-based Errors Analysis

Schmidt plate errors relative to a plate-based coordinate system are so large and complex that usual single plate reduction procedures cannot eliminate them.

The PPM catalogue is a good base for investigation of such kind of errors because it gives about 300 – 400 stars in 7 - 11 magnitude range for every GSC plate. Taking all GSC plates from pole to pole, considering 400 cells 19.2 per 19.2 arcmin and averaging (GSC - PPM) star coordinate differences in every cell, we obtained the results shown in Fig. 1 and Fig. 2.

Figure 1 represents the Palomar Schmidt plate errors (northern hemisphere) and Fig. 2 the UK Siding Spring Schmidt plate errors (southern hemisphere). Both figures show approximate results but they look very regular due to the large quantity of stars included in the investigation. Each error vector is the mean of about 500 stars for the northern sky and about 600 stars for the southern one. The vector scale (1") is shown in the lower right corner of the figures.

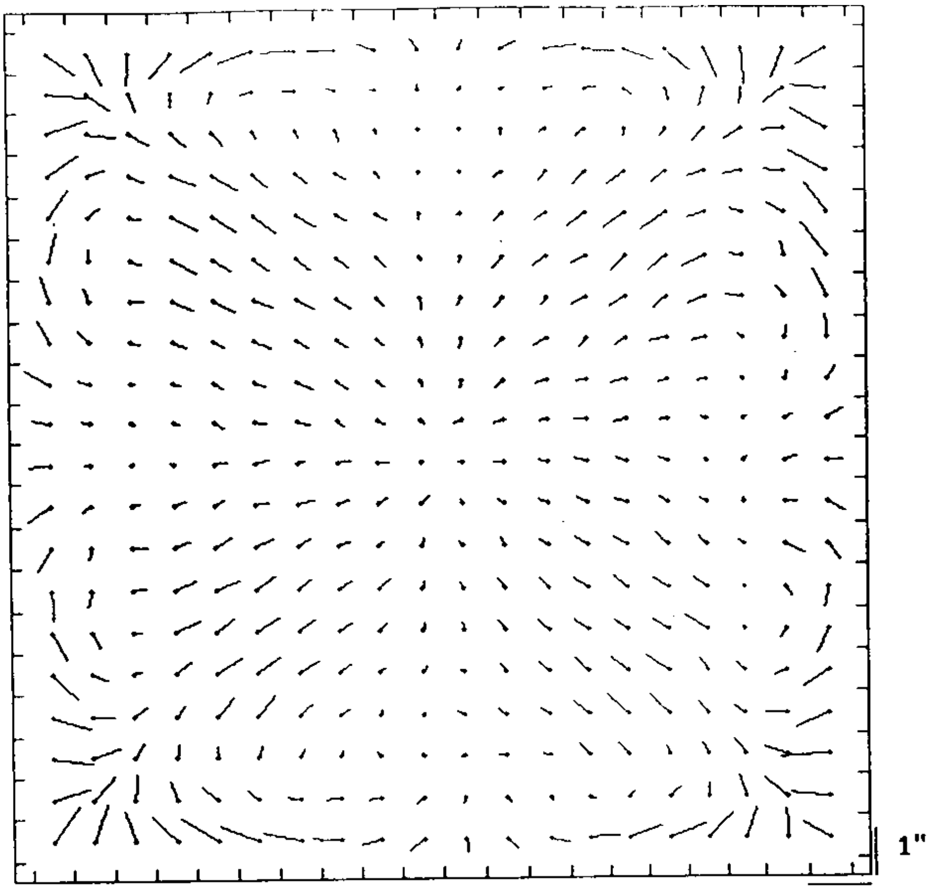

Figure 1. (GSC - PPM) differences vs. star position on GSC plates before correction. Northern hemisphere.

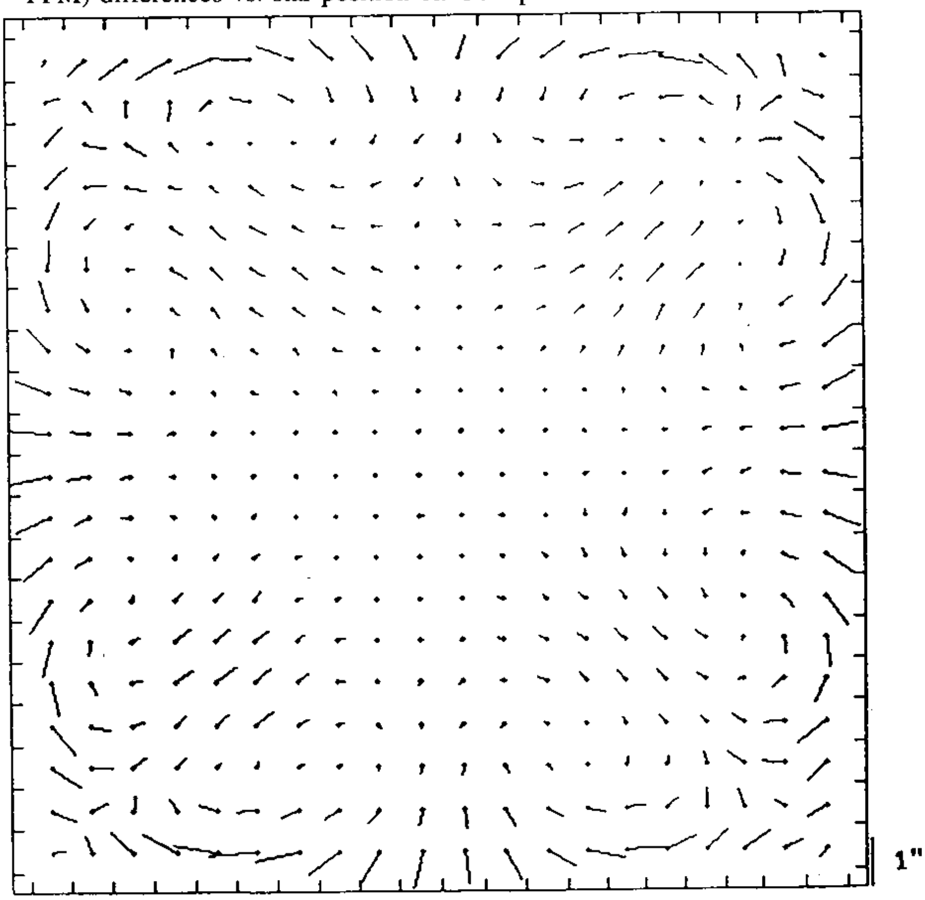

Figure 2. (GSC - PPM) differences vs. star position on GSC plates before correction. Southern hemisphere.

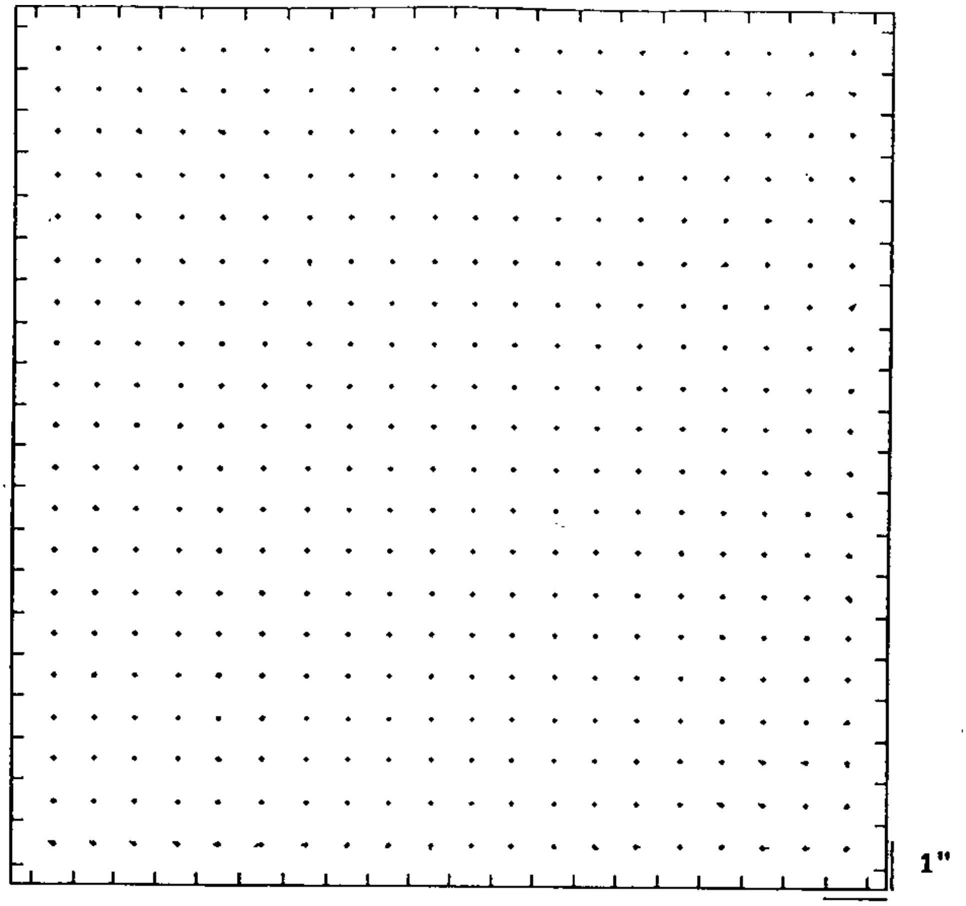

Figure 3. (GSC - PPM) differences vs. star position on GSC plates after correction. Northern hemisphere.

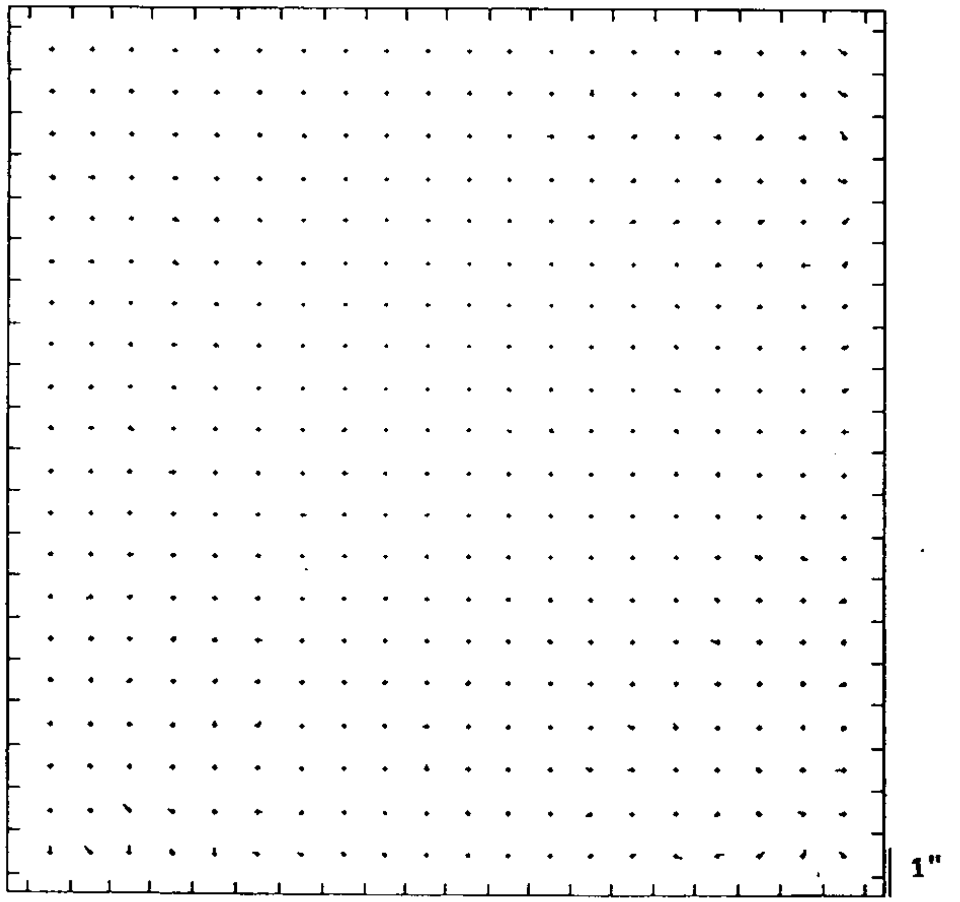

Figure 4. (GSC - PPM) differences vs. star position on GSC plates after correction. Southern hemisphere.

It can be said that:

- both figures are very similar to one another, i.e. they reflect mainly properties of Schmidt telescope optics;
- both figures show significant plate errors not only near the plate edges, but also at the central parts, i.e. GSC is worse than it is thought to be;
- both figures show that plate errors are very regular and symmetric, i.e. they can be easily and reliably corrected and GSC can be significantly improved.

Figure 3 and Fig. 4 show similar representations after applying mean corrections to each cell. Systematic plate differences are now practically absent.

3. Concluding Remarks

We present our examination of the Hubble Space Telescope Guide Star Catalog. We have found that this catalogue is distorted by two kinds of systematic errors. Some of them are plate-based errors produced by Schmidt telescope optics and by the pure reduction model. The other ones are sky-based errors produced by reference catalogues.

We have developed a subroutine (in BASIC and FORTRAN for PC) that, connected with GSC CD-ROM, gives out GSC star positions corrected for both kinds of systematic errors. Stars for any magnitude range and any sky field, limited by two right ascension and declination circles, can be obtained.

We hope that our work will be useful for those who need better reference stars in dense fields, at least till the appearance of the Hipparcos catalog or of a new reduction of the Guide Star Catalog.

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The Sub-Plate Method and Wide-Field Astrograph Plates

With the invention of the sub-plate technique (Taff 1989), the problem of reducing Schmidt plates in an astrometric fashion has been successfully solved. As one result of this success, NASA has provided funds to us to make the sub-plate code portable and therefore available to all. Given this enlarged future usage of the strategy, we have looked for additional problems for it. An obvious likely application is to *wide-field* plates taken with an astrograph. We have analyzed a set of 64 wide-field astrograph plates, each covering 11° × 11°, both by the sub-plate algorithm and the traditional approach. These 64 plates comprise the 'South Polar Cap' region of the Yale catalogs (Hoffleit 1971). The plate material is described in Lü (1971). Herein we merely note that the original reduction was with a ten constant plate model in each coordinate. The tenth term is a color index/coordinate term. Finally, these plates were measured by hand and have rather large measurement errors. The estimated standard deviation about the mean of the x and y values is 0″.4 after conversion from microns via the plate scale.

Both the original reduction of this material (Lü 1971) and our own preliminary analysis — using spectral type as a substitute for color index (Lang 1992) — led us to believe that the presence of the color index term was superfluous. Thus, the global plate model we used between x, y and ξ, η was:

$$
\begin{aligned}
x &= a + b\xi + c\eta + d\xi^2 + e\xi\eta + f\eta^2 + g(m - m_0) + h\xi(m - m_0) + i\eta(m - m_0) \\
y &= A + B\xi + C\eta + D\xi^2 + E\xi\eta + F\eta^2 + G(m - m_0) + H\xi(m - m_0) + I\eta(m - m_0)
\end{aligned} \qquad (1)
$$

where m is the apparent magnitude of a star and m_0 is the average apparent magnitude of all the stars on this plate.

Using the Astrographic Catalogue Reference Stars (ACRS) work of Corbin & Urban (1988) as a reference catalog (all our work was repeated using the Positions and Proper Motions catalog of Roeser & Bastian [1989] as a substitute), we re-reduced an entire plate. No use was made of the 50% geometrical overlapping of the plates.

One difficulty not encountered in our earlier Schmidt plate work was the off-centering and rotation of some of these plates. Without investing the time and effort to first solve for the necessary translation and rotation parameters, some plates could not always be fully covered with our basic sub-plate pattern of 8 × 8 (or 15 stars per sub-plate). Hence, they suffer from either a lack of full areal coverage or of larger than desired sub-plates owing to this artificial difficulty. When this is the case and the results from the sub-plate technique are locally poor, we attribute the inferior results to this geometry problem and have deleted the plate from further consideration in the error statistics below. This occurred, repeatedly, for the same three plates. There were also a few, 3, bad stars in the files for they were rejected by both techniques (and both the PPM and ACRS models). The five plates they were on were also eliminated from further consideration.

As has been shown to be beneficial in our sub-plate work, we always use an external, objective standard of comparison to evaluate our results. Internal, mathematically generated measures of goodness-of-fit are all too often worthless or worse, misleading. Given the far southerly declination of this plate material and our desire to have a dense coverage of the field-of-view, we have chosen the International Reference Star catalog (Corbin 1991) as the comparison catalog. Just to be clear, since we used the International Reference Star catalog as our test criteria, those IRS stars in either the ACRS and PPM were deleted from our versions of the latter star catalogs before any plate solutions — whether traditional or sub-plate — were performed. On the average, there were 846 ± 123 ACRS stars per plate after 72 ± 10 IRS stars have been deleted (the corresponding PPM numbers were

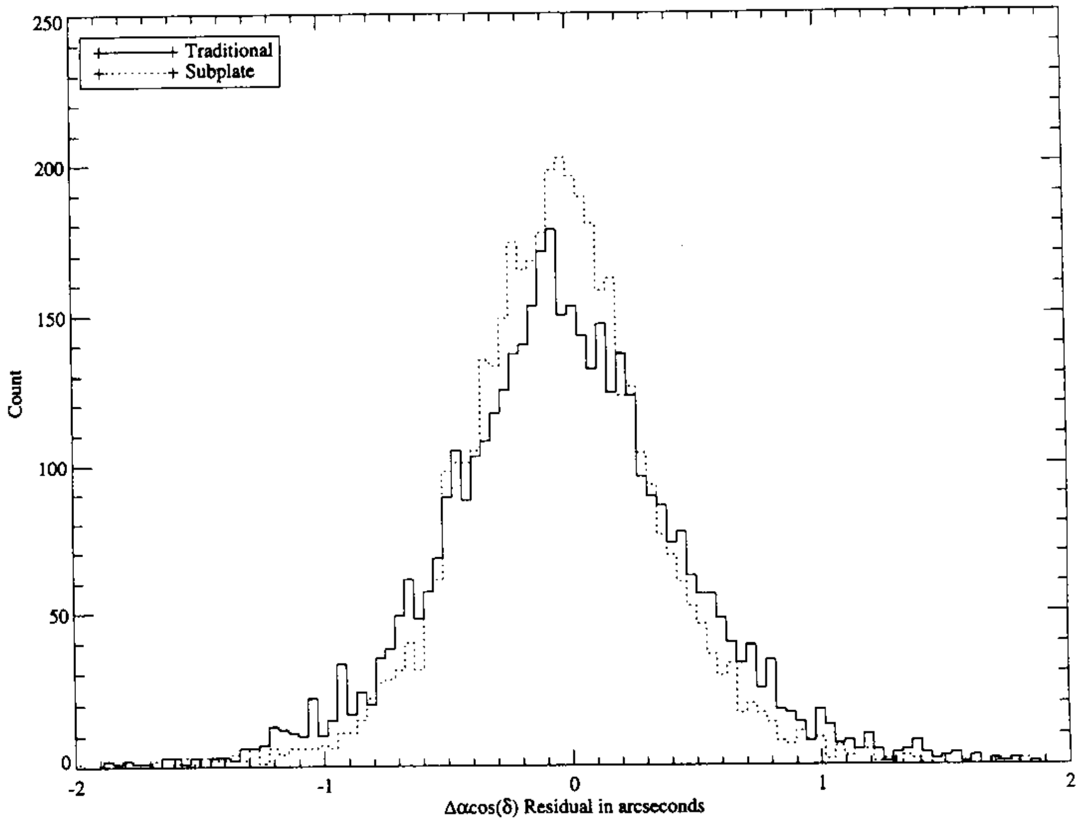

Figure 1a. Distribution of the residuals in right ascension on a great circle for the sub-plate and traditional solutions (based on the ACRS catalog) and the IRS values. The dashed curve is for the sub-plate algorithm and is noticeably more centrally peaked and narrower than for the customary method.

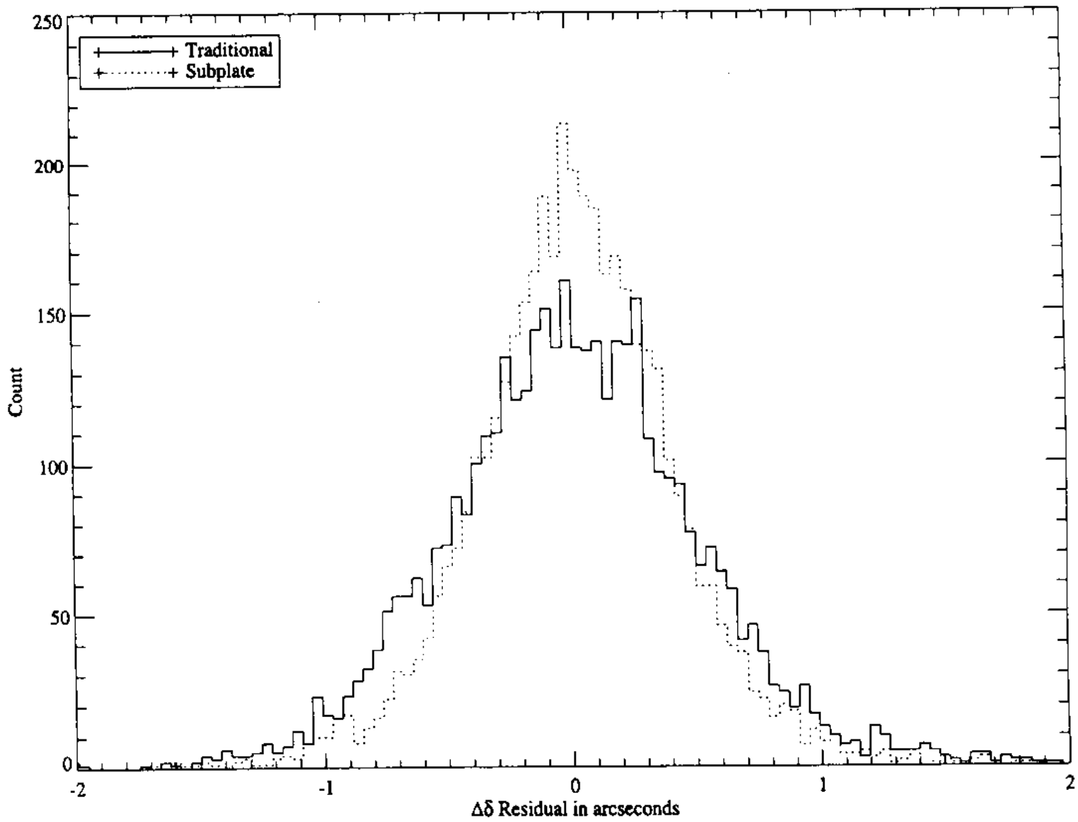

Figure 1b. Same as Fig. 1a but for the declination residuals. The reduction in width is 22% in both cases.

1011 ± 129). This translates into 13.2 (15.8) reference stars per sub-plate in our nominal 8 × 8 basic pattern.

The standard deviation in the equatorial coordinate differences between the sub-plate position for an IRS star and the catalog value was 0.″403 and 0.″419. These values compare favorably to the estimated measuring standard deviation of 0.″4. Thus, the primary contribution to the final positional errors is measurement error. For the traditional method the corresponding values were 0.″490 and 0.″510, 22% higher than for the sub-plate results. (The comparable values for the PPM re-reduction were 0.″495 and 0.″510). The distributions of the equatorial coordinate residuals are shown in Figs. 1a and 1b. Clearly the sub-plate approach is superior, on these *wide-field* astrograph plates, to the traditional, global plate model algorithm employed herein. More of the plates reduced the sub-plate technique have mean errors closer to zero than not and the wings of the sub-plate distribution in Figs. 1a and 1b are narrower than the wings of the traditional method's distribution. The effect is a consistent 22%, in both equatorial coordinates, as measured by the standard deviations about the mean of their distributions.

Acknowledgements

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Near Infrared High Resolution Imaging Camera System

1. The 2.16m Telescope

The largest telescope made in China was installed at Xinglong station of Beijing Observatory. The clear aperture of the primary mirror is 2.16m and its f-ratio 3 (f/3). There are three foci in this telescope; Cassegrain (f/9), coudé (f/45) and prime focus.

2. Adaptive Optics System

An Adaptive Optics System will be mounted at the coudé focus on an optical table. It will be serviced to remove the effect of atmospheric turbulence on the imaging observations and to improve the spatial resolution. A 21-elements adaptive optics system would be used to equip the 2.16m telescope for near infrared observations. The optical layout is as shown in Fig. 1.

M0 is a mirror, which reflects the light from the telescope to the A0 system. M1 is a spherical mirror as collimator. The light beam size will be fitted to the size of a wavefront corrector. The wavefront corrector consists of two tip tilt mirrors and a 21-elements deformable mirror (DM) driven by piezocrystals. The first tip tilt mirror (TM1) is used to correct the low frequency (2.5Hz) and large amplitude Image movement caused by atmospheric turbulence and the tracking error from the telescope. The control signal of TM1 is from an image Tube+CCD system (I-CCD) and a position error detective system. The second tip tilt mirror (TM2) is used to correct the high frequency (2.5–10Hz) and small amplitude image movement. The deformable mirror (DM) is used to correct the high-order aberration caused by the atmosphere.

The TM2 and DM are driven by a control signal from a wavefront detector and processor. A dichroic mirror S2 splits the light into two beams, one optical and the other infrared. The optical

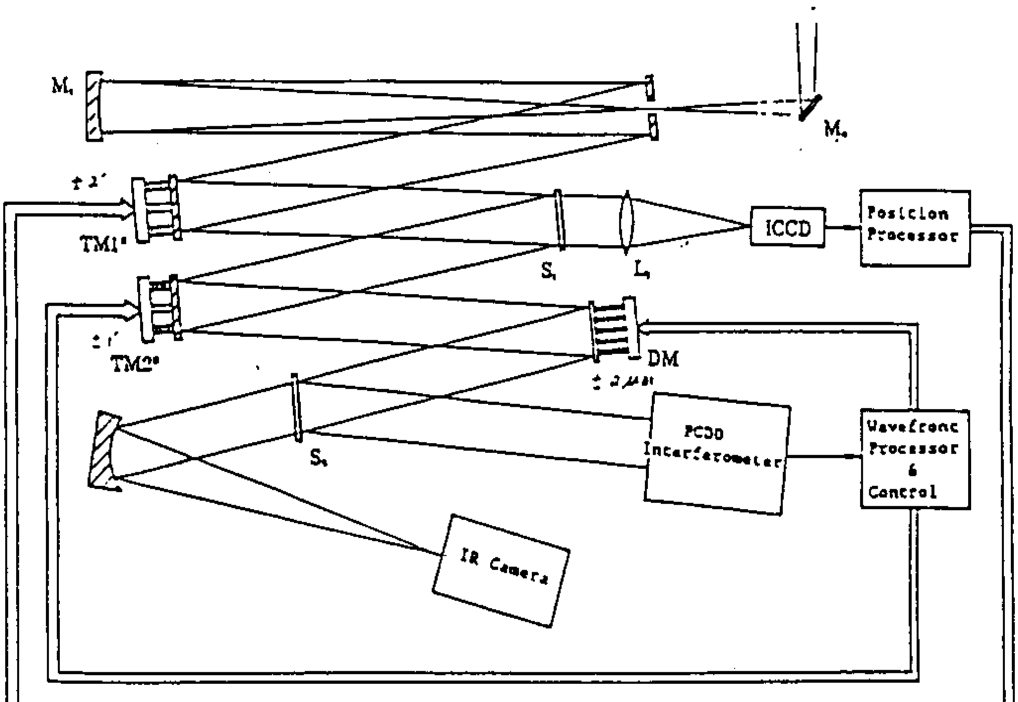

Figure 1. Optical layout of the Adaptive Optics System.

beam is used for wavefront detection. In the system the wavefront detector is a photon counting dynamic differential interferometer. It can measure the wavefront tilt at each element in the direction of X and Y. The wavefront processor gives a control signal to drive the TM2 in two directions and drives a piezocrystal element in the DM.

The total deformable elements are 21. In the X and Y directions there are 32 sub-apertures to detect the wavefront deform. The size of each sub-aperture is about 40 cm. It is fitted with the size of r0 at 2 μm.

The A0 system works as a loop-locked control system. It could correct the deformation of the wavefront due to atmospheric turbulence and prove the spatial resolution of astronomical near infrared imaging observations. It is hoped to reach the diffraction limitation i.e. for the 2.16m telescope this is about 0.3 arcsec.

3. The PtSi Infrared Camera

The 512 x 512 PtSi IR CSD (Charge Sweep Device) which was developed by the Mitsubishi Electric Company of Japan has been selected for the detector of the camera system. The PtSi Schottky-Barrier diode array does not have high quantum efficiency but has an excellent uniformity and stability, a large format size and a low read-out noise. In this case the PtSi image sensor is more effective than a high quantum efficiency detector with small format.

This camera system is shown in Fig. 2. The total system contains: Camera Dewa (Flank Low HDL-8), the PtSi IR CDS is cooled by a solid nitrogen down to 52K; Preamplifier and A/D Converter (ADC 4322, 16 bits, 2MHz); Clock Pattern Generator (CPG); Frame Memory; Host Computer (Sun workstation).

The wavelength range is 1 - 2.5 μm with both wide band filters (J.H.K) and narrow band filters. The Optical Focus Reducer for the Cassegrain focus is f/3 (0.6"/pixel); 5.0′ x 6.0′) and f/6 (0.3"/pixel; 2.5′ x 3.0′) without adaptive optics system.

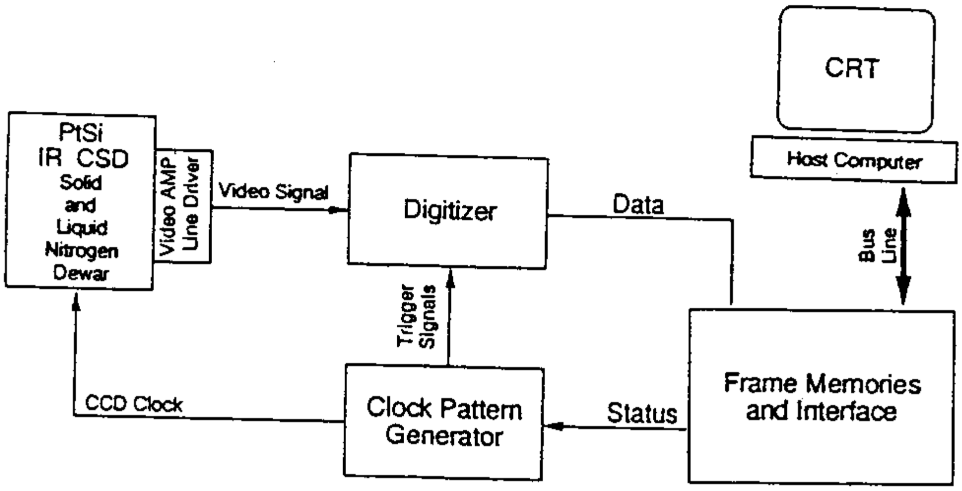

Figure 2. The block diagram of the PtSi IR camera system.

Acknowledgements

This program is in collaboration with the National Astronomical Observatory of Japan, Beijing Astronomical Observatory and the Institute of Optics and Electronics of Chengdu, China. The Max Planck Institut für Astronomie of Germany has given us much help towards this collaboration. This system is going well now. We hope it will be completed in Autumn of this year.

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A CCD Camera (ST-6) at Rozhen Observatory: the BVRI System

Abstract. The use of the BVRI system with Shott filters at Rozhen (1750 m above sea level) is described. The mean colour equations are given. The instrumental system occurs close to the standard and only the R system is slightly deviated to shorter wavelengths. The mean extinction coefficients in BVRI are 0.38, 0.26, 0.18 and 0.12 respectively (based on data taken in the Summer of 1993).

Beginning in the Summer of 1993, a SBIG Model ST-6 camera became operational at the RC focus of the 2m telescope of the Rozhen Observatory. This camera was kindly made possible by EAS/ESO support of astronomy in the Central/Eastern European countries.

The dimensions of the CCD camera ST-6 array are 242 x 375 pixels, the scale is 0.30 x 0.34 arcseconds per pixel and the image size is about 1.5 x 2.0 arcminutes. The working temperature of the camera is -40 degrees and the typical exposures are 10 - 20 minutes. More detailed information of the camera is given in the paper by Pravec (1993). The camera ST-6 at Rozhen represents a simple and stable astronomical instrument, useful only for large fields.

A BVRI photometric system with ST-6 was made possible with Shott filters, using the recommendations of Bessel (1990), as follows:

B: 1GG13+1BG12+1BG39;
V: 2GG495+1BG39;
R: 2OG570+2KG3;
I: 3RG9.

In the period July - September 1993 we observed standard stars of Landolt (1983) and Christian et al. (1985). The observations of 24 stars from 10 good nights were used to derive the mean colour equations and the atmosphere extinction coefficients for the Rozhen Observatory (1750m above sea level). The connection between the standard BVRI system, the instrumental bvri system and the air mass X = 1/cosZ, where Z is the angular zenith distance, were obtained in the range B - V = -0.2 - 1.6 and X = 1.1 - 1.5:-

$$V - v = -0.001(b-v) - 0.259X + const$$
$$V - v = -0.025(v-r) - 0.259X + const$$
$$V - v = -0.007(v-i) - 0.260X + const$$
$$B - b = 0.027(b-v) - 0.386X + const$$
$$R - r = -0.133(v-r) - 0.173X + const$$
$$I - i = -0.060(v-i) - 0.125X + const$$
$$B - V = 1.027(b-v) - 0.128X - 0.590$$
$$V - R = 1.108(v-r) - 0.086X + 0.289$$
$$R - I = 0.951(r-i) - 0.072X + 0.801$$
$$V - I = 1.053(v-i) - 0.135X + 1.094$$

The mean square deviations of these regression coefficients are 0.04 - 0.05 mag, the maximum deviations are 0.1 mag and the estimated errors of the coefficients are about 5%. Our instrumental system occurs close to the standard one. Only the R system is slightly deviated to the short light waves.

The mean extinction coefficients, obtained from the inverse colour equations, are as follows: in B - 0.38, in V - 0.26, in R - 0.18 and in I - 0.12.

Acknowledgements

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Can we search for WR Stars with ST-6?

Abstract. He II 468nm and continuum 576nm narrow band photometry of three OB associations in the M33 galaxy are presented. Known WR stars are well separated from the other members of the associations in the colour-magnitude diagram. Based on that, a new WR candidate is suggested.

1. Introduction

During October 1993 our group has performed a study of some parameters of OB association in nearby galaxies using intermediate-band photometry. We obtain CCD images of three OB associations in M33 containing WR stars using the SBIG Model ST-6 Imaging Camera. This camera was kindly granted to the Bulgarian astronomers in the framework of the EAS/EFC support of astronomy in the Central/Eastern Europe countries.

The WR stars which are easily detectable at great distances allow us to study the processes of massive star formation in nearby galaxies (Massey & Armandroff 1991). To make correct conclusions it is necessary to know the completeness of the sample which we work with. It is accepted that almost all stars in 2.5 kpc vicinity of the Sun and in the Magellanic Clouds are known (Testor & Schild 1993). But it is not the case for the other nearby galaxies. According to photographic observations of M33 about one hundred WR stars are found (Massey et al. 1987). However CCD observations show that this sample is far from being complete (Armandroff & Massey 1985). This kind of observation is quite time consuming which makes such observations inefficient for work on large telescopes. The aim of this paper is to study the possibilities of searching for WR stars in M33 with intermediate-band filters established with ST-6 on the 2m Ritchey-Chrétien-Coude (2m RCC) reflector of the Bulgarian National Astronomical Observatory (BNAO) at Rozhen, Rodopa mountains.

2. Observations and Data Reduction

The observations were performed on the 2m RCC of BNAO on 17th and 18th October 1993 with ST-6 and two interference filters centred on He II 468.6nm (FWHM = 18.7nm) and continuum at 575nm (FWHM = 22.4nm). The observations include OB 127, OB 17 and OB 59 (Humphreys & Sandage 1980). After each image was taken the corrections were performed for CCD bias, dark current and flat-field effects. For each object all the images obtained in each filter were co-added before analysis. The image processing was performed using the ESO-MIDAS software package. The final resolution of the summed images obtained by PSF fitting procedure of DAOPHOT was 2 arcsec.

3. Results and Discussion

The mag468/(mag468-mag575) diagram for OB 127 and OB 17 is shown in Fig. 1. There is clear separation between the two known WR stars (WR8 and WR9, Massey et al. 1987) and the rest of the association members on the diagram. The stars WR8 and WR9 are marked with filled circles. The asterisk in Fig. 1 refers to the star marked in Figs. 2a and 2b. From this diagram it can be seen that (with the filters used) the segregation of the WR stars in the sample of blue objects is possible. However, the observations in only two filters do not give a full solution of the problem of the precise spectral classes and do not segregate WR stars from the other He II 4686 emission objects. On the

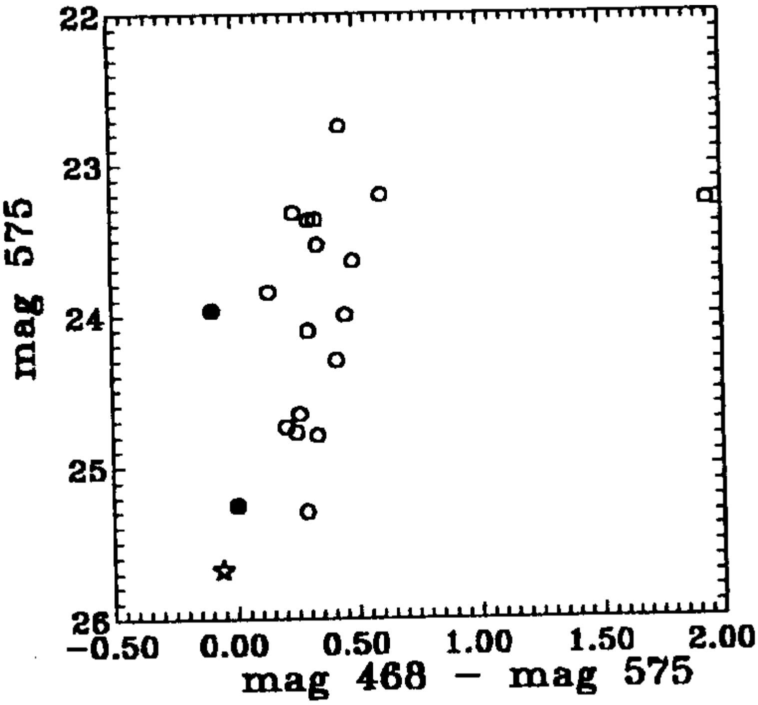

Figure 1. The diagram mag468/(mag468-mag575) for OB 127 and OB 17. The two known WR stars are marked with filled circles and the new WR candidate with an asterisk.

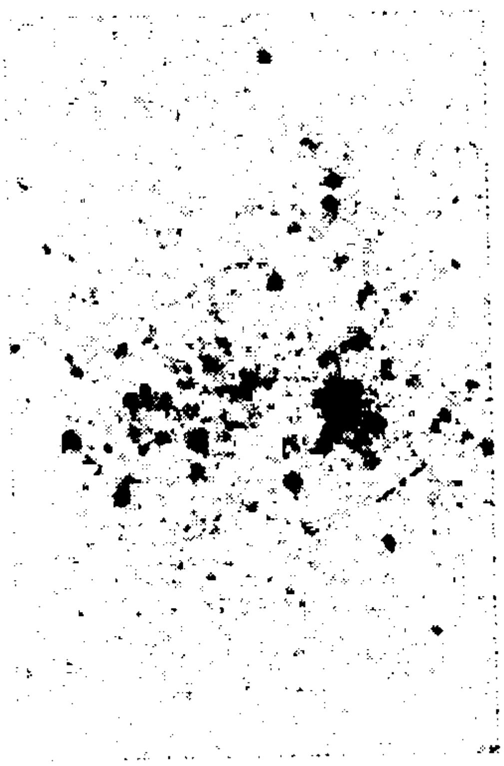

Figure 2a. The image in filter 468.6nm. North is up, east is left.

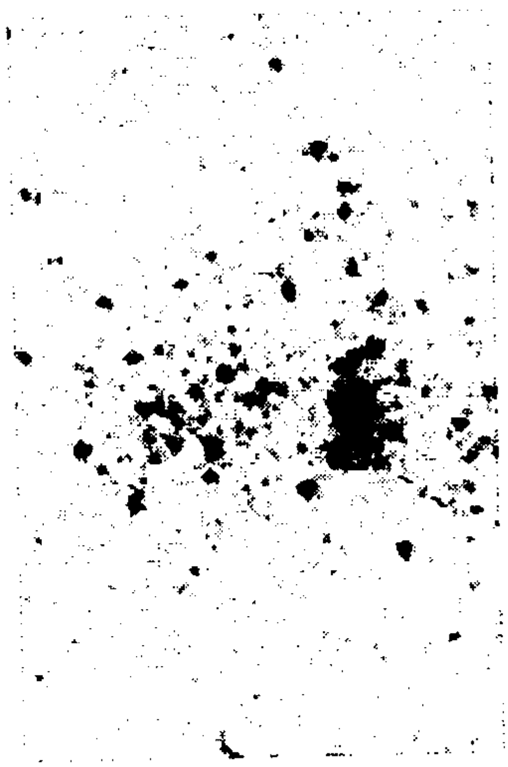

Figure 2b. The image in filter 575 nm.

the other hand the use of more and narrower filters does not give a unique solution either. Such observations always need spectral confirmation.

In Figs. 2a, b the images obtained for OB 127 are shown. In Fig. 1 the object marked comes in to the 'WR stars area'. This star is not reported by Massey et al. (1987) as a possible WR star. In the Humphreys & Sandage (1980) study there are no estimates of the B and V magnitudes either. On the 6 UBV plates obtained on the 2m RCC at BNAO (Kunchev & Nikolov, 1986), we have made eye estimations giving V = 20.3 mag, B = 19.8 mag and U-B = 0. On all plates the stellar morphology of the object can be clearly seen.

We consider that this star is a possible WR candidate, but spectral confirmation is needed.

Acknowledgements

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Galactic Structure Surveys and the Kinematic Properties of the Galaxy's Stellar Populations

1. Introduction

We describe a sample survey programme in stellar photometry and astrometry (Robin et al. 1993), with an aim to study the galactic structure and stellar evolution. In the framework of the current programme, new UBV and absolute proper motion surveys were carried out in three selected areas of the Galaxy. We have analyzed the large stellar samples, with reliable absolute proper motions and without biases of selection in kinematics or metallicity. The algorithm SEM (Stochastic-Estimation-Maximization; Celeux & Diebolt 1986) was used for the deconvolution of the stellar populations up to large distances above the plane, allowing us to study their statistical properties independently. New estimates of the kinematical parameters of the thin and thick disks have been deduced.

2. Sample Survey

The combination of the OCA, ESO, Tautenburg and Palomar Schmidt plates was used to derive the multicolour absolute proper motion for the following three fields at intermediate latitude:

- field in the direction of galactic anticentre (l = 167°, b = 47° [Ojha et al. 1994a]);
- field in the direction of galactic centre (l = 3°, b = 47° [Ojha et al. 1994b]);
- field in the direction of galactic antirotation (l = 278°, b = 47° [Bienaymé et al. 1994]).

All the Schmidt plates were measured with the MAMA machine at the Observatoire de Paris.

3. Results

The combinations of the new data sets with different statistical methods have given until now a number of results concerning the galactic structure and stellar evolution:

i) From the number ratio of the thin and thick disks stars in a pair of directions towards galactic centre and anticentre, we deduced the scale length h_R of the thin disk and thick disk, which is found to be 2.6 ± 0.1 and 3.6 ± 0.5 kpc, respectively (Ojha et al. 1994a, c).
ii) The thin disk population is found with (<U + W>, <V>) = (1 ± 4, -14 ± 2) km sec^{-1} and velocity dispersions (σ_{U+W}, σ_V) = 35 ± 2, 30 ± 1) km sec^{-1} (Ojha et al. 1994a, b).
iii) The thick disk population is found to have a rotational velocity of V_{rot} = 177 km sec^{-1} and velocity dispersions (σ_U, σ_V, σ_W) = (67, 51, 42) km sec^{-1} (Ojha et al. 1994a, b; Bienaymé et al. 1994). Our data are consistent with no dependence of the thick disk's asymmetric drift with distance (up to z ~ 3 kpc) above the galactic plane (Ojha et al. 1994b).
iv) The density laws for stars with $3.5 \leq M_V \leq 6$ as a function of distance above the plane, follow a single exponential with scale height of ~ 260 pc for $150 \leq z \leq 1200$ pc, and a second exponential with scale height of ~ 770 pc for z distances from ~ 1200 pc to at least 3000 pc. We identify the 260 pc scale height component as a thin disk, and the 770 pc scale height component as a thick disk (Ojha et al. 1994c).

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A Survey for Low Surface Brightness Galaxies in Virgo using Tech Pan Films

1. Introduction

Searches for faint, low surface brightness galaxies (LSBGs) have in the past been limited either by detector area or detector efficiency. Conventional UKST plates cover large areas but have inherent signal-to-noise (S/N) limitations, while CCDs reach deep limits but sample much smaller areas of the sky in a given amount of time. A new, very promising way to overcome the S/N limitations of Schmidt plates while retaining the same area coverage is the use of Kodak Tech Pan 4415 film as a replacement for conventional IIIa plates.

The fine grain, high quantum efficiency and improved sensitivity of Tech Pan compared to traditional IIIa emulsions mean that fainter limiting isophotes can be attained in 75 minute sky limited exposures. A detailed photometric study of 5 known Virgo Cluster galaxies from COSMOS scans of Tech Pan films (Phillipps & Parker 1993) has shown that typical pixel-to-pixel variations on 1" scales are as low as 0.7%, i.e. a factor 3 improvement in uniformity over the corresponding IIIa-F emulsion. This very low sky noise means that we can perform surface photometry to a limiting isophote of 27.0 $R\mu$, equivalent to only 0.25% of the sky brightness. Tech Pan film therefore offers a gain of about 1.5 magnitudes over IIIa-F plates in this respect.

We are now benefiting from the substantial advantages of 4415 film in undertaking a survey of LSBGs in the Virgo cluster. Besides reaching fainter surface brightnesses than previous LSBG surveys (e.g. Binggeli et al. 1985; Davies et al. 1988; Impey et al. 1988), our higher S/N per pixel will allow the inclusion of objects with considerably smaller angular diameters, thus contributing a significant new population of LSBGs to that currently known.

2. The Virgo Film Survey

Nearby clusters such as Virgo offer the ideal environment in which to search for LSBGs. It is now known that LSBGs dominate cluster numbers (Turner et al. 1993, and references therein), and can therefore represent a significant fraction of a cluster's total baryon content. Furthermore, preliminary results from a CCD field survey (Schwartzenberg & Phillipps 1994) show that very few apparently large LSBGs are present in random field areas, and thus a cluster environment must be sampled if we are to find large numbers of LSBGs.

Our overall LSBG survey will be based on COSMOS digital scans of eight independent Tech Pan exposures ($\approx$ 75 minutes each) of a $5^\circ \times 5^\circ$ area of the Virgo Cluster. A preliminary 'eyeball' search in a 0.5 square degree subset of this field, using just one film, has revealed previously uncatalogued LSBGs with central surface brightnesses $\mu_o(R) \approx 23.5 - 24.0$ and scale lengths 4 - 5 arcseconds (Schwartzenberg, Phillipps & Parker 1994a, b). We have also identified, with remarkable ease, some of the faintest LSBGs included in the study of Impey et al. (1988) who used photographic contrast enhancement techniques.

The search over the whole 25 square degree area will use co-added (or more precisely, median stacked) data from the set of available films and will be carried out in an automated fashion, using connected pixel detection algorithms which should enable the detection of LSBGs down to very small scale lengths, $\alpha \approx 3''$, corresponding to about 250 pc at Virgo (assuming $d_{Virgo} \approx 18.5$ Mpc). This linear scale length is comparable to that of the dwarf spheroidals in the Local Group (Caldwell et al. 1992). We will therefore be sampling not only to fainter limits when compared to previous Virgo surveys (Binggeli et al. 1985; Impey et al. 1988), but also to smaller angular sizes, thus allowing for the inclusion of the more numerous, physically smaller LSBGs (Irwin et al. 1990).

3. Conclusions and Future Prospects

Our discovery of new LSBGs in the Virgo cluster has highlighted the potential of Tech Pan films for the detection and photometry of faint galaxies. Further gains are obtained from the combined use of

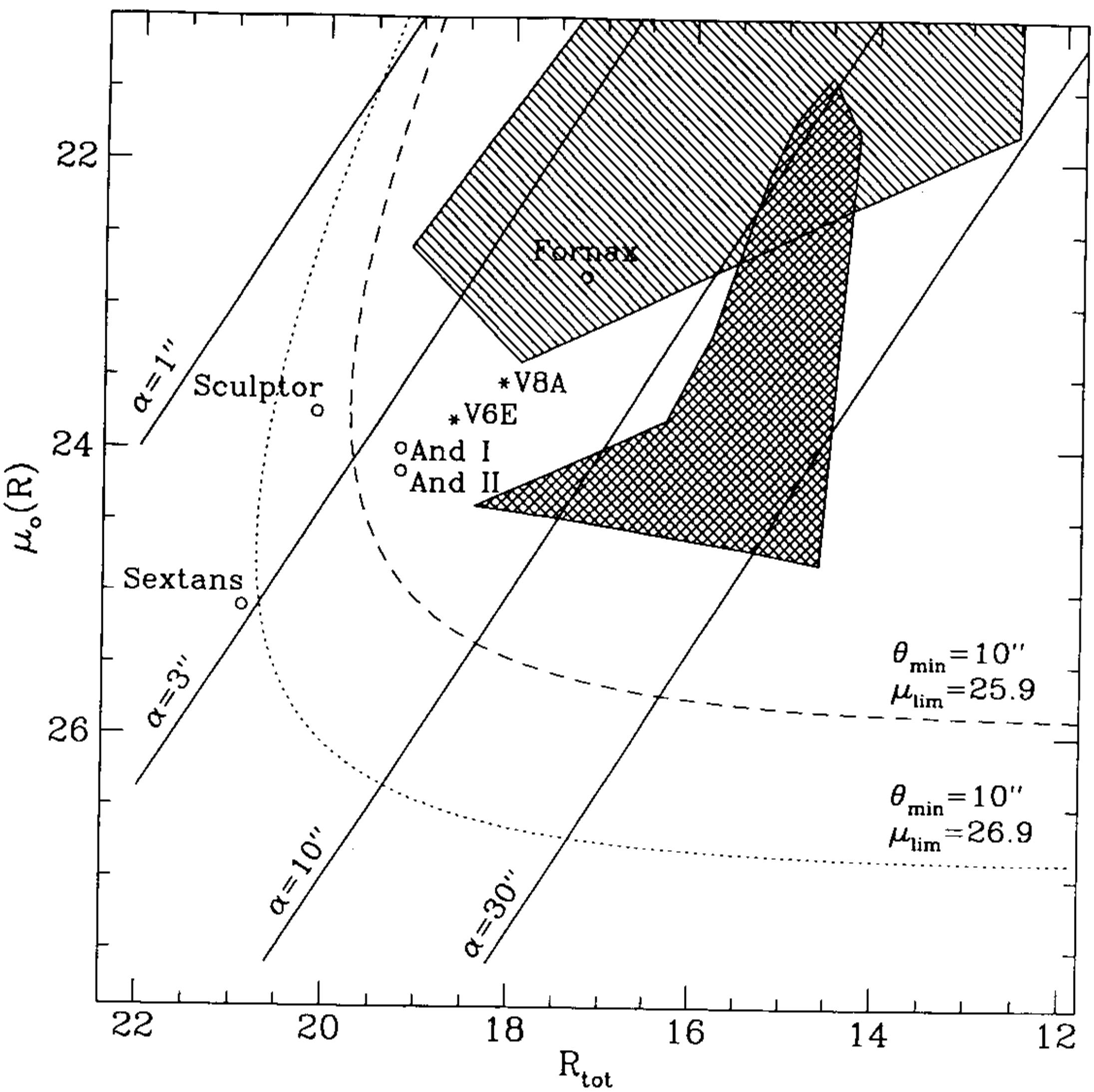

Figure 1. The distribution of Virgo LSBGs in the magnitude-central surface brightness plane. The hatched and cross-hatched regions represent the areas of parameter space covered by the Binggeli et al. and Impey et al. samples, respectively. The asterisks mark new Virgo LSBGs detected in our preliminary 'eyeball' survey. The dashed and dotted curves mark the loci of galaxies with image diameters of 10" at the isophotal levels reachable with a single film and with 6 stacked films. The diagonal long lines indicate particular galaxy scale lengths. The circles show the positions which some of the Local Group dwarf spheroidal galaxies would occupy if they were placed at the distance of Virgo, emphasising the point that even galaxies as small as these will be detectable in the current survey.

our six best individual exposures, which pushes the detection limit another 0.7 magnitudes fainter compared to the best single frame. Artefacts present on individual frames are also removed by means of median-stacking rather than simple addition. As the number of LSBGs increases rapidly with decreasing scale length ($n(\alpha) \propto \alpha^{-2}$ [Irwin et al. 1990]), the small angular size limit of our survey, combined with its fainter surface brightness limit, will allow us to detect many more cluster members than any previous survey. Thus we will be able to investigate in much more detail the contribution of LSBGs to the cluster luminosity function, their covering factor and their spatial distribution.

We show in Fig. 1 the regions of (scale-size, surface brightness) parameter space which will be accessible to the new survey. Indicated are the regions for which galaxies would have diameters above 10" at about the $26R\mu$ (single film) and $27R\mu$ (stacked film) isophotes. A particularly important point to note is that we are well into the regime of Local Group dwarf spheroidals (the positions some of these would occupy if at the distance of Virgo are also shown in the figure). This is the first time that any survey has been able to reach such objects anywhere outside our immediate environment.

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