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IMAGE PROCESSING TECHNIQUES IN ASTRONOMY

Edited by C. de Jager and H. Nieuwenhuijzen

VOLUME 54

PROCEEDINGS

D. REIDEL PUBLISHING COMPANY

DORDRECHT-HOLLAND/BOSTON-U.S.A.

IMAGE PROCESSING TECHNIQUES IN ASTRONOMY

PROCEEDINGS OF A CONFERENCE HELD IN UTRECHT
ON MARCH 25–27, 1975

Edited by

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D. REIDEL PUBLISHING COMPANY
DORDRECHT-HOLLAND / BOSTON-U.S.A.

Library of Congress Cataloging in Publication Data

Main entry under title:

Image processing techniques in astronomy.

(Astrophysics and space science library ; 54)
Bibliography: p.
1. Astrophysics—Congresses. 2. Spectrum analysis—Congresses. 3. Astronomical instruments—Congresses.
I. Jager, Cornelis de. II. Nieuwenhuijzen, H. III. Series.
QB461.I48 522 75-23032
ISBN 90-277-0650-6

Published by D. Reidel Publishing Company,
P.O. Box 17, Dordrecht, Holland

Sold and distributed in the U.S.A., Canada, and Mexico
by D. Reidel Publishing Company, Inc.
306 Dartmouth Street, Boston,
Mass. 02116, U.S.A.

Printed in The Netherlands by D. Reidel, Dordrecht

INTRODUCTION

The primary inducement for organizing an international Conference on 'Image Processing Techniques in Astronomy' was the fact that the recording microdensitometer VAMP ('Vol Automatische Micro Photometer') of the Utrecht Astronomical Institute was operative for a few years. The necessity of comparing the instrument and its performance with similar instruments nowadays available at many other institutes, was stimulating enough to organize a meeting on the above subject. It took place in Utrecht on March 25, 26 and 27, 1975.

The Scientific Organizing Committee consisted of J. Borgman (Groningen), R.B. Dunn (Sacramento Peak), H. Elsässer (Heidelberg), L.D. de Feiter, T. de Groot, J.R.W. Heintze, C. de Jager, H. Nieuwenhuijzen (Utrecht) and W. Wiskott (Genève).

About 175 scientists from 14 countries participated in the meeting which appeared to be successful and offered a good opportunity of exchanging information and comparing experiences.

The VAMP was bought with financial support of the Utrecht University and the Netherlands Foundation for Scientific Research (Z.W.O.).

The conference was organized with financial support from
The Netherlands Ministry of Science and Education,
The European Southern Observatory,
The Leids Kerkhoven-Bosscha Fonds,
The Astronomical Institute of Utrecht,
to which Institutes and Organisations we express our sincere gratitude.

C. de Jager
H. Nieuwenhuijzen

editors

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WHAT INFORMATION DO WE NEED, FOR WHICH ASTRONOMICAL PROBLEM?

ASTROMETRY

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INTRODUCTION

Considerable progress has taken place in astrometry over the past two decades.

Along with other fields of astronomy, effective use has been made of new technical developments both in regard to the improvement of performance of existing telescopes as well as in the design of new ones.

New automatic or semi-automatic measuring machines along with high speed computers have increased the accuracy and the ease of obtaining the data from photographic plates.

New areas have been added to astrometry in the form of radio and space astrometry which give promise of high precision. Because of the magnitude of the problems, and the need for global coverage, several international programs have been initiated and others have already been successfully carried out.

Added impetus to astrometry has been received from other fields of astronomy and astrophysics. These fields have generated needs for astrometric data for such programs as stellar evolution and luminosities, stellar kinematics, statistical parallaxes and galactic research. Requirements for increased accuracies of stellar positions and proper motions, especially for fainter stars, have also been generated from satellite geodesy and geophysical research.

In the following, an attempt is made to review the present status of some areas in astrometry especially in need of data and

de Jager/Nieuwenhuijzen (eds.), Image Processing Techniques in Astronomy. 3-10.

to mention the implementation or improvements which might be considered in regard to instrumentation and observations.

REFERENCE SYSTEMS

One of the objectives of astrometry is to make precise observations and to construct catalogs of the positions and motions of stars and solar system objects in order to provide an appropriate reference system of coordinates, including a local standard of rest.

Basic to this problem are the observations of the brighter objects which are carried out at present with transit circles and with astrolabes.

Within recent years there has been a substantial decline in the number of transit circles in operation. It would have been very critical for the continuation of such observations if significant improvements had not been made at the same time in the rate of acquisition and in the accuracy of the observations made with those still active.

In the first half of this century the accuracy of a single observation of good quality was about $\pm^{s}.020\sec\delta$ and $\pm 0''.40$ in right ascension and declination respectively (Fricke 1973). In the AGK3R program, where the observations were still carried out with the travelling wire micrometer, the transit circles showing the best performance had internal mean errors of $\pm 0^{s}.012\sec\delta$ and $\pm 0''.21$ (Scott 1967).

Further improvements in the internal accuracy of the conventional transit circle have been obtained by Høg (1972) with the Hamburg instrument located at Bickley, Australia, during the Southern Reference Star (SRS) program using a photoelectric multi-slit micrometer of his own design, and by Requieme (1973) at Bordeaux with his photoelectric tracking photometer.

Considerable improvement in speed and accuracy of the reading of the angular position of the instrument has been attained with the automatic circle scanning system first developed by the Copenhagen astronomers. The miniaturized version of this system now in operation on the 6-inch transit circle at the U. S. Naval Observatory (USNO), scans the circle in six places and produces a digital read out with a repeatability of 10 micro-degrees.

Another angular position system which provides continuous read out of the telescope during the observation is the inductosyn-system (an electronic angular position transducer) which is now being tested on the 6-inch USNO transit circle. It also has a repeatability of 10 micro-degrees. The operation of this telescope in conjunction with an IBM 1800 computer, permits the data to be available the morning following a night's observation.

Besides the present transit circles with their potential improvements in performance, there are three new types in various stages of development. All three are aimed at minimizing the troublesome flexure and thermal problems of the conventional instrument.

The horizontal transit circle at Pulkovo Observatory (Pinigin et al. 1974) is now reported to provide observations in right ascension with mean errors of $\pm 0^{s}.011 \sec\delta$ and to be essentially free from systematic errors.

At the USNO in Washington a 24cm Cassegrain type automatic transit circle which, in the design stage gave promise of accuracies of $\pm 0''.05$ in both coordinates, is approaching completion after long delays by the manufacturer in correcting numerous deficiencies in design and fabrication. The positional accuracy which can be achieved with this instrument is therefore uncertain at this time.

Finally, the most recent design of a new type is the so-called glass horizontal transit circle by Høg (1974) which will be relatively simple in design, have very small flexure, and will require a smaller building than the conventional meridian circle.

Of special importance to future work is the further development of photoelectric micrometers, with promise of the possibility of observing objects as faint as 14th magnitude, thus allowing a substantial number of galaxies to be tied directly to the fundamental system. While the present transit circles of 15 to 20cm aperture have a limiting visual magnitude of 10 using the travelling wire micrometer, and the photoelectric method at present has made possible a gain of approximately one magnitude in sensitivity, the continued improvement in sensitivity of the phototubes seems to make the additional gain of three, perhaps four, magnitudes not unrealistic.

What are the programs in meridian astrometry which need our attention over the next 10-20 years and what means do we have to accomplish them? I believe there is a continuous need for the observation of solar system objects both for the improvement of their ephemerides and the fundamental system. The AGK3R program, which was so successfully carried out in an international cooperation, has a mean epoch of 1959, and should therefore be repeated for a mean epoch near 1980. This would provide an additional interval of some 20 years to the time-base upon which the proper motions are determined. Similarly, a repetition of the SRS program is especially critical because of the paucity of early reliable observations to provide first epoch positions for proper motions.

I hope that the same successful international cooperation can be organized again with the observations carried out either with the new types of telescopes or the conventional ones in their updated, computerized versions.

I am aware of the proposed space projects which promise observations with precision as much as 2 orders of magnitude greater than the ground based equipment just mentioned. There is the project by Lacroute of measuring angular distances of 90° across the sky in either the Spacelab option or in the automatic Tiros Delta satellite option. Another project is associated with the Large Space Telescope (LST) project and involves measuring angles of variable size across the sky with high precision. The Spacelab, scheduled for launch in late 1980 but as yet not funded, is designed for 50 missions of 7 days duration each. It has to date 240 separate proposals for payloads with which the Lacroute project has to compete. The LST project is an approved NASA project but is also unfunded. It will contain an astrometric package for the observation of double stars, proper motions and parallaxes, but the gyro project has been dropped because of costs.

I do not wish to make predictions of the future of these space projects, nor do I wish to dispute their claims for high accuracy, but I am convinced we should continue the ground based observations until such time when they have definitely been superceded by the new methods in accuracy and operational reliability.

ASTROGRAPHIC CATALOGS

I would like to mention next the problem of there being no astrographic catalogs covering the entire sky, which are based on modern observations.

For the northern hemisphere there is the recently completed AGK3 catalog which contains positions near the epoch of 1958 of approximately 180,000 stars in the northern hemisphere to a limiting visual magnitude of 9.5. Proper motions of these stars were derived with the aid of the AGK2 catalog (epoch 1930) which was revised to the FK4 fundamental system. However, since both first and second epoch plates were measured without the benefit of modern automatic measuring machines, the potential accuracy of the plate material was not fully realized, neither in regard to positions nor limiting magnitude.

Plans are already in progress to produce a new, improved photographic catalog for the northern hemisphere with a limiting visual magnitude of at least 11 (de Vegt 1974). The Hamburg Bergedorf Observatory has acquired a new astrograph with an aperture of 23cm for this purpose. It is intended to use the AGK2 plates which will be remeasured as first epoch for the proper motions. The overall positional accuracy from the measurements with a modern automatic measuring machine is estimated at 0".14. With a baseline in excess of 40 years, the centennial proper motions will have an estimated mean error of 0".50 or nearly half the error of the AGK3 proper motions.

Photographic observations of the entire southern sky with the Cape astrographic camera have been completed with a total of approximately 6,000 plates providing a fourfold overlap. These plates have been transferred to Herstmonceux to be measured on the Galaxy machine. As reported by Clube and Nicholson (1974) the anticipated relative positional accuracy is of the order of 0".05 over a fairly wide area of the sky. If this mean error is attainable, the accuracy will be substantially greater than previously obtained in the Cape zone catalogs where the positional mean errors range from ±0".22 in the earliest catalog to ±0".14 in the latest (Dieckvoss 1963).

It is hoped that the necessary support can be obtained for both of the above mentioned programs, thereby providing general catalogs of position and proper motion to a limiting visual magnitude between 11.5 and 12 for both hemispheres, with an average of 8 to 10 stars per square degree.

TRIGONOMETRIC STELLAR PARALLAXES

I would like to call your attention next to the current activities of determining trigonometric stellar parallaxes. We find that most of the observatories which contributed the major share of the earlier parallax series are still active in this area.

With the exception of van Maanen's parallaxes with the Mt. Wilson 60-inch and 100-inch reflectors, the telescopes used were long-focus refractors. These are still providing good results for parallaxes of the brighter stars, but they are not effective for stars fainter than visual magnitude 13, because of excessive long exposure times combined with the substantial number of plates required in modern parallax series.

The 61-inch astrometric reflector of the U. S. Naval Observatory has now been in operation since 1964. Including a third catalog which is now in press they contain parallaxes for approximately 300 stars, of which 75% are fainter than $m_V = 13$.

Since most of the stars for the program were initially selected from the Lowell proper motion survey because of the availability of identification charts, parallaxes have been obtained thus far for only a few stars fainter than $m_V = 16$. Fainter stars selected from the Luyten 48-inch Palomar Schmidt proper motion survey, are now on the program. With exposure times of 50 minutes, a photographic or visual magnitude of 18 is reached.

Including results from the third catalog, 21 stars have been found within 10 parsecs, none of which had previously published parallaxes, and 99 within 20 parsecs. Significantly, four new stars within 5 parsecs have been added to the list of 45 systems of 60 stars previously known (van de Kamp 1971).

The substantial number of parallaxes obtained in the program was predicated on the use of a telescope designed and dedicated primarily to parallax work, an automatic measuring machine, and automation of data handling (Strand 1966, 1971).

At the present time, the only other reflectors being used for parallax work are the one meter aperture Turin astrometric reflector recently installed and the 98-inch Isaac Newton Telescope. With the latter telescope, because of the limited availability of time for such work, a small program restricted to some 20 faint stars between photographic magnitude 16 and 18.5 is being carried out (Murray 1974).

While efforts in the northern hemisphere appear to be satisfactory in regard to parallax determinations, the situation in the southern hemisphere is critical with only the Cape refractor engaged in this area.

There is, therefore, a need to make time available on reflectors of sufficient aperture to carry out the observations of the many low luminosity stars lacking parallaxes. For lack of a reflector specifically dedicated to this work, and the need of a fairly rigid observing schedule, however, it will be difficult to carry out an effective program.

Perhaps the proposed program by Murray (1974) of using the UK Schmidt at Siding Springs might produce results which will promote interest in parallax work in the southern hemisphere.

VISUAL DOUBLE STARS

The observations of visual double stars is another area of astrometry in which progress has to depend upon a very small group of participants in spite of the fact that direct information concerning the masses of individual stars is entirely dependent upon such observations. In addition to the study of the relative motions of the components in binary systems, there is also the need for the determinations of their mass ratios, their parallaxes and proper motions, as well as the search for invisible companions.