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DETERMINING PRECISE POSITIONS OF SUPERNOVAE

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Abstract

A 0.24m/0.32m lensless Schmidt camera mounted piggyback on the University of Rhode Island (URI) astrometric reflector (Penhallow 1978) is used to determine the positions of supernovae to within 0.1 second of arc. Measurable 15.5 magnitude images can be obtained on hypered Kodak SR-5 x-ray film in 4 minutes under favorable conditions. Five exposures with about 16 reference stars are normally used.

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1. Introduction

Supernovae are the most spectacular of variable stars. In these catastrophic explosions, many fundamental astrophysical processes occur. Originally visual, photographic, and spectroscopic observations provided the clues. Today there is an impressive array of additional instruments in space and on the ground which can gather information at many wavelengths in a coordinated fashion (cf. Panagia 1985). However, as Marsden (1984) points out, immediate astrometry and spectroscopy are needed to confirm discoveries and enable these various instruments to be properly pointed so that full coverage can be obtained.

In order to obtain positions to 0.1 arc-second free from systematic errors and on a well-defined system, care must be taken to use the following:

1) a catalogue of star positions of suitable accuracy

2) a good telescope

3) suitable photographic material

4) a good measuring engine

5) a computer and software to properly model the field.

2. Telescope and Star Positions

One needs a field of view sufficient to capture enough good reference stars at a suitable scale. In the northern hemisphere, the best catalogues for this purpose are The **Third Katalog der Astronomischen Gesellschaft** (Smith 1976) (AGK3) and The **Third Reference Catalogue** (Smith 1977) (AGK3R), and south of the equator, the **Smithsonian Astrophysical Observatory Star Catalog** (Haramandanis 1966) (SAO). Typical errors of position in these catalogues at the present epoch are AGK3R, 0"25; AGK3, 0"3 - 0"5; and SAO, 0"6 - 1"0.

These Catalogues contain respectively about 250,000, 22,000, and 500,000 stars. The AGK3R is the reference star catalogue used to determine the photographic positions in the AGK3. The Southern Reference System (SRS), which corresponds to the AGK3R and has about the same number of stars, will be available in the near future, according to Hughes (1986).

A 9.5"/12.5" f/6.3 lensless Schmidt was chosen for simplicity and has a 60" focal length with a 3.8o field on a 4-inch circle which covers about 11 square degrees. The smallest images are 40 microns in size. The plate scale is 135"/mm or 7.4 microns/". Assuming that one can find at least 6 AGK3R stars along with 10 AGK3 stars, the weighted mean could produce a frame of 0."1 accuracy. See Equation (1).

$$\frac{0.''25}{6\ \mathrm{AGK3R}} + \frac{0.''3 - 0.''6}{10\ \mathrm{AGK3}} \rightarrow 0.''1 \qquad (1)$$

If more AGK3R stars can be found in the field, all the better.

3. Photographic Material

Hypersensitized Kodak SB-5 x-ray film is used. It is faster than hypersensitized 103a0 but a little grainier and cuts off at a little shorter wavelength, according to Smith et al. (1985). 4" x 5" sheets are baked one at a time, in a modified 6-quart pressure cooker. The air is pumped out for 5 minutes using a mechanical pump with the cooker filled to 15#/in^2 guage with dry nitrogen and placed in a Cenco oven at 67^{o}C for one hour. The cooker is then taken out, evacuated for 5 minutes and then filled to 15#/in^2 with forming gas (93%N_2, 7%H_2) and baked for 5 hours at 67^{o}C. The cooker is then evacuated for 5 minutes and filled with a little dry N_2 (-20#/in^2 guage) until ready for use. The hypered film is 2.5 - 3.0 times faster than hypered 103a0. Also the unhypered film is faster than unhypered 103a0. At 9.5" aperture easily measurable 15.5 magnitude stars are recorded in 4 minutes.

The film holder for the Schmidt is a modified 4-inch film canister. The bottom is replaced by a 4-inch diameter aluminum disc 1/8" thick which has a convex focal surface of 60-inch radius. The film is attached to this surface with rubber cement. In order to minimize the magnitude effect, a piece of thin neutral-density film is placed in contact with the x-ray film. The neutral density film has a 1^{o} diameter hole in its center. The presence of the neutral density film seems to have no detrimental effect on the images. After exposure, the aluminum is grounded (to minimize sparking) and the film carefully peeled off.

4. Measuring Engine

The two axes of the URI visual measuring engine have been carefully checked against a Zeiss optical scale and are correctable to better than 1.4 microns RMS. The ability to visually bisect an image (using 2 or 3 tries) is about 1/25 the image diameter, hence 1/25 x 40 microns $\simeq$ 1.6 microns, and at 7.4 microns/" one should get 1.6 microns/7.4 microns $\simeq$ 0."2 and with 5 images one should be down to $\simeq$ 0."1. With 5 exposures of 4 minutes each and 16 reference stars, there are 85 images to measure direct and reverse.

5. Models

A 6-constant linear program is first run so that differential refraction can be applied. A certain amount of cubic distortion is assumed in x and in y and the linear program repeated. The residuals are carefully monitored as different amounts of cubic distortion are tried. In the process, stars with large residuals are discarded. More complicated models have been tested but do not improve the results.

Using the techniques described above, the position of Nova Cygni 1986 was determined within four days of the announcement of its discovery and was in excellent agreement with the position by J. B. Tatum of the University of Victoria (Penhallow and Tatum 1986).

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REFERENCES

Haramandanis, K. L. 1966, **Smithsonian Astrophysical Observatory Catalog,** Smithsonian Institution, Washington, DC.

Hughes, J. A. 1986, U. S. Naval Observatory, private communication.

Marsden, B. G. 1984, **IAU Cir.** No. 3995.

Panagia, N. 1985, **Space Telescope Science Institute, Preprint Series 83.**

Penhallow, W. S. 1978, **Sky & Telescope 56,** No. 5, 455.

_______________ 1986, **Proceedings IAU Symposium 118,** Instrumentation and Research Programmes for Small Telescopes (in print).

Penhallow, W. S. and Tatum, J. B. 1986, **IAU Cir.** No. 4246.

Smith, A. G., Phillips, C. A., Hahn, E. J., and Leacock, R. J. 1985, **AAS Photo-Bulletin 39,** 8.

Smith, C. 1976, **Third Katalog der Astronomischen Gesellschaft** (magnetic tape), Astronomical Data Center, NASA Goddard Space Flight Center, Greenbelt, MD.

Smith, C. 1977, **Third Reference Catalogue of Astronomical Studies** (magnetic tape), Astronomical Data Center, NASA Goddard Space Flight Center, Greenbelt, MD.