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AN INNOVATIVE TELESCOPE DESIGN FOR CCD PHOTOMETRY

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Abstract

The development of a dedicated telescope for CCD photometry creates a number of opportunities for innovative solutions to old problems. The small field of the CCD enables simple Newtonian optics to be used. The addition of computer modelling for the telescope structure makes a simplified altitude-azimuth mounting attractive. It also enables two foci to be taken through the altitude bearings, simplifying the cabling. This arrangement is an approximation to the Nasmyth mounting and provides a simple but robust mount suitable for automatic operation.

1. Introduction

This project is a response to the demand for accurate faint photometry in a number of areas of astronomy:

1. Parallel measurements with observers in other wavebands, e.g., satellite X-ray or high resolution radio, to provide a visible photometric baseline for irregularly variable objects.
2. Long-term monitoring of eruptive variables, e.g., cataclysmic variables, to determine rotational periods and flag the onset of periods of heightened activity.
3. Continuous observations of exceptional eruptive variables in a global network, e.g., gamma burster error boxes.
4. Programs of precision photometry to monitor long period variables.

This brief paper describes a system that is being constructed at the University of Bradford. The objective is reliable robotic operation for CCD photometry at a remote site with only electricity and a telephone link to the outside world. The system is designed to make photometric observations of faint stellar objects in the region of 17th magnitude in crowded fields. The field of the CCD is required for effective pattern-recognition algorithms to provide assurance that the target object has been observed. It is intended that the telescope design will be scaled to the largest size that can be erected on a remote mountain top by two people without the assistance of heavy lifting gear. This is about one-metre aperture. After commissioning it is intended that such a telescope will operate autonomously with regular servicing.

2. Optics Design

The closely-defined astronomical objectives and the use of a CCD allows the normal photographically-based specification of the optics to be relaxed. This telescope is designed for a CCD detector operating at cryogenic temperatures. The CCD has a 385 by 585 pixel format and is supplied by EEV of Chelmsford, England. (Similar CCD's are available from other manufacturers, e.g., Thompson CSF of France, Hammamatsu of Japan, and Tectronix of USA.) The sensitive area of the CCD is approximately 8 mm by 12 mm and each pixel is 22 microns square. The field size of the CCD is effectively defined by the focal length of the system.

For pattern recognition to provide target assurance it is necessary to have a significant number of objects in the field and a short (<2m) focal length. For direct imaging photometry of faint objects, it is desirable to match the atmospheric seeing limit of about one arc second to the pixel size of the CCD. This requires a longer (>4m) focal length. A good solution to this problem is to use a short focal length system, about 2 metres, and to use a lens associated with the filter assembly to project the image and match the image scale to the optimum for photometry. The large instrument space in this design facilitates this solution. For bright objects it is sufficient to defocus the image and so provide a faster throughput.

A focal length of 2 metres would produce a pixel size of 2.3 arc seconds. With Newtonian optics of this focal length, a mirror of less than one-metre diameter, and a field the size of the CCD, there are no serious optical aberrations in the center of the field. The outer pixelated images are adequate for pattern recognition. The advantage of Newtonian optics is that they are robust and easily set up.

3. Design of the Mounting

The mechanical simplicity and strength of the altitude-azimuth mounting provide considerable weight savings over the equatorial solution and has led to its adoption in this design. The rapid fall in the cost of computing power has made it possible to utilize computer models of the telescope structure and drives to generate precision motion. The models were developed for large telescopes by P. T. Wallace in Fortran (Wallace 1987). They are available from STARLINK (Disney *et al.* 1982) under the SLALIB (Wallace, STARLINK User Note 67) and TPOINT (Wallace, STARLINK User Note 100) directories. These have been ported to C-code and implemented on an IBM compatible 386SX machine (Eaton 1990).

The models include parameters to compensate for all the normal sources of error in telescope operation, e.g., the mechanical axes not being perpendicular or coincident with the optical axes. In order to use the models with the drive system, it is necessary to use a backlash-free drive. In this case the model can be used to compensate for the errors in the drive system. It is possible to include all the parameters necessary to model simple drive systems, e.g., for the drive axes being neither perpendicular to the drive wheel nor central in the wheel.

With full computer control it makes little difference whether the mounting is equatorial or altitude-azimuth. There are considerable advantages to using an altitude-azimuth system. The disadvantages are that the telescope cannot track objects through the zenith (the zenith hole problem), and the image produced by the telescope rotates as the telescope tracks around the sky. These are not serious problems. The zenith hole is small for a telescope with a rapid tracking speed and can easily be scheduled out of the observations. Sky rotation can easily be compensated for. The rotational resolution required is comparable to the ratio of the pixel size to the dimensions of the CCD. One-arc-minute rotational resolution is ample for the GEC chip.

4. The Nasmyth Innovation

This innovation is not a true Nasmyth, in which the Cassegrain focus is folded through the altitude axis. In this innovation it is the prime focus of the Newtonian system which is folded through the altitude axis. The design is shown in Figures 1a and 1b. The secondary Nasmyth mirror is placed to reflect the prime focus to a point just outside the yoke. The telescope tube is balanced by a ring of weights. The computer modelling of the telescope tube makes this innovation possible with no penalties in the telescope operation. There are considerable advantages:

- There are two major instrument locations without serious constraints on the size or weight of the instrument package.
- The instruments are easily accessible for servicing and construction.
- The cable wrap is simplified.
- The focus position can be altered easily and rapidly by rotating the Nasmyth mirror.
- The detector is removed from the side of the telescope tube, removing an asymmetrical stress.
- The design of the focussing movement and the filter change movement is simplified.

The disadvantages are a considerable increase in the weight of the tube in order to achieve balance without unacceptable increases in length. The relaxed optical resolution of the mirror to match the CCD pixel size means that a thin light mirror can be used. For a one-metre system, the weight of the mirror and support cell can be kept well below 100 kg.

5. The Drive and Encoder Design

The system used here is a direct friction drive of steel on steel to eliminate backlash. Each axis is powered by a stepper motor with 25,000 steps per revolution manufactured by Parker Hannifin Corp. (Compumotor Division, 1179 N. McDowell Blvd., Petaluma, CA 94952, USA). This is reduced by a 10-to-1 intermediate wheel onto a 40-to-1 drive wheel. The ratios of the reduction wheels are determined by the hardness of the steels and the pressure on the drive surfaces of about 150 kg per square cm. The wheels flex slightly eliminating hunting due to inaccuracies in the alignment of the axes. The result is a drive resolution of about five steps per arc-second.

The encoders are of the incremental type attached directly to the axes. They include datum markers and have a resolution of one arc second. They rely on an optical interference effect in the infrared. They are relatively inexpensive and are manufactured by Metronic Technology Ltd. (St. Maximilian House, 63 Jeddo Rd. London W12-9EE).

6. Conclusion

The construction of the telescope, computing system, and software are currently under way. First light is expected in 1991.

References

Disney, M. J. and Wallace, P. T. 1982, *Quar. J. Roy. Astron. Soc.*, **23**, 485.
Eaton, S. J. University of Bradford, Dept. of Electrical Engineering, *Internal Report No. 1990.*
Wallace P. T. 1987, "Pointing and Tracking Algorithms for the Keck 10-Meter Telescope", *Instrumentation for Ground Based Astronomy, Present and Future. The Ninth Summer Workshop in Astronomy and Astrophysics. Lick Observatory. July 13-24*, Springer Verlag.

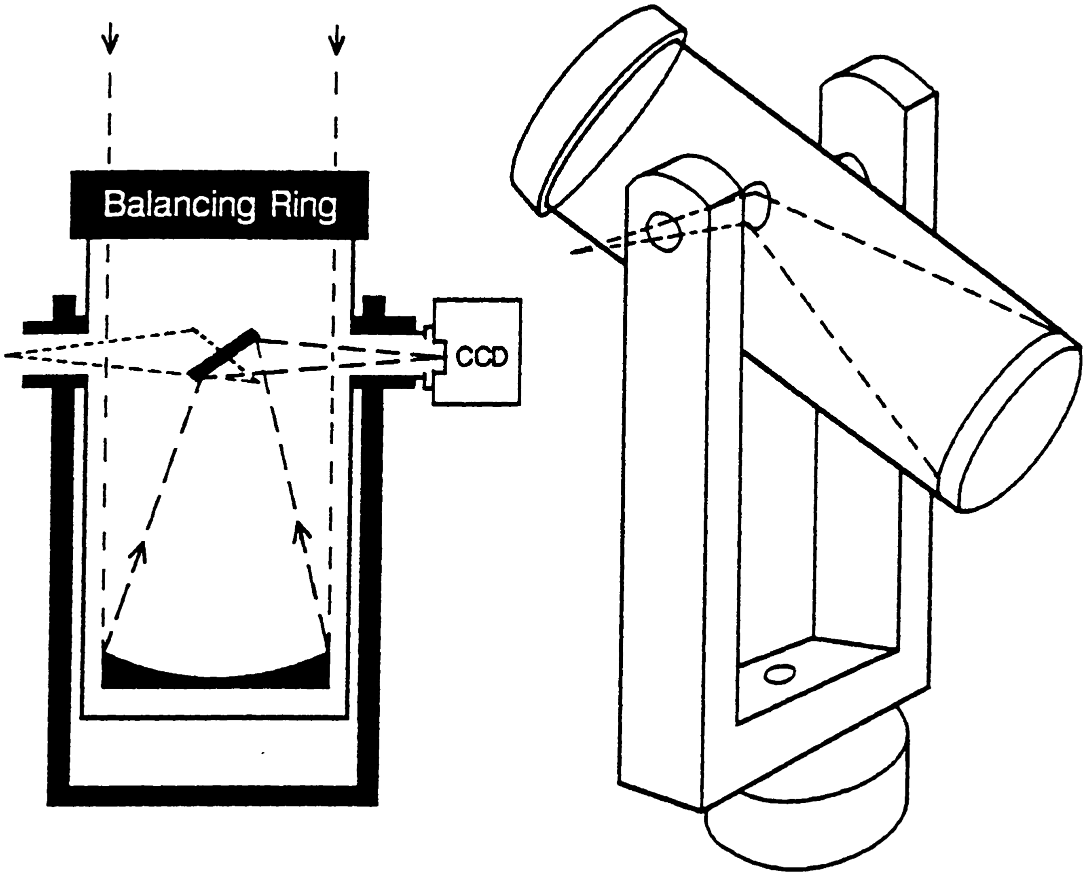

Figure 1a.

Figure 1b.

Figure 1. A Nasmyth Innovation