THE U. S. SPACE TELESCOPE: ASTROMETRIC CAPABILITIES

William H. Jefferys
Department of Astronomy
University of Texas
Austin, Texas 78712

ABSTRACT: This paper describes the Space Telescope and the instruments it will carry which will be used for astrometry. Particular attention is paid to the two imaging cameras and to the Fine Guidance Sensors. A brief outline of the kinds of programs which are to be carried out is also given.

I. INTRODUCTION

Space Telescope, which will be launched by Space Shuttle in 1983, offers significant improvements in relative astrometry over that which is routinely obtained on the ground. Space Telescope is a 2.4 meter aperture, f/24 Ritchey-Chretien telescope in a Cassegrain-type configuration. It may well be the most important optical telescope to be built for astronomy in the next few decades - and it has reasonably good prospects for making observations into the early part of the 21st century. Sponsored jointly by NASA and ESA (which will provide the solar panels and one of the two cameras), it is an international effort worthy of discussion at this meeting of the IAU.

Of the six instruments aboard Space Telescope, four - the two cameras, the Fine Guidance Sensors, and the High Speed Photometer - have astrometric capabilities. Of the latter instrument I will say little except that it could be used for highly precise occultation measurements. The two cameras offer direct imaging capabilities over relatively narrow fields of view. The Wide Field/Planetary Camera has two modes of operation, one with a field of view 2.67 x 2.67 arcmin, and the other with a 68 x 68 arcsec Field of View (FOV). The detector consists of four silicon chips, each containing 640,000 sensitive elements arranged as an 800 x 800 array. The four chips are optically mosaiced to provide complete coverage of a 1600 X 1600 pixel area. In its narrow field mode, this camera should be able to attain a precision of ±0.002 arcsec for relative positions of two stars. Its silicon chips give it a very large dynamic range, which would also be of great advantage.

Patrick A. Wayman (ed.), Highlights of Astronomy, Vol. 5, 789–794.

The Faint Object Camera (FOC), being designed and built by ESA, may also be used for astrometry. It uses electron imaging technology and will probably be less stable than the Wide Field Camera as a result, but is particularly useful in the UV. In particular, there is a possibility of an f/288 mode being included which would provide, through speckle techniques, diffraction-limited performance in the UV.

II. FINE GUIDANCE SENSORS

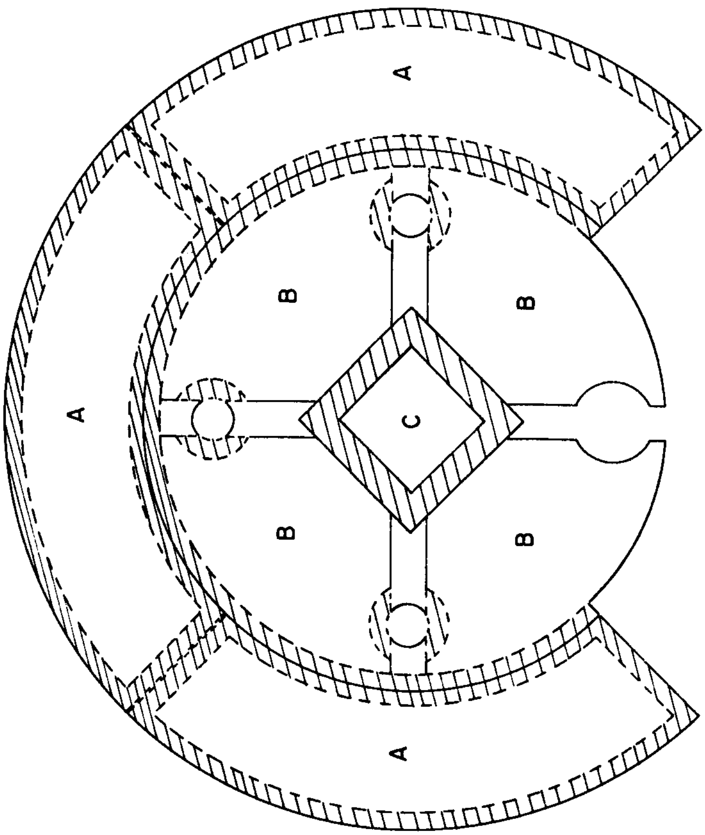
Space Telescope is stabilized by its fine Guidance Sensors, (FGS), devices which in the guiding mode can accurately track a star of magnitude 10-14 (approximately) and provide an error signal for the correction of telescope pointing. The fields of view of the three Fine Guidance Sensors are located in the annular region as shown in Figure 1. Each scans a quarter of the annulus and has a field of view of about 60 square arcminutes. Unlike the cameras, the Fine Guidance Sensors can observe only one star at a time. A system of rotating mirrors, called star selectors, can bring the image of any star within the FGS FOV to the detector. The schematic optical path (Figure 2), illustrates the collimator and a refractive group to correct for off-axis aberrations, the star selectors, reimaging lenses and detector. The detector, which is the heart of the sensor consists of a Koester's prism interferometer which can accurately measure the tilt of the incoming wavefront.

To guide the telescope, two of the FGS units are locked onto two preselected stars. The signals from these units are fed back through the spacecraft computer and used to stabilize the pointing of the telescope in all three axes. The accuracy of this is sufficient to keep the telescope pointing in the desired direction to within ±0.007 arcsec jitter.

Once guide stars have been acquired and the telescope is pointing in the desired direction, observations may be made with any instrument. In particular, since one FGS unit is not needed for pointing control, it can be used for astrometry. Several modes of operation are possible.

Multiple Star Mode. By moving the image of a double star across the fine-mode detector, a response will be obtained for each component. Independent responses are obtained from each of the two coordinate axis detectors, and by analyzing the responses, the position angle and separation of the two stars are obtained. It should be possible to measure stars which are somewhat closer together than the point-spread function of the telescope, provided they are sufficiently close in brightness. This mode is expected to be valuable in improving both the statistics of and masses of close binary stars.

Astrometry Mode: In the astrometry mode, the FGS is positioned on an object, and the signal from the FGS unit itself is fed back to the star selectors so as to keep it centered on the object. The



-A- FGS Field of View
-B- Axial Scientific Instrument Data Field
-C- Wide Field Camera Data Field

Figure 1

https://doi.org/10.1017/S1539299600004743 Published online by Cambridge University Press

position of the star selectors is read out as the star position and telemetered to ground. After measuring one object in the FGS FOV, the star selectors are moved to the predicted position of a second object and the process is repeated. This is then done for a third object, a fourth one, and so on until the relative positions of every preselected object have been measured. Typically, it is expected that from ten to fifty objects may be measured, with the number depending on the uses to which the data are to be put, as well as other considerations such as how stable the FGS FOV is over time, and how well it has been calibrated. Obviously since stars are measured one at a time, one must spend more time if more stars are to be observed.

Specifications for Space Telescope are that it be able to measure relative positions with an accuracy of ±.002 arcsec, and that it be able to measure at a rate of 10 stars in 10 minutes. Stars from the 10th to the 17th magnitude will be measurable, and perhaps fainter objects can be reached with an increase in integration time. These specifications will, if achieved, make substantial improvements in the accuracy of astrometric data.

Although the calculations indicate that systematic errors due to such causes as color or magnitude differences among stars will be considerably smaller than the ±0.002 arcsec requirement, filters will be available to enable the effects of differential color to be measured. In addition, a neutral density filter will be available to extend the magnitude range to brighter than 10th magnitude stars.

III. SPACE TELESCOPE AND HIPPARCOS

Hipparcos (which was described in the previous paper) and Space Telescope are quite different in their astrometric capabilities; it is important to thoroughly appreciate this fact. Hipparcos is a survey instrument that will provide a large number (100,000) of positions, parallaxes and proper motions. The positions are "absolute" in the sense that they will be of good quality and low systematic error, uniformly over the entire sky. The parallaxes will also be absolute. However, Hipparcos is restricted to stars brighter than 11th magnitude if it is to obtain the full accuracy of which it is capable.

Space Telescope, on the other hand, can observe much fainter objects than can Hipparcos, without loss of accuracy. But it is not a survey-type instrument. While we expect astrometric observations to obtain a fair share of telescope time, (initially, one-seventh of the available observing time) Space Telescope will be a scarce resource. Observing lists must be made with great care and attention to the scientific results to be obtained. Only a relatively small number of astrometric observations will be made by Space Telescope, but their quality will be extremely high. Finally, all measurements

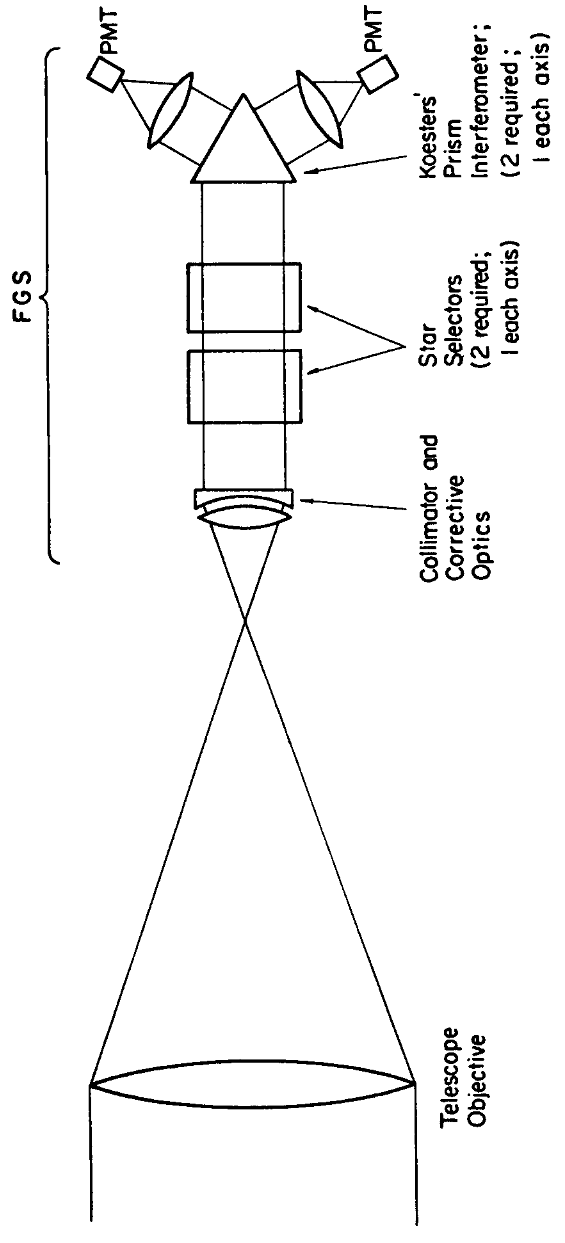

FGS
PMT
PMT
Koesters' Prism Interferometer; (2 required; 1 each axis)
Star Selectors (2 required; 1 each axis)
Collimator and Corrective Optics
Telescope Objective

Figure 2

with Space Telescope are relative, and over small angles in the sky. Thus parallaxes from Space Telescope must be interpreted with care, and reference stars selected with this in mind.

The limitations and strengths of both Hipparcos and Space Telescope mean that both are needed for astrometry. Indeed, each one can help the other. For example, Space Telescope can make observations of stars on the Hipparcos list and nearby faint quasars with the purpose of tying down the Hipparcos proper motion system to an absolute frame of reference. On the other hand, parallax measurements by both Hipparcos and Space Telescope would serve as a check on the corrections that must be applied to Space Telescope relative parallaxes.

IV. SCIENTIFIC PROGRAMS

Since the later papers in this session will address themselves to the scientific impact of space astrometry in great detail, I will be brief, and just list some of the areas which will be studied with Space Telescope. With Space Telescope, more open clusters will be within range of good relative parallaxes, which will greatly improve our understanding of the distance scale. Also, some Cepheid variables and RR Lyrae stars will for the first time come within the range of direct trigonometric parallaxes, as well as a number of other stars of astrophysical interest which until now have been too far away. Statistics and orbits of close double stars will be greatly improved, an area which is in desperate need at present. Highly accurate proper motions of stars in clusters will enable more subtle dynamical effects to be studied. It may be possible to tie the fundamental reference frame to quasars with greater accuracy than before, particularly if Hipparcos data become available. Finally, some highly accurate solar system observations, particularly of some of the satellites, will become possible.

ACKNOWLEDGEMENTS

The Author would like to thank his colleagues on the Space Telescope Astrometry Team for all of their contributions, without which this work would be impossible. The support of the National Aeronautics and Space Administration, under Contract NAS8-32-06, is gratefully acknowledged.