FGS1R: HST's Interferometer That Can!

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HST Fine Guidance Sensors

Introduction

The unprecedented pointing precision required by the Hubble Space Telescope (HST) motivated the design of the Fine Guidance Sensors (FGS). These are large field of view (FOV) interferometers that are able to track the positions of luminous objects in HST's focal plane with ~1 millisecond of arc (mas) precision. The FGS can also scan an object's interferogram with sub-mas resolution. These capabilities enable the FGS to perform as a high-precision astrometric science instrument and high resolution interferometer which can be applied to a variety of topics and objectives, including:

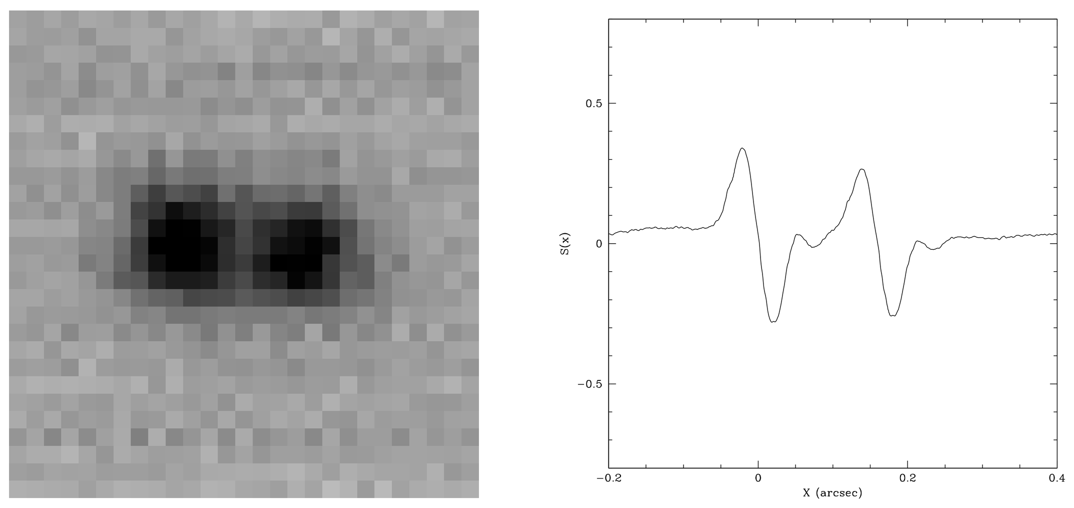
- Visual orbits for binary systems with separations as small as 10 mas. Detection of duplicity down to 7 mas.
- Measuring the angular size of extended objects.
- Relative astrometry at the 0.2 mas level ($m_V < 14.5$).
- 40 Hz relative photometry (e.g., flares, occultations) with milli-mag accuracy

Transfer Mode Observing

In Transfer Mode the FGS scans an object to obtain its interferometric fringes with sub-mas resolution. This is conceptually equivalent to imaging an object with sub-mas pixels. This makes the FGS ideal for studying binary systems and extended objects over a large magnitude range ($3.0 < m_V < 16.0$).

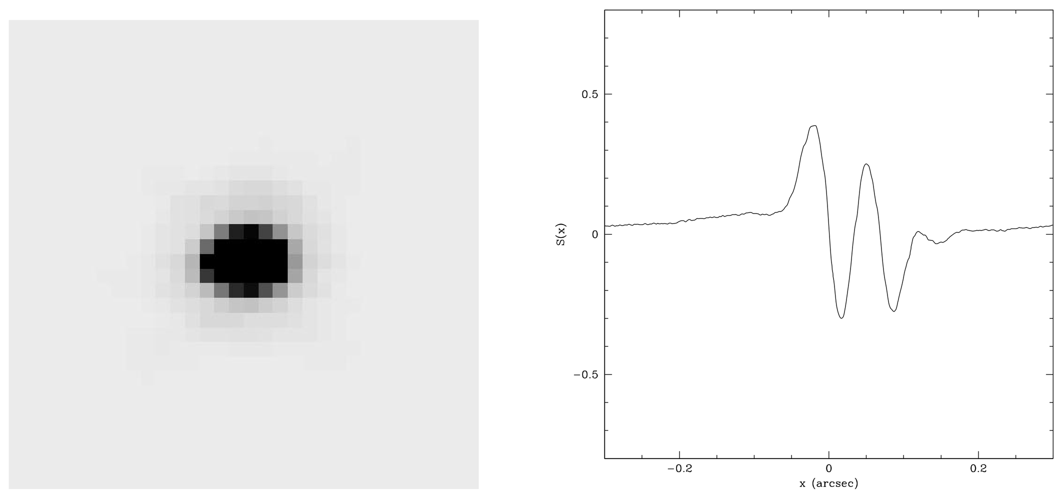
Binary Systems

Actual WFPC2 and simulated FGS Observations of a 168 mas binary system.



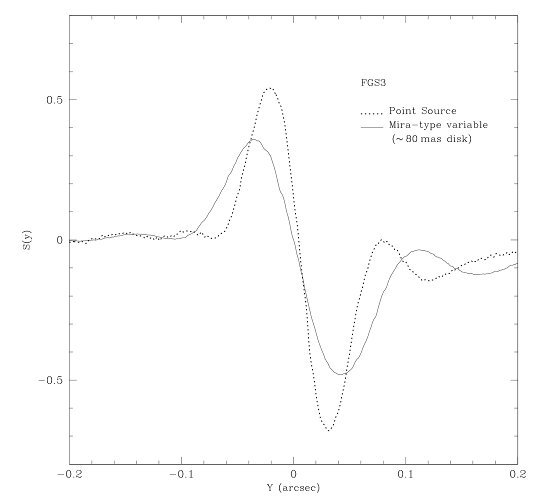
Although the binary in this example is clearly resolved by the WFPC2 Planetary Camera (PC) (Niemela *et al.* 1999), the FGS could measure the component separation and relative brightness with greater accuracy (± 1 mas v. ± 30 mas).

Simulated WFPC2 and FGS Observations of a 70 mas binary system.



Although a PC detection would be questionable at 70 mas, the FGS clearly isn't challenged in detecting duplicity and measuring separations. Detections of duplicity down to 7 mas are possible with the FGS.

Angular Diameters



The FGS has been used successfully to determine the angular diameters of non-point sources. the example given in the figure at left shows the Transfer Function of a Mira-type variable (Lattanzi *et al.* 1997) superposed on the S-Curve of a point source. The extended source - a disk of 78 ± 2 mas - is clearly distinguishable from a point source.

In addition to stellar disks, the FGS has also been used to determine the angular sizes of Active Galactic Nuclei (AGNs), asteroids, and extragalactic star formation regions.

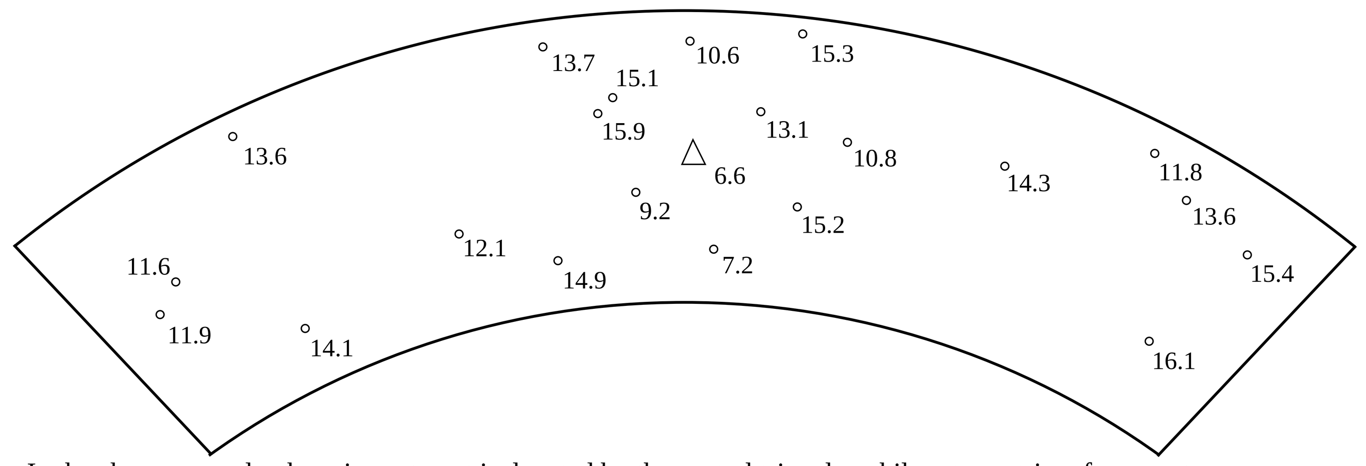
Position Mode Observing

As an astrometer, the FGS can measure the relative positions of stars in its Field of View (FOV) with a *per-observation* precision of ~ 1 mas. Key characteristics of observing in Position Mode include:

- A large (69 arcmin^2) Field of View (FOV).
- A large dynamic range ($3.0 < m_V < 16.0$).
- Binary and variable star astrometry.
- Down to 0.2 mas relative astrometry for multi-epoch observing programs (achievable in ~ 12 HST orbits)

In Position Mode, the FGS has been successfully used to measure astrometric parallaxes to a number of targets, including the nearby dwarfs Proxima Centauri and Barnards Star (Benedict *et al.* 1998), and the dwarf novae SS Aurigae, SS Cygni and U Geminorum (Harrison *et al.* 1998).

The FGS FOV and a "Typical" Astrometric Star Field.



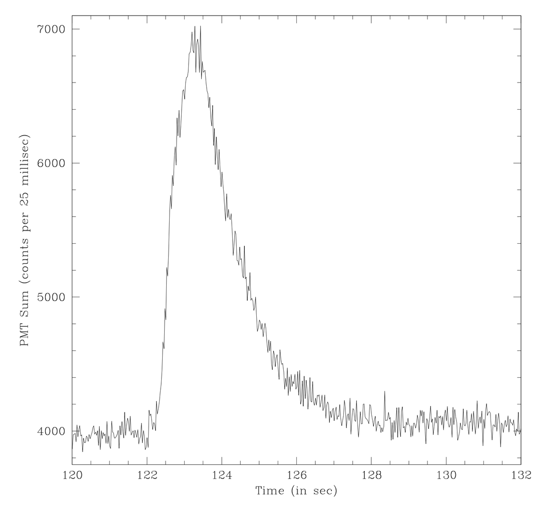
In the above example, the science target is denoted by the central triangle, while astrometric reference stars are denoted by circles. Magnitudes of individual objects are given beside each target. Note the magnitude range, from $m_V = 6.6$ to $m_V = 16.1$.

Relative Photometry

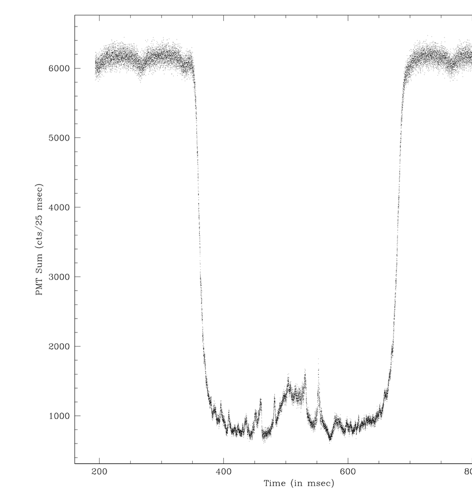
While conducting Position Mode observations, FGS3 successfully captured a flare event on Proxima Centauri (Benedict *et al.* 1998). In another series of observations, the FGS observed the occultation of a 10.6 magnitude star by the Neptunian moon Triton (Elliot *et al.* 1998).

The absolute FGS photometric response has been stable to 2% over the past seven years (Abramowicz-Reed 1997). For relative photometry, on time scales of orbits, the FGS is stable to about 1 milli-magnitude at a rate of 40 Hz. This affords an opportunity for 0.1 to 0.2% time-series photometry for most targets.

Flare Outburst on Proxima Centauri



Stellar Occultation by the Moon Triton



Cycle 9 Call for Proposals

The HST Cycle 9 Call for Proposals will be released in June 1999, with a GO proposal deadline of Friday, 10 Sep 1999 at 8:00PM EST. ***Propose early. Propose often. Propose wisely!***

References

Benedict, G.F. *et al.* 1998, AJ, 116, 429.
Elliot, J.L., Strobel, D. F., Zhu, X., Wasserman, L. H., and Franz, O. G. 1998, DPS, 30.4901.
Harrison, T.E. *et al.* ApJ, 515, L93.
Lattanzi, M.G., Munari, U., Whitelock, P.A., and Feast, M.W. 1997, ApJ, 485, 328.
Niemela, V.S., Shara, M.S., Wallace, D.J., Zurek, D.R. and Moffat, A.F.J. 1998, AJ, 115, 2047.
Abramowicz-Reed, L. 1997, *private communication*.