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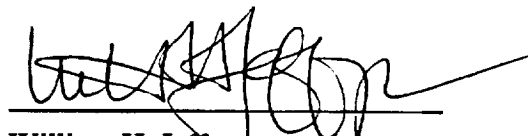
Sixth Semi-Annual Progress Report  
NASA Grant NAG5-1603  
Hubble Space Telescope GTO Program  
Astrometry Science Team

1994 January 1—1994 June 30

Prepared for  
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### Meetings and Travel

STAT meetings were held on January 27 in Austin, TX and on 20 April in Charlottesville, VA.

Benedict attended Servicing Mission Science Working Group meetings at GSFC on 2/17/94 and 5/20/94.

Benedict organized the Astrometry Mini-Symposium, which was held at STScI 21 April 1994.

Benedict attended the AAS Division on Dynamical Astronomy meeting held 28-29 March 1994 in Kingsville, TX. He reported on our Proxima planet search and on a dynamical study of NGC 4314.

Benedict, McArthur and Wang attended the 184th AAS meeting (Minneapolis, MN) to present reports on our planet search, software development, and calibration efforts.

Hemenway continued on his "research sabbatical" at the University of St. Andrews, St. Andrews, Scotland. He maintained his active participation in the HST Astrometry Science Team and in the observation and reduction of the GTO program with Duncombe to tie the Hipparcos reference frame to extragalactic objects, as described above.

Hemenway attended a Hipparcos Project meeting in Hamburg at the end of March, where he presented the current status of the HST program to tie Hipparcos to extragalactic objects. The presentation was done in collaboration with Mario Lattanzi at STScI. The status of the reduction of Hipparcos data to the final catalogue was discussed, with a projected completion of the end of 1995. The HST data must be reduced and provided to the Hipparcos project in final form by June 1995. JPL has been given the task of making the final tie solution using all available data types. To this end, we are collaborating with the JPL personnel to insure that their models adequately take into account the nature of the HST data. Their models will be such that they can be run with HST data only to compare our solutions with theirs (See the discussion of Andrew Lalich's Master's Thesis later in this report.)

### Calibration

Benedict continues to monitor the scale stability of HST FGS 3 astrometry with Proxima Centauri field monitoring and Long-term Stability Test (LTSTAB) data. Shortly after the servicing mission we detected a large change in the scale-like parameter,  $\rho_A$ . We also determined that a delta-OFAD would be required to restore our 2 mas-precision astrometry capability.

Whipple worked primarily on the analysis and modeling of the distortions present in the FGS. He wrote the proposal for the delta-OFAD calibration that was run on 27 April 1994 and has worked with other members of the Astrometry team on the analysis of these data. Wang, Whipple, McArthur, and Jefferys are continuing their efforts to derive a time dependent model for the FGS distortions.

Shelus has been working with HDOS to try to invent a new way of looking at the lateral color data, which are still puzzling and difficult to understand.

## GTO Program (Texas)

### *Planetary Companion Search*

Benedict leads the team's efforts to discover planetary companions orbiting Proxima Centauri and Barnard's Star. On 4 May 1994, we obtained the last of 48 observation sets for Proxima Centauri. As of 15 May 1994 we have obtained 13 of 25 total sets for Barnard's Star.

The Proxima Centauri observations show that the precision of a single observation is at or below 2 MAS (RSS of x and y) for stars located in the center of FGS 3. Parallax and proper motion precision are 0.0004 arcsec and 0.0004 arcsec/yr respectively.

Photometric results for the first 200 days of Proxima Cen monitoring indicated a 40 day photometric period, likely due to rotational modulation of bright or dark star spots. Subsequent observations over 400 additional days strongly suggest an 80 day period. A possible interpretation is that a spot group disappeared from the surface of Proxima Cen.

As for the planet search, with 48 observation sets we continue to find a suspicious peak near 77 days in the periodogram for both the x and y residuals. Until we have exhausted all possible instrumental and systematic effects, the 77 day variation is only possibly (20-30% false positive) a planet with mass of Jupiter. Benedict continues groundbased collaborative efforts to 1) confirm the photometric periodicity of Proxima Cen, and 2) detect radial velocity variations. These could be as great as  $\pm 170$  meters per second, should the planet actually exist.

### *HST Hipparcos Extragalactic Link Data:*

We continue to make observations of the separations between Hipparcos stars and extragalactic objects with the FGS astrometer. The first observation was made in April, 1993. To date we have obtained 13 GTO and 62 GO observation sets. The data through the end of 1993 was completely reduced, but will have to be re-reduced with the following calibration changes when they are available: a time-variable OFAD, including lever arm drift, a more accurate plate scale, and a cross filter calibration for the neutral density filter. The data through day 64 of 1994 are partially reduced. The remainder of the 40 GTO hours allocated to this project are scheduled for Cycle 4, and should produce a significant number of separation changes (proper motions) at the milliarcsecond level of accuracy. Two observations of the same pair observed 14 days apart yielded separations within a milliarcsecond of each other. Dr. E.P. Bozyan of the University of Rhode Island continued to analyze and characterize the Hipparcos Link FGS data. She finds that bright non-VLBI and faint ( $V > 16.0$ ) fail acquisition, in general. Analysis by Nelan (prompted by the minor planet work) indicates that the walkdown length is insufficient to reach the main null of the S-curve, but gets to the first "dip." For bright objects, the first dip is sufficient to trigger fine lock, but for fainter objects it is not and the target suffers from "scan step limit exceeded" and is not acquired in fine lock. A change in the uplinked parameters (the course track-to-fine lock bias) will move the walkdown position over the main S-curve null, and we expect to get lock on our fainter targets.

### *Preliminary Hipparcos data from 30 month solution.*

In the Hipparcos Link Project, we have 87 Hipparcos star-extragalactic object pairs. We have received preliminary positions and proper motions with milliarcsecond accuracies for 72 of the Hipparcos stars in our list. These data are being used for initial coordinate frame system solutions and for testing the veracity of the HST data.

### *Lalich Thesis*

Andrew Lalich, supervised by Duncombe and Hemenway, has been processing the Hipparcos Link Data. He has also been working on his Master's thesis, with the expectation of finishing by the summer this year. His main contributions to the programs include setting up an extensive series macro spreadsheets on the Macintosh to process our HST data, adding Hipparcos Parallax to the data analysis, adding the FGS plates scale as a parameter to the overall solution, and incorporating extragalactic targets with non-VLBI positions into the solution for the time variable rotation only. The large positional uncertainties of non-VLBI targets are removed by considering the separation *changes* only, thereby eliminating the errors in position. The computed changes in separation come from the accurate Hipparcos proper motions.

#### *Hipparcos Plate Scale.*

Included in the data for the Hipparcos Tie are observations of two Hipparcos stars in the Pickle at the same time. The first of these observations, on 1993 day 200, yielded a separation which coincided with the separation of the Hipparcos stars from the preliminary Hipparcos reduction data to 0.004 arcseconds, which is entirely consistent with the errors of both the HST observations and the preliminary Hipparcos data. The separation was of the order of 275 arcseconds.

#### *Minor Planet Plate Scale*

Mailoux and Kloepper ran ephemerides of minor planets 1474 and 1626 for observation with the FGSs to determine the plate scale of the astrometer FGS 3 to an accuracy of a milliarcsecond over the length of the pickle. Hemenway, Kloepper, and Mailoux prepared the proposal for the observation of minor planet 1626 in July. Nelan checked the proposal and the commanding system to optimize the proposal and the FGS uplink parameters to give the best chance of success given our current knowledge of the FGSs. Alex Storrs and others at STScI spent considerable effort to put the proposal into the system in a timely fashion to be observed in July. The observations are scheduled for July 9/10.

#### *David Lee's Senior Project.*

Hemenway supervised the senior project of St. Andrews undergraduate David Lee. The project was to determine the astrometric capability of the Gregory Telescope in St. Andrews, with respect to measuring asteroid positions for HST plate scale calibration. Lee showed that the CCD on the telescope is capable of relative astrometric accuracies of the order of 0.1 to 0.2 arcseconds, and may be used in the future for astrometric observations of minor planets. The M35 OFAD data from the FGS astrometer calibration was used in the study as an astrometric standard region.

### **Software**

McArthur's primary activities have been reduction of the HST data, including maintenance and improvement of the pipeline. She has also assisted in maintaining GaussFit, as well as providing OFAD reduction, LTSTAB and Proxima, including special reductions and statistical analysis services.

McCartney translated the Pickles class library from Smalltalk to C++. Pickles currently has 69 classes of its own plus about 70 from the Power Plant class library. The new version compiles under Metrowerks C++ compiler and is 70% complete now.

## Subcontractors

### *Lowell Observatory*

Franz and Wasserman devoted most of their effort during this semiannual report period to the reduction and analysis of post-SMOV FGS TRANS data obtained under the following proposals:

#### *Proposal 4892: Search for duplicity among faint Hyades stars*

Thirteen post-SMOV scan sets for eleven targets were analyzed with the use of color-calibrated single-star transfer functions derived from post-SMOV scans of Hyades members previously identified as "single." Among these eleven targets we found three certain "new" binaries and one probable binary yet to be confirmed. The total of certain detections now stands at 8 binaries among 26 Hyades cluster members examined under this proposal. Fourteen targets remain to be investigated.

#### *Proposal 5174: Astrometric Companion Search*

The aim of this proposal is the direct detection, at visible wavelengths, of astrometric ("unseen"), low mass companions to six nearby M dwarfs. Among four objects observed during the report period, we have detection, confirmation, and reconfirmation of the predicted astrometric companion for the following three targets:

$$5174\_1 = \text{BD}+67.552$$

$$5174\_2 = \text{AC}+48.1595-89$$

$$5174\_3 = \text{W922}$$

Other activities during the report period included:

Presentation of a paper on binary star investigations with HST-FGS in the TRANS-mode at the AAS-DDA meeting at Kingsville, TX.

Presentation at the Minneapolis AAS meeting of a poster paper on the detection of binaries among faint Hyades cluster members from pre-SMOV TRANS-mode observations.

Preparation (and acceptance) of four abstracts on various aspects of the Faint Hyades Binary Search for presentations at the ESO Workshop "The Bottom of the Main Sequence—and Beyond" to be held at Garching 8-10 August 1994, and at the subsequent IAU General Assembly.

### *University of Virginia*

A few frames on the southernmost targets were taken in early and late January at Siding Spring Observatory while on two observing runs for a different project.

Considerable time was spent preparing for the STAT presentation at the Space Telescope Science Institute in April.

In the same time frame and running into May we had to redo the guide star selections for the six astrophysically interesting targets. This involve remeasuring a few plates and

entering the data into preexisting Pickles files. This made the final selections less time consuming.

Most of the time during late May and all of June has been spent reviewing research notebooks in search of binary stars that will yield useful data from HST astrometric observations. For example, there is a well observed double lined spectroscopic binary of very early spectral type (O5V+O5V) which may be close enough to yield an orbital parallax and hence the individual masses. There are no accurate masses for stars of such early types on the main sequence. A list of 15 possible binary systems has been compiled so far.

### *Yale University*

#### *GTO Globular Cluster Internal Motions*

Image reconstruction has been started on the Planetary Camera exposures of M15 by T. Girard and Y. Li. Reconstruction improves both the detectability and precision of the image centers. A preliminary exploration of the modeling of the distortion across the PC field was also made using the multiple, overlapping exposures. Results have been reported on the 67th STAT meeting at STScI on April 21 and the 68th meeting at Austin on July 8, respectively. A poster paper "Differential Astrometry with the HST Planetary Camera" was presented at the 184th AAS meeting at Minneapolis in June.

#### *GTO Hyades Cluster Member FGS Parallaxes*

The second epoch March observations were made of the Hyades after some last minute help by our superb technical support friends at the STScI. X. Guo obtained the output data of the pipeline preprocessing and looked at the behavior of the checking stars and the RMS of the solutions in both X and Y for each field between the 2nd epoch observations (March 1994) and the 1st epoch observations (September 1993). On the checking stars, positional drifts of different check stars in a same field are some time inconsistent. The difference is probably caused by time and position dependent errors. We have to look into the coordinate drift issue in detail in future. The typical RMS is about  $\pm 8$  MAS, while the Y solutions seem to be better than the X solutions. Since the solutions are between two epochs before and after the servicing mission and the OFAD is different, we will look at the RMS again when the revised OFAD is installed in the pipeline.

#### *GTO Parallel Observations*

A catalogue of the GTO Parallel observations made with the HST WFC continues to be archived at Yale by Graduate student R. Mendez.

#### *Fixed Head Star Trackers*

Work on the FHST Waffles Catalogue has continued with the goal of improving the accuracy of the data in the catalogue and removing the duplicate entries. Research Assistant Y. Li has removed the duplicate entries in the catalogue, and replaced all of the existing data with improved accuracy data where available. D. Hoffleit and Research Assistant R. Koopmann are examining in detail several thousand probable duplicate entries to determine if they are duplicate entries or separate stars. The positions and proper motions in the FHST Catalogue have been replaced in order of preference by data from the FK5 and Supplement, IRS, ACRS and PPM, while the magnitudes, colors and spectral types have been updated with data from the Hipparcos Input Catalog and new UBV photoelectric photometry. A new release is being prepared for inclusion in J. McCartney's Waffles program. Y. Li also improved the Annex file which mainly contains information on the

duplicity and variability of stars in the Catalogue with the WDS (of the latest version) and GCVS, NSV.

Mendez has successfully expanded his model of the Galaxy to compute the brightness distribution at low galactic latitudes. The data will be used to search for coincidences in the failure of the FHST as a function of the integrated brightness of the background. Great effort was made to improving the algorithms and data base for dealing with interstellar reddening and absorption, both of which are critically important in the galactic plane. 6 low Galactic latitude GSC plates were extracted to test his model. At least for 5 plates, the prediction in star count of model to observation is very good, while the remaining one might have a problem in measurement due to crowdedness.

#### *Hipparcos Link to the Extragalactic Reference Frame*

At the request of the Hipparcos Project, we have undertaken to establish the preliminary Hipparcos link to the groundbased absolute proper motions with respect to galaxies. The Lick Observatory Northern Proper Motion program and Yale-San Juan Southern Proper Motion Program data will be combined to yield about 6000 NPM and 1000 SPM absolute proper motions of Hipparcos stars. Upon receipt of the Hipparcos data, I. Platais and T. Girard started to rereduce our SPM data in about 1000 square degrees around the South Galactic Pole in order to better define the plate constants. Use of the remarkably accurate Hipparcos positions has allowed us to determine the higher order plate constants with greater confidence and that should result in more systematically correct absolute proper motions. The absolute proper motions derived from those improved plate constants will then be used to establish the Hipparcos link to the groundbased absolute proper motions with respect to galaxies.

### The Mini-symposium

The team presented on 21 April 1994 a series of brief reports of work in progress to many of the people who have over the years enabled astrometry with HST. Here is a list of those reports.

**Astrometry with Hubble Space Telescope  
A mini-Symposium  
Space Telescope Science Institute Auditorium  
21 April 1994  
1:30-4:30 PM**

FGS Performance Characteristics	E. Nelan and D. Story
Plate Scale Status Report	M. Lattanzi and L. Taff
Maintaining the Astrometric Calibration of FGS #3	W. Jefferys and G. Benedict
Millisecond of arc double star astrometry with HST	O. Franz
Incidence of Duplicity in the Hyades	O. Franz
Crowded field Astrometry with an HST Fine Guidance Sensor	M. Lattanzi and L. Taff
Astrometry with the HST Planetary Camera	T. Girard and Wm. van Altena
The HIPPARCOS/Extragalactic Tie-in: Status Report	R. Duncombe and P. Hemenway
Parallaxes of Astrophysically Interesting Objects— The Six we Picked and Why	L. Fredrick
HST: A Generator of sub-millisecond of arc Parallaxes	G. Benedict
A Planetary Companion to Proxima Centauri: Status Report	G. Benedict
Poster: GaussFit—a Modeler's Tool	B. McArthur
Poster : Pickles—a Graphical Observation Planning Tool	J. McCartney