Kitt Peak Speckle Interferometry Program Database Generation

Alex S. Teiche
California Polytechnic State University, San Luis Obispo

Abstract During our fall 2013 run on the Kitt Peak 2.1-meter telescope, we gathered over 1000 speckle measurements of double stars. These observations occupy roughly 1.3 terabytes of disk space. This paper describes the current format of the database, the process used to produce it, and makes format and database recommendations for future speckle interferometry programs of this scale.

Introduction

At Kitt Peak in October of 2013, we made over 1000 observations of double stars, resulting in roughly 1.3 terabytes of FITS cubes. Separately, we logged the TCS (Telescope Control System) information in a text file along with the catalog number of the object observed.

This information was merged into the headers of the FITS cubes to make it easier to access, particularly during automated data processing and reduction. An Excel spreadsheet was then generated with one entry per observation, containing all relevant information from the FITS header and TCS log.

Database Layout

The database is separated into 4 folders, "*Cubes*", "*Merge_Logs*", "*Other*", and "*Pictures*". The "Cubes" folder contains all FITS data collected. This is further divided into "*Calib*" and "*Observations*". "*Calib*" contains all camera calibration data taken, including flat fields, dark frames, and drifts. "*Observations*" contains all observations, including both double stars and single stars. The FITS cubes in the "*Observations*" folder have been renamed to place the sequence number first (Andor SOLIS places it last by default). Also, the TCS data has been merged into their FITS headers.

The "Merge_Logs" folder contains notes from merging TCS logs into FITS headers. There is a list of all the FITS cubes for which a matching TCS log could not be found (*cubes_without_tcs.txt*), a list of all incomplete TCS log instances(*incomplete_tcs.txt*), a list of FITS cubes renamed (*cubes_renamed.txt*), and a list of all changes made to the TCS logs (*tcs_log_changes.txt*). The list of FITS cubes renamed is in the format of a UNIX shell script, and could be run on a folder containing untouched FITS cubes to reproduce the filename changes. These changes were due to a variety of causes, most frequently a misspelled HIP or WDS identifier.

The "*Other*" folder contains strut temperature logs (copied from Kitt Peak's rose system each morning), an untouched copy of the TCS logs, and files from a CCD sensor linearity test conducted during the run.

The "*Pictures*" folder contains pictures taken by several people on the run. Also present in the root folder is an Excel spreadsheet (*KPNO_DB.xls*), and this document. The Excel index contains one line per FITS cube, and has all the relevant information from the FITS headers, as well as all the information about the target contained in the Washington Double Star Catalog**.**

Spreadsheet

The spreadsheet has 43 pieces of information for each FITS cube, in addition to the FITS cube file name. The first seven columns contain the information necessary for automated data reduction. A description of each follows:

DS – Double or single star. The only valid values are D for double star and S for single star.
DSFN – Double star file name.
RSFN – Reference(single) star file name. They were selected using the algorithm described below.
Lstθ, Lstρ – Most recent measurements of theta and rho.
CA – Camera angle, in degrees.
PS – Plate scale, in arc-seconds per pixel.
Target – The target identifier number, with a preceding catalog identifier for all cubes except WDS cubes.
Type – The type of object observed. Possible options for this particular run were WDS, HIP, GH, and LH (all abbreviations for catalogs), and NOTCS (no telescope control system data).
TCS RA, TCS Dec, RO, DO – Precision pointing information with RA and Dec offsets from the telescope control system. RO and DO are measured in arc seconds.
TCS Time – Mountain Standard Time as reported by the TCS.
Focus – Primary focuser position as reported by the TCS, measured in microns. This value is likely not meaningful, as the visiting instrument had its own focuser (Moonlite Crayford-type) that was set twice during the run.
ZD – Zenith distance, as reported by the TCS in degrees.
I – Integration time specified in the Andor SOLIS FITS header, reported in seconds.
Gain – Electron-multiplier gain specified in the Andor SOLIS FITS header. It is a unitless value between 0 and 1000.
FITS Cube Time – GMT of the acquisition of the first frame in the FITS cube, specified in the Andor SOLIS FITS header.
DC – Discoverer code and number.
Comp – Components, when more than two are present.
First, Last – Year of first and last observation.
No – Number of observations.
Fstθ, Fstρ – First measurement of theta and rho.
Mag1, Mag2 – Magnitude of primary and secondary star, respectively.
Spectral 1, 2 – Spectral class of primary and secondary, respectively.
PRA, Pdec – Primary proper motion in RA and Dec.
SRA, Sdec – Secondary proper motion in RA and Dec.
DM, N, B, C, – Durchmusterun number, notes, differential magnitudes, orbital or linear solution.
Decimal RA + Dec – Precision RA and Dec in decimal format (J2000).
RA, Dec – Precision RA and Dec in traditional format (J2000)**.**
ROI – The four ROI columns contain the region of interest information found in the Andor SOLIS FITS header. The format of this information is currently unknown.

Merging TCS Data

The TCS data includes local time, telescope RA and Dec, RA and Dec offsets, epoch, focus, zenith distance, equinox, and the name of the telescope. This data along with the target (manually entered by the person recording TCS logs) was added to the FITS header for each cube. Comments as they appear in the TCS system were copied to corresponding FITS header comment fields. TCS data was added to the FITS header in a field using its TCS name prefixed by "TCS_". In situations where this resulted in a field name over 8 characters, a HIERARCH card was added to permit the longer name.

On the 2.1-meter telescope this data is exposed through a network socket on a machine named "rose." We accessed this data using the Windows telnet program, and manually copy/pasted it into Notepad (along with the object name) for each observation.

Each time the telescope was slewed to a new target, the telescope operator would call out the name of the target. The camera operator and TCS logger would each record this information, and the camera operator would alert the TCS logger as soon as the exposure was started. No data to correlate individual FITS cubes to TCS logs was recorded other than timestamps.

As the Andor SOLIS software used to record FITS cubes does not have support for adding arbitrary FITS header fields, the TCS logs had to be added to FITS headers after the fact. The author wrote a Python script to match FITS cubes to TCS log instances, and merged the data. The STSI PyFITS library was used to modify the FITS files.

First, the data was separated into groups by night and processed individually. The script then iterated through each FITS cube, generating a list of all TCS logs from the same target.

This was determined by searching for the target name (manually entered by the TCS logger during the run) in the filename of the FITS cube. In most cases this was a 1:1 correlation, and TCS data could be written to the FITS cube.

In cases where a target was observed more than once on a given night, the TCS log instance with the closest time stamp was used. Unfortunately, as the FITS and TCS time stamps were generated by two different computers (Kitt Peak's rose and the laptop running Andor SOLIS), there was significant deviation even for cube/log pairs that were known to be correct. A cube/log pair with a time difference of less than one hour was considered a "good match", and the TCS log instance was flagged to prevent multiple cubes from being matched to it. All matches with a time difference greater than one hour were skipped at this stage and handled later.

After all "good matches" were found, the program iterated through the remaining cubes and found the closest match (among both matched and unmatched TCS instances). The script recorded these in the FITS header with a note explaining that the TCS log merged was from a different cube, and named that cube.

After the first run through, there were 126 unmatched FITS cubes. A variety of factors caused this, the most common being two numbers switched in the target name (either in the FITS cube file name or TCS log), prefixing a double star with WD instead of WDS, or a number missing from the target name. Most of these were manually corrected by searching for other cubes with the same RA/Dec, and in the end only 22 cubes were left unmatched. All changes made to TCS logs or filenames were logged in the "*Merge_Logs*" folder.

Assigning Single Deconvolution Stars to Doubles

The suitability of a reference star to a double star for deconvolution depends on many factors, related to both the object itself and the observations. Important properties of the two observations include their relative difference in air mass, parallactic angle, atmospheric dispersion, and time of measurement. Important properties related to the objects are spectral class and relative position. As the observations were roughly 90% double stars and 10% single stars, an algorithm to select single stars based on all these criteria would have been impractical.

Instead, the best single star for each double star was selected solely based on time between observations and difference in declination. It was assumed that if two objects are physically close and observed at similar times, their relative air mass, zenith distance, and parallactic angle would all be within reasonable limits. The parameter for selection for a given double star was the closest single star (compared in Dec only), observed within three hours of the double.

Conclusions and Recommendations

While some human errors were expected, almost 10% of the data we collected had a naming error. This drastically complicated the merging process, and required significant human intervention to fix. Uncorrected, these errors could have resulted in a significant amount of unusable data.

There are a number of ways this could be prevented in the future. One easy way is decreasing the number of steps it takes to save FITS cubes. On this run, we saved data into folders by night, then by sections of the sky (two hours in RA and 20 degrees in Dec). In the future, we could save all cubes to one folder, and automate the process of separating by night or sky-region.

Acknowledgments
A special thanks to Russ Genet for inviting me to observe at Kitt Peak, to everyone present on the run for a wonderful experience, and to Kitt Peak National Observatory for providing time on their telescope. This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory. PyFITS is a product of the Space Telescope Science Institute, which is operated by AURA for NASA.