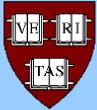# The DASCH Data Processing Pipeline and Multiple Exposure Plate Processing

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Introduction

The Harvard College Observatory plate collection consists of approximately **530,000 photographs** produced by over 80 telescopes spanning over **100 years** from about 1885 to the 1992. The goal of the Digital Access to a Sky Century @ Harvard (DASCH) project is to digitize this entire collection and provide photometry measurements for all images. With the successful completion of a high speed plate digitizer we have digitized over **10,000 plates**. The analysis of this digitized data presents a number of challenges which are no longer encountered with modern CCD photographic techniques. One of these challenges is to extract accurate photometric and astrometric data from multiple exposure plates.
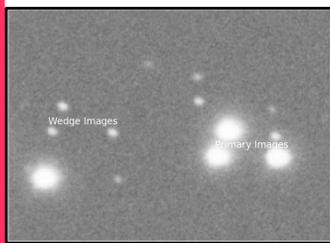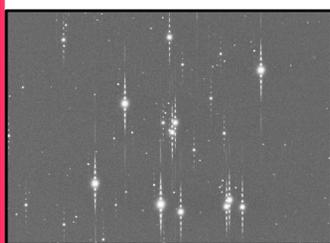
Multiple Image Plates
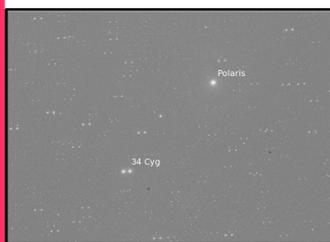
Superposition of two fields to calibrate stars in Cygnus with the North Polar Sequence. See the **Multiple Exposure Loop** for more details.
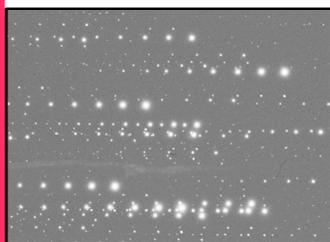
Extension of dynamic range using nine exposures with each successive exposure half the duration of the preceeding exposure.

Ghost images produced by a Pickering or Racine Wedge. See the **Pickering Wedge** section for more details.

Low dispersion images produced by a coarse grating placed in front of the telescope objective. The geometry of the grating determines the relative brightness of the images.

Number of Multiple Exposure Plates

Logbook transcription has been completed for only 40% of the collection to date. These transcriptions show that approximately 2.6%, or over **13,000 plates**, are multiple exposures. Coarse gratings are less frequent with only 100 known grating plates. Unfortunately, the logbooks make no systematic mention of the use of Pickering Wedges.

References

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J. Grindlay et al. "DASCH to Measure (and preserve) the Harvard Plates: Opening the ~100-year Time Domain Astronomy Window", Astronomical Society of the Pacific Conference Proceedings, Volume 410, page 101-110, 2009

S. Laycock et al., "Digital Access to a Sky Century at Harvard. II: Initial Photometry and Astrometry", AJ, Volume 140, Number 4, November 4, 2010

S. Tang et al., "DASCH Discovery of Large Amplitude 10-100 Year Variability in K Giants", ApJ, 710:L77-L81, 2010 Feb 10.

M Servillat "Correcting the Astrometry of DASCH Scanned Plates", A companion paper presented at this ADASS conference.
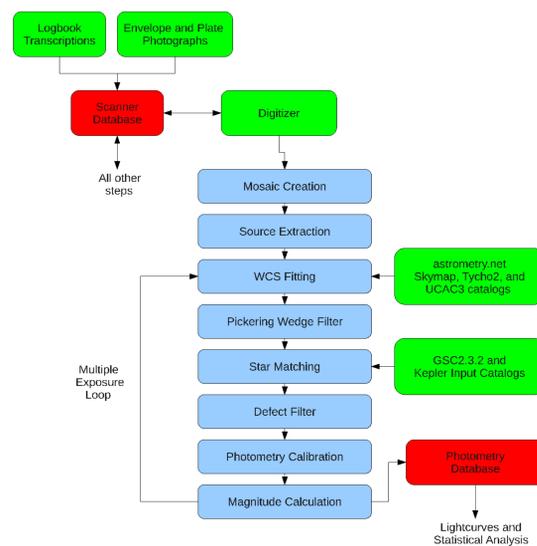
The DASCH Photometry Pipeline

- The digitizer produces 45 mm square tiles, 60 of which are aligned geometrically to produce a typical 200 x 250 mm mosaic.
- **SExtractor** extracts the images and provides PSF parameters.
- **Astrometry.net** determines plate centers with a 99.75% success rate.
- **WCSTools** provides further refinement of plate centers and scale.
- **IRAF/ccmap** and now **SCAMP** account for distortions of the original telescope optics.
- The whole-sky **GSC2.3.2 catalog** provides reference positions and magnitudes. Where applicable, the **Kepler Input Catalog** provides better calibration standards.
- PSF parameters of catalog-matched stars help identify emulsion defects
- Piecewise-linear weighted (**lowess**) fitting determines a unique instrumental vs catalog magnitude curve for nine annular regions of each plate independently of all other plates.
- An additional magnitude correction applied on 50 x 50 rectangular grid elements provides correction for non-uniform emulsions and development.
- The lowess calibration curves and local corrections determine the magnitudes of all images on the plate from their SExtractor isophotal magnitudes.

The Multiple Exposure Loop

- To find multiple exposures, **rerun the pipeline** with any **unmatched images**.
- If an image from one exposure overlaps an image from another exposure, flag the two different catalog matches as "**blended**" if the total catalog flux changes the brightness by more than 0.1 mag
- After the last exposure has been found, any remaining unmatched images always have an **uncertain exposure date**.
- Abort the loop if the new plate center is too close to previously known plate centers.

The DASCH Database

- Implemented primarily as **MySQL** tables.
- Contains digitized logbook entries for determining exposure date
- Tracks the scanning and photometric pipeline workflow
- Contains plate WCS parameters to allow searches for plates containing given objects.
- **Binary files** allow rapid retrieval of lightcurves with a spatial index consisting of **1/4096 square degree rectangles** aligned to RA and Declination coordinates.
- Currently contains **10**9 magnitudes**, including measurements of **43x10**6 GSC2.3.2 catalog stars**.
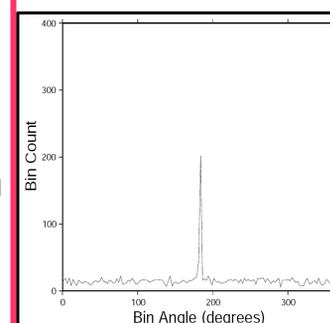
The Pickering Wedge Filter

The Pickering Wedge is a low-dispersion prism placed near the telescope objective to create **ghost images for more accurate photometry** when the primary images saturate. A spatial correlation technique described below allows identification of Pickering Wedge ghost images. We discovered that this technique works well for ghost images believed to have been caused by **misaligned telescope optics**.
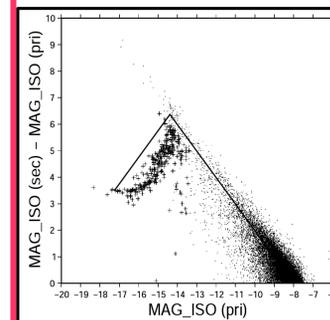Although not currently implemented, this filter combined with the multiple exposure loop could process **grating images**.
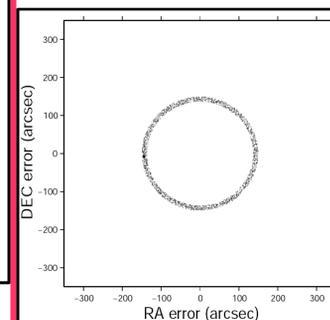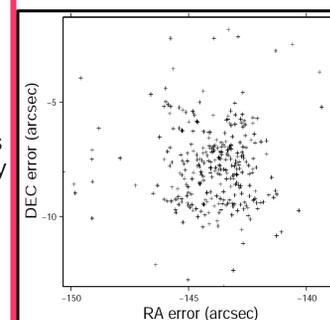

Overlay annuli surrounding 300 brightest images. The radius depends on measurements of previously known Pickering Wedge plates.

A single peak indicates a Pickering Wedge. A dual peak indicates a grating.

A plot in magnitude space separates the population of wedge images from field images.

The final plot of selected wedge objects show that wedge positions vary slightly across the plate.

Results

We have implemented multiple image detection techniques which increase the usefulness of many plates for the discovery of flares, novae, and asteroids.

- The multiple exposure loop has successfully identified as many as **six individual exposures** on a single plate.
- Our current best estimate is that the procedure can correctly identify **31%** of double exposures and **18%** of triple exposures.
- We found **481 plates** which showed more solutions than transcribed logbook entries.
- The Pickering Wedge Filter flagged **784 of 10,000** scanned plates.