A Comparative Analysis of Glass Plate Digitization Methods: Methods Motivated by Stellar Variability

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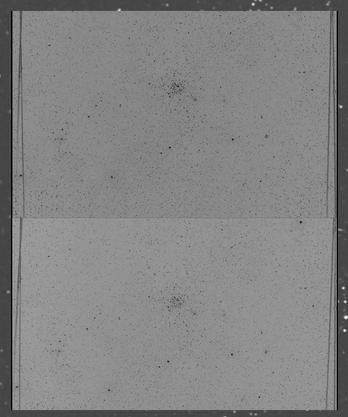
While many of the > 150,000 plates stored at Yerkes Observatory are on the scale of 3”-12”, much of the remaining glass plate media are not suited for digitization by a commercial scanner. To combat this issue the Yerkes Glass Plates Digitization Group has been testing the use of an affordable Canon DSLR camera. Paper II demonstrated our Epson scanning method on Plate 8 of E.E. Barnard's *A Photographic Atlas of Selected Regions of the Milky Way*; we have chosen to test our camera methods on the same plate. Plate 8 was chosen for its relatively low star density, which enables straightforward analysis.



Above: Plate 8, digitized via Epson (top) and Canon (bottom)

Methods

Epson: The inner 6x6 in. are scanned at 1200 dpi.
Canon: The image is photographed in the center at a size that results in a reasonable arcsecond per pixel value. This image was taken with a shutter speed of 1/50s and an aperture value of 6.

In the manual analysis, the FITS files are solved by astrometric software for coordinates. The image is then transformed with derived transformation equations, and sources are identified and cataloged in APT.

Scanner

Pros:
- Precise
- Less vulnerable to human error

Cons:
- Limit < 12 in., flat media
- Complex astrometric errors

Camera

Pros:
- Portable
- Can photograph a wide array of media

Cons:
- Complex settings
- Small area of capture

Pipeline

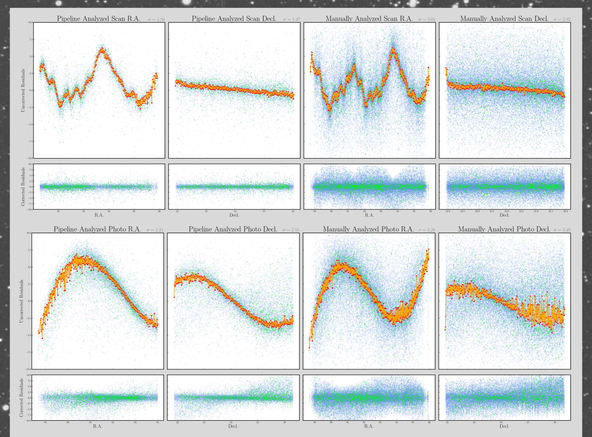
In the past year, we have improved on our methods in three ways:

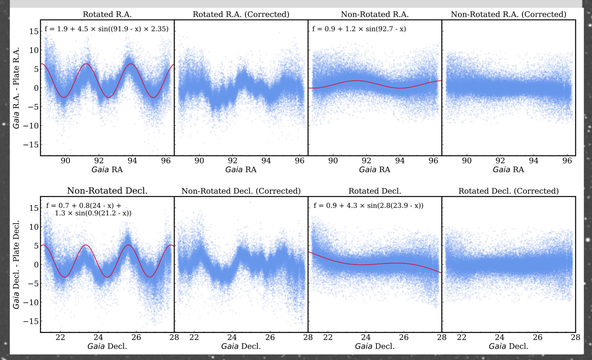
- **Efficiency:** We have begun to create a pipeline which receives a TIFF plate scan or CR2 RAW photo and produces a transformed FITS image with a WCS solution and a matched source catalog. Processing each plate to this point takes ~30 minutes by hand. The pipeline reduces this to ~5 and removes the need for frequent human intervention.
- **Astrometry:** The pipeline includes an advanced form of wiggle correction. (see below)
- **Photometry:** We can use the pipeline to compare photometric values to SDSS frames. The low PSF of galaxies works effectively with this method, but stars can work in fields without galaxies (e.g., Plate 8.) This streamlines transformation.

Wiggle Correction

Our new correction method uses KDE binning to fit a spline to the astrometric residuals. The data is separated into distinct bins of a manually-chosen size and the mode is found for each bin. These modes are connected and smoothed by a spline and then subtracted from the data. In Paper II, we obtained SDs of 1.85 for each coordinate with a by-eye analysis. With this method, we find comparable SDs in the 2-3 range for much more complex wiggles.

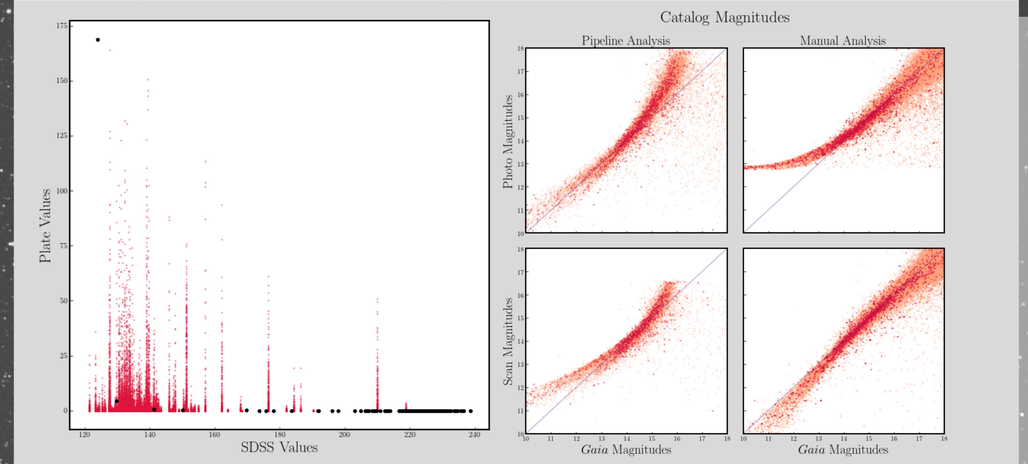
Top Right: Novel wiggle correction method for a) Epson and b) Canon. The green dots represent confirmed variable stars **Bottom right:** Previous method performed on Epson.





Transformation Calibration

Our new calibration function allows us to find a transformation equation for the image more efficiently than our previous trial-and-error method.
This method compares SDSS frames directly with our images and fits the comparison with a logarithmic function, providing the general form of the transformation. This function tries multiple objects on the image to find the best-fitting equation.



Left: Figure used to calibrate the Canon image. The black dots represent the transformed values. **Right:** Comparison of results from the pipeline and manual method with Gaia DR3. While the pipeline does provide an effective transformation, improvements are necessary.

Stellar Variability

Our group is particularly interested in the study of variable stars, as 1) glass plates cover a great time range of astronomical data, and 2) variable stars provide a comparative estimate of our methods' effectiveness. In the image above, we demonstrate the use of the Epson, Canon, pipeline, and manual methods on all the confirmed variable stars on Plate 8.
As our methods become more precise we can better identify variable stars by their deviation from a 1-to-1 magnitude correlation to present-day values. If we assume variable star magnitude ranges are normally distributed, even small improvements in our SNR can greatly enhance our ability to calibrate plate magnitudes and identify variable stars.

Conclusion

With a better understanding of various methods of digitization, we look forward to digitizing the other plate media that is inaccessible to the scanner (e.g. bent, large, or broken plates.) Additionally, as we continue to update and perfect our analysis methods we hope to use the pipeline to begin digitizing photographic survey plates at a greater volume.
For more about the Yerkes Glass Plates Group Digitization Project see our previous papers:

- Paper II: *Photometric Measurements and Analysis of a Barnard Atlas Photographic Plate Using a Commercial Scanner*
- Paper I: *Precise Photometric Measurements from a 1903 Photographic Plate Using a Commercial Scanner*

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