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Applying Historical Observations to Study Transient Phenomena

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Abstract. Astronomy has an enviable wealth of historical observations. Some verge on the archaeological, and display rare events such as novæ and supernovæ; others range up to 100 or more years in age, and bear unique information about events that will never repeat in detail. Yet most astronomers today know little of those resources and the scientific potential which they harbour, so rather infrequent use is made today of those historical data. The problem is that historical data were perforce obtained in analogue formats, and because of those formats the data too tend to be regarded as hailing from a culture whose scientific significance is passé. But *the medium is not the message!* Astronomy's archives of photographic observations constitute an irreplaceable resource. The change in technology from analogue to electronic recording in the late 20th Century was abrupt, and it left most of today's astronomers unable to handle and use photographic data, and led to a general skepticism of the value of photographic observations for present-day studies of variability in the cosmos. But that is precisely what older data can do; in particular, the older the data the more reliable the base-line against which one can measure new trends, refine orbital parameters, discern period modulations, etc.

Keywords. instrumentation: detectors – astronomical data bases – surveys – stars: variables – stars: long-term variability

1. Background

Astronomy has an enviable wealth of historical observations, mostly ranging up to 100 years or so in age. Some verge on the archaeological, and display evidence of rare events such as novæ and supernovæ. All bear unique information about transient events that may never repeat, or not exactly, in detail. Yet most astronomers today know little of those resources and the rich scientific potential which they could tap.

The problem is accessibility. Historical data were recorded in analogue formats, and in the present era of born-digital data they are regarded as hailing from a culture whose scientific significance has been completely overtaken by that of modern data. This is a serious misrepresentation of the facts; our archives of photographic observations are irreplaceable, and constitute an invaluable resource†. The technology change to electronic data in the latter half of the 20th Century was abrupt and in some ways cathartic, but it left most of today's astronomers unable to handle photographic data, let alone to appreciate the feasibility of including "old-fashioned" technological output in the service of research. True, photographic observations suffered from low DQE and relatively low time-resolution, and the application of electronic detectors, in particular the ability to observe fainter objects than before and (more recently) to resolve with sufficiently high time-resolution so as to detect very rapid flickerings, opened up new vistas in research, *but they cannot look backwards in time.* Not all astrophysics can be conducted with

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† The fact that the whole of classical astrophysics was based upon photographic observations has been forgotten. There has not been a perceived need to re-do everything with CCD data

sufficient thoroughness, or even meaningfully, on the basis of observations that span less than 20–25 years.

2. The Need for an Action Plan

Our photographic observations have the potential to contribute unique information to *present-day* studies of variability in the cosmos. Furthermore, the older the data, the longer (for *longer*, read *more reliable*) the base-line against which one can measure new trends, determine orbital parameters, discern period modulations, assess changes and distributions of features on the Sun, and so on. But all analogue data are vulnerable to damage and destruction, and the older the data, the more will they *and their supporting documentation* have already been subjected to the ravages of time, vermin and natural hazards. Non-digital data must therefore be regarded as “data at risk”, and should be an Action Item on every observatory’s agenda.

This problem will not evaporate by our continuing to do nothing. Discussions have been under way for some time as to how best to rescue that historical information from becoming impaired as the plates age, or (in some cases) get discarded “for lack of interest”, but it always comes back to the same road-block: the competition for funding between new hardware that promises to break new ground, versus allocating even relatively small amounts to re-visiting an outdated technology. What is needed first is a strong propaganda campaign that demonstrates the contributions that historical data have already made, and will continue to make, to modern studies of transient phenomena. In 2000 the IAU accepted a Resolution that expressed concern over the plight of its heritage data and the losses threatening to accrue to the science, and voiced the need to encourage digitizing programmes. In a fresh attempt to bring the urgency of the situation to the attention of astronomers worldwide, a new IAU Resolution (B3 2018) builds on the earlier one but emphasizes the dangers of continuing to do nothing.

A full digitizing programme of this scale will clearly require skills, hardware, and sufficient funds to see it through. Suitable variants of specialist hardware for scanning plates correctly can now be designed and built, so it is up to the community to garner the necessary support to set up major digitizing programmes, including the corresponding log-books or equivalent records for the all-important meta-data. That support will be nourished by rehearsing some of the triumphs achieved when information from historical data has been included alongside modern observations. Exemplary projects and some individual scientific cases are summarized below.

3. New Science Already Achieved

3.1. *Multi-million light-curves from DASCH*

What seemed originally an ambitious project to scan the entire collect of over >500,000 sky images in Harvard College Observatory’s plate archive is now nearing completion, and is resulting in an enormous wealth of new knowledge. The project’s website at dasch.rc.fas.harvard.edu/status.php reports 0.2 billion photometric estimates, from which 50 million light-curves have been generated. But in addition to those impressive statistics are many “odd balls”, the objects that do not conform to any previously known pattern and whose discoveries are ripe for following up with high-resolution spectrographs. Here is new science in abundance!

The precedent set by the *DASCH* project at Harvard has triggered pilot studies elsewhere (e.g., Yu, Zhao, Tang, & Shang 2017), and will be an inspiration for others.

3.2. *Transient phenomena detected via the digitized Byurakan survey*

The objective of the Plate Archive Project (www.aras.am/PlateArchive) of the Byurakan Astrophysical Observatory in Armenia was to digitize all 37,000 plates obtained between 1947–1991, to derive astrometric solutions, create extraction and analysis software, and build an electronic database plus a webpage and an interactive sky map. The 1800 plates in the Markarian Survey (a.k.a. the First Byurakan Survey, FBS) were digitized in 2002–2007, from which the Digitized FBS (DFBS; www.aras.am/Dfbs/dfbs.html) was created. The archive is comprised of low-dispersion spectra, and is supporting new scientific projects. The database of the Armenian Virtual Observatory (ArVO; www.aras.am/Arvo/arvo.html) will accommodate these new data, and provide the standards and tools needed to use the scientific output efficiently and integrate it into international databases. Full details of the project are given in Mickaelian *et al.* (2016). The DFBS is a valuable resource in the search for transients, and can be conducted by comparing the same fields observed at different epochs, and by comparing BAO plates with POSS 1/2 (DSS 1/2) records. It also provides some cover for the gap years between POSS1 and POSS2, and may reveal new transients and variables. A separate study has revealed asteroids at positions not previously recorded, and is helping to correct their ephemerides and provide templates of their low-dispersion spectra. 7 extremely high-amplitude variables (differences of 7^m–8^m or more between two epochs) were also discovered by comparing BAO with DSS fields.

3.3. *The unsolved enigma of ϵ Aurigae*

ϵ Aurigae is no ordinary star; at least, it certainly doesn't seem to be. An early-F supergiant in a binary system with a period close to 27 years, it undergoes eclipses that last for nearly 2 years, but no-one has yet been able to fathom the nature of the companion that causes the eclipses. Moreover, ϵ Aur is not just a terribly faint smudge whose spectrum is hard to resolve; it is a *third magnitude* object. Its binary nature was recognized over a century ago.

ϵ Aurigae went through eclipse from 2009–2011. Communities of observers – some professionals, but mostly "backyard" amateurs – were galvanized into action, supplying high-quality series of ground-based digital spectra from the UV to the near IR. Our plate archives contain series of high-dispersion spectra recorded during both the 1955–57 and the 1982–84 eclipses. Eclipses are not quite total, but quantitative comparisons between the spectrum during eclipse, as recorded on those earlier occasions, and the most recent one had not been attempted, leaving unanswered a number of critical questions regarding the physical constancy of the (unknown) eclipsing body, or period modulations triggered by mass-loss, mass exchange, or flaring. Series of plates taken during the two previous eclipses from the Mount Wilson and the DAO plate archives were digitized with the DAO's PDS microdensitometer (PDS ≡ Photometric Data Systems; no longer in business). Comparing the older spectra with new CCD observations (also recorded at the DAO) revealed fascinating features about the system that could not otherwise have been learned (Griffin & Stencel 2013), in particular that a stream of material rich in rare-earths (*Why??*) from the primary is constantly being accreted by the secondary.

3.4. *Variations in stratospheric ozone: a transdisciplinary challenge*

Ground-based observers and observatories know only too well that the Earth's atmosphere absorbs incoming radiation at wavelengths that permit only the optical window to be transmitted. The UV is blocked by bands of ozone that are totally opaque – and very necessarily so, from the point of view of the health of terrestrial bio-organisms.

For astronomy it means observing from space, and the concomitant expenses and limitations are well rehearsed. However, valuable science can be gained by inverting the problem and investigating the properties of the atmosphere rather than the properties of the stars. This is especially important in the case of the UV ozone. Ozone is now monitored externally from space, but for some 50 years the only routine monitoring was carried out by observing the Sun from the ground (actually mile-high ground) at Arosa in Switzerland. Unfortunately, the noise levels in the early data were not as low as in modern data, making it somewhat difficult to know if the concentrations that were typical during the 1920s, when monitoring commenced, held steady until freed chlorofluorocarbons (CFCs) started to destroy ozone catalytically in the 1970s (the Antarctic "ozone hole"), or whether they undergo natural variations. The way to discover is to examine historical data from other sources, such as tree rings or ice-cores. One such (untapped) source is astronomy's historical spectra of early-type stars, whose far-UV spectra are uncluttered.

Appropriate spectra, borrowed for the purpose from elsewhere, were digitized with the DAO's PDS, and the broad absorption bands of ozone in the wavelength region $\sim\lambda\,3050$–$3350\,\text{Å}$ were analyzed and modelled. A pilot study successfully validated the method of analysis that was developed (Griffin 2005), though progress was hindered by a total lack of *any* observatory plate inventory being on-line (and was halted by a serious equipment failure). But the potential remains, and represents a way of contributing indispensable information to a science that affects us all.

3.5. *Studying the dynamical evolution of trapezium systems*

Knowledge of the internal motions in multiple trapezium-like systems is necessary to understand their dynamical evolution. Despite relatively low accuracy, historical observations provide a long time-baseline. Carefully selected historical measures of the separations and position angles (selected from the best observers) enable the construction of dynamical evolution models of trapezium systems; detailed results for a dozen or so such systems have been described by Allen *et al.* (2018) and in papers referenced therein. Monte Carlo N-body integrations were performed, yielding extremely small dynamical lifetimes for these systems (10 to 40 thousand years). Literature searching turned up data for only 10 systems likely to be true trapezia, which indicates that trapezia are very scarce, as would be consistent with the short dynamical lifetimes that were found.

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