CELESTIAL OPTICAL TRANSIENTS FROM 532 BCE TO 2015 AD.

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Introduction

The earliest recorded optical transients occur in oriental records at least as early as 532 BCE (there is a possible earlier record of a nova, c.1400 BCE, on Chinese oracle bones (Hsi 1958), but with insufficient detail to be of modern value). Among these are events now recognised as novae and supernovae, the most famous of which is the supernova of AD1054, with the Crab Nebula as remnant. Within the past few years some of the ancient ordinary novae have been identified from their ejected shells or from the nature of the remnant binary star; more can be expected to be found with the upcoming all-sky surveys, such as LSST and Pan-STARRS. Here I discuss the current status of the observations and the recent the discovery of an eclipsing dwarf nova, with an ejected shell, that is probably the remnant of the Chinese nova of AD 483.

Oriental transients

Records were kept by Chinese, Japanese and Korean imperial astrologers who had been instructed to keep their emperors informed on the state of the heavens, which were considered to reflect the state of terrestrial affairs. Included in the records *inter alia* were new (guest) stars, rainbows, sunspots, snowstorms, comets, meteors, meteor showers, solar and lunar eclipses, aurorae, lightning, and hail. Among the new stars were what we now recognise as novae and supernovae, including the supernova of 4 July AD 1054, only identified for certain as the origin of the Crab Nebula by Oort in 1942. There are several catalogues that list and interpret the oriental records, the most important of which are Hsi (1958), Ho (1962), Clark & Stephenson (1977), Xu, Pankanier & Jiang, (2000), Nickiforov (2010). A complication that arises in relating oriental guest stars to modern objects is the absence of an early universal grid system, like declination and right ascension. Instead, a 'mansion' or 'palace' reference was used, defined by a bright asterism and the strip of sky from pole to horizon that included that asterism at the time of observation. There were 28 mansions, mostly near the ecliptic plane (to describe where the moon was at any time); locations of novae deduced from the oriental descriptions are rarely better than about 10 degrees (Nickiforov 2010).

AT Cnc

Shara et al (2012b) have found a second fragmented nova shell around a Z Cam star – that of AT Cnc. It is 3' in diameter and has an ejecta mass ~ 5 x 10^{-5} $M_{\odot}$. AT Cnc has galactic coordinates (198°,32°) which are close to the Korean novae of 1031 AD (207°, 30°) and 1645 AD (207°, 30°) in Nickiforov's (2010) list.

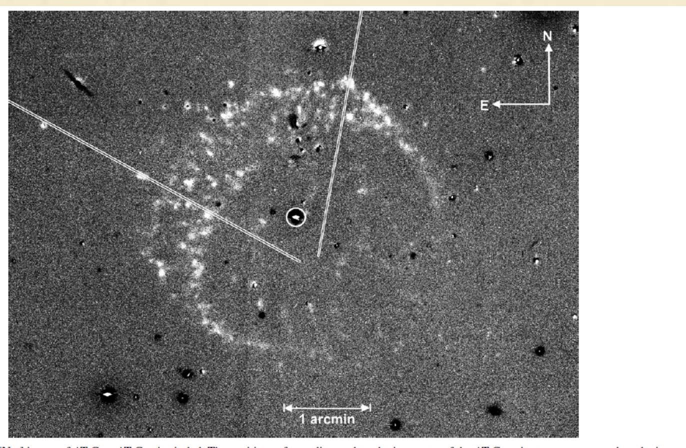


Figure 2. Net Hα + [N II] image of AT Cnc. AT Cnc is circled. The positions of two slits used to obtain spectra of the AT Cnc ejecta are superposed on the image.

Modern identification

Current understanding of the evolution of cataclysmic variable (CV) stars is that they are all close binary stars, with mass transferring from (usually) a main sequence donor onto a white dwarf (Warner 1995). The build-up of hydrogen-rich material on the surface of the white dwarf leads eventually to a thermonuclear runaway, with expulsion of the accreted gas; intervals between such nova eruptions in theory should be ~ 10^{4-5} y. Following the eruption, the heated white dwarf cools down, reducing irradiation of the donor and hence the mass transfer rate (perhaps to zero for a long time – leading to a phase of 'hibernation" (Shara et al 1986)); during the descent or subsequent rise the star becomes a standard dwarf nova, with cyclical outbursts of its accretion disc – an example is GK Per, which was nova Per in 1901 and started outbursts around 1966 (brightening ~ 3 magnitudes every ~ 3 y).

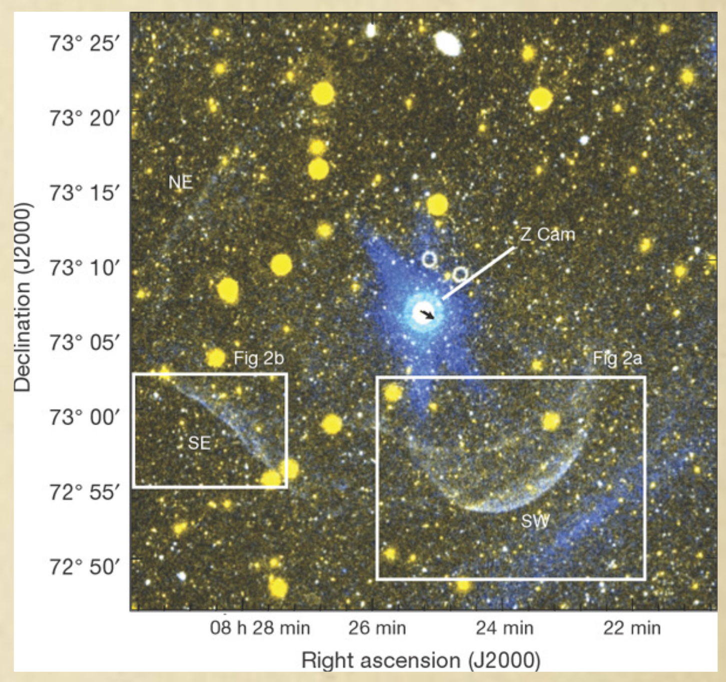
BK Lyn

BK Lyn was identified in 1982 in a search for stars with ultraviolet excesses and later found from spectra to be a CV with orbital period 108 mins and *very low amplitude* photometric variations. Spectroscopically it was classified as a nova-like variable, the only one with a period less than 2 h. Assiduous monitoring for 20 years paid off during 2011 when BK Lyn *transformed into a dwarf nova*, with outburst intervals ~ 5 d (Patterson et al 2013). Hertzog (1986) proposed from a study of the oriental novae that BK Lyn can be securely identified as the remnant of Nova Lyn AD 101 (N15 in Nickiforov's (2010) list; positioned very accurately relative to a bright star (Hsi 1958)).

Z Cam

Z Cam is the type star of dwarf novae that have standstills and is one of the brightest and best observed CVs. Not until 2007 was it noticed that the GALEX (ultraviolet) image of Z Cam is partly surrounded by an emission nebulosity with a radius of ~ 15' (Shara et al 2007, 2012a), physically an order of magnitude larger than the size of novae observed during the past century. The derived mass of the shell is similar to that of recent novae, and is much larger than what would be ejected by winds during nova outbursts. There is no detectable expansion of the shell, which is presumed to have been decelerated by interaction with the interstellar medium.

Johansson (2007) pointed out that a guest star in 77 BCE located between α UMi (the North Pole star) and α UMa could be the origin of the nova shell. I note, however, that there are possible alternative identifications with novae near α UMi in AD 158 and AD 305 (Chinese novae N19 and N28 in Nickiforov's (2010) list).



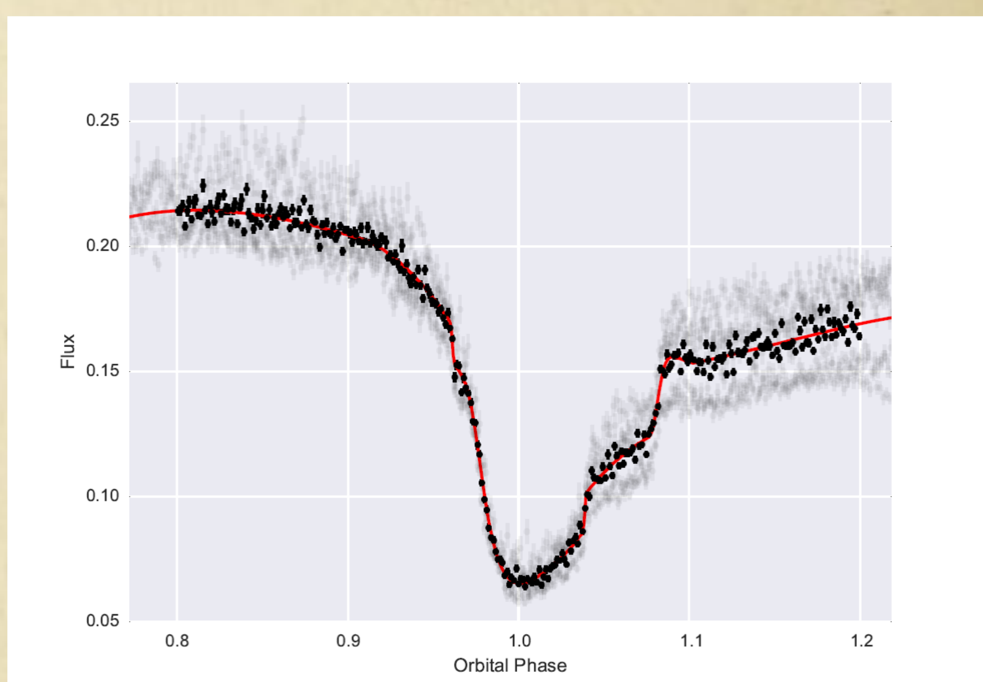
Te 11

Jacoby et al (2010) reported on a professional/amateur (largely citizen science) project that searched for previously unknown planetary nebulae recorded on digital sky surveys. Among the ~ 60 PN candidates one stood out as having unusual morphology and spectrum; Te11 has a low excitation nebula spectrum, is near to the large gaseous structure known as Barnard's Loop and a distorted shape which was noted to be close to the molecular cloud complex that surrounds (in projection) the stars in Orion's Belt. Much of this Orion emission nebulosity appears close to ς Ori at a distance ~ 400 pc (Goudis 2012), which is very close in the sky (and in distance – see later) to Te11. In their ongoing photometric study of faint CVs, especially outbursting dwarf novae, Woudt and Warner observed the Catalina Real-Time Transit Survey (Drake et al 2009) source CSS 111003:054558+022106 during an outburst in December 2013, finding it to be an eclipsing system with orbital period of 2.90 h (just within the CV orbital period gap). The CRTS light curve shows 5 recorded outbursts over 10 years. Independently, in his follow-up survey of planetary nebulae Brent Miszalski had photometrically observed the central star of Te11 and found it to have eclipses.

Comparisons of experiences showed that Te11 and the CSS star are identical – *the central star of Te11 is a classic dwarf nova.* This excludes it from being a planetary nebula, the central stars of which are hot subdwarfs, and their nebulae are of high excitation.

Further photometric and spectroscopic observations, and modelling (Miszalski et al 2015), of Te11 have shown that its white dwarf has a mass ~ 1.2 $M_{\odot}$ and effective temperature ~ 13000 K. The high mass suggests that there should be nova eruptions more frequently than those of classical novae (i.e. a Recurrent Nova, with eruptions every hundreds or thousands of years: Warner 1995). Using the relationship given by Warner (1987) and recalibrated by Patterson (2013) between orbital period, disc inclination and maximum apparent brightness during dwarf nova outbursts, together with modelling of the dwarf nova quiescent light curve, give a distance to the star of 330 ± 50 pc.

The gas in the Orion OB Association is mostly at a distance of 460 pc (Goudis 1982), including Barnard's Loop, which Te11 is close to and may be immersed in.



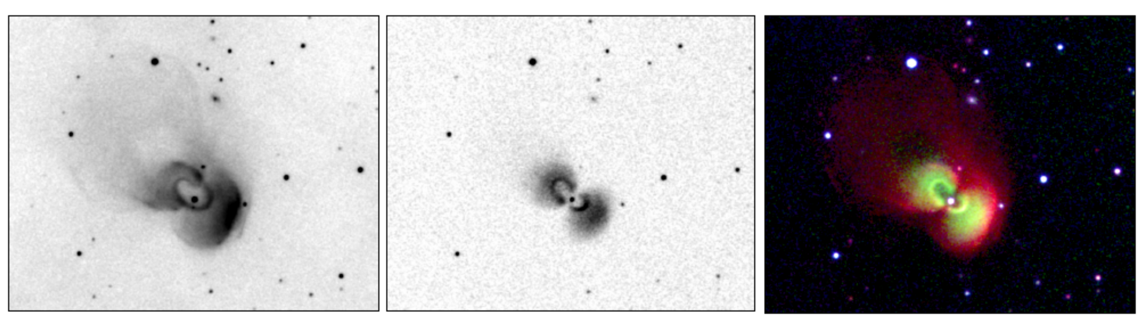


Figure 1. VLT FORS2 images of Te11 obtained through Hα+[N II] (left) and [O III] (middle) filters. The colour-composite image (right) is made from Hα+[N II] (red), [O III] (green) and SDSS g (blue) and contextualizes the complex ionization structure of the nebula. All images measure 2.5'-by-2.0' with North up and East to left.

Te11 as the remnant of Nova Ori AD 483

The location of Te11 just to the east of the Orion's Belt star ς Ori (Alnitak in early European astronomy) shortens any search for an early oriental candidate. ς Ori is a significant star in ancient Chinese astronomy – it is the dominant star in Lunar Mansion 21 (*Shen*, or *Three Stars* in translation – referring to Orion's Belt). There is only one obvious candidate: Nova N40 in Nickiforov's (2010) list - the nova of 14 December AD 483, which was described as "Emperor Xisosen of Wei, 7th year of the Taihe reign, period 10th month. There was a guest star east of Shen as large as a peck measure and like a fuzzy star". The reference to "fuzzy star" might be thought to indicate a comet, but Nickiforov (2010) finds that many of the "fuzzy star" descriptions cannot refer to comets and must be novae.

The suggested nova remnant around Te11 is relatively small, which may be the result of rapid deceleration of the expanding nova ejecta by the gas in the Orion region (10 or 100 times the density of the ISM). One side of the remnant appears to be a shock cause by ploughing of the ejecta into the surrounding gas.

Conclusion

With additional identifications of remnants from early oriental novae it should be possible to map out the longer-term development of ejecta shells and the recovery of their central stars as normal cataclysmic variable between eruptions.

Acknowledgements

Details of the Te11 observations will be published separately (Miszalski et al, 2015), the part given here is largely that contributed by myself. I am grateful to Brent Miszalski and Patrick Woudt for provision of some of the illustrations, and to Kerry Paterson for assistance with layout of the text. My research is supported by the National Research Foundation and by the University of Cape Town.

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