THE BAA OBSERVERS' WORKSHOPS

Cambridge	Winchester	York
2003 February 15	*2003 April 26*	*2003 September 6*

Dr Nick Hewitt continues our series of extracts from the talks at the Observers' Workshops.

Observing variable nebulae

by Nick Hewitt

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Introduction

Most deep sky observers enjoy their Universe for the aesthetic beauty on display, and to strive to pull out detail in their quarry, or capture the gossamer detail by drawing, by photographs, or more recently using CCDs. Only a minority consider doing real science and pursuing any of the deep sky observing projects that the British Astronomical Association promotes. Nevertheless there are some areas that can be regarded as scientifically useful. These include:

- Supernova patrolling
- Measuring double stars
- Extragalactic nova patrolling
- Monitoring Active Galactic Nuclei
- Observing variable stars within deep sky objects
- Variable nebulae.

It is this last discipline that I wish to introduce and promote.

What are variable nebulae?

Variable nebulae are reflection nebulae that may show true changes in brightness, shape or position. These nebulae are associated with new Young Stellar Objects (YSOs) that are also variable stars. Most YSOs do not have optically visible nebulae associated with them, but many can be seen in the infrared. Nevertheless there are four that can be seen or imaged in amateur equipment and hence interest amateurs and professionals alike. Other nebulae may show variability too, such as the Eta Carina nebula in the southern hemisphere and the nebula associated with R Aquarii, but the mechanisms are different and amateur observation is difficult.

YSOs are formed in the molecular clouds to be found in the spiral arms in the Milky Way galaxy. We can only see the nearer examples, though presumably the phenomenon is common. But many YSOs are obscured in the dusty and gaseous regions of the Galaxy. The nearest dark molecular clouds are in Taurus, and indeed many YSOs are to be found there, but anywhere where there is gas and dust one may find examples. The best understood example is NGC 2261, and the modern model for this nebula is outlined below. Nevertheless, the other examples are less well understood, and all have individual quirks. Because they change, often in relatively short time scales, the four examples to be described still need regular monitoring to improve our understanding of their behaviour.

Hubble's variable nebula (NGC 2261)

While Hind's nebula (NGC 1554/5) was the first to be shown to be variable (see below), it is not the easiest to observe. This distinction certainly falls to Hubble's variable nebula and beginners should attempt this first, as it is easy enough to find and observe with modest equipment. It is a small comet-like fan-shaped nebula some 2 minutes of arc in length, and is part of the rich seam of deep sky objects in the area of northern Monoceros. It was discovered by William Herschel in 1783, but no special comments were made. At its apex sits R Monocerotis, the first variable star to be discovered in that constellation, by Julius Schmidt in 1861. The variability of the fan itself was found by the young Edwin Hubble while at Mount Wilson Observatory. In 1916 he compared past photographic plates of the nebula that showed changes in brightness and dark areas on the 'fan' of the nebula that did not correspond to the variations in R Monocerotis itself. This prompted Carl Lampland, a pioneer astrophotographer at Lowell Observatory, to take over 1000 photographs of the nebula between 1919 and 1951. Much was gleaned from this work, and his observations are still used to help develop the current model of this and other variable nebulae.

Later observers, working with improved technology and across the electromagnetic spectrum, had spectacular results, none more so than David Malin, working at the Anglo-Australian Observatory. He managed to capture the faint southern fan with a very deep photograph, and much other detail with filtered photography, proving that this was a bipolar nebula. Recent studies using both old material and newer infrared techniques have refined the models, such as those described by Lightfoot (1987) and Close (1997), which seem very complete for Hubble's nebula.

The current model is now reasonably accepted. The new star (YSO) remains surrounded by a torus of gas and dust left

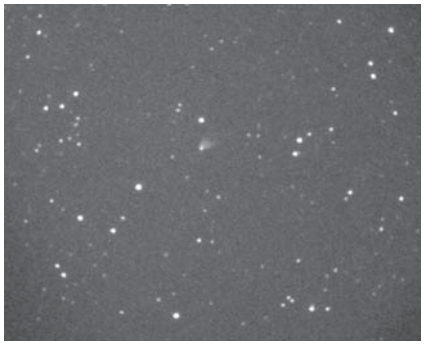

Figure 1. Photograph of Hubble's variable nebula by Nick Hewitt. 200mm SCT at f/5 on Agfa 1000 film, 10minute exposure, 1988.

Variable nebulae available to amateur observers

Nebula	RA	Dec	Star	U.2000 map	Size (arcsec)	Star mag. (max)	Visual	Photo	CCD
Hubble's nebula NGC 2261	06h 39.2	+08° 44′	R Mon	U.183	120	~10.0	Yes	Yes	Yes
Hind's nebula NGC 1554/5	04h 21.8	+19°32′	T Tau	U.133	30	~9.4	?	No	Yes
Corona Australis NGC 6729	19h 01.9	–36° 57′	R & T CrA	U.379	60	~9.7	Yes	Yes	Yes
Gyulbudaghian's nebula	20h 45.9	+67 58′	PV Cep	U.32*	60	~11.0	No	No	Yes

* Neither variable nor nebula is shown in *Uranometria*. It appears on *Megastar*.

over from material in the protoplanetary disc. Due to the inclination of the system to our line of sight, the southern component is obscured, unless exceptionally deep exposures are used. R Monocerotis itself is a massive 10-solar-mass star surrounded by an optically thick accretion disc, so it is best studied in the infrared. It varies by more than 4 magnitudes in brightness. Strong polar winds from this active youngster have collimated a clear narrow 'throat' through the accretion disc. This 'throat' is about 75 AU wide (0.1") and 45 AU north of R Mon, and is the source of most of R Mon's light in the visible spectrum. Material falls towards the star under the influence of gravity and is also collimated into long filaments, which are carried back northward by this strong wind. This ejected material has formed the reflection nebula NGC 2261.

The nebula is thought to be a thin-walled (<800 AU) parabolic shell, almost a cone. Its major axis is aligned along P.A. 350° and inclined 20° toward us. R Mon is at its base. Visible and near infrared light escaping through the 'throat' illuminate the walls of the nebula which are transparent at wavelengths greater than 4 microns. Streamers of dust that form at 1–2 AU from R Mon cast shadows onto the walls of the nebula as they rise through the 'throat'. The shadow play of the silhouettes so projected seems to show proper motion velocities that exceed the speed of light, but this is a cosmic illusion. The bright part of the nebula that is available to amateurs is approximately 0.2 lightyears wide (east–west) and 0.4 lightyears long (north–south).

The nebula continues to change in brightness over a period of days and weeks. Shadows may 'move' by 4 arcseconds a day. These changes include

- movement of well defined dark areas or 'shadows' across the face of the nebula
- large, less defined regions of the nebula that change in brightness over several weeks
- a region several arcseconds north of R Mon that changes in brightness and structure frequently.

The shadows spiral in an anti-clockwise direction, this being the same as in the Lampland images; however, recent studies tell us that the shadow transits have much greater northward velocity than those seen in the Lampland series.

Also, studies suggest that large parts of the nebula do not change, especially the fainter northern parts. Lampland's work remains valuable as his images taken sixty years ago show many of the same features seen today. Nevertheless, modern observers who emulate Lampland's work by taking sequences of images can enjoy making simulated 'movies' of the changes in the nebula over short timescales such as a few weeks.

Hind's variable nebula (NGC 1554/55)

The first variable nebula to be discovered is much more enigmatic, and worthy of regular study by amateurs. It was a truly unique object in the later 19th century, especially for the few years after its discovery in 1852 October. J. R. Hind was sweeping the ecliptic for asteroids from Regent's Park, London, using George Bishop's 7-inch (180mm) refractor when he chanced upon an unmarked 10th magnitude star near the Hyades that would become designated as T Tauri. He also noted a small nebula (later NGC 1554/5) just to the southwest. To the amazement of the observers of the time, the nebula faded from 1861 and was undetectable visually by 1868. It wasn't seen again until 1890 when it was barely recovered by E. E. Barnard and S. W. Burnham using the 36" (910mm) Lick refractor on Mt Hamilton. Even these eagle-eyed observers could not find it in 1895, but it was photographed at the turn of the 20th century and has been available since. Not only had the nebula been variable in brightness, but had also changed position from southwest to directly west of T Tauri. We await its next changes with interest.

T Tauri itself is worth monitoring. Its range is from mags 9.3 to 14 and its period is irregular, but it varies by a few tenths almost daily. Its spectrum varies from G4 to G8 as it flickers due to a mixture of mass accretion and gravitational contraction. It radiates strongly in both UV and IR radiation. It is relatively close at a distance of 460 light years.

The main reflection nebula associated with T Tauri is Hind's, but there is also a tiny one named Burnham's nebula that is very close to the star and is invisible when T Tauri is brighter than 14th magnitude. It is only 4" across and I am unaware of any amateur observations. Hind's nebula has been observed by a small handful of observers around the world and has been fairly static of late. But no-one can tell when it may fade, brighten or seem to move. As with Hubble's nebula, its changes do not reflect the variations in behaviour of T Tauri.

Corona Australis (NGC 6729)

The third variable nebula does vary in time with the two nebular variables associated with it. The Corona Australis nebula (NGC 6729) is a small comet-like wisp within a much larger and very beautiful reflection complex in the apparent vicinity of the globular star cluster NGC 6793, in the adjacent constellation of Sagittarius.

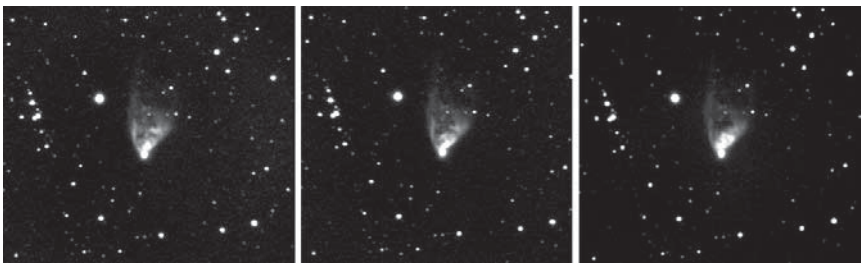

Figure 2. Images of Hubble's variable nebula taken by Steve Goldsmith with a 300mm SCT and HX516 CCD. *Left:* 2000 December 25; *Centre:* 2001 January 25; *Right:* 2001 March 13.

Figure 3. A superb colour image of Hind's nebula by Chris Schur, 318mm f/5 Newtonian with SBIG ST4 CCD. See more of Chris Schur's work at http://www.psiaz.co/schur/astro/ccdimage/ngc1554.html

The variable stars T and R Corona Australis are quite easy small telescope objects, and the nebula itself is easy too, though almost impossible from the UK as it skirts the southern summer sky at best three degrees above the horizon. It has not shown much change other than in brightness in step with the stars, but it has not often been recorded sequentially. In fact, its observation highlights many of the pitfalls for the amateur, as the appearance can seem to change dramatically with different apertures, equipment, sky conditions, exposure and so forth. It is important to record change in this and other variable nebulae by using the same methods and processing techniques each time, and recording the sky conditions during which the observation was made. British 'astro-tourists' might like to observe this complex while at lower latitudes.

Figure 4. NGC 6729 (Corona Australis nebula). Digital Sky Survey image.

Gyulbudaghian's nebula

This final variable nebula for amateurs is not well known, and resembles a small faint version of Hubble's nebula. It was described by Armen Gyulbudaghian of Byurakan Observatory in 1977, and is a fan associated with the variable star PV Cephei. It has shown considerable change in its appearance since it appeared on the Palomar Observatory Sky Survey plates in the early 1950s, then appearing as a faint sliver. It is now a fan-shape, also orientated to the north, as with Hubble's nebula; the southern component is also obscured, presumably by an accretion torus inclined from our line of sight. There are currently a few observations of the nebula, but only very few sequential pictures. More would be welcome, as its behaviour is not well understood.

Figure 6. CCD image of Gyulbudaghian's nebula by Chris Deforeit, 450mm Newtonian + SBIG ST8E camera, 2002 September 11. Note the dusty environment. http://astrim.free.fr/gyulb.htm

Why observe variable nebulae?

The main reason to observe these nebulae is to compare their appearance over time and interpret any changes that occur. Those of Hubble's nebula are quite well understood, as mentioned above, but it remains the best of the group on which to practise. The rest are far less well monitored, and could surprise us at any time.

All four are good targets for CCD observers, being fairly small yet large enough to show detail. Hubble's nebula will be a suitable target for visual observers and photographers also. Hind's and Gyulbudaghian's are difficult visual observers' challenges, and for serious study a CCD is to be preferred.

However the observations are made, it is best to keep to the same equipment and use the same processing routine (photo or CCD). Observe weekly if this is possible, with weather and Moon willing. Send in observations with details of equipment and processing, time and date etc. While enjoying the nebulae, don't forget the variable stars! Estimates of their brightness are essential for complete observation of the nebulae.

Figure 5. These two very different appearances of the Corona Australis complex highlight the problems of varied technique when imaging variable nebulae. *Left:* Image by Motoki et al. (Japan), taken from New Zealand on 2001 October 6 with a Celestron C8 at f/8.7 +AO-7 ST7E CCD. *Right:* Image from the Grasslands Observatory, Arizona, with a 600mm f/5 Newtonian.

Conclusions

In the variable nebulae we have a small number of objects that can be monitored simply for change, and as they are spread over the seasons, one or more is available at most times of year. ▶

Observing variable nebulae – *continued from previous page*

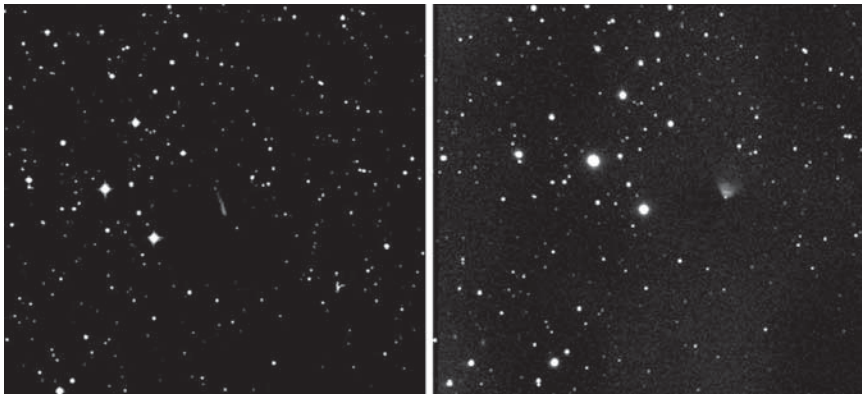

Figure 7. *Left:* PV Cephei and Gyulbudaghian's nebula on the Digital Sky Survey (1950). *Right:* Image of Gyulbudaghian's nebula taken by Steve Goldsmith with a 300mm SCT at f3.3 and HX516 CCD, 2001 October 6.

▶ Their history suggests fascinating behaviour, but only one has been comprehensively monitored.

They provide challenges for all deep sky observers, whatever the equipment used and levels of experience. Observations are potentially useful to build up our knowledge of patterns of behaviour, and of course, variable nebulae are fun!

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Bibliography and sources of amateur images

An overview of current models of Hubble's variable nebula: http://www.umanitoba.ca/faculties/science/astronomy/cbrown/imaging/hvn/introduction.html

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Animations of Hubble's variable nebula by Tom Polakis: http://www. psiaz.com/polakis/n2261/n2261.html; http://www.psiaz.com/polakis/n2261/n2261_1999.html