A STAR IS BORN... A GUIDE TO YOUNG STELLAR OBJECTS

MIKE POXON

The concept of star birth is something that has always filled me with awe. Even if for some reason it doesn't do the same for you, it is worth realising that studies of the formation and early history of stars are coming increasingly in demand by the professional community since we can learn a great deal about how stars and also planetary systems are formed. A growing number of amateur observers will be necessary to provide visual, CCD, and multiwavelength observations of these fascinating objects. Oh yes - and they're often fun to observe as well. Some idea of how important visual observations of these stars can be is illustrated in the paper by Guertler et al:

The light variations due to varying circumstellar extinction, open a unique way to study the structure of the circumstellar dust shells, the properties of the individual dust clouds, and the characteristics of the dust grains... However, only the study of the long-term behaviour of the light variations provides information on the statistical properties of the cloud ensemble and the structure of the circumstellar envelope[1].

Without, for the moment, going into the physics above, what is noteworthy is that the sole source of actual raw data for their paper was the AAVSO database! So what are these strange objects, and why should the VSS be interested in them?

Stars are born inside giant clouds of gas and dust when the swirling gas condenses into some sort of core region, whose increasing mass causes the process to mushroom ever further. Eventually a rotating core is formed surrounded by a disc of infalling material. It is likely that this fast rotation produces a magnetic field leading to heavy star spotting, which may be a major source of the observed light variations. Depending on the mass of the object (not strictly a star, since the fusion process has not yet begun) we emerge with one of two types of star. If the mass is between about 0.5 to 2.5 solar, we get a relatively cool T Tauri star, of spectral type G to M. Greater masses produce Herbig Ae-Be stars. When these objects evolve onto the main sequence as bona fide stars, the T Tauri group will become stars similar to the Sun, whilst the Herbig stars will turn into much more massive, powerful stars like Vega. Bear in mind that Vega itself is still surrounded by a dusty disc which may contain planets [2].

The light-curves of T Tauri stars are of fairly small amplitudes, rarely exceeding 1 magnitude, but nevertheless show constant, irregular changes on a fairly gentle scale. Observations more than once a night are not necessary as a rule. Crucial to the process of variation is the behaviour of the circumstellar disc. Due to several environmental factors, the material in the disc may coagulate into definite clumps which may then proceed to grow in size. A planetary system can be formed at this stage. However, some of these regions of matter may be disrupted by the forming star, and smash down onto its surface producing a fairly sudden increase in light output. These phenomena are the FU Orionis stars, formally called slow novae (stars like **RT Ser**, **V1057 Cyg** and **Z CMa**)

In all events, there will come a stage where the embryonic star resembles a bath filling with water. It will fill its equipotential sphere and can take on no more material. Unfortunately, the gas and dust in the disc doesn't know that (the taps have been left on), and must go somewhere (the bath overflows). The excess material can only be emitted through a *safety valve* (the overflow) which, for our forming star, is the region least affected by the mass of the total system - the poles. Matter is expelled from the poles out into the gas cloud. This so-called T Tauri wind is another crucial stage. Without it, interactions between the stellar core and the circumstellar disc would cause the star to break apart! T Tauri winds can not only physically reveal the star to us by evaporating the material in the gas cloud, but can also trigger additional bursts of star-formation by compressing and shifting material in nearby regions of the cloud. Sometimes the outflows are visible as little fan-shaped nebulae, and at other times they show themselves by their effects on the surrounding areas. These are Herbig-Haro objects.

The *interesting variable stuff* happens when we have a system which is edge-on to us, so that the disc, and any material in it, eclipses the star itself. This phenomenon is much more pronounced in the more massive Herbig Ae-Be objects, possibly because the greater mass of the system produces a concomitantly larger dust-grain size which accretes material to it at a greater rate, thus generating larger clumps that obscure the star. These stars in which large (up to about 3 magnitudes) Algol-like dips in light occur are the UX Orionis stars. Indeed, a quick trawl of the GCVS shows that **IL Cephei** is listed there as an Algol star rather than the UX Ori star it actually is!

Observationally, many of these objects are within the range of small telescopes or even good binoculars. Here are a few to be going on with:

Star	**Max**	**Min**	**Type**	**Notes**
T Tau	9.0	11.0	T Tau	
CQ Tau	8.7	11.6	UX Ori	AE
RR Tau	10.0	14.0	UX Ori	AV
MIS V1147	13.0	16?	UX Ori	AE
RY Tau	8.6	11.0	T Tau	AN
V380 Ori*	8.2	11.1	?	AN
VX Cas	10.0	13.3	UX Ori	A
RW Aur	10.0	13.6	UX Ori	A
VV Ser	11.8	14.5	UX Ori	P
BO Cep**	11.0	13.7	UX Ori	P
WW Vul	10.0	12.6	UX Ori	A

Notes: A = on AAVSO programme; E = extremely active; V = very active; N = attached to or involved in nebulosity; P = chart (unofficial!) by author. *V380 Ori is quite hard to estimate, as it is inside the reflection nebula NGC 1999 and surrounded by Herbig-Haro objects (actually HH1 and HH2, the first discoveries). I have not stuck to the GCVS details religiously, since they are quite clearly wrong in some cases (for example **BO Cep is given a maximum of 11.9 whereas it is usually near magnitude 11.0).

To sum up, nebular variables have so far been under-observed by amateur observers to a degree which is inversely proportional to their importance. Adding a few stars of this type to the observing programme (or, dare one say, initiating a YSO list?) will not only help the professionals, but provide us with some more interesting targets for those rare evenings when the clouds roll back.

References: 1 Guertler,J. et al, Astron. Astrophys. Suppl. Ser. 140, 293{307 (1999)}
2 http://www.gsfc.nasa.gov/gsfc/spacesci/origins/dustdisk.htm