UXOR Hunting among Algol Variables

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Abstract The class of variable typified by UX Orionis (UXORs or UXors) are young stars characterised by aperiodic or semiperiodic fades from maximum. This has led to several of the class being formerly catalogued as Algol-type eclipsing binaries (EAs), which can show superficially similar light variations. With this in view, I propose a campaign to search for more UX Ori type stars.

1. History

UX Orionis is the prototype of a subset of Young Stellar Objects (YSOs) which spend most of their time at or near maximum brightness, but which undergo periods of fading which can vary in any of: 1. amplitude; 2. duration; or 3. regularity.

No UXORs are known that exhibit amplitude, duration, or regularity as predictably as do typical Algol-type eclipsing stars, even though in the past several objects presently classified as UXORs were erroneously listed as EA-type variables, due largely no doubt to incomplete or inadequate observations. An example is BO Cephei, of which Wenzel (1991) said:

> The reader must be aware of the fact that obviously the minima are of very different depth and that moreover in numerous cases they cannot be realized at all at the predicted dates.... A thorough spectroscopic investigation of this important object is clearly overdue. In this connection we remind (sic) of two more kinds of "eclipsing" stars with vanishing minima, represented by Kohoutek's central star V 651 Mon of a planetary nebula.... Maybe these cases are more numerous than hitherto supposed. The large number of eclipsing variables, for which no period could be found, could be explained in this way....

When BO Cep was discovered (Morgenroth 1934) it was classified as an Algol (with a rather scary range of 14–<15.5) but by the time of Wenzel's article its true nature was of course known.

It is also possible for UXORs to be allocated other types; for instance, GT Ori in Table 1 was originally thought to be an SRd variable, presumably on its F0 spectrum and dearth of observational evidence. UXORs may also be confused with the R Coronae Borealis stars, which show similar aperiodic fades, as well as another type of young object typified by FU Orionis, previously lumped under the "slow novae" category though totally unrelated to novae, an example being the star CB 34V (Tackett and Herbst 2003). In this campaign, however, I am concentrating purely on the EA stars.

2. Astrophysical background

UXORs are drawn almost exclusively from early spectral type stars with masses $>2_{\odot}$ as distinct from, say, the T Tauri objects, which tend to be of types G to M and of masses comparable to, or slightly less than, the Sun. One peculiarity of UXORs is that when a fade has taken place the spectral signature moves bluewards. This phenomenon tends to support the model of an UXOR as a star surrounded by an accretion disc possibly consisting of accreting planetesimals, with the disc obscuring the actual star, scattering its light, with the shorter-wavelength blue light predominating—essentially the same phenomenon that produces blue skies here on Earth. Many physical factors come into play at this stage, chief of which is probably the inclination of the system with respect to the observer. The lesser amount of light contributed by the star itself means that the disc provides more (scattered) light, which contributes to the blueing effect. Inclinations approaching 90° should therefore show no excess of scattered light over starlight, since both star and disc continue to contribute to the total light output, but also for this reason there should be no fades seen either, unless the star itself is independently variable, which is a possibility. In addition, since the disk is obscuring the star at such an inclination, the light source itself will be very faint, and only the scattered light will be seen. Clearly, however, there will be a whole "spectrum" of variational behavior from this cause since we can expect inclinations to be randomly distributed. The wide variety of amplitudes can be seen in Table 1, which shows those stars currently considered to be UXORs.

Most star formation occurs in discrete areas of the sky where progenitor molecular clouds occur. Stars formed in these regions have become known as T-associations or OB-associations, depending on whether the main variables found there are the low-mass T Tauri stars or the more massive early-type variables, respectively; it is the latter type that concerns us here, although in practice both types may be found in the same region. These associations are named from the constellations where they are found, thus Ori T2 is that starforming region centred on the Orion nebula and includes our old friend T Ori. Another is located around λ Ori and includes several AAVSO program stars such as CO Ori. As can be seen in Table 1, both T Ori and CO Ori are UXORs, but occur in areas where T Tauri stars also occur, GW Ori, for instance, in the case of CO Ori, and a host of others in the case of the M42 variables.

A third type of stellar association is that associated with reflection nebulae, the R-association. These have B-type stars as their earliest spectral type members, and there are notable examples of such regions in Monoceros, Canis Major, and Vela.

Table 1. Stars presently classified as UX Orionis type (VSX; Watson *et al.* 2015).

Star	R.A. (2000) h m s	Dec. (2000) ° ′ ″	Range
ASAS J072505-2545.8	07 25 04.95	–25 45 49.6	12.6–15.4 V
VX Cas	00 31 30.69	+61 58 51.0	10.5–13.3 V
MQ Cas	00 09 37.56	+58 13 10.7	10.8–13.9 V
NSV 5178	11 22 31.67	–53 22 11.5	6.75–6.79 V
SV Cep	22 21 33.21	+73 40 27.1	10.35–12.15 V
BG Cep	22 00 30.64	+68 28 22.8	13.2–14.3 p
BH Cep	22 01 42.86	+69 44 36.5	10.79–12.7 V
BO Cep	22 16 54.06	+70 03 45.0	11.5–12.4 V
BS Cep	22 29 05.43	+65 14 41.9	13.9–16.0 p
GM Cep	21 38 17.32	+57 31 22.0	12.9–15.1 V
IL Cep	22 53 15.61	+62 08 45.0	9.24–9.61 V
LO Cep	21 19 43.01	+61 42 26.6	13.4–15.0 V
V373 Cep	21 43 06.81	+66 06 54.1	11.82–13.3 V
ASAS J152008-6148.4	15 20 07.38	–61 48 27.7	12.1–13.9 V
V517 Cyg	20 47 23.59	+43 44 39.8	12.1–15.6 V
V1686 Cyg	20 20 29.35	+41 21 28.4	12.5–17.2 V
V1977 Cyg	20 47 37.47	+43 47 25.0	10.8–11.8 V
NSV 20441	15 56 41.89	–42 19 23.3	8.27–8.60 V
VY Mon	06 31 06.93	+10 26 05.0	12.8 V–17.4 p
IRAS 06068-0643	06 09 13.70	–06 43 55.6	14.5–20.1 CV
KR Mus	11 33 25.44	–70 11 41.2	6.67–6.92 V
ASAS J172056-2603.5	17 20 56.13	–26 03 30.7	12.7–13.9 V
T Ori	05 35 50.45	–05 28 34.9	9.5–12.6 V
UX Ori	05 04 29.99	–03 47 14.3	9.48–12.5 V
BF Ori	05 37 13.26	–06 35 00.6	9.69–13.47 V
CO Ori	05 27 38.34	+11 25 38.9	10.0–12.8 V
GT Ori	05 43 29.25	+00 04 58.9	10.6–13.4 V
HK Ori	05 31 28.04	+12 09 10.3	11.2–12.3 V
V350 Ori	05 40 11.77	–09 42 11.1	10.57–13.5 V
V586 Ori	05 36 59.25	–06 09 16.3	9.48–11.41 V
V1012 Ori	05 11 36.55	–02 22 48.5	11.8–<14.2 V
ASAS J055007+0305.6	05 50 07.14	+03 05 32.5	11.1–13.1 V
NSV 16694	05 50 53.72	+03 07 29.4	11.8–13.4 V
RZ Psc	01 09 42.05	+27 57 01.9	11.25–14.2 V
NX Pup	07 19 28.26	–44 35 11.3	9.0–11.2 V
V718 Sco	16 13 11.59	–22 29 06.6	8.75–10.30 V
V856 Sco	16 08 34.29	–39 06 18.4	6.77–8.0 V
V1026 Sco	15 56 40.02	–22 01 40.0	8.57–9.5 V
NSV 8338	17 13 57.44	–33 07 46.0	12.4–<16 V
XX Sct	18 39 36.99	–06 43 05.7	13.0–16.6 p
GSC 05107-00266	18 27 26.08	–04 34 47.5	10.96–13.2: V
VV Ser	18 28 47.87	+00 08 39.9	11.5–<13.6 V
RR Tau	05 39 30.51	+26 22 27.0	10.2–14.3 V
CQ Tau	05 35 58.47	+24 44 54.1	8.7–11.9 V
HQ Tau	04 35 47.33	+22 50 21.7	12.1–14.5 V
EM Vel	08 35 40.30	–40 40 07.2	11.7–13.2 V
FX Vel	08 32 35.77	–37 59 01.5	9.4–11.5 V
WW Vul	19 25 58.75	+21 12 31.3	10.25–12.94 V
PX Vul	19 26 40.25	+23 53 50.8	11.4–12.8 V

UXORs tend to be of B to F spectra and so these areas could be considered as prospective hunting grounds also.

3. Observational possibilities

Table 1 reveals that many of the presently-known UXORs are reasonably bright objects, indeed, AB Aur is visible entirely with binoculars (though it does not appear in Table 1 because it is not simply an UXOR type). However, simple "eyepiece" observation of stars thought to be Algol types is a highly unprofitable exercise for several reasons:

1. there are far too many EA stars to monitor (VSX lists over 20,000);
2. breaks in observation due to weather or other circumstances;
3. some stars may have unsuitable parameters (too faint, too small amplitude).

With this in mind, we need to perform some serious pruning. Most starforming regions lie on or near the galactic equator since that is where most of the progenitor material is found, and so the likelihood of finding an UXOR in these areas increases. It is true that in recent years we have found stellar associations away from the galactic plane—for example in the far-southern constellation of Chamaeleon; it remains true that to unearth an UXOR means that we should stick to the most active areas of the sky. Therefore I have drawn up a list of stars currently assumed to be Algol-type systems that lie within 5°

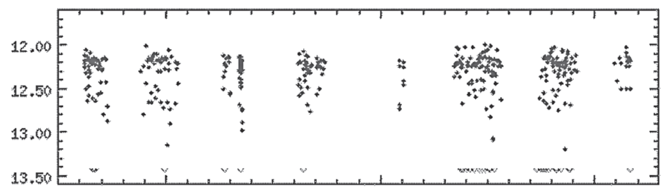

Figure 1. A typical light curve of AL Tau, an Algol star with a period of about a day but which lies in a starforming region close to such UXORs as RR Tau and CQ Tau. The x-axes in this and in Figure 2 are unlabelled since what we are interested in here is not the period, but merely the presence of a regularity; and indeed there appears to be a strong regularity here, so we can assume that AL Tau is not an UXOR. Light curve data are from ASAS3 (Pojmański *et al.* 2013).

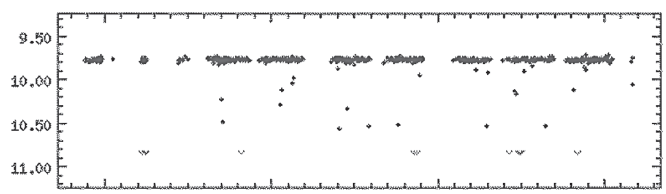

Figure 2. Shows a typical light curve for FP Car, again located near a starforming region. While the fades do not appear to be as regular as those for AL Tau (there are also fewer data points) note that the "fainter than" symbols do seem to occur at reasonably regular intervals; one can mentally insert a hypothetical "fainter than" where it appears to be absent. But for these reasons maybe we should not be in such a hurry to drop this star from our list as in the previous example. Light curve data are from ASAS3 (Pojmański *et al.* 2013).

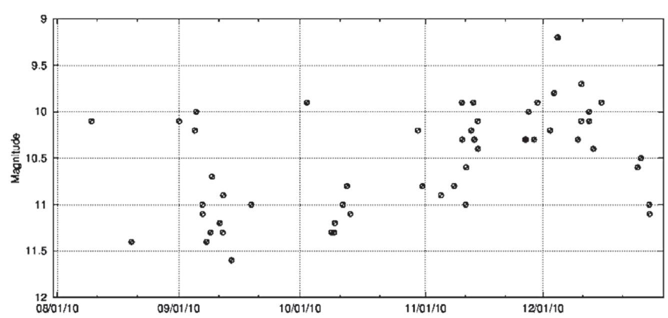

Figure 3. Light curve for a known, and highly-active, UXOR (CQ Tau) for comparison. This time we are using AAVSO data from the AAVSO Light Curve Generator, and it can immediately be seen that while there may be a vague periodicity to some minima, the fades when they occur are not always of the same depth or duration. This should be enough to tell us that we are not dealing with an Algol-type star.

of the galactic equator. This provides us with a list of 357 stars. Still a fair few, but a step down from 20,000 objects!

We can narrow this list down even more if we consider the light curves of selected stars. We need to look for the presence of strict regularity, which will strongly suggest that we are dealing with a genuine Algol variable, and so can eliminate it from our search list. A good resource for this is ASAS (Pojmański *et al.* 2013; http://www.astrouw.edu.pl/asas/?page=aasc&catsrc=asas3) although currently curves are only available for stars South of +28°.

Figures 1 through 3 are a selection of curves illustrating what can be seen.

4. Summary: future of the campaign

As of the present (March 2015) several observers have expressed an interest in following the UXOR hunt and have been provided with a list of the stars discussed above. There are now search facilities on the YSO section website (http://www.starman.co.uk/ysosection) via a queryable MySQL database where observers can filter targets to suit their needs.

In order for the central list to be trimmed even more it would be useful if any details involving the existing candidates (definitely proven Algol type, and so on) could be communicated to me so that I can remove them from the database.

From what was discussed above, it is also probably a truism to say that EA stars with accurately-determined periods which can be shown to have a high degree of regularity should indeed be considered to be bona fide Algols and therefore eliminated from the original list—although there are a very small number of stars such as KH15D that exhibit a high degree of regularity while being a YSO rather than an Algol star (see for example Kearns and Herbst 1998). However, to compensate for this, we may want to consider not only those EA stars within 5° of the galactic equator but also those in R-associations, for the reasons pointed out earlier.

The list currently comprises all types of variation within the EA parameters—a wide range of periods, amplitudes, and brightness levels—so it will be coverable by visual and CCD observers, ensuring that a comparatively large number of observers can participate. In the near future I would also like to add some additional stars in the region of certain R-associations, in which regard I would like to thank Prof. Bill Herbst for his helpful suggestions.

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