Two High-Latitude UXORs

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Abstract The active variables V1117 Her and RZ Psc are discussed with a proposition that star formation can occur far from the galactic plane and in relatively small, isolated environments, and that some YSOs may last longer in such places and help highlight the existence of high latitude star formation.

1. Introduction

YSOs are, almost by definition, to be found in the region of the parent gas clouds from which they condensed, and since these clouds lie overwhelmingly along the galactic equator or in starforming regions close to it, the notion of such variables being found at high galactic latitudes may be a puzzling one. The two objects examined here have galactic latitudes (b values) in excess of 30° and do not have starforming clouds or similar regions associated with them. Both stars show visual light curves punctuated by quasiperiodic Algol-type fadings characteristic of the class of star typified by UX Orionis (UXORs), although the spectral type of RZ Psc of K0 IV is highly atypical for these objects which are of much earlier spectral types as a rule.

Observed UXOR fades are believed to be be a combination of two basic factors: firstly, the presence of a circumstellar disc with a high axial inclination relative to the observer and so appearing edge-on or nearly so to our line of sight. Secondly, the presence in this disc of clumps of matter such as forming planetesimals which, because of the view we have of them, can occasionally "eclipse" the parent star and thus produce the observed dips in brightness. In fact some UXORs such as BO Cep and MQ Cas were originally thought to be Algol-type Eclipsing Binaries, and indeed one of the stars in this paper, V1117 Her, was once listed as a long period variable having an amplitude of 1.9 magnitudes, and period of 114 days, none of which parameters actually apply to it.

Assuming that the stars were originally formed at low galactic latitudes, we need to ask how they ended up where they are today; far away from any areas of star formation. While a high value for b does not alone confer such peculiarity (for example UX Orionis itself has b = –25° but it does lie close to a very extensive starforming region in the neighborhood of M42) most YSOs discovered so far inhabit regions with low galactic latitudes. Below is a quick list of random UXORs together with their distances from b = 0:

Table 1. Some UXOR-type variables together with their distances from the galactic equator.

Star	*abs (b)°*
VX Cas	00.8
GM Cep	03.8
DG Cir	04.2
GT Ori	15.0
RZ Psc	34.7
XX Sct	00.5
CQ Tau	04.0

With the exception of GT Ori (due to the fact that the Orion starforming region is so extensive that parts of it lie relatively quite far below the galactic equator; see the quoted example of UX Ori above) all the members of this admittedly small sample lie within 5 degrees of the galactic plane, and they are quite typical as regards this parameter.

2. The stars

RZ Psc (2MASS J01094205+2757020, ASAS J010942+2757.0) is catalogued as a bona fide UXOR variable, though it is hardly typical of the class. As regards galactic latitude Grinin *et al.* (2010) give an expression for the physical distance z from the galactic plane:

$$z = D \sin b - z_{\odot} \quad (1)$$

$z_{\odot}$ here is the distance of the Sun from the plane, taken as +25 parsecs, and D the distance to the star in parsecs. Inserting appropriate values for RZ Psc gives us a distance of –130 parsecs with reference to the galactic plane.

Determining a ballpark figure for the age of RZ Psc, which will relate to this distance, can yield a wide range of results, though none point to extreme youth as would be expected for an UXOR, and most methods are reliant on variables whose values are imprecise. For example, the value of D in equation (1) is arrived at indirectly here, using assumptions about its absolute magnitude M based on its spectral type and assumed age which are then used to derive a value for D. However, as we shall see next, the age of RZ Psc is the subject of debate.

One method that has been employed for some time is to determine the proportion of Lithium in the atmosphere. Lithium is a signature of youth since it is rapidly destroyed by nucleosynthesis as the star enters and then proceeds along the main sequence. Grinin *et al.* (2010) estimated an age for RZ Psc based on its Lithium abundance of between 10 to 70 Myr which was later refined to between 20–30 Myr—so, young but not as one might say "YSO-young" since this figure would lead us to expect that the circumstellar material should effectively have been used up to form a planetary system or dust features after such time, but studies have shown that there is IR excess present to an extent that suggests that there is still an active disc of some sort that interfaces with the parent star. Other estimates based on the star's proper motion when combined with gravitational mechanics of the Galaxy itself yield a slightly higher figure of about 50 Myr, and in this context another theory has emerged that relates to Gould's Belt.

Gould's Belt is a partial ring of relatively young, massive early-type stars in a plane spread around the sky, with a break in the direction of the galactic center and a diameter thought to be ~1 Kpc. The plane is inclined to that of the Galaxy by about 20° and the O- and B-type stars that define it are in the region of 50 Myr old. Also, including many well-known naked-eye stars such as Rigel, the belt also harbors active areas of massive star formation such as the Cep and Cas OB and Sco-Cen OB associations.

Although its cause—assuming that it is a real entity of course—has not been definitively established, one suggestion is that, since there is a break near the galactic centre, something extragalactic such as a huge gas cloud or even a region of dark matter ploughed into a spiral arm, generating a huge burst of star formation which resulted in those hot young stars of the belt and, in the same process, possibly ejecting some stars away from the arm. Some of those stars may have been in the process of forming independently at the time and, so to speak, are still carrying their youth with them. The proper motion of RZ Psc is reasonably high (25.4α, –11.9δ mas yr^{-1}), and in a direction away from the galactic plane, which has led some credence to this idea. However, if we look at a plot of proper motions of stars in the area of RZ Psc in Figure 1 we can see that there are several other stars with similar direction vectors comparable to that of RZ Psc or which actually exceed it, such as the star at about R.A. 01^h 11^m, Dec. 27° 50' ($\mu_{\alpha,\delta}$ = 36.9, –29.4 mas yr^{-1}) .

V1117 Her Although not catalogued as a UX Ori star, the second star in this paper, V1117 Her, shows UXOR-like dips in brightness and in fact at the time of writing (August 2016) has just emerged from one of these fades, as can be seen from examining the observations given in Table 2.

These fades are both deep and rapid as can be seen from the above observations, and the better-observed fade series in fact demonstrate that a typical minimum is around 15.0mv, an amplitude and duration similar to that of some active Herbig Ae stars such as V730 Cep. There appears to be some regularity to these major fades, which Kun *et al.* (2014) largely using AAVSO observations determine as 408 days, and suggest some form of eclipse of the parent star by a clump. Figure 2 shows the light curve of this star from 2002 to 2016 and it appears on a cursory examination that the fades are tending to become deeper. If this is indeed the case then it may point to evolution of the clump(s). The relative regularity of the fades could be indicative of a persistent clump, something that has been hypothesized in the case of another star on the AAVSO YSO program, GM Cep, a most definitely young star in the Cep OB2 association involved with the IC1396 starforming region and one that I urge observers to follow.

Spectral features such as the presence of Hα in emission and prominent Balmer-series absorption in the star indicate a spectral type of A for V1117 Her. But YSOs of such type are to be found closer to theatres of star formation and evolve so quickly that by the time they have reached the galactic latitude of 33° they would have lost any circumstellar material; and in any case there are no such star formation areas in the neighborhood of V1117 Her. Considering the proper motion of the star ($\mu_{\alpha,\delta}$ = –7.9, –5.9 mas yr^{-1}) we cannot even postulate a scenario like that hypothesized earlier for RZ Psc; tracing the space motion back over a time span similar to the expected age of the star encounters no suitable star formation areas. A plot of the proper motions of stars in the neighborhood of V1117 Her is shown in Figure 3, where positions are in galactic coordinates.

Assuming that the star is at, or near the ZAMS (Zero-Age Main Sequence) and its spectrum is indeed A-type then it should have M ~ +2. Comparing this M with its observed visual maximum of 12.1 whilst assuming minimal space reddening due to its observed distance above the galactic plane we can employ the formula for distance modulus:

$$m - M = 5 \log d - 5 \qquad (2)$$

and rearrange for d to give a value of about 870 pc, which

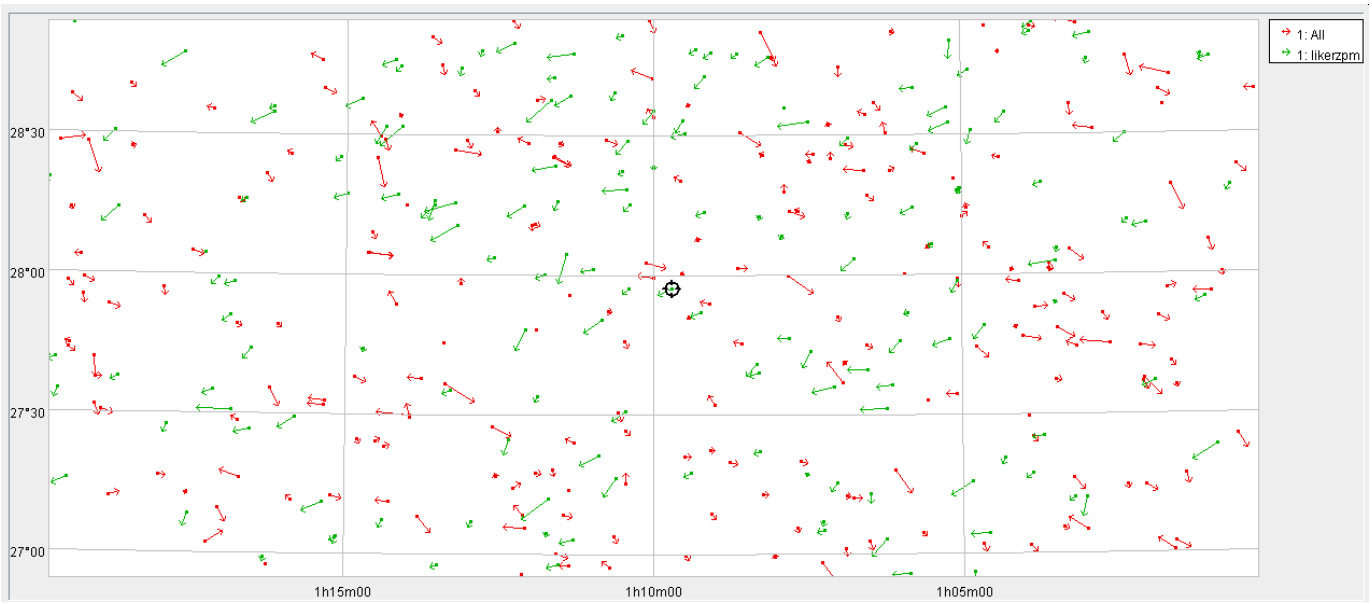

Figure 1. Proper motions of stars in the area of RZ Psc (circled). Position vectors similar to that of RZ (α +ve, δ –ve) in green. All vectors are to scale. Produced using the TOPCAT software tool.

Table 2. Visual observations of V1117 Her.

JD	*UT*	*Magnitude*	*AAVSO Observer Initials*
2457575.458	2016 Jul. 05.95800	12.9	PYG
2457587.440	2016 Jul. 17.94000	13.4	PYG
2457588.445	2016 Jul. 18.94500	13.5	PYG
2457594.435	2016 Jul. 24.93500	14.3	PYG
2457599.440	2016 Jul. 29.94000	14.0	PYG
2457600.43	2016 Jul. 30.93000	13.7	PYG
2457601.432	2016 Jul. 31.93200	13.5	PYG
2457605.427	2016 Aug. 04.92700	13.1	PYG
2457606.436	2016 Aug. 05.93600	12.5	PYG
2457607.4451	2016 Aug. 06.94510	12.5	POX

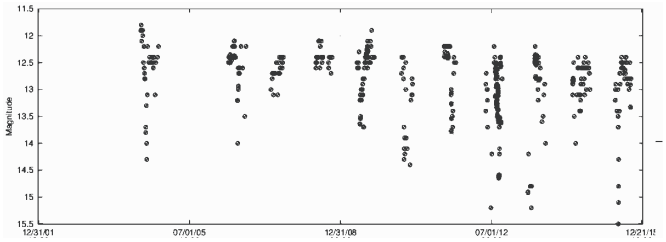

Figure 2. 15-year light curve of V1117 Her from the AAVSO light curve generator. Note the periodicity of the fades and their tendency to become deeper.

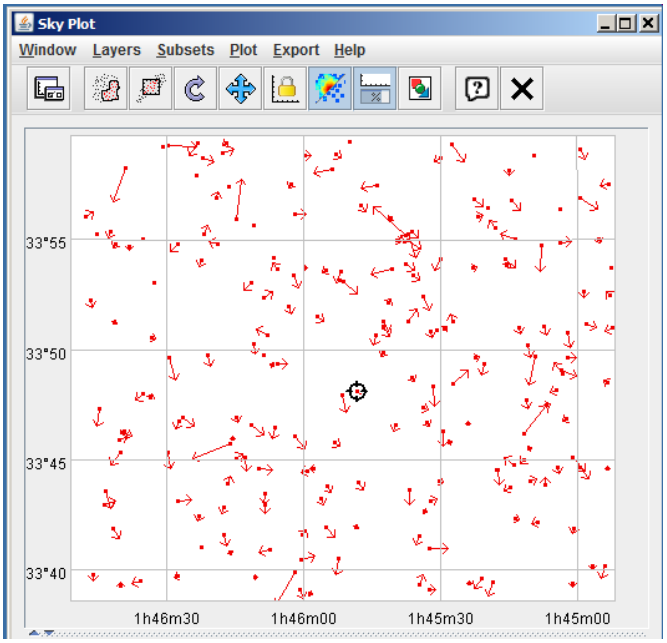

Figure 3. Proper motions of stars around V1117 Her (circled). Note its small vector when compared with many of the other objects in the plot. Coordinates are galactic. Plot prepared using TOPCAT software.

leads through trigonometry to a distance of ~400 pc above the plane, where ordinarily we would not expect to find starforming material, though there is a complex of dark nebulae near the star μ Serpentis of which the largest is LBN19. The proper motion of V1117 Her is, somewhat perversely toward, rather than away from, this area! However, the presence of nebular material at this position of b = 37.3° should demonstrate that nebulae are not only to be found at low galactic latitudes, and indeed in recent years several stellar associations known as T-associations (since they contain a high proportion of T Tauri stars) have been discovered well away from the galactic plane such as the nearby Tucana-Horologium association with b values at or greater than –50° and ages around 30 Myr, together with quite extensive molecular clouds in (for example) Octans, with an approximate b value of –30° and thus comparable to the values for the stars discussed here. Although most of the members of T-associations are of lower mass and later spectral types than a typical UXOR, early-type stars are typically found to be constituents of such groups, and this may be relevant to a suggestion to be made in the following conclusion.

3. Conclusion

We have seen that both stars show UXOR-like behavior in terms of the light variations and both have been shown to possess circumstellar discs. V1117 Her looks, from its spectrum, more like a typical UXOR than does RZ Psc. Similar variable types such as R Coronae Borealis stars also show deep fades, but these fades are random in depth, duration, and occurrence, and the variations of our two objects are more regular and show, at least in the case of V1117, some suggestions of dynamical processes such as clump evolution. RCB stars are also hydrogen-poor and this does not apply to the stars discussed here. However, the high galactic latitudes and distance from star-forming areas would seem to militate against their being stars comparable in age to a typical UXOR. So is it possible that RZ Psc and V1117 Her are members of a hitherto different variety of YSO that are actually formed away from the galactic plane? After all, as we saw in the previous paragraph above, there may be other places to look for starforming regions other than the immediate galactic equatorial area. If RZ Psc and V1117 Her were actually born at high latitudes out of such clouds then the gravitational influence of nearby stars in a stellar association (or indeed of the general mass of the immediate Galaxy) might not be so effective at disrupting the circumstellar environment, allowing the disc to persist for longer.

So—should we start looking for YSO's away from the galactic plane?

4. Acknowledgements

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