To Everything, Turn, Turn, Turn – Or Not: Misclassified ASAS-SN Rotators

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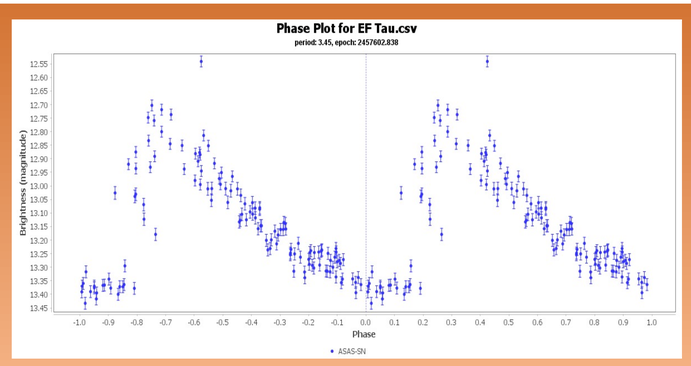
The ASAS-SN (All-Sky Automated Survey for Supernovae) project used machine learning techniques to identify, characterize, and classify over 400,000 variable stars. However, as noted by John Percy and collaborators (2019), the associated automated light curve analysis algorithm has difficulty discerning the complex periodicities and subtypes of pulsating red giants.

Rotating variables are also known for their complex behaviors, including varying amplitudes and mean magnitudes and periodicities that are not precisely defined (due to changing numbers and sizes of spots). It is therefore likely that the ASAS-SN algorithm will likewise encounter difficulties in classifying and analyzing periods for rotating stars.

This study utilized VStar software to analyze the ASAS-SN light curves and phase plots of 96 stars classified as general rotator (ROT) by ASAS-SN. These stars were selected due to their having Argelander letter/V-number names in VSX, suggesting that their behavior/classification is more likely to be well-known with reasonable confidence than stars that are known only by their ASAS or ASAS-SN names. To maximize the likelihood that stars are falsely classified as ROT, stars of magnitude ranges 0.35+ were used, as most rotating variable classes are more likely to have relatively smaller amplitudes (Percy 2007).

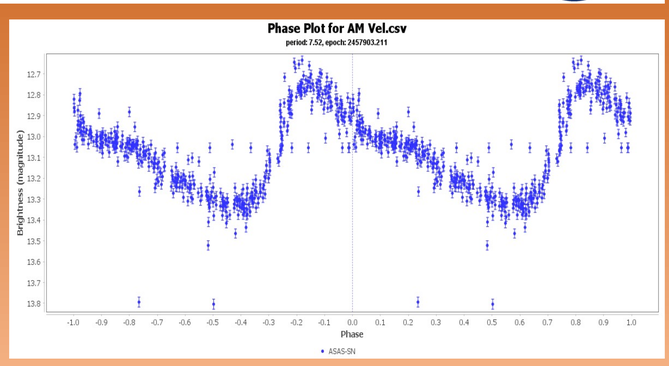
While 58% of the stars were also classified as rotating stars in VSX, all had defined sub-classes (e.g. RS, BY, TTS, etc.) in VSX that are not noted as part of the ASAS-SN algorithm. Roughly one third of the entire sample (31%) was found to have ASAS-SN periods that significantly disagreed with those found in VSX (largely multiples of the VSX period) or periodicities were found where none is listed in VSX, and are therefore potentially spurious. In one case (V1598 Ori) VStar analysis of the ASAS-SN light curve demonstrated the existence of a periodicity where none was published in VSX, although the ASAS-SN generated period was a multiple of the true value. A fifth of the sample (19%) was found to be instability strip (IS) stars - Cepheids (Classical and W Virginis), RR Lyrae stars, or related AHB1 (XX Vir) stars - an interesting finding, as a critique of the original ASAS catalog algorithm was the number of rotating stars it misclassified as Cepheids (P. Wils, through D. Welch, 2012). The converse is therefore also true. Note that there was a higher percentage of IS type variables in the largest amplitude band (0.5 mag and up), which correlates with them generally having higher amplitudes than true ROT stars.

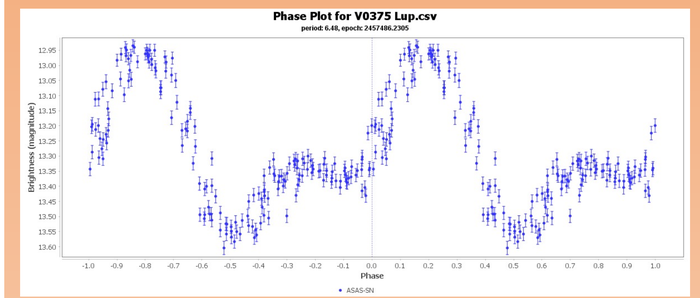
The ASAS-SN public light curve interface currently includes a warning about potential blending of star data in crowded fields and limitations of the "saturation correction procedure" for data points brighter than 10th-11th magnitude (Shields & Stanck 2018).. However, many of the misclassified stars are much dimmer than this limit and are not. This suggests that it is the light curves themselves that confound the algorithm, information that could be of use when considering datasets of less-well studied ASAS-SN-discovered variables in VSX.



Left: EF Tau is classified as a DCep on VSX, which is clearly supported by the ASAS-SN light curve, despite the ASAS-SN classification as ROT. The periods agree to three decimal places.

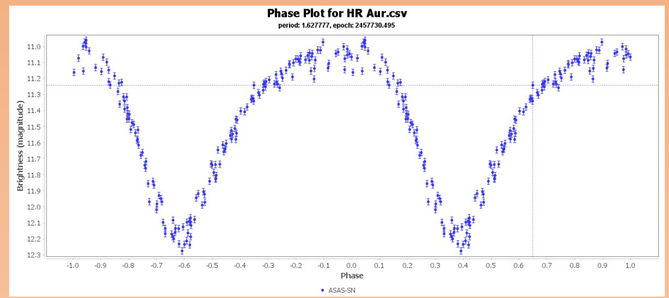
Right: AM Vel is also classified as a DCep in VSX, again, clearly supported by the ASAS-SN light curve (in contrast to the ASAS-SN class of ROT). The periods agree to the second decimal place.

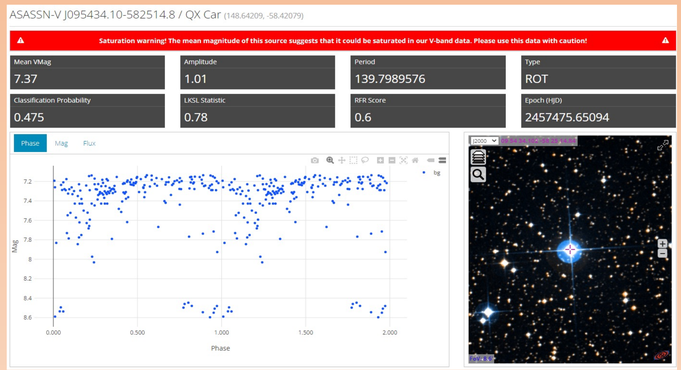




Left: V0375 Lup is a CWB W Virginis pulsating variable, not a rotator (as classified by ASAS-SN). The ASAS-SN period of 12.955 d is twice the VSX value (shown here).

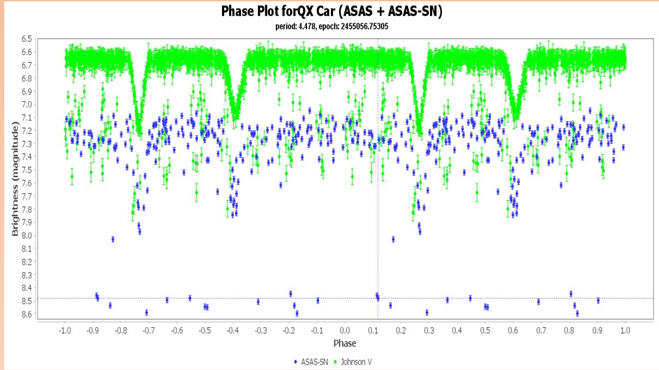
Right: HR Aur is not a rotator but an eclipsing binary with chromospheric activity (E/RS). The period is correctly identified by ASAS-SN.

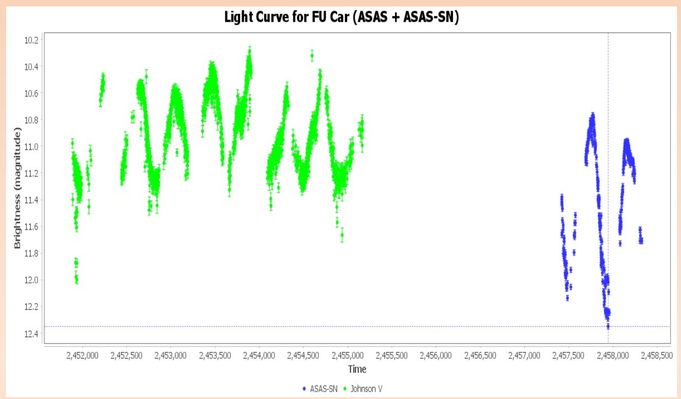




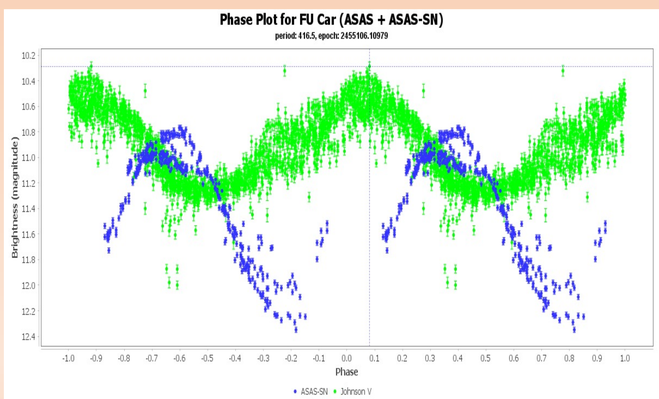
Left: The ASAS-SN page for QX Car clearly notes that the data should be considered with caution due to saturation effects (the star varies between 6.6-7.21 V). The ASAS-SN algorithm claims a period of 139.8d.

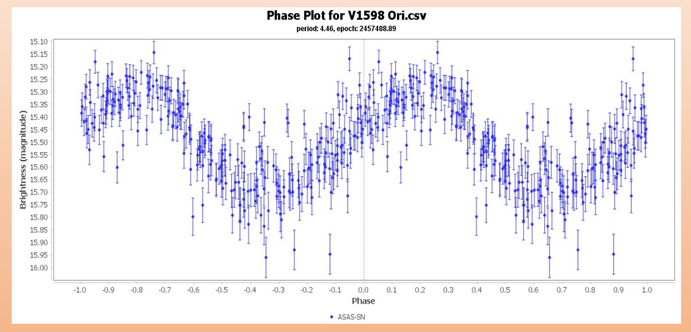
Right: However, the true period is much shorter (4.478 d), and can be clearly seen in both the ASAS-SN and ASAS data. This star is clearly an eclipsing binary, not a rotator (EA)



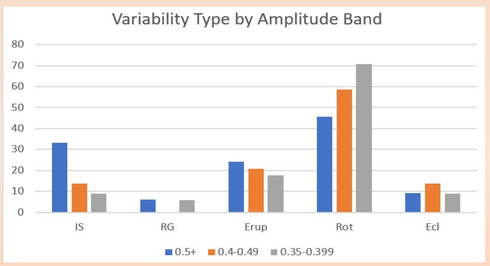


Left: The combined ASAS + ASAS-SN light curve for FU Car agrees with its VSX classification as a Mira-type variable and not a rotator.
Right: While both sets of data independently agree with the VSX period (416.5 d), the two data sets are shifted by 0.4 of a phase. This is not unexpected, given the ~2200 d gap between the two data sets and the likelihood of period changes in M-type variables. See **below** WWZ analysis of the period shift in the ASAS data.

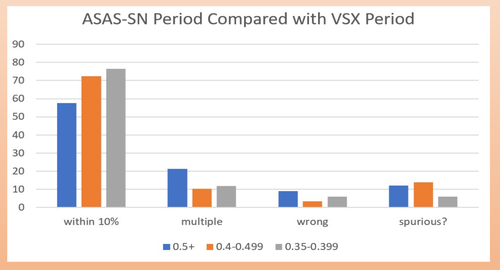




Left: A case where ASAS-SN was correct. V1598 Ori is an IN irregular, eruptive variable. Some of these stars are also rotating variables, as in this case. Here ASAS-SN picked up a rotational period not yet reported in VSX.



Left: Variability Type by Amplitude Band (33, 29, and 34 stars from highest to lowest magnitude range).
IS = Instability Strip (Classical Cepheids, W Virginis, RR Lyrae, XX Vir)
RG = Red Giant (Mira or Semiregular)
Rot = rotational variables
Ecl = Eclipsing binaries



Left: Agreement between VSX and ASAS-SN period. Note that there were more true ROT for smaller mag. ranges, as expected.

Multiple = ASAS-SN per. 2X, 3X, or half the VSX value
Wrong = ASAS-SN is more than 10% different from VSX value
Spurious? = no per. in VSX; most very faint (limited data)

References:

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