# Observations of 36 Accreting Cataclysmic Variables (CVs)

**Abstract**

This study describes robotic telescope observations of 36 accreting cataclysmic variables. In particular, 15 VY Scl type cataclysmic variables and 21 dwarf novae cataclysmic variables were imaged. Typically cataclysmic variables involve a white dwarf and a relatively low mass donor star. In this case, material from the outer envelope of the donor star can be more gravitationally attracted to the white dwarf than the donor star itself, leading to accretion. The optical light that observers see in most accreting white dwarfs is a combination of the light from the white dwarf, the light from the donor star, and the light from the accreting material. The light from the accreting material can dominate the observed light at some times, and at other times the light from the donor star dominates the observed light. Generally the optical light from a white dwarf is the smallest component. Since white dwarfs are both less massive and larger in radius than neutron stars and black holes, accreting white dwarfs tend to gravitationally liberate a smaller fraction of energy from the accreting material, in comparison with accreting neutron stars and accreting black holes.

**Introduction and Background**

Dwarf Novae are a type of non-magnetic cataclysmic variable where the variability observed is due to variations in the accretion flow onto the white dwarf. For long periods of time, a dwarf nova system will only slowly accrete matter onto the white dwarf. But a change in the viscosity of the accretion disk dramatically increases the rate of mass transfer through the disk, heating the disk. This leads to strongly increased optical output that is typically not as bright as in a classical nova. These fainter outbursts are the origin of the name of this class of systems. Many dwarf nova undergoes these outbursts frequently, with varying times between outbursts. VY Scl systems are typically characterized by high average accretion rates which keep the disk in a stable hot state, equivalent to a permanent outburst. Occasionally the accretion rate drastically drops ("low state"), unveiling the white dwarf. These low states provide a window in which the underlying accreting white dwarf can be observed. Within the VY Scl and dwarf novae categories, there are numerous cataclysmic variable subcategories including:

AM

AM Herculis-type variables: Close binary systems consisting of a dK-dM type dwarf and an extremely strong magnetic white dwarf primary, in which the magnetic field of the primary not only prevents the formation of an accretion disk but also synchronizes the primary's rotation with its orbital period. They are characterized by variable linear and circular polarization of light. The total range of light variations may reach 4-5 magnitudes in V. These are also known as polars.

DQ

DQ Herculis type: Magnetic cataclysmic variables with a red dwarf secondary and a white dwarf primary component that generates a magnetic field weaker than the field associated with AM Herculis stars and that is not strong enough to synchronize the orbits of the rotating white dwarf with the orbital period of the system. These are also known as intermediate polars (IP).

E

Eclipsing binary systems. These are binary systems with orbital planes so close to the observer's line of sight (the inclination of the orbital plane to the plane orthogonal to the line of sight is close to 90 deg.) that the components periodically eclipse each other. Consequently, the observer finds changes of the apparent combined brightness of the system with the period coincident with that of the components' orbital motion.

IBWD

Interacting Binary White Dwarfs: Close binary systems with ultra short periods (5-70 minutes). Also known as AM CVn-type stars or Helium dwarf novae because they lack hydrogen lines in their spectra. Outbursting IBWD objects can be identified by some outburst properties; short (5-6 day) super outbursts, rapid fadings but long-fading tails lasting 100-200 days and without IR-excess, smaller amplitudes than UGWZ stars and fainter superoutburst absolute magnitudes (<4).

NL

Nova-like stars: Cataclysmic variables where the mass transfer rate is above a certain limit and their accretion disks are stable because they are nearly fully ionized to their outer (tidal cut off) boundary. This condition suppresses dwarf nova outbursts. Also known as UX (UX Ursae Majoris stars).

UG

U Geminorum-type variables: These are quite often called dwarf novae. They are close binary systems consisting of a dwarf or subgiant K-M star that fills the volume of its inner Roche lobe and a white dwarf surrounded by an accretion disk. Orbital periods are in the range 0.003-0.5 days. Usually only small, in some cases rapid, light fluctuations are observed, but from time to time the brightness of a system increases rapidly by several magnitudes and, after an interval of from several days to a month or more, returns to the original state. Intervals between two consecutive outbursts for a given star may vary greatly, but every star is characterized by a certain mean value of these intervals, i.e., a mean cycle that corresponds to the mean light amplitude. The longer the cycle, the greater the amplitude. These systems are frequent sources of X-ray emission. The spectrum of a system at minimum is continuous, with broad H and He emission lines. At maximum these lines almost disappear or become shallow absorption lines. Some of these systems are eclipsing, possibly indicating that the primary minimum is caused by the eclipse of a hot spot that originates in the accretion disk from the infall of a gaseous stream from the K-M star. According to the characteristics of the light changes, U Gem variables may be subdivided into three types: SS Cyg-type (UGSS), SU UMa-type (UGSU), and Z Cam-type (UGZ).

UGZ

Z Camelopardalis-type stars: These also show cyclic outbursts, differing from UGSS variables by the fact that sometimes after an outburst they do not return to the original brightness, but during several cycles retain a magnitude between maximum and minimum. The values of cycles are from 10 to 40 days, while light amplitudes are from 2 to 5 magnitude in V.

UGSS

SS Cygni-type variables: They increase in brightness by 2-6 magnitudes in V in 1-2 days and in several subsequent days return to their original brightnesses. The values of the cycle are in the range 10 days to several thousand.

UGSU

SU Ursae Majoris-type variables: These are characterized by the presence of two types of outbursts called "normal" and "super-outbursts". Normal, short outbursts are similar to those of UGSS stars, while super-outbursts are brighter by 2 magnitudes, are more than five times longer (wider), and occur several times less frequently. During super-outbursts the light curves show superposed periodic oscillations (super-humps), their periods being close to the orbital ones and amplitudes being about 0.2-0.3 magnitudes in V. Orbital periods are shorter than 0.1 days; companions are of dM spectral type.

VY

VY Scl subtype: These are cataclysmic binary systems with a hot (35,000-65,000 K) and luminous white dwarf that occasionally undergo fadings of more than 1 magnitude (up to several magnitudes) due to a low rate of mass transfer. These fadings might last from days to years. At maximum they vary up to 1 magnitude. They are usually nova-like variables that show no outbursts but some dwarf novae also show similar fadings. Orbital periods usually range between 0.12 and 0.18 days.

ZZB

ZZ Cet-type variables of DB spectral type (DBV stars) having only helium absorption lines in their spectra. Also known as V777 Herculis stars.

E

Eclipsing binary systems. These are binary systems with orbital planes so close to the observer's line of sight (the inclination of the orbital plane to the plane orthogonal to the line of sight is close to 90 deg.) that the components periodically eclipse each other. Consequently, the observer finds changes of the apparent combined brightness of the system with the period coincident with that of the components' orbital motion.

**Methods**

The photometry data for these 38 accreting cataclysmic variables was obtained primarily from the AAVSO VSX (American Association of Variable Star Observers; International Variable Star Index) (Kloppenborg 2022) database. Specifically, the data was in the Johnson-Cousins BVRI photometric magnitude ranges (Johnson B at 400-500 nm, Johnson V at 500-700 nm, Cousins R at 550-800 nm, and Cousins I at 700-900 nm). Additional data was obtained from the database of the ASAS-SN (All-Sky Automated Survey for SuperNova) (Shappee, et al. 2014) global network of robotic telescopes. The ASAS-SN photometric magnitude range is Sloan g (402.5-551.5 nm). An ASAS-SN light curve was computed for 500 days for each of the objects, combined with the Johnson-Cousins BVRI data, and analyzed with the AAVSO VStar (Benn, D. 2012, “Algorithms + Observations = VStar”, JAAVSO, v40, n2, pp.852-866) software. VStar is a multi-platform variable star data visualization and analysis tool. Specifically, Fourier analysis of the combined photometric data was performed to yield a detailed periodogram for each of the CV objects from which periodicities and other variations can potentially be identified.

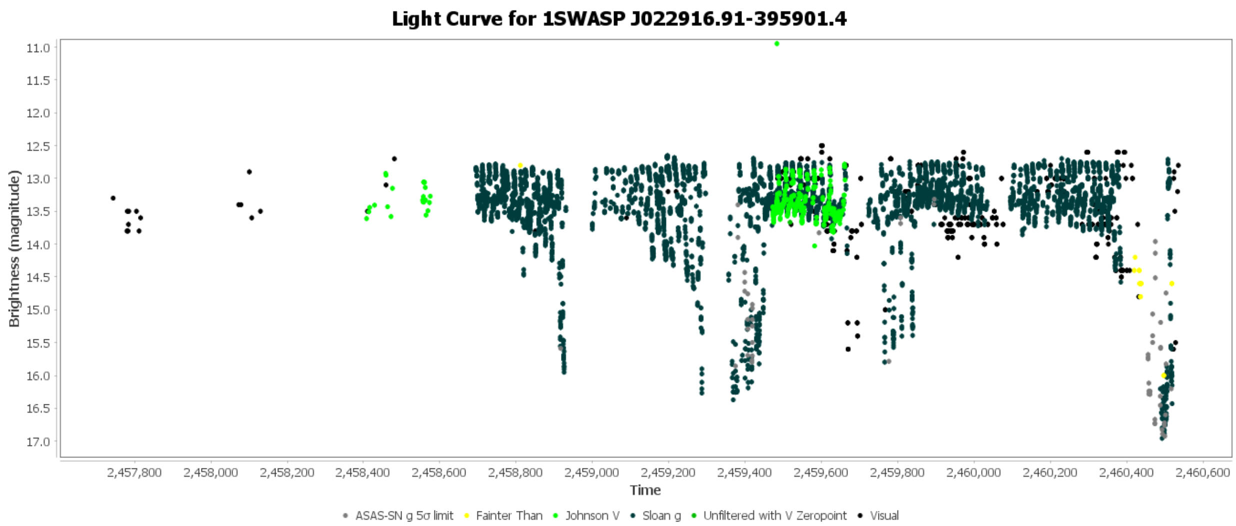
VStar utilizes the Date Compensated Discrete Fourier Transform (DCDFT) algorithm (Ferraz-Mello 1981) to produce a power spectrum, a period range, and a resolution. The Date Compensated DFT compensates for gaps in the data, which is common for variable star observations. The resulting analysis can include one or more periods and one or more harmonics. These can be selected to create a model that can also include a polynomial function that is used as a smoothing mechanism to capture key aspects of the data set without all the noise and fine fluctuations. When a model is created, it is subtracted from observations in the series to yield a second series called residuals. The residuals can also be analyzed to look for other signals (periods) in a process called pre-whitening. Periodicities and other potential variations were analyzed utilizing BVRI and Sloan g photometry, models created from the photometry, computed mean series, and residuals to obtain all possible variations.

## Analysis and Results

### *VY Scl Cataclysmic Variables*

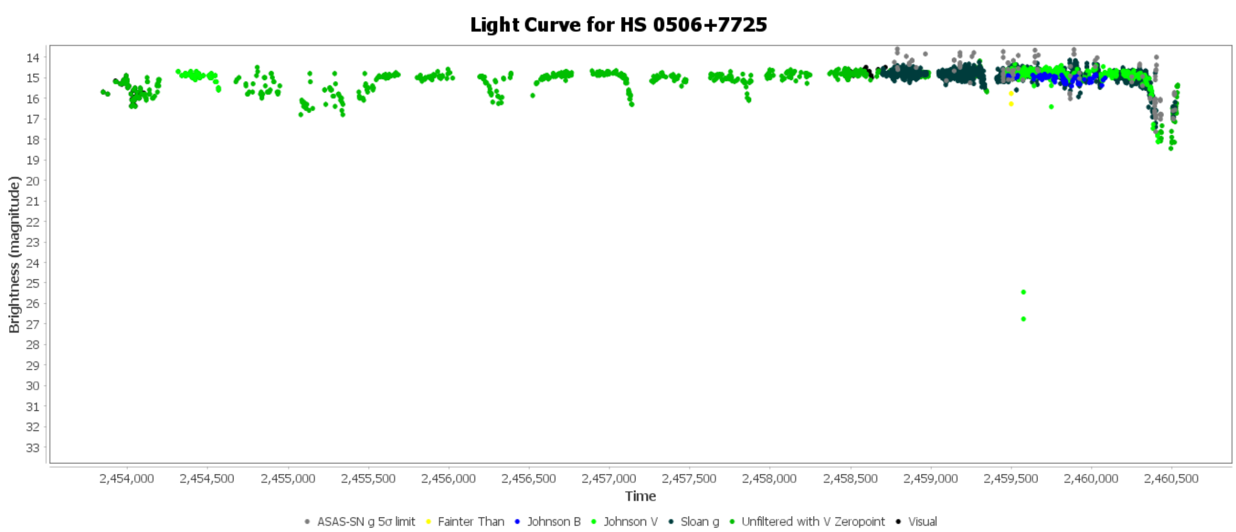
### 1SWASP J022916.91-395901.4

1SWASP J022916.91-395901.4 is a UGZ/IW+VY cataclysmic variable.



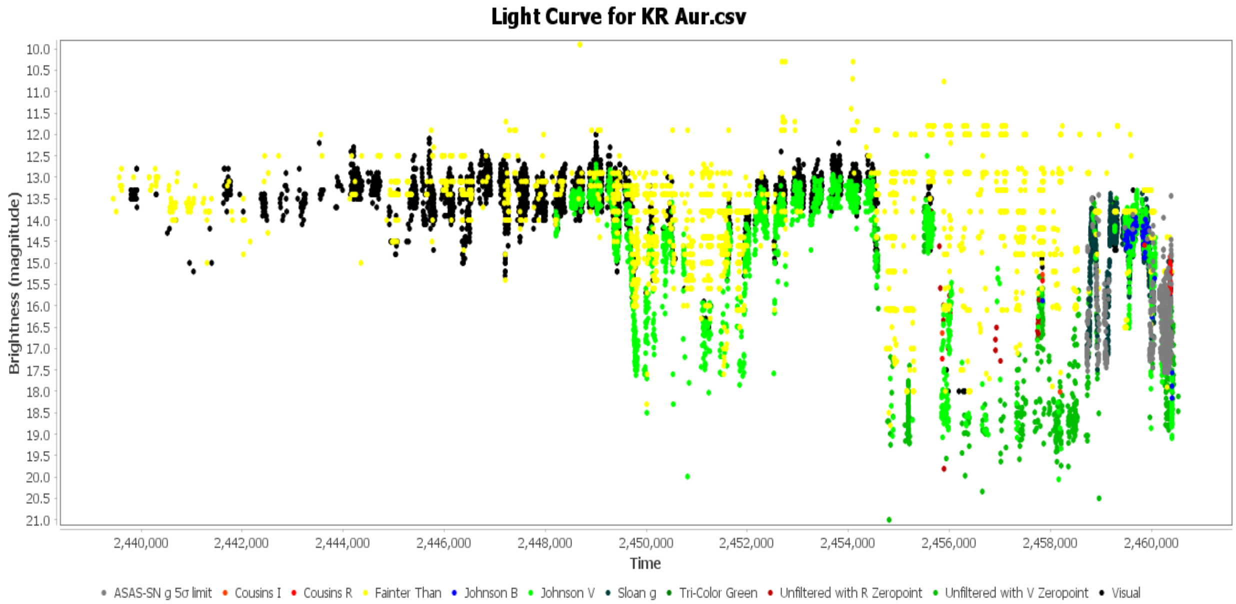

### HS 0506+7725

HS 0506+7725 is an NL/VY cataclysmic variable.



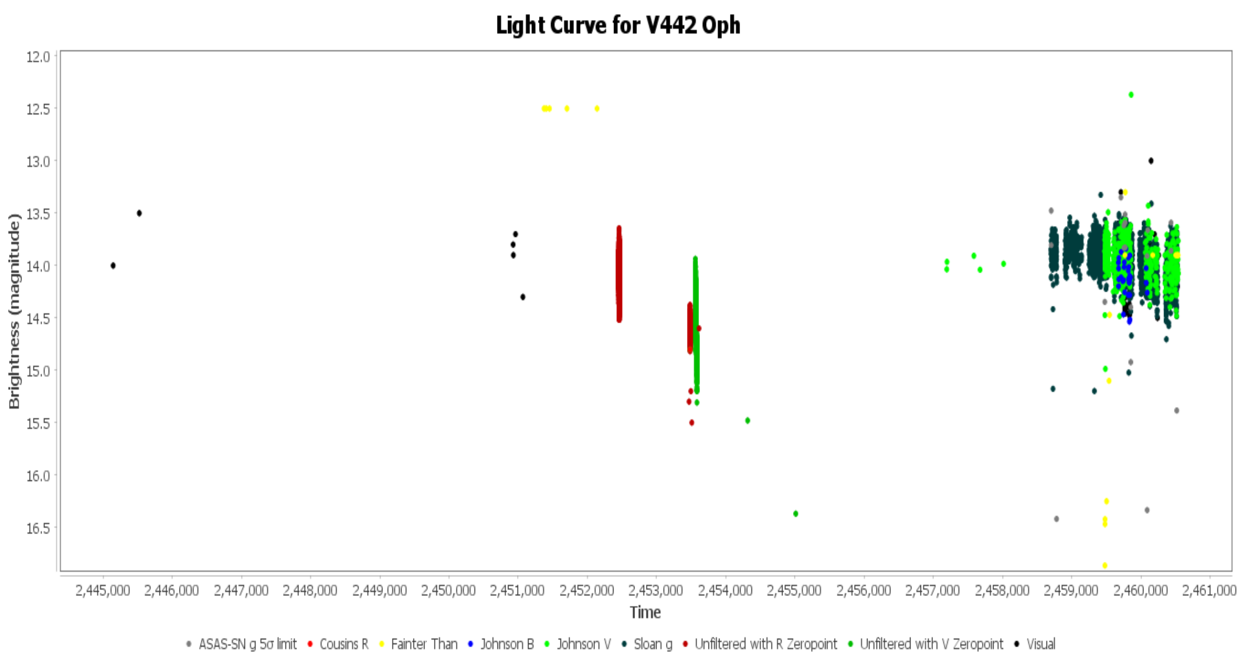
## KR Aur

KR Aur is an NL/VY cataclysmic variable.



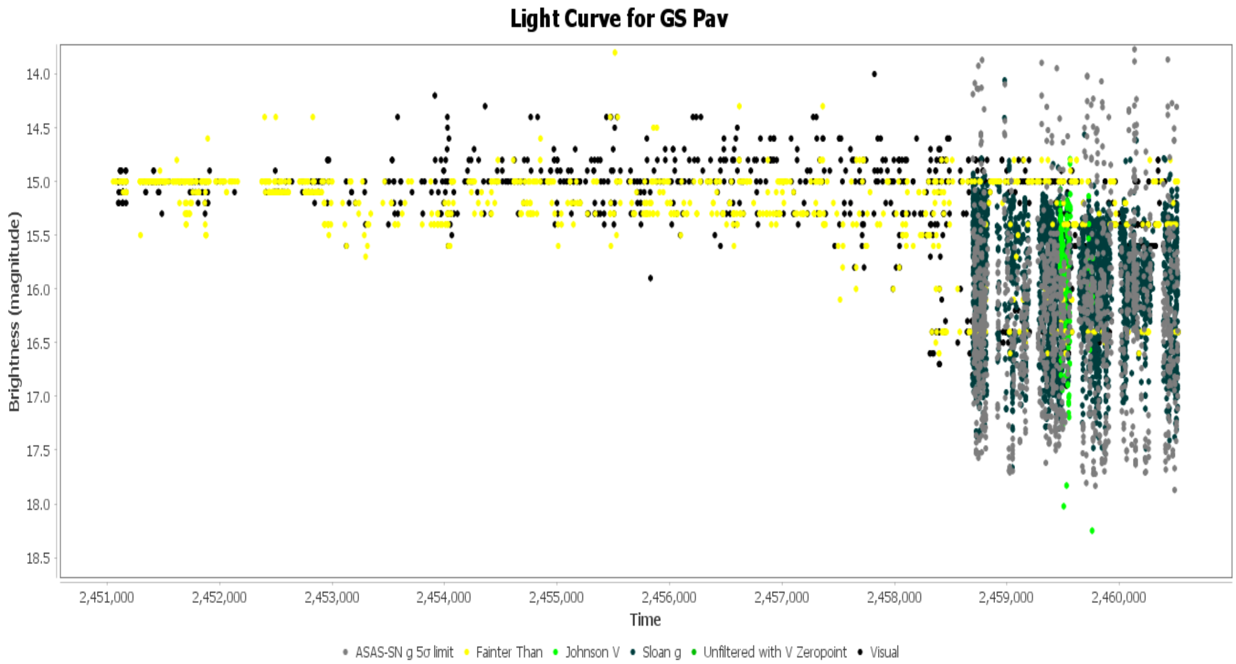

## V442 Oph

V442 Oph is an NL/VY cataclysmic variable.



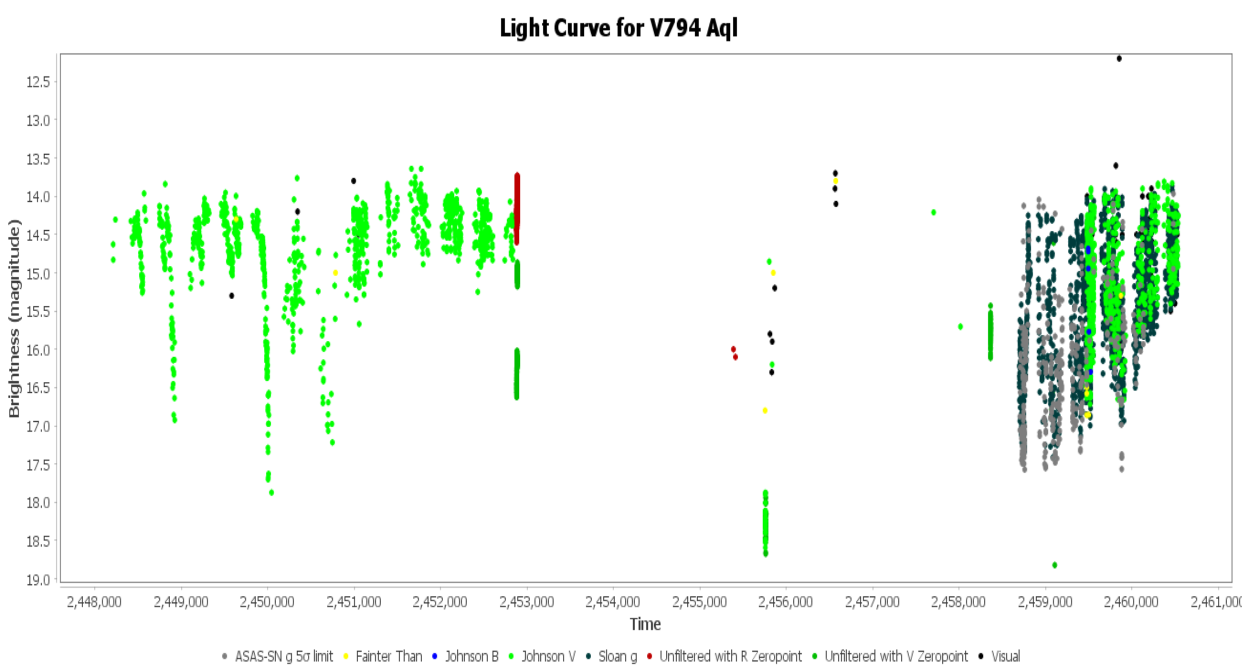
## GS Pav

GS Pav is a UGSS+E cataclysmic variable.



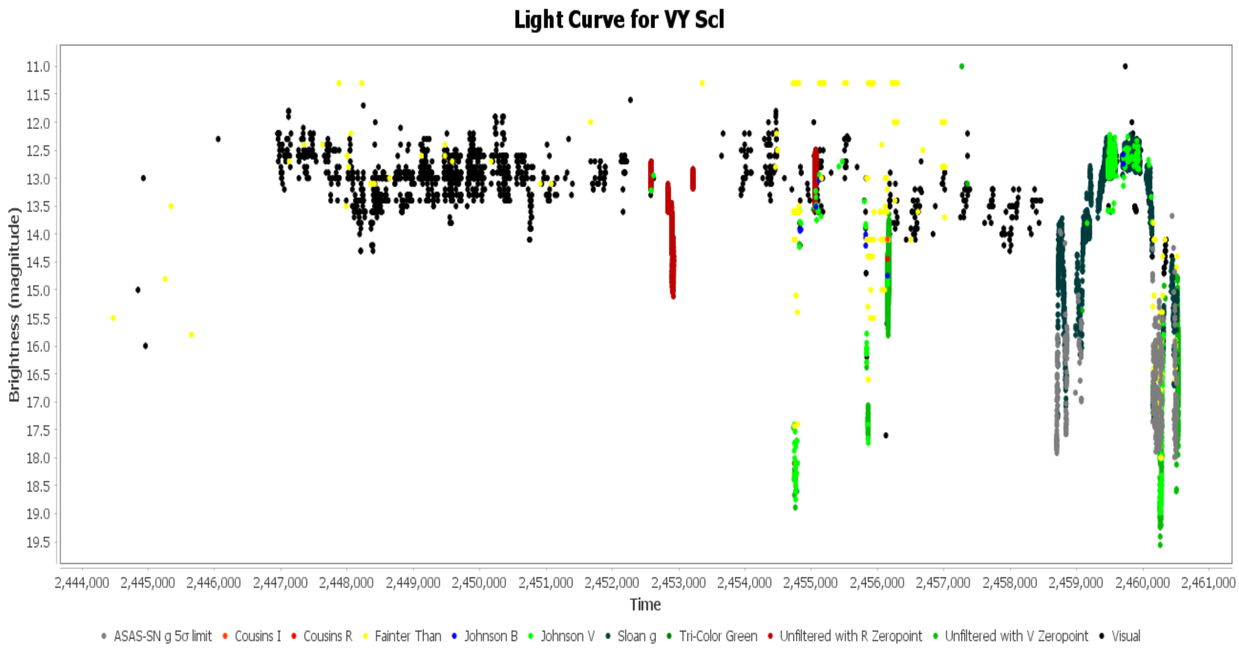

## V794 Aql

V794 Aql is a UGZ+VY cataclysmic variable.



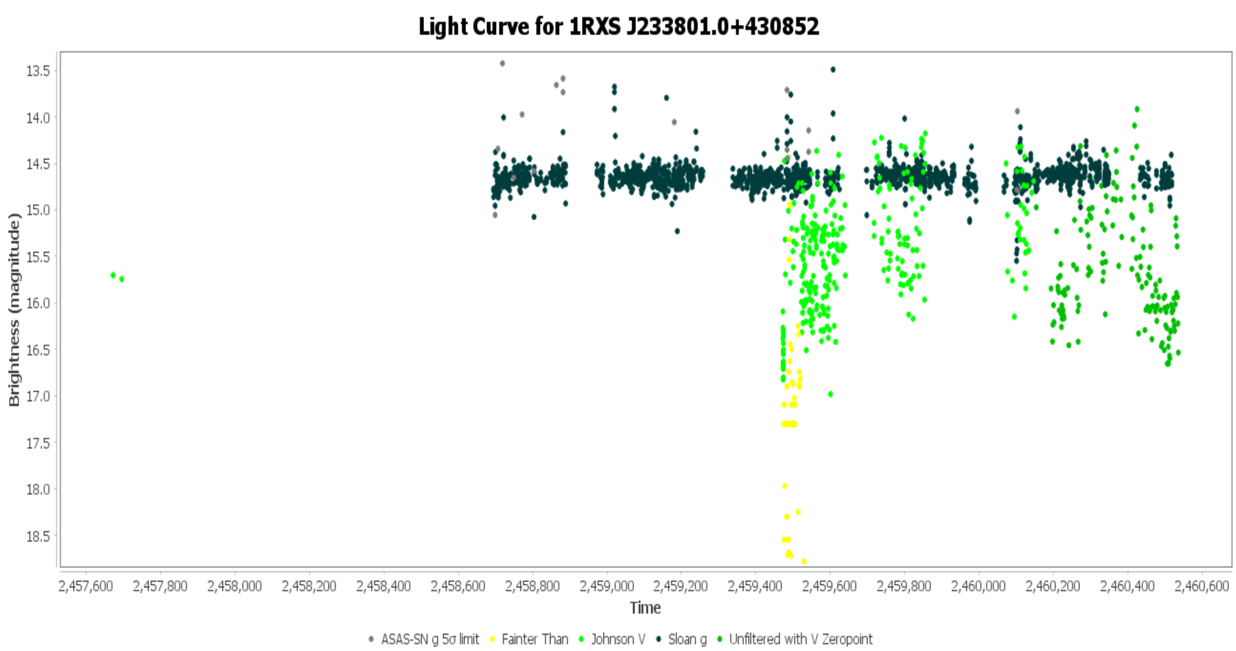
## VY Scl

VY Scl is an NL/VY cataclysmic variable and is the prototype for this subcategory.



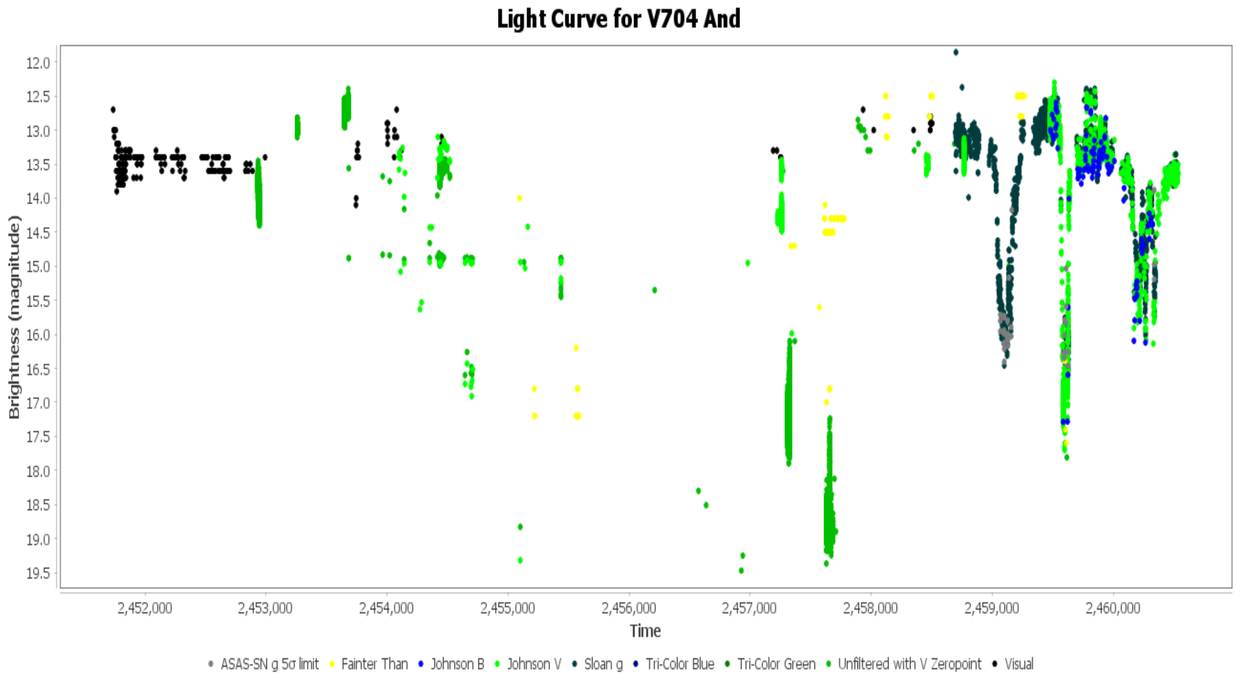

## 1RXS J233801.0+430852

1RXS J233801.0+430852 is an NL/VY cataclysmic variable.



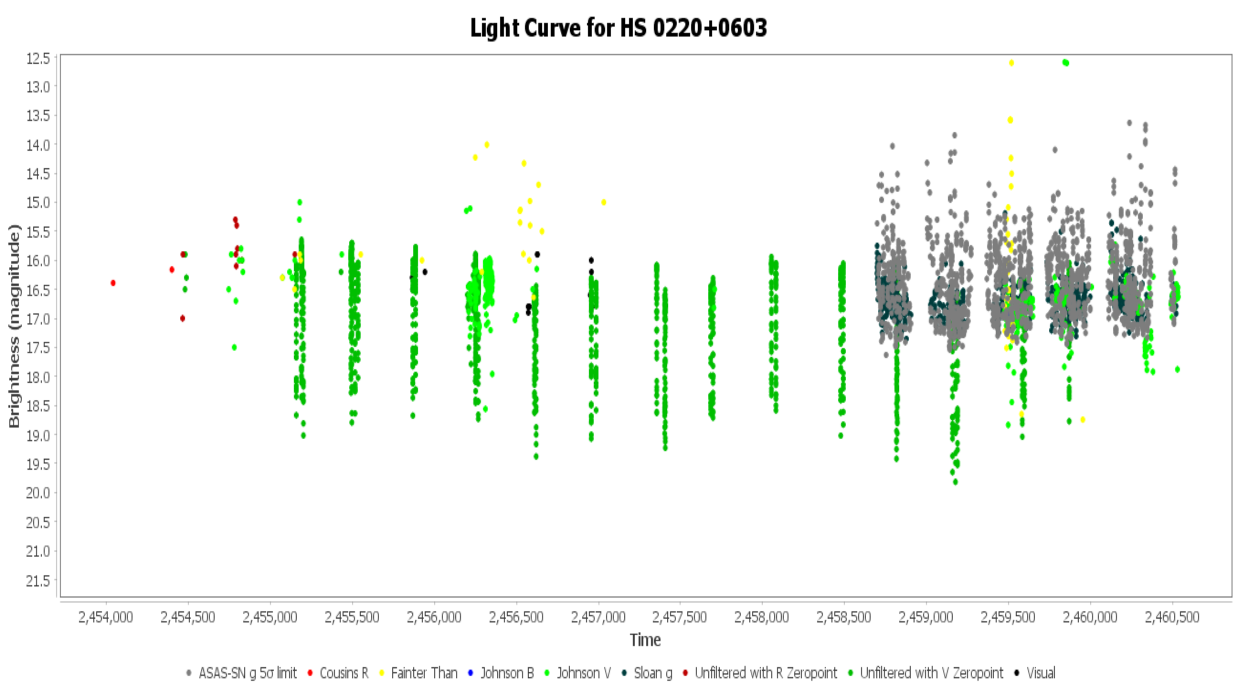
## [V704 And]

V704 And is an NL/VY cataclysmic variable.



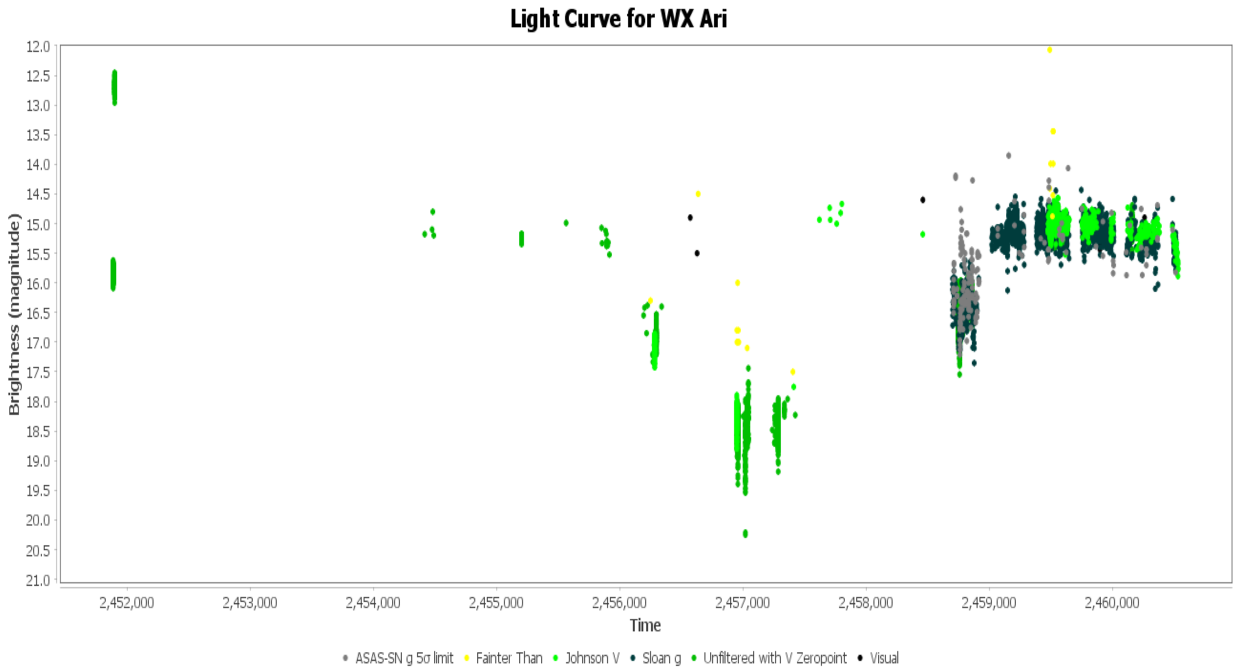

## [HS 0220+0603]

HS 0220+0603 is an NL/VY+E cataclysmic variable.



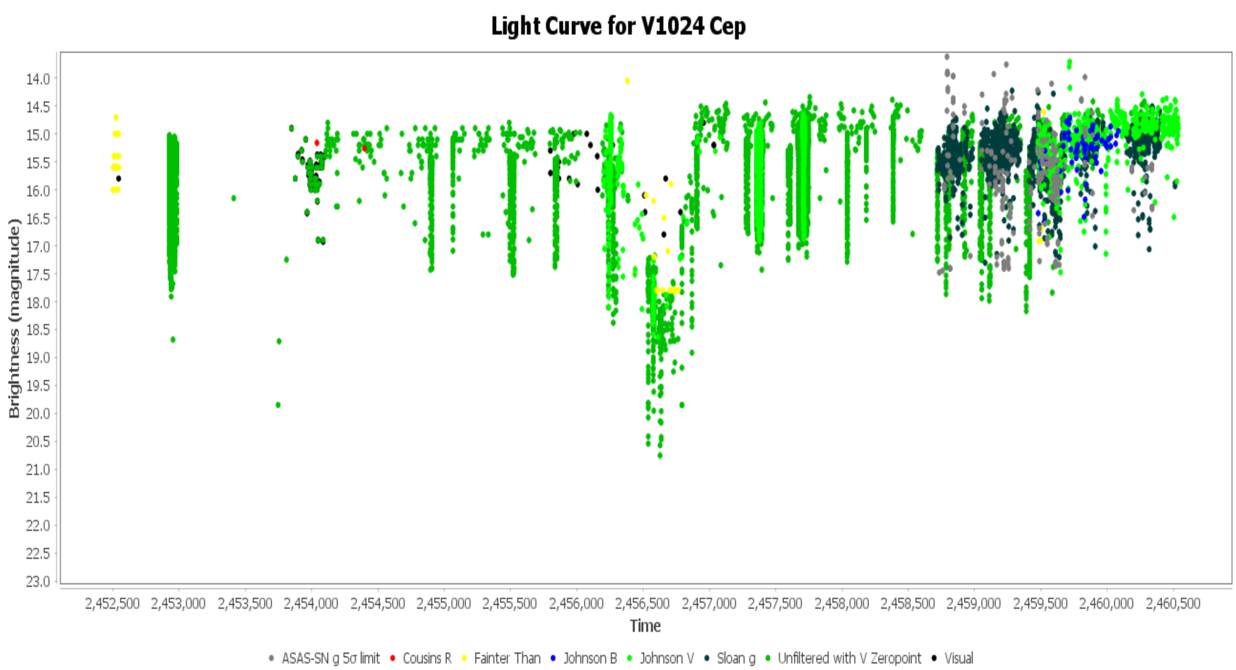
## WX Ari

WX Ari is an NL/VY+E cataclysmic variable.



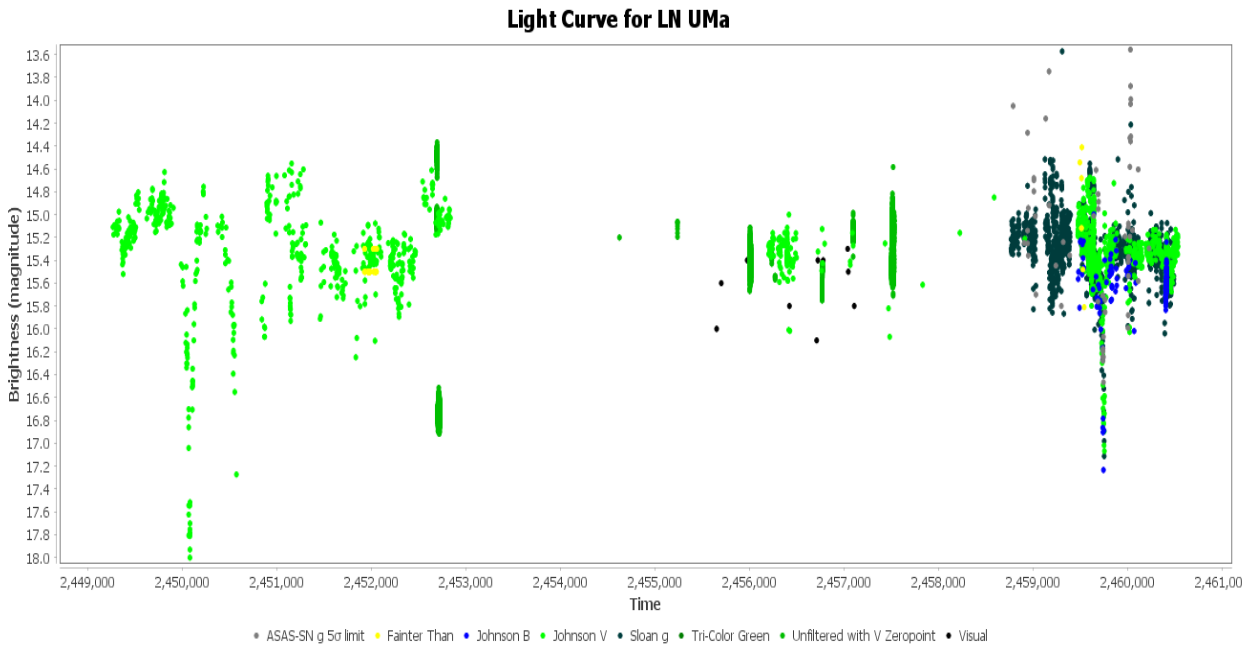

## V1024 Cep

V1024 Cep is an NL/VY+E cataclysmic variable.



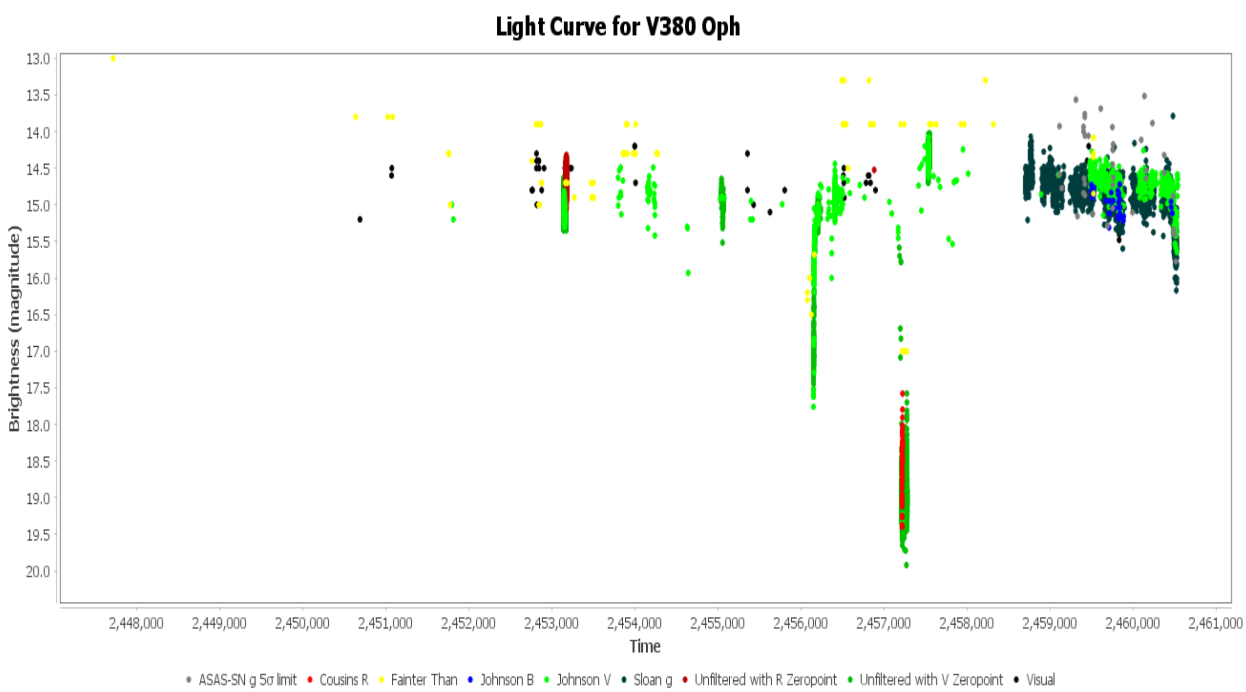
## LN UMa

LN UMa is a UGZ/IW+VY cataclysmic variable.



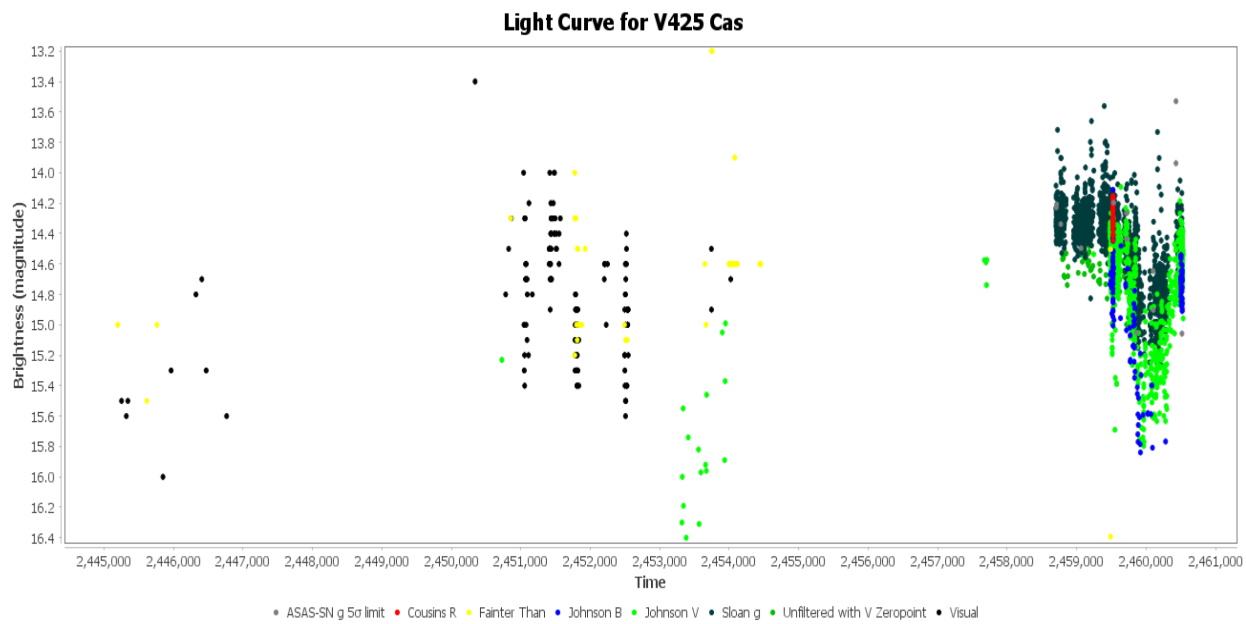

## V380 Oph

V380 Oph is an NL/VY cataclysmic variable.



## V425 Cas

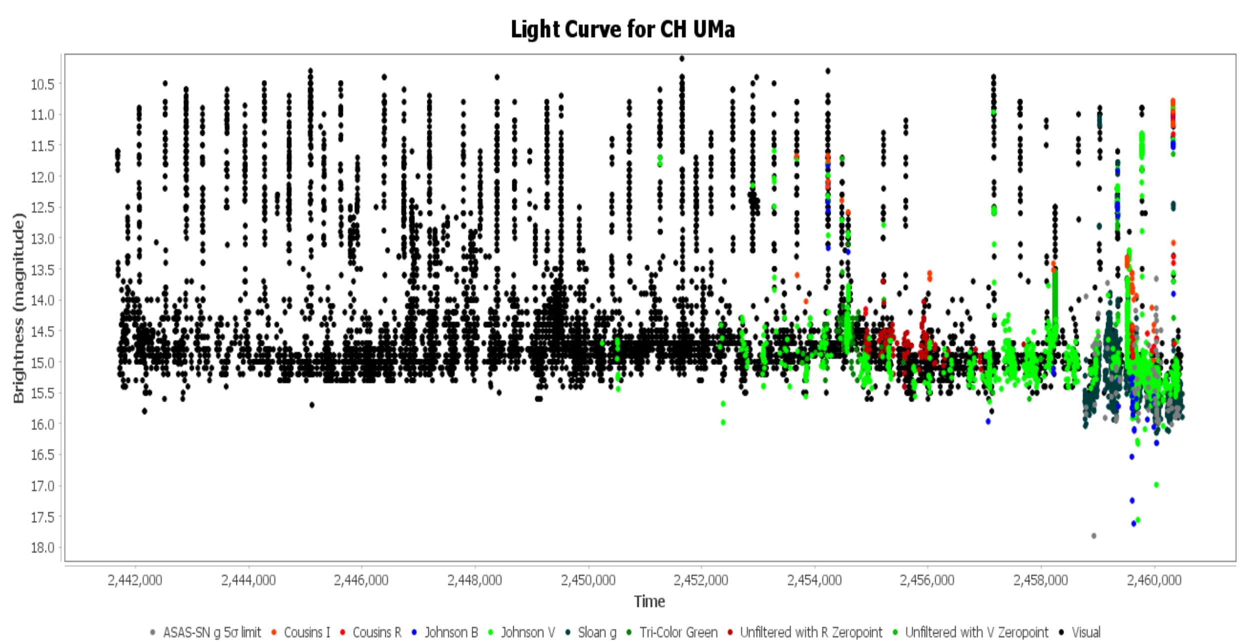
V425 Cas is an NL/VY cataclysmic variable.




### *Dwarf Nova*

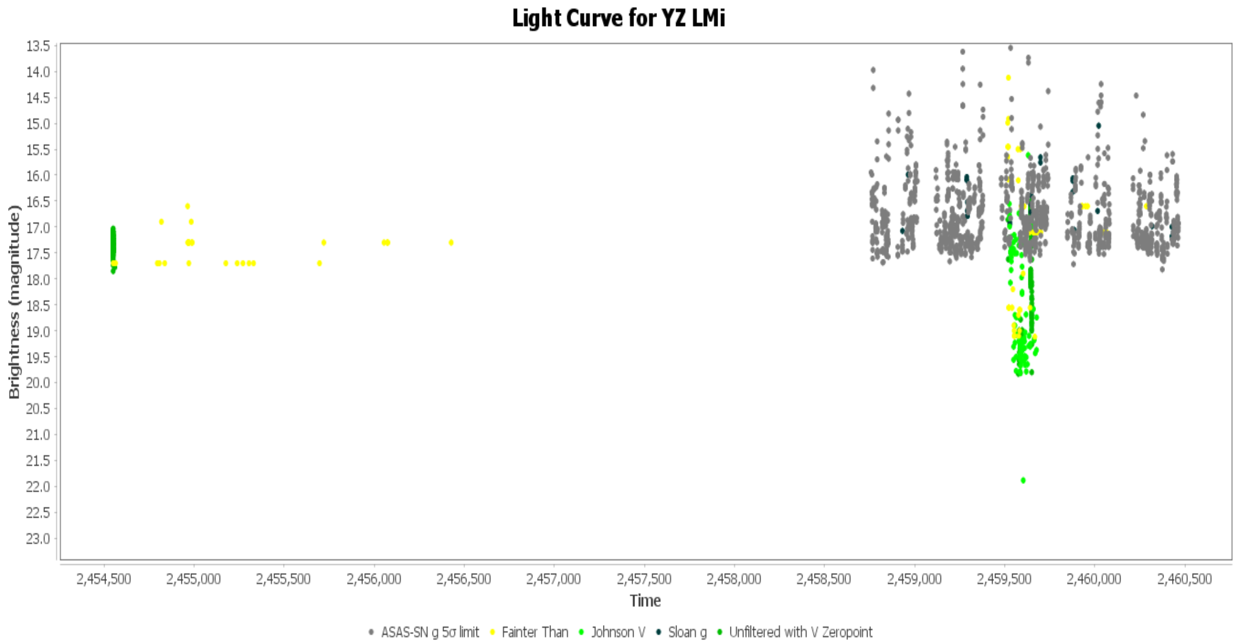
## CH UMa

CH UMa is a UG cataclysmic variable.



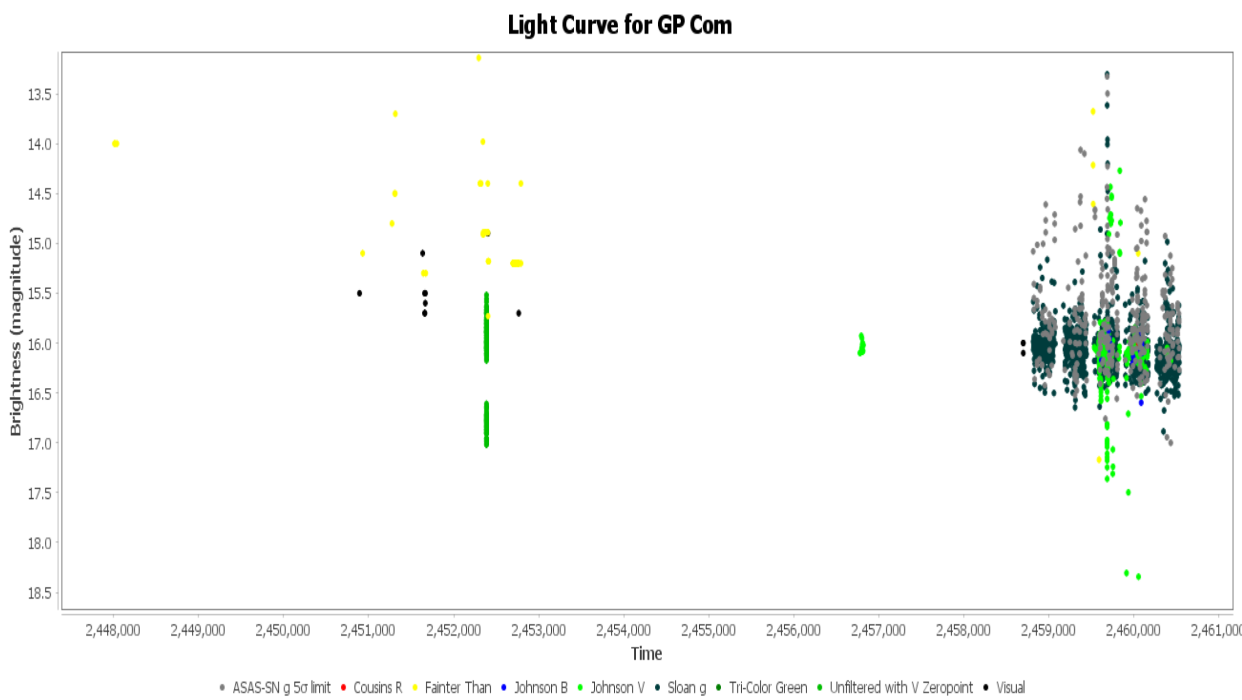
## [YZ LMi]

YZ LMi is a UGSU/IBWD+E cataclysmic variable.



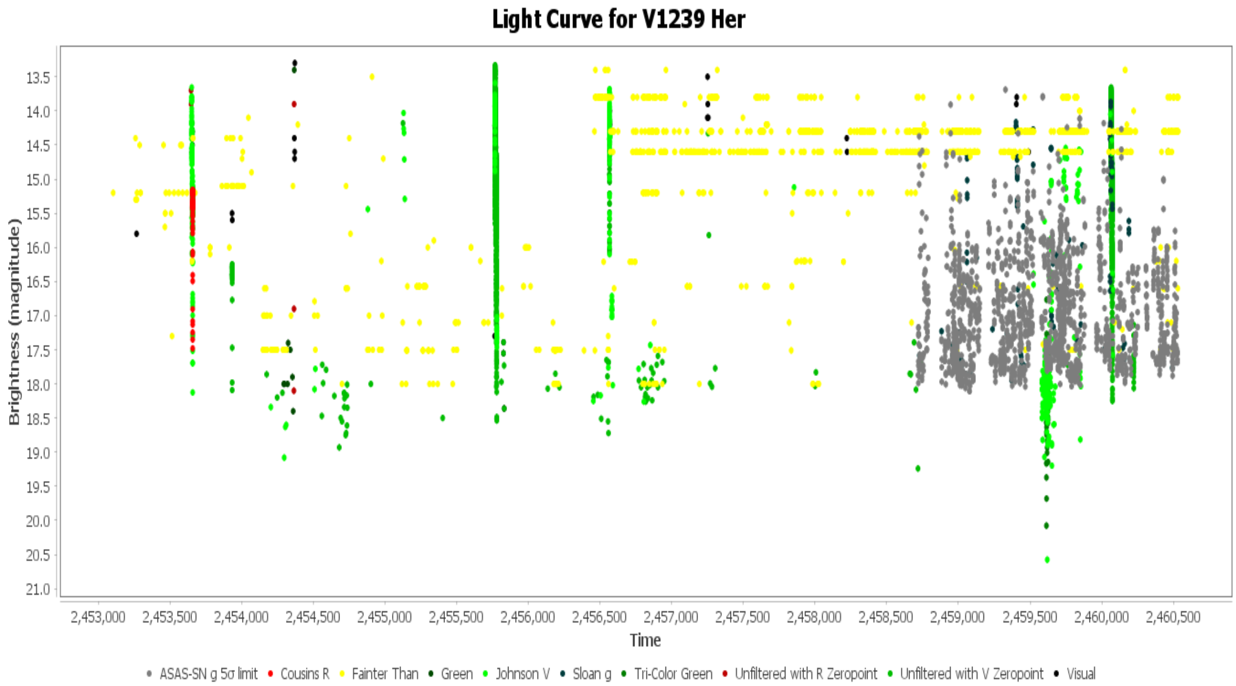

## [GP Com]

GP Com is a UBWD cataclysmic variable.



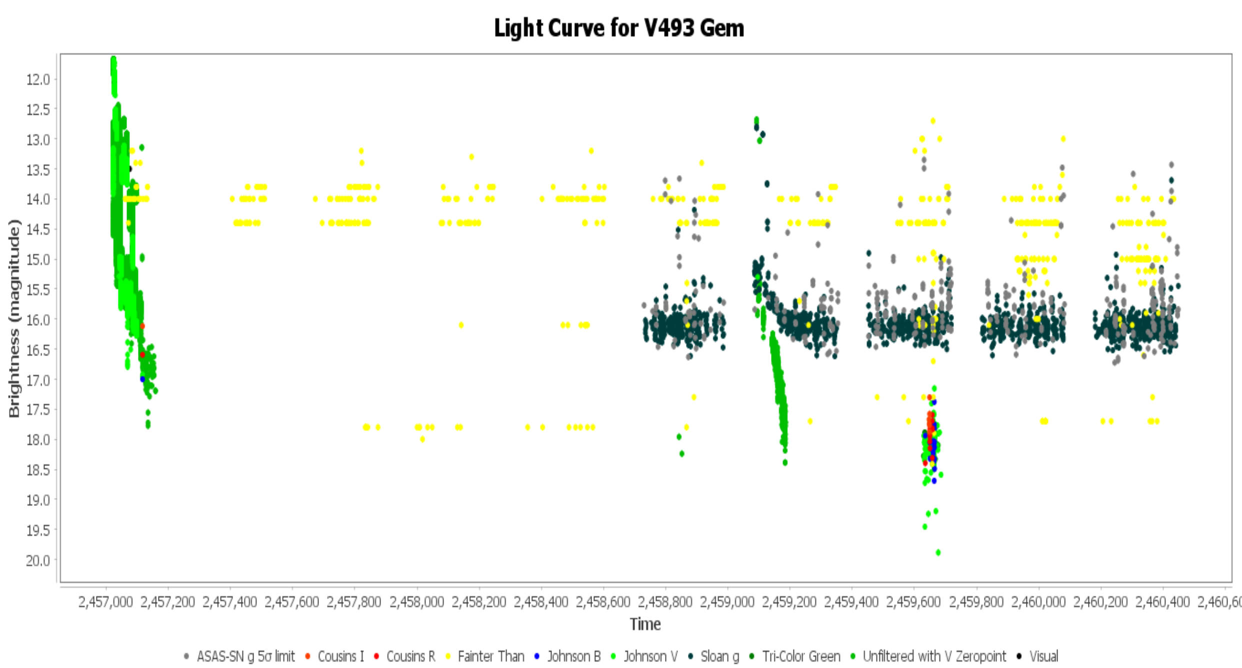
## V1239 Her

V1239 Her is a UGSU+E cataclysmic variable.



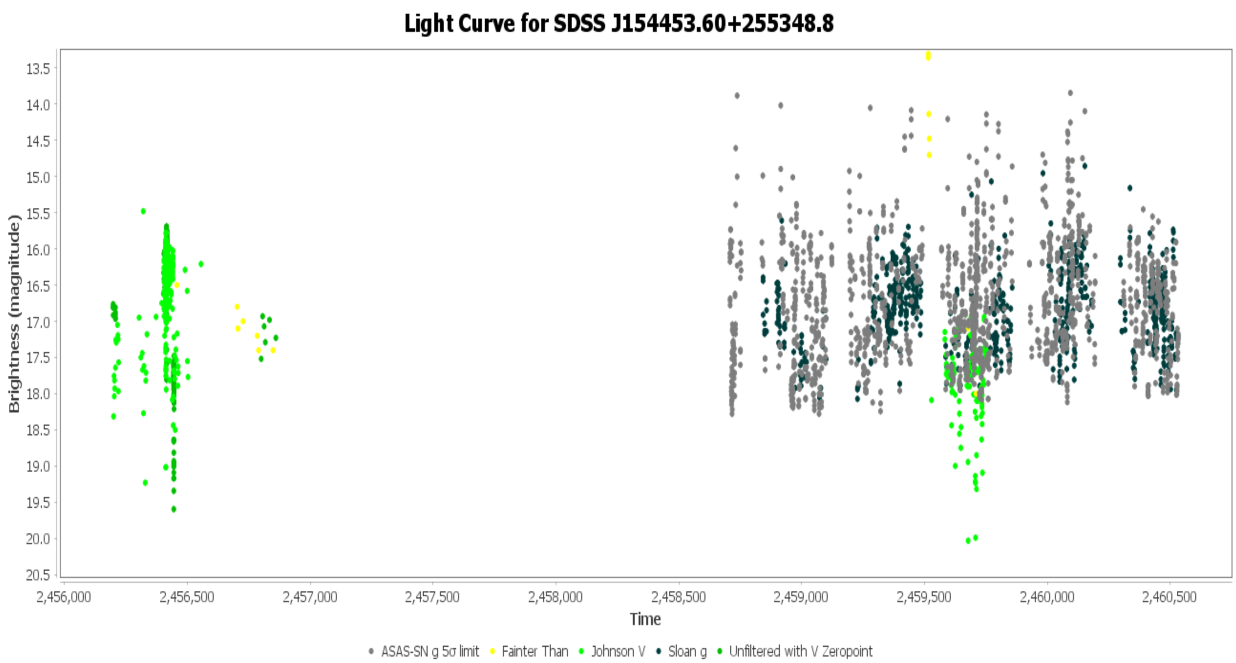

## V493 Gem

V493 Cam is a UG/IBWD cataclysmic variable.



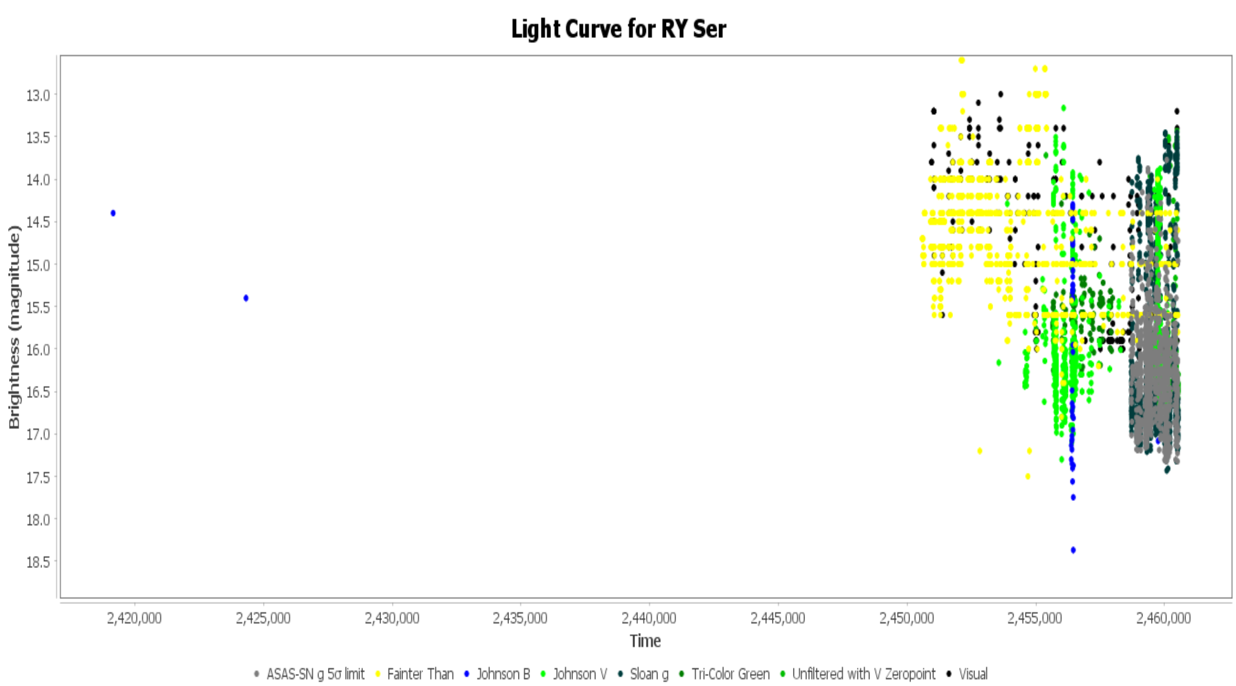
## [SDSS J154453.60+255348.8]

SDSS J154453.60+255348.8 is an NL+E cataclysmic variable.



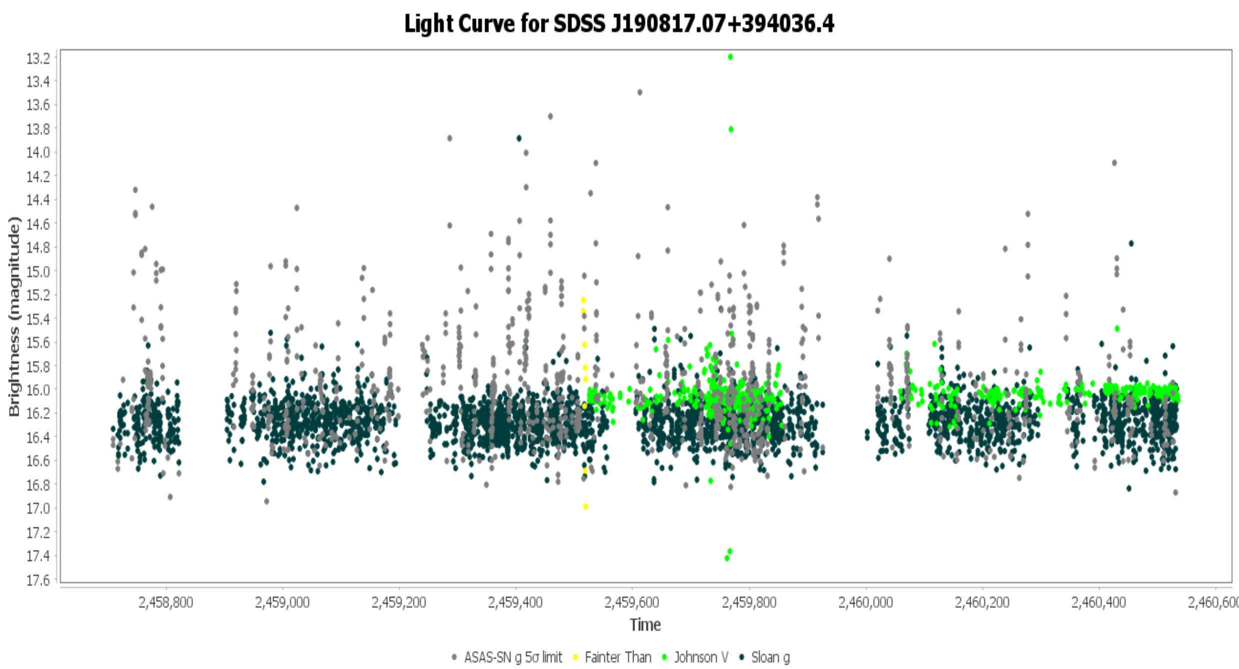

## [RY Ser]

RY Ser is a UG cataclysmic variable.



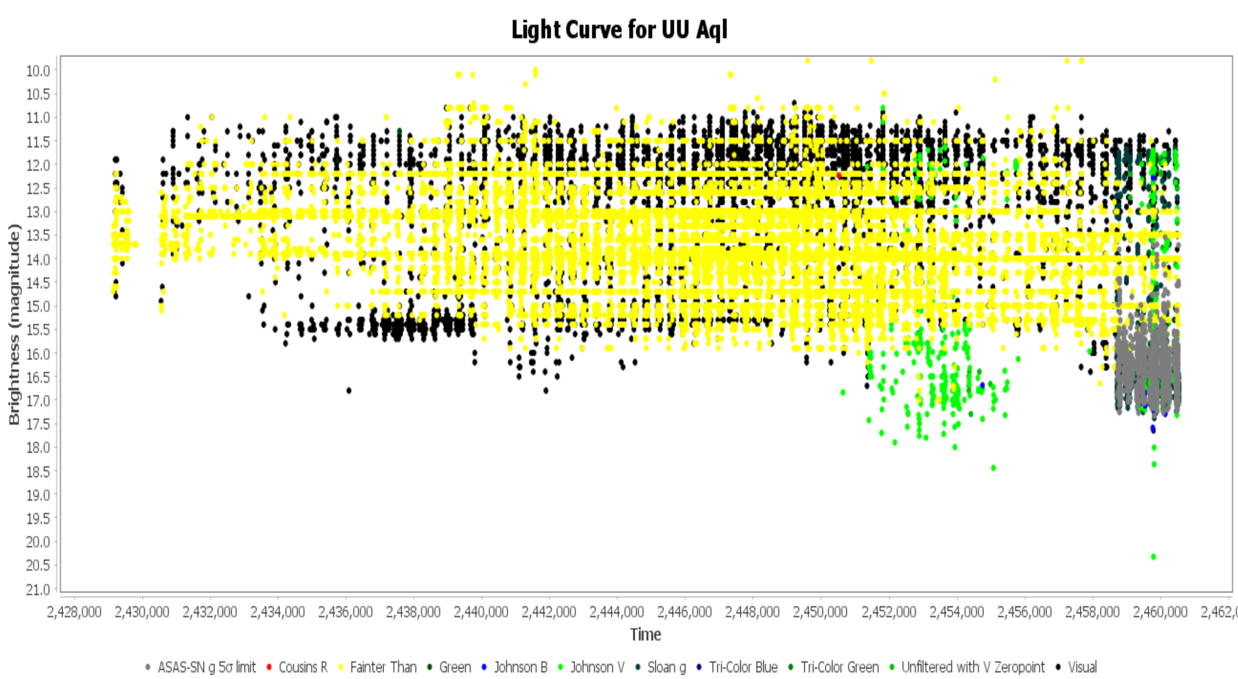
## SDSS J190817.07+394036.4

SDSS J190817.07+394036.4 is an IBWD cataclysmic variable.



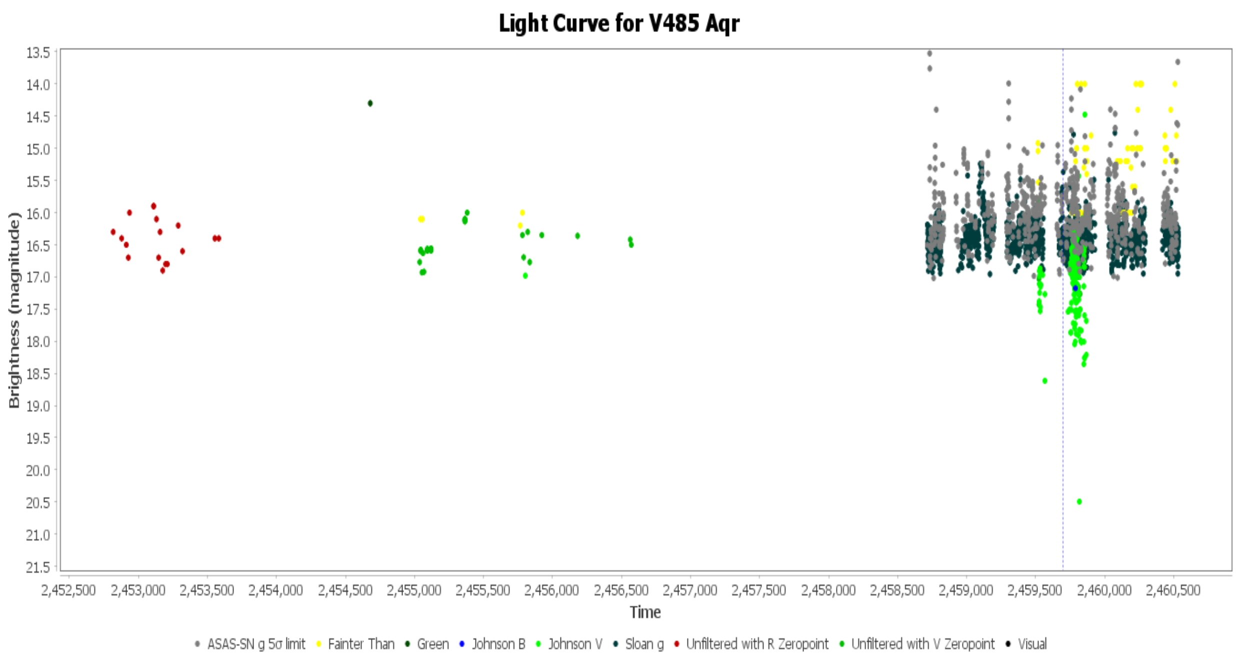

## UU Aql

UU Aql is a UGSS cataclysmic variable.



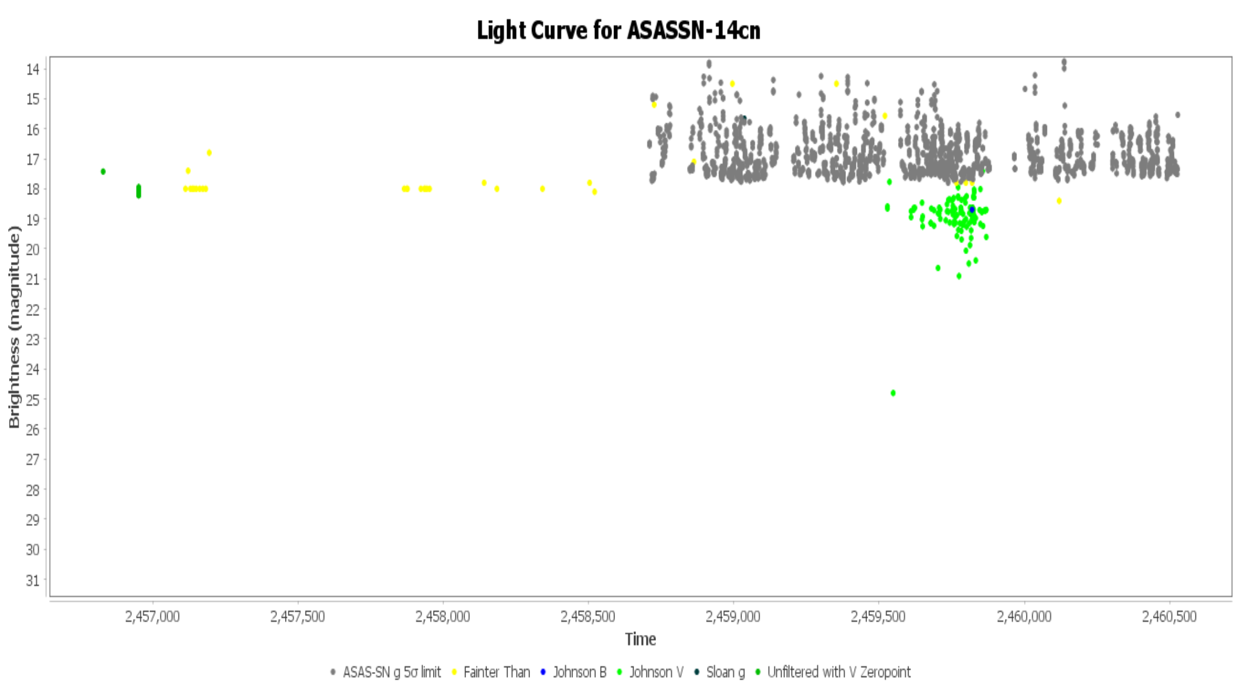
## V485 Aqr

V485 Aqr is a UG cataclysmic variable.



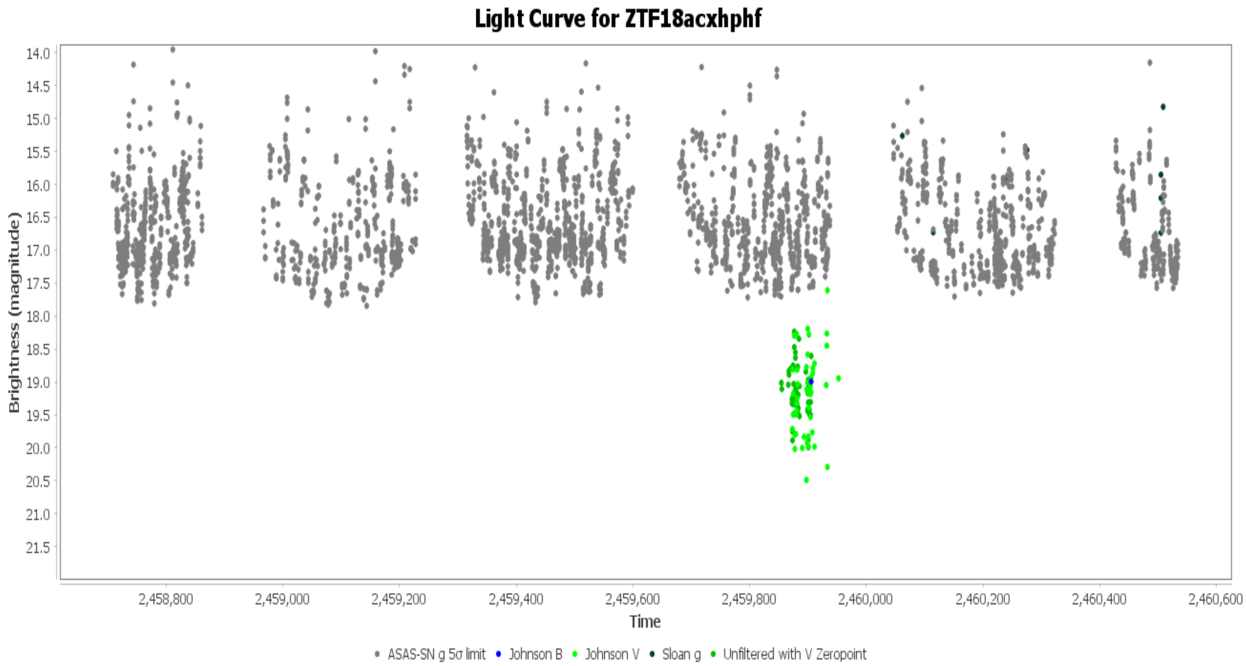

## ASASSN-14cn

ASASSN-14cn is a UG/IBWD+E cataclysmic variable.



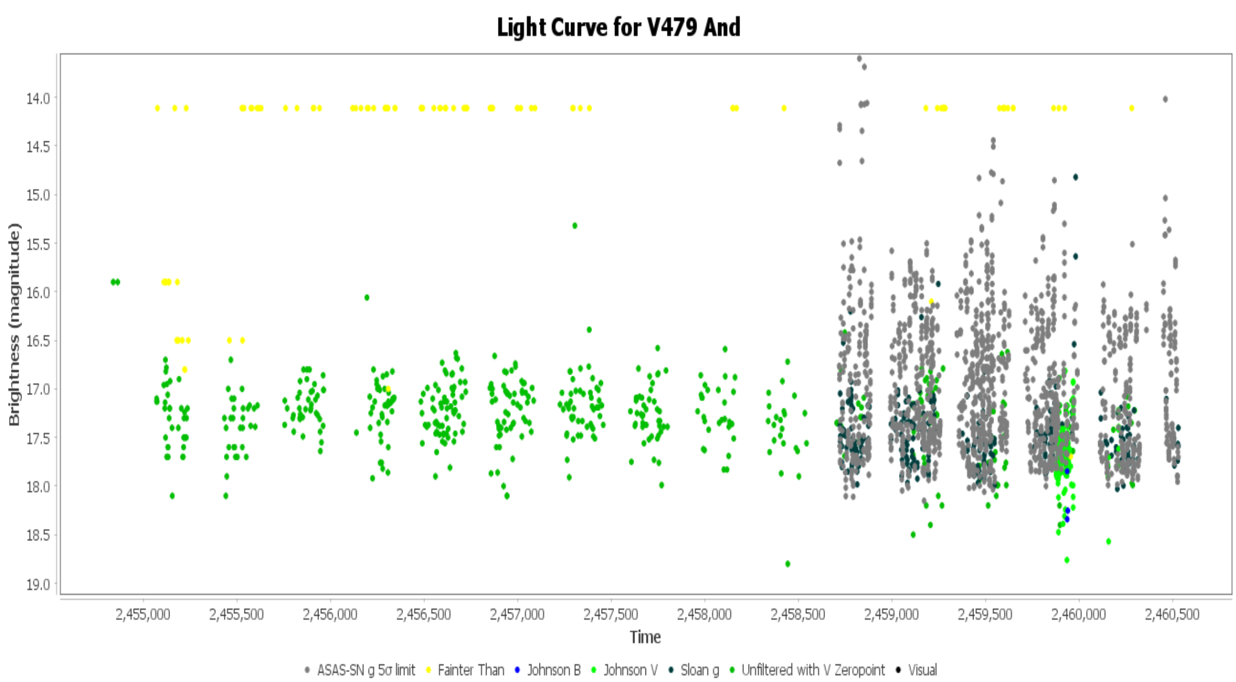
## [ZTF18acxhphf]

ZTF18acxhphf is an IBWD+E cataclysmic variable.



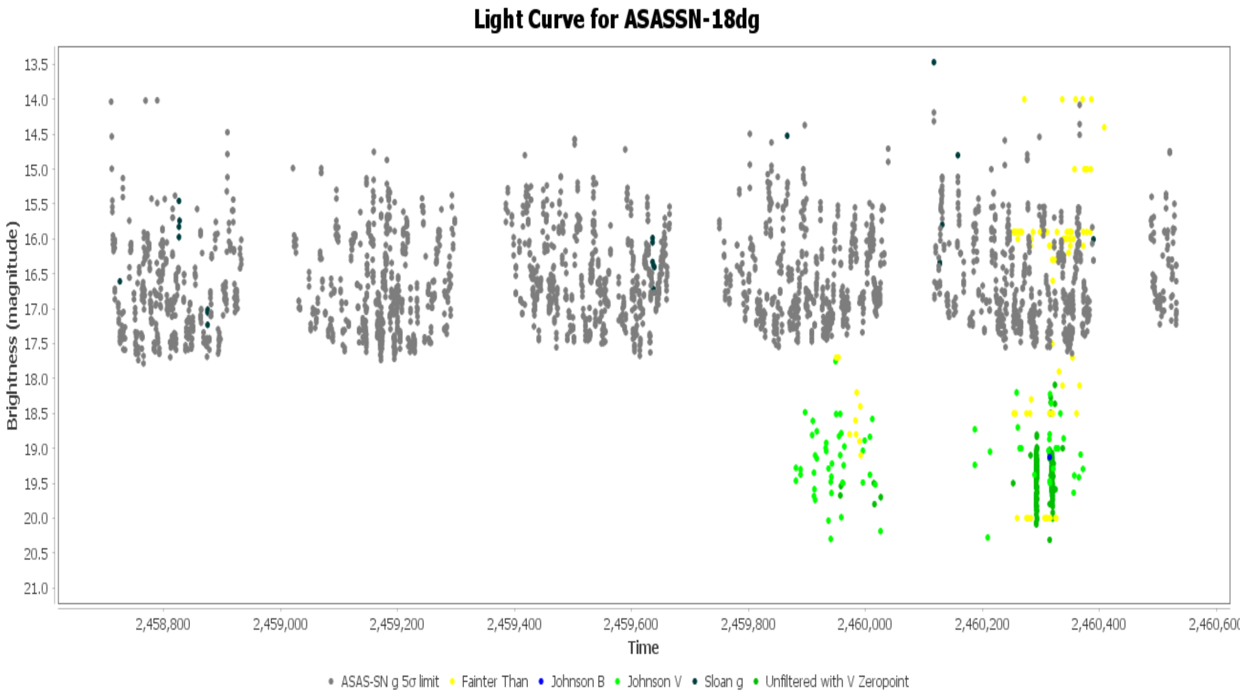

## [V479 And]

V479 And is an AM cataclysmic variable.



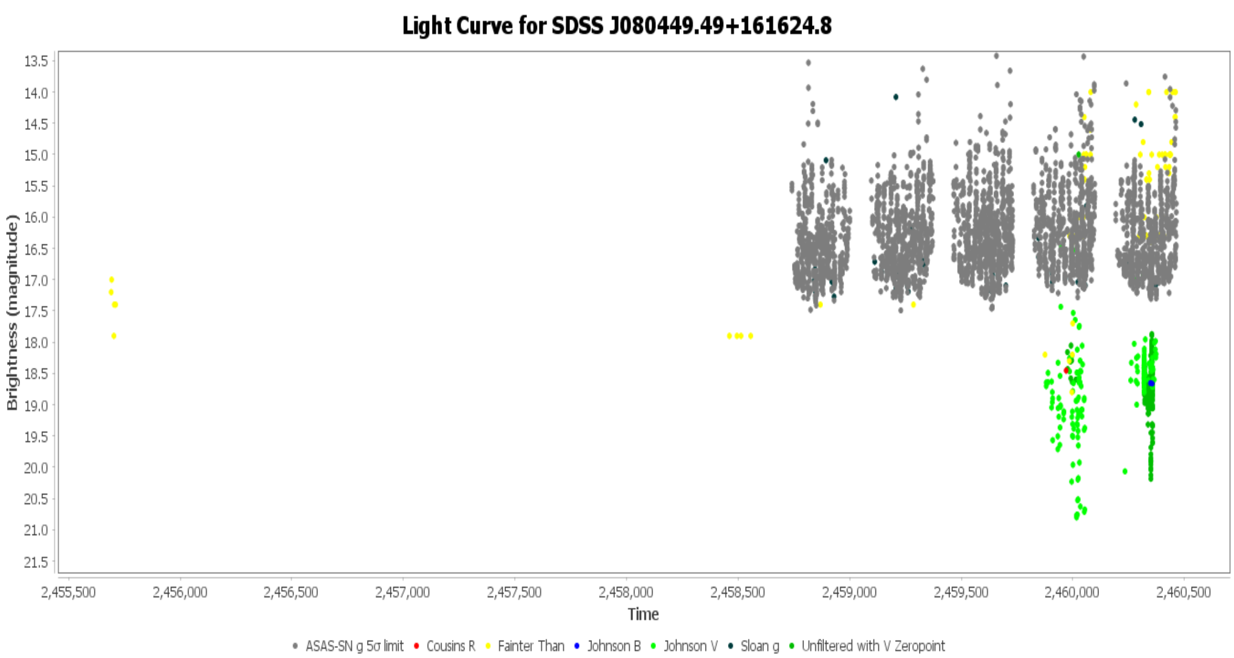
## ASASSN-18dg

ASASSN-18dg is a UGSU/IBWD+E cataclysmic variable.



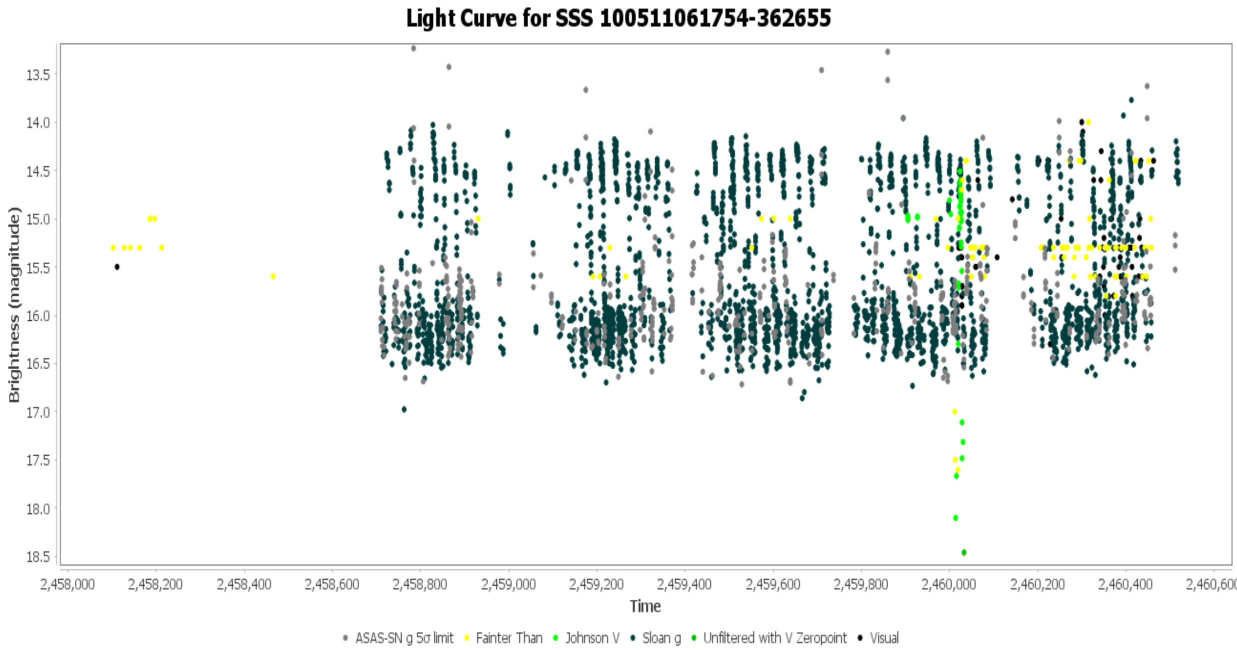

## SDSS J080449.49+161624.8

SDSS J080449.49+161624.8 is an IBWD cataclysmic variable.



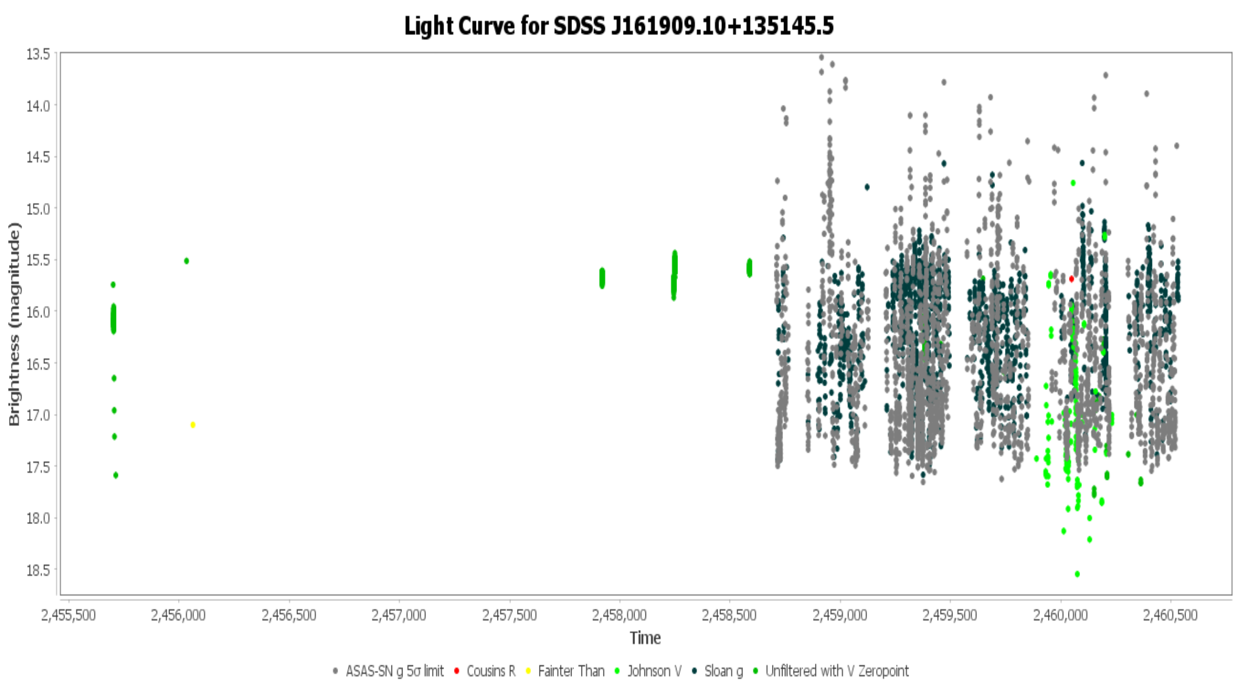
## [SSS 100511:061754-362655]

SSS 100511:061754-362655 is a UG cataclysmic variable.



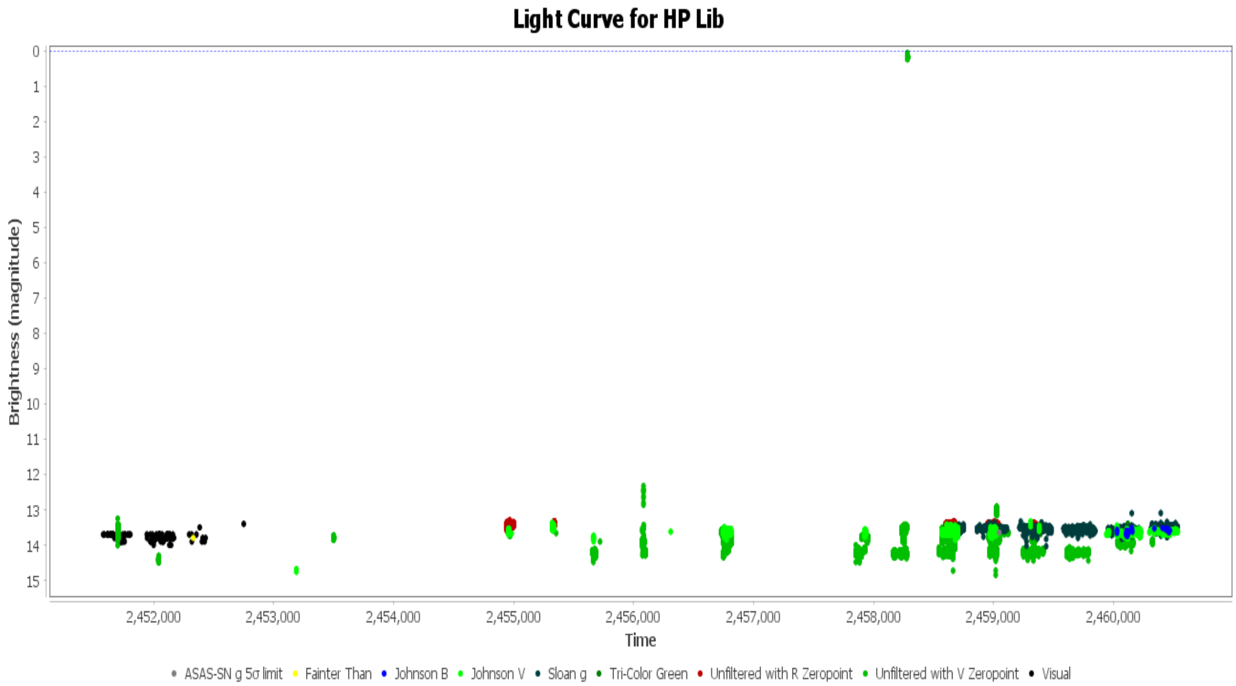

## [SDSS J161909.10+135145.5]

SDSS J161909.10+135145.5 is a UGZ cataclysmic variable.



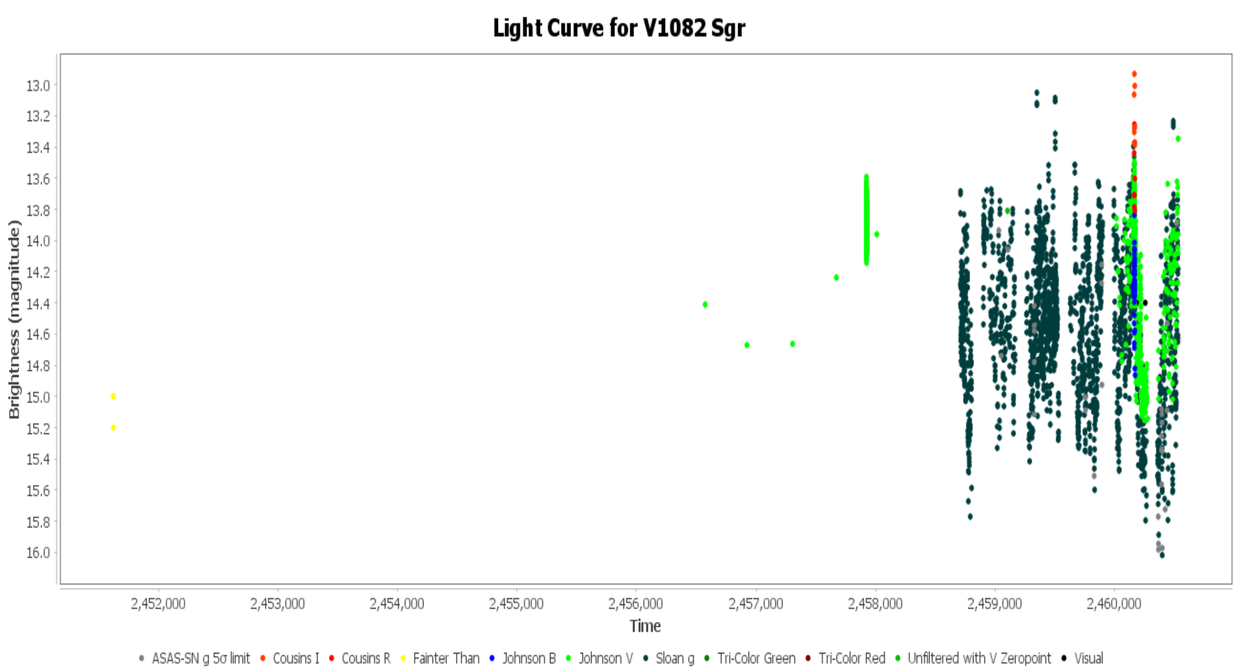
## HP Lib

HP Lib is an IBWD+ZZB cataclysmic variable.



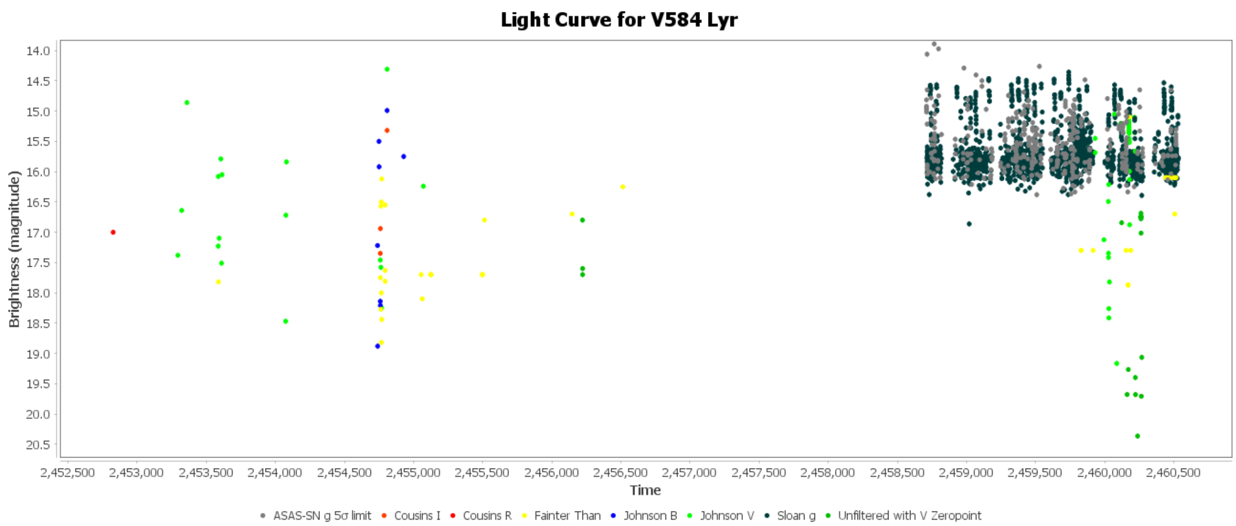

## V1082 Sgr

V1082 Sgr is a DQ cataclysmic variable.



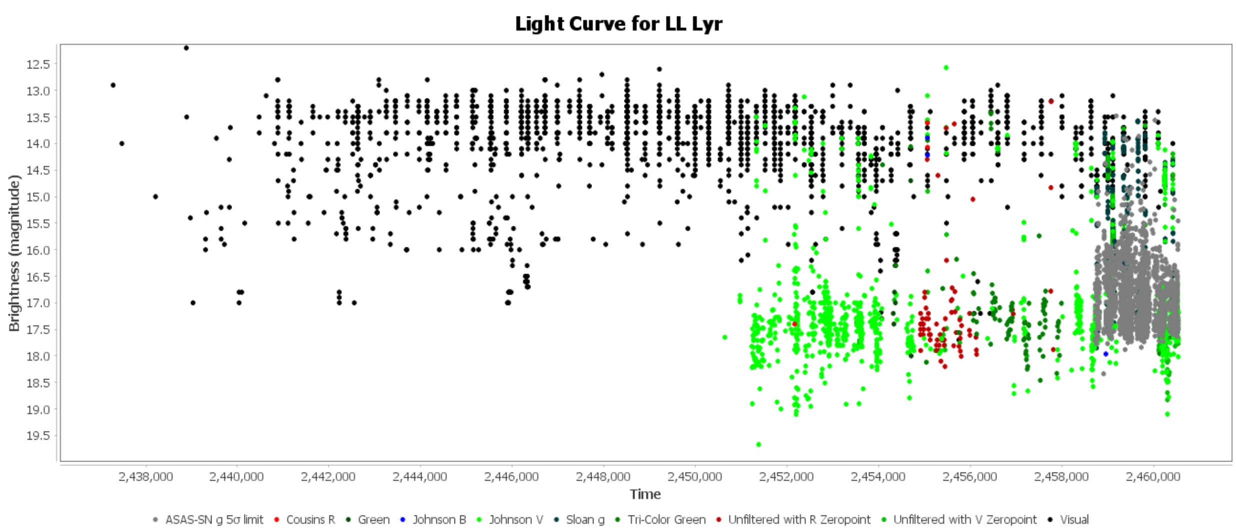
## V584 Lyr

V584 Lyr is a UG cataclysmic variable.




## LL Lyr

LL Lyr is a UG cataclysmic variable.




## Discussion and Conclusions

As can be seen from the wide variety of light curves for the 36 accreting cataclysmic variable objects, characterization can be very challenging. Future research and continuing observations of these objects will be required to fully understand the underlying mechanisms of each CV.

## References

Benn, D. 2012, “Algorithms + Observations = VStar”, JAAVSO, v40, n2, pp.852-866 (https://www.aavso.org/vstar) AAVSO VStar data analysis software.

Ferraz-Mello, S. 1981, Estimation of Periods From Unequally Spaced Observations, Astron. J., vol 86, p619. (https://adsabs.harvard.edu/full/1981AJ.....86..619F)

Kloppenborg 2022, American Association of Variable Star Observers (AAVSO) (https://aavso.org).

Kloppenborg 2022, American Association of Variable Star Observers (AAVSO) International Variable Star Index (VSX) (https://www.aavso.org/vsx/). This research has made use of the International Variable Star Index (VSX) database, operated at AAVSO, Cambridge, Massachusetts, USA.

Kloppenborg 2022, American Association of Variable Star Observers (AAVSO) AAVSOnet. A global network of robotic telescopes operated by the AAVSO.

Shappee, et al. 2014, ASAS-SN (All-Sky Automated Survey for SuperNova) (https://asas-sn.osu.edu/). This research has made use of The All-Sky Automated Survey for Supernovae (ASAS-SN) Light Curve Server v1.0.