# Kepler K2 observations of the bright intermediate polar FO Aquarii

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Accretion disks are widespread in astrophysics, from the formation of stars and planets to the brightest AGN. Cataclysmic variable binary stars, in which mass transfer from a low-mass star forms an accretion disk around a white dwarf, are excellent subjects for studying accretion and have enabled many ideas about accretion to be developed and tested (e.g. viscosity, instability outbursts, disk precession). In particular, the accretion light dominates the optical band, making it easy to study, and varies on timescales of minutes, hours and days that are highly amenable to investigation.

In the "intermediate polar" (IP) subclass the white dwarf is strongly magnetic, disrupting the inner accretion disk and producing prominent pulsations at the white-dwarf spin period. Such systems are idea for studying the interaction of magnetic fields with accretion disks.

FO Aquarii (= EPIC 206292760) is one of the brightest and best-studied IPs, with ADS listing 24 refereed papers with "FO Aqr" in the title. Fortunately, it is on-silicon for K2 Field 3, the only bright IP in any of the K2 fields (FO Aqr has $V$ = 13.2, the only other IPs in K2 fields are fainter at $V > 16$). We thus have the opportunity to obtain the best-ever lightcurve of an IP, a 80-d lightcurve that will exceed the quality of any existing lightcurve by an order of magnitude, and so form a landmark in the study of magnetically-channelled accretion flows.

The basis of the science aim is this: The white dwarf produces X-ray, UV and optical light pulsed at the 20.9-min spin period of the white dwarf. This forms a "searchlight" spinning round and illuminating the accretion disk and other accretion structures, such as the mass-transfer stream from the secondary star. Since much of the disk structure (e.g. the stream–disk impact point) is fixed in the 4.85-hr *orbital* frame, we see re-processed optical light at the "beat" cycle between the spin and orbital period, namely at 23 mins. Indeed, high-quality lightcurves (e.g. Patterson et al. 1998, PASP 110, 415) show variations at the orbital sidebands $\omega - 2\Omega$, $\omega - \Omega$ and $\omega + \Omega$ (where $\omega$ and $\Omega$ are the spin and orbital frequencies respectively). The spin-cycle pulsations have a high amplitude, typically 0.3 magnitudes, and thus all of these can be tracked to high precision with Kepler-quality photometry of a relatively bright star.

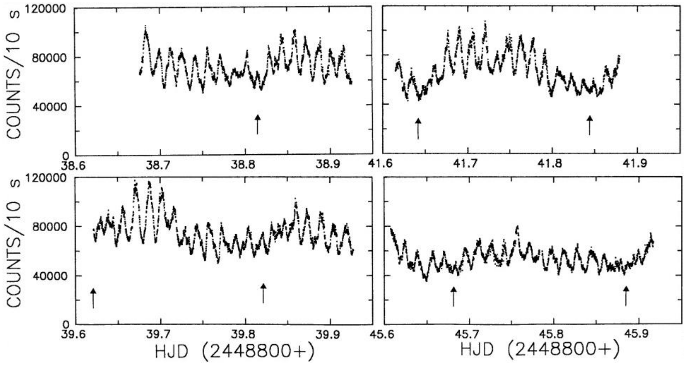

Fig. 1: Typical optical lightcurves of FO Aqr showing dramatic 20.9-min spin-period pulsations and changes in these pulsations over the 4.85-hr orbital period (arrows). This proposal aims for a continuous 80-day version of this 4-night observation. (From Patterson et al. 1998, PASP, 110, 415).

Further, we know that the pulse profiles and the pattern of sidebands, and thus the accretion-disk structure, are very different when looked at in different observations separated by weeks, months or years (e.g. the study of 5 different X-ray observations by Beardmore et al. 1998, MNRAS, 297, 337). However, we do not have a well-sampled lightcurve covering such changes. The usual ground-based data typically cover one 4.85-hr orbital period in a night, usually repeated for a few nights with day-time gaps. X-ray observations last a few days, interspersed with low-Earth-orbit gaps. Times between observations are typically months. This is sufficient to tell us that the accretion flow is variable on a daily, weekly and monthly timescale, but not sufficient to track such changes and allow us to trace out the changes in the accretion flow. A 80-day lightcurve from K2 would dramatically change this and produce an unparallelled lightcurve.

We expect to see changes in how the accretion stream impacts the disk, changes in its azimuthal location, the size of the "splash" created, and the degree to which the stream over-flows the disk. We might see such changes correlated with precession of an asymmetric or warped disk, at an expected precessional period of $\sim$4 days. There are hints of all of these things in existing datasets, but none of those datasets compare to the intensity and duration of coverage that can be achieved with K2.

We would achieve a high-quality "reverberation mapping" of the accretion flow that would vary with the changes in the accretion-flow structure expected on timescales of days to weeks. FO Aqr is the ideal target for this work, being among the brightest IPs and with a high pulsation amplitude. It also has a high inclination ($\sim 70^\circ$) with a grazing eclipse of the accretion disk, which means that accretion structure produces shadowing and obscuration effects that make the changes obvious in the reprocessing lightcurves.

## Short v Long Cadence:

The science aim revolves around monitoring the 20.9-min spin period and orbital sidebands of that period. Good time resolution, short compared to the 20.9-min spin period, is thus essential for the science aims and we thus require Short Cadence observations.