Polars, a Growing Family

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Abstract For years, AM Herculis was the only member of a class of cataclysmic variable stars now known as *polars*, whose systems are characterized by a strongly-magnetized white dwarf and the absence of an accretion disc. A number of ground-based and satellite observing missions, particularly the ROSAT All-Sky Survey, have located many more members of the polar family. To date, however, AM Her is the only polar whose long-term variability has been studied in detail.

1. Once upon a time in Hercules

In 1924, a short notice was published by M. Wolf in *Astronomische Nachrichten* on the discovery of a new variable star in the constellation Hercules, later to be known as AM Herculis. In the decades to follow, AM Her remained a sleeping beauty.

Fifty years later, it attracted attention again as the optical counterpart of the then-unidentified *Uhuru* X-ray source 3U 1809+50 (Berg and Duthie 1977). Flickering observed at optical and X-ray wavelengths raised the suggestion that AM Her is a cataclysmic variable (CV) of the U Geminorum type.

However, the detection of linear and circular polarized radiation (Tapia 1976a, b, c) revealed the true nature of this then-unique object: a CV containing a strongly magnetized white dwarf. Tapia interpreted the observed polarized optical flux as cyclotron emission from hot electrons gyrating in a strong magnetic field, and estimated a field strength of 200 MG (which later turned out to be overestimated by an order of magnitude). The presence of such a strong magnetic field in a close interacting binary should prevent the formation of an accretion disc, so far a vital ingredient for a CV.

*deceased March 22, 2004

The natural observational consequence after such an exciting discovery was the hunt for other CVs harboring magnetic white dwarfs. Searching the emission of known variable binaries for polarized radiation yielded two quick hits: VV Pup (Bond and Wagner 1977; Tapia 1977) and AN UMa (Krzeminski and Serkowski 1977). The latter authors coined the name *polars* for this new class of CVs from their most outstanding property, the strong optical polarization. Krzminski and Serkowski also suggested that all these systems should be sources of soft X-ray emission, paving the way for new discoveries.

2. The impact of the ROSAT All-Sky Survey

After the first three quick discoveries, the search for polars became tedious work. Due to their soft X-ray emission, most of the systems were found from the HEAO-1, EINSTEIN, and EXOSAT missions. However, a few objects were also found from optical surveys of blue stars (Palomar Green) or from emission line objects (Case Western).

The ROSAT mission, thanks to its unprecedented sensitivity to soft X-ray wavelengths, and to the first all-sky survey performed at X-ray wavelengths, was *the* chance to discover new offspring for the polar family. Beuermann and Thomas (1993) started a program to identify all soft X-ray sources of more than 0.5 cts. Some ten nights of follow-up observations led to the identification of ≈30 new polars, doubling the pre-ROSAT census.

3. Long-term variability

The long-term variability of polars is known in detail only for the brightest member, AM Herculis (Figure 1). The system reaches $V \approx 12.5$ at maximum and can fade down to $V \approx 15$. In the bright state, the *high state*, most optical emission originates in the accretion stream and in the accretion spot on the white dwarf. During the *low state*, the light from the system is dominated in the blue by the white dwarf photosphere and in the red by the secondary star (e.g., Gänsicke *et al.* 1995). The absence of an accretion disc is reflected in the small amplitude of the high-state to low-state variations of ≈3 magnitudes.

The light curve (Figure 1) shows that changes in brightness (= accretion rate) can occur on a wide variety of time scales: the system can drop into the low state in a couple of days (e.g., JD 2447650), but can also gradually fade (e.g., JD 2448350). On some occasions a sudden brightening occurs (e.g., JD 2449000), reminiscent of dwarf nova outbursts, although the mechanism must be of a completely different nature. Similarly, short drops in brightness are observed (e.g., JD 2449130).

It is important to notice that the changes in brightness in polars *directly* reflect a variation of the mass loss rate of the secondary star, as no matter-buffering disc is present. The origin of this long-term variation is still not understood. Even though two mechanisms have been proposed so far to explain the changes in brightness

(King 1989; Livio and Pringle 1994), no detailed modeling of the long-term light curve has been done so far.

4. Addendum, 2006

At the time of publication in 2006, the number of known polars has grown close to 90.

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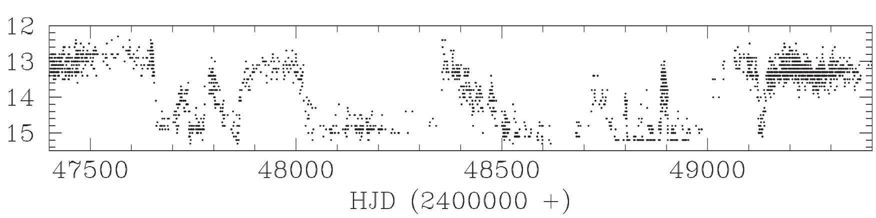

Figure 1. The long-term optical light curve of AM Herculis from August 1988 to February 1994 (courtesy AAVSO).