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Strong circumstantial proofs about the intermediate polar nature of the cataclysmic variable SS Cygni

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Abstract. This paper is the updated version of that published in the proceedings of the Integral/Bart Workshop 2011 (Giovannelli & Sabau-Graziati, 2012a). SS Cyg is a cataclysmic variable usually classified as dwarf nova, a subclass of the non–magnetic cataclysmic variables. The goal of this paper is to demonstrate — on the basis of the many arguments and circumstantial proofs derived from the numerous multifrequency data obtained from the SS Cyg binary system — that such classification is wrong and that the intermediate polar nature of SS Cyg is the most probable.
We derive the magnetic field intensity at the surface of the white dwarf in SS Cyg as B $\simeq 1.6 \pm 0.7$ MG. This value is in complete agreement with the evaluation made by Fabbiano et al. (1981) (B$\leq$ 1.9 MG) using simultaneous X-ray, UV, and optical data.

Key words. Cataclysmic variables - Dwarf novae - Intermediate polars - Optical - Spectroscopy - Photometry - sub-mm - IR - Radio - UV - X-rays - individual: SS Cyg $\equiv$ BD+42° 4189a $\equiv$ AAVSO 2138+43 $\equiv$ 3A 2140+433 $\equiv$ 1H 2140+433 $\equiv$ INTEGRAL1 121 $\equiv$ 1RXS J214242.6+433506 $\equiv$ EUVE J2142+43.6 $\equiv$ SWIFT J2142.7+4337.

1. Introduction

Cataclysmic variables (CVs) are binary systems in which the primary star is a white dwarf (WD) and the secondary star is a late-type main sequence star. For recent reviews see the papers by Giovannelli (2008) and Giovannelli & Sabau-Graziati (2012b, these proceedings, and references therein).

CVs constitute the best laboratory for studying the physics of the processes of the mass accretion onto compact objects. Depending on the magnetic field intensity at the WD, the accretion of matter from the secondary star onto the primary can occur either via an accretion disc (in the so-called Non-Magnetic CVs: NMCVs) or a channelling through the magnetic poles (in the case of Polars: PCVs) or in an intermediate way (in the case of Intermediate Polars: IPCVs).

SS Cyg is the most observed and intriguing CV. For reviews see the papers by Giovannelli & Martinez-Pais (1991), Giovannelli (1996),

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Giovannelli & Sabau-Graziati (1998; 2012a). The most extensive review about SS Cyg before the advent of space era is that by Zuckerman (1961). The light curves of SS Cyg are continuously produced by the AAVSO observations since 1896 (Mattei, et al., 1985; Mattei, Waagen & Foster, 1991, 1996; Mattei, Menali & Waagen, 2002; AAVSO web page (http://www.aavso.org/).

The optical outbursts of SS Cyg are not always the same. Howarth (1978) discussed about the three possible kind of outbursts, long, short and anomalous with average periodicity of 50.21 days. Giovannelli et al. (1985), Lombardi, Giovannelli & Gaudenzi (1987), Gaudenzi et al. (1990; 2011), and Giovannelli & Martinez-Pais (1991) discussed about such outbursts that originate different optical, UV and X-ray behaviour of the system.

On the base of its optical light curves, SS Cyg was classified as a dwarf nova (Bath & van Paradijs, 1983), with the white dwarf mass equal to Chandrasekhar's limit (Patterson, 1981). On the contrary, we will discuss about its intermediate polar nature analyzing its multifrequency behaviour and the different interpretations of data coming from the literature. Moreover, on the basis of more realistic values of its orbital parameters, we will try to reconcile all experimental multifrequency data with the magnetic nature of SS Cyg.

2. On the controversial nature of SS Cyg

With the historical classification of CVs based on the optical outburst properties, SS Cyg (α_{2000} = $21^h42^m48^s.2$; δ_{2000} = +43° 35' 09".88 with the galactic coordinates l_{2000} = 090.5592, b_{2000} = -07.1106), whose distance is 166.2 ± 12.7 pc (Harrison et al., 1999), is a dwarf nova and of those the brightest one. Its optical magnitude ranges from ∼ 12 to ∼ 8.5 during quiescent and outburst phases, respectively.

Because of these characteristics, it is the most observed CV, not only in the optical, where measurements are available from the end of the 19th century to the present, but also in other wavelength regions.

SS Cyg shows oscillations of ∼ 10 s both in optical and in X-ray ranges, orbital modulations ($P_{orb} \simeq 6.6$ h) of the intensities of Balmer and UV emission lines and of the continuum, and almost periodic outbursts ($P_{outb} \sim 50$ days, Howarth, 1978). All these characteristics together with the relative high luminosity both in outburst and in quiescence render SS Cyg the most appropriate laboratory for studying the physical processes occurring in dwarf novae and in CVs in general.

The orbital parameters of the binary system were derived by Giovannelli et al. (1983) using theoretical and experimental constraints from measurements obtained in different energy regions. They are $i = 40°^{+1}_{-2}$, $M_1 = 0.97^{+0.14}_{-0.05}$ $M_\odot$, $M_2 = 0.56^{+0.08}_{-0.03}$ $M_\odot$, $R_2 = 0.68^{+0.03}_{-0.01}$ $R_\odot$, $R_{od} = 2.9 \times 10^{10}$ cm, $R_{id} = 3.6 \times 10^9$ cm, where 1 and 2 refers to the primary and secondary star, respectively. R_{od} and R_{id} are the outer and inner accretion disk radius. These parameters have been confirmed by direct measurements of radial velocities (Martinez-Pais et al., 1994). Martinez-Pais et al. determined also that the optical companion of SS Cyg system is a K2–K3 late-type star.

The mass of the white dwarf of the binary system SS Cyg was considered for long time as high as Chandrasekhar's limit – because of a paper appeared in the Astrophysical Journal (Patterson, 1981) – a value completely unuseful for any sort of serious interpretation of the many multifrequency experimental data and for modeling.

Bisikalo et al. (2008), studying the matter flow structure in SS Cyg using Doppler tomography technique, found that the R_{id} = $(2.6 - 3.3) \times 10^9$ cm that is another important confirmation of the goodness of Giovannelli et al.'s parameters.

Despite the enormous amount of multifrequency experimental data spread over many years, the morphology and the nature of SS Cyg are still unsettled questions. Indeed, SS Cyg was classified as a non-magnetic CV (NMCV) by Bath & van Paradijs (1983). Ricketts, King & Raine (1979) explained the X-ray emission from SS Cyg as owing to the radial inflow of matter onto a magnetized white dwarf ($B \sim 10^6$ G) from a disrupted accretion disk. Fabbiano et al. (1981), using coordinated optical-UV and X-ray measurements of SS Cyg, noted that its behavior is not compatible with a viscous disk model and confirmed the magnetic nature of the white dwarf with $B \leq 1.9 \times 10^6$ G. SS Cyg at quiescence is quite similar to AM Her and its behaviour are consistent with a picture of polar magnetic accretion. Further multifrequency data of SS Cyg showed the incompatibility of its behavior with that of NMCV, and strongly favored its classification as that of an intermediate polar (see, e.g. Giovannelli et al., 1985; Giovannelli & Martinez-Pais, 1991; Kjurkchieva, Marchev & Ogłoza, 1999; Marchev, Kjurkchieva & Ogłoza, 1999; Gaudenzi et al., 2002; Long et al., 2005; Schreiber, Hameury & Lasota, 2003; Schreiber, & Lasota, 2007; Giovannelli & Sabau-Graziati, 2012a).

Moreover, in SS Cyg, $L_{\rm hard-X} < L_{\rm UV+soft-X}$. This is compatible with thermonuclear burning onto the WD surface. Thermonuclear burning was first suggested by Igor Mitrofanov (1978). Gaudenzi et al. (2002) found that thermonuclear burning can occur in $\sim$ 24% of the WDs surface. Körding et al. (2008) detected a radio jet from SS Cyg. The hardness intensity diagram shows an analogy between X-ray binaries (XRBs) and SS Cyg. This result supports the presence of a rather strong magnetic field at the white dwarf' surface. Upper limits to linear and circular polarizations have been found as $3.2 \pm 2.7\%$ and $-3.2 \pm 2.7\%$, respectively.

INTEGRAL/IBIS and SWIFT/XRT observations have shown that a conspicuous number of CVs have a strong hard X-ray emission (Landi et al., 2009; Scaringi et al., 2010). In their published sample of 22 CVs, 21 are classified as magnetic CVs (MCVs) (intermediate polar: IP) and only one (SS Cyg) as NMCV, meanwhile all its characteristics are practically equal to those of the other 21 objects. This is one more strong circumstantial proof in favor of the magnetic nature of SS Cyg. Scaringi et al. (2010) reported the detection of one more IP: AO Psc, which is added to the former sample. The experimental evidence that SS Cyg emits in the hard X-ray energy range is, in our opinion, the conclusive evidence about its magnetic nature.

However, in the literature there are many papers that seem to contradict the intermediate polar nature of SS Cyg. Indeed, Gnedin et al. (1995) found from observations of intrinsic circular polarization in SS Cyg performed in the wings of the Balmer hydrogen lines that the true value of the magnetic field probably lies in the range $0.03 < B < 0.3$ MG.

Using the Extreme Ultraviolet Explorer satellite observations, Mauche (1996) detected quasi-periodic oscillations (QPOs) from SS Cyg with a period in the range 7.19–9.3 s. This variation correlates with the extreme ultraviolet (EUV) flux as $P \propto I_{\rm EUV}^{-0.094}$. With a magnetospheric model to reproduce this variation, he found that a high-order, multipole field is required, and that the field strength at the surface of the white dwarf is $0.1 < B < 1$ MG. This field strength is at the lower extreme of those measured or inferred for bona fide magnetic cataclysmic variables. However, Mauche (1996) does not exclude the possibility that at an outburst the accretion of matter could occur onto the magnetic poles of the white dwarf. Giovannelli (1981) found QPOs from SS Cyg – during a rise up to a maximum of one long optical outburst – with periods in the range 8.96–9.91 s that show the inverse relationship between outburst luminosity and oscillation period as general properties of CVs (e.g. Nather & Robinson, 1974; Nevo & Sadeh, 1978). The amplitude of the optical oscillations has a maximum at the maximum of the outburst. At the optical maximum, the hard X-ray emission is lower than during the quiescence and all the energy in X-ray region is emitted below 2 keV (Ricketts, King & Raine, 1979).

With regard to the question of a possible magnetic nature of SS Cyg, Mauche et al. (1997) discussed the case of UV line ratios of CVs, which seem to be almost independent of the nature (magnetic or not) of CVs. Okada, Nakamura & Ishida (2008) found from CHANDRA HETG observations in SS Cyg that the spectrum in quiescence is dominated by H-like K_α lines, and in outburst it is dominated by He-like lines, which are as intense as H-like lines. The broad line widths and line profiles indicate that the line-emitting plasma is associated with the Keplerian disk. In quiescence the lines are narrower and are emitted from an ionizing plasma at the entrance of the boundary layer. Ishida et al. (2009) found from SUZAKU observations of SS Cyg that the plasma temperature in quiescence is 20.4 keV and in outburst 6.0 keV. The 6.4 keV line is resolved in narrow and broad components, which indicates that both the white dwarf and accretion disk contribute to the reflection. The standard optically thin boundary layer is the most plausible picture of the plasma configuration in quiescence. The reflection in outburst originates from the accretion disk and an equatorial accretion belt. The broad 6,4 keV line suggests that the optically thin thermal plasma is distributed on the accretion disk, in a manner similar to that of a solar corona.

Long et al. (2005) found by fitting the double-peaked line profile in SS Cyg that the FUV line-forming region is concentrated closer to the white dwarf than the region that forms the optical lines. Their study provides no evidence of a hole in the inner disk. However, they cannot fit SS Cyg data by a simple model as white dwarf plus accretion disk.

The system SS Cyg is also important as laboratory for the study of circumstellar dust in CVs. Indeed, Jameson et al. (1987) detected IR emission from SS Cyg in outburst in the IRAS Bands I and II (11.8 μm and 24.4 μm). The most likely origin of the IR emission is circumstellar dust heated by the enhanced UV flux during outburst. Dubus et al. (2004) performed optical and mid-IR observations of several CVs including SS Cyg in quiescence. For SS Cyg the measurements at 11.8 μm are consistent with the upper limits obtained by Jameson et al. (1987) when the source was not yet in full outburst. The observed variability in the mid-IR flux on short time scales is hardly reconcilable with intrinsic or reprocessed emission from circumbinary disk material, while on the contrary a free–free emission from a wind should be. If any sizeable circum-binary disk is present in the system, it must be self-shadowed or perhaps dust free, with the peak thermal emission shifted to far-IR wavelengths.

Gaudenzi et al. (2011) discussed about the reasons of the variable reddening in SS Cyg and demonstrated that this reddening is formed by two components: the first is interstellar in origin, and the second (intrinsic to the system itself) is variable and changes during the evolution of a quiescent phase. Moreover, an orbital modulation also exists. The physical and chemical parameters of the system are consistent with the possibility of formation of fullerenes.

The SPITZER space telescope detected an excess (3-8) μm emission from Magnetic CVs, due to dust (Howell et al., 2006; Brinkworth et al., 2007). This is a strong push for observing carefully SS Cyg with SPITZER. However, weak IR excess was discovered in SS Cyg looking at the SPITZER data, but no conclusions were given since data at different wavelengths were not simultaneous (Harrison et al., 2010).

3. The intermediate polar nature of SS Cyg

In our opinion there are several incontestable arguments in favour of the IP nature of SS Cyg, namely:

i) the strong analogy of SS Cyg with the well established IP EI UMa (Reimer et al., 2008). Table 1 shows the parameters of EI UMa and SS Cyg;

ii) in the diagram log L_X vs log $\dot{M}$ for the IPs (Warner, 1996), SS Cyg lies just in the place of IPs (Fig. 1, upper panel). The X-ray luminosity of SS Cyg ($L_X \sim (6.6 - 9.8) \times 10^{32}$ erg s^{-1}) has been derived by the values of the distance of SS Cyg: 166 pc (Harrison et al., 1999) and its X-ray flux: $F_X \sim (2 - 3) \times 10^{-10}$ erg cm^{-2} s^{-1} (Giovannelli & Martinez-Pais, 1991; McGowan, Priedhorsky & Trudolyubov, 2004). The average mass accretion rate $\dot{M} \sim 2 \times 10^{17}$ g s^{-1} (Gaudenzi et al., 1990, and the references therein; Schreiber & Gänsicke, 2002);

iii) in the diagram log $\dot{M}$ vs log P_{orb} (Warner, 1996) SS Cyg lies just in the place of IPs (Fig. 1, lower panel). The orbital period of SS Cyg is P_{orb} = 6.6 h (e.g. Martinez-Pais et al. 1994);

iv) SS Cyg has been detected in the hard X-ray range, together with other tens of very well known IPs (Landi et al., 2009; Scaringi et

Table 1. Comparison of the characteristic parameters of EI UMa – a well established IP (Reimer et al., 2008) – and SS Cyg (Giovannelli et al., 1983; Lombardi et al., 1987; Gaudenzi et al., 1990, 2002; Giovannelli & Martinez-Pais, 1991; Schreiber & Gänsicke, 2002).

EI UMa	SS Cyg
P_{orb} = 6.434 h	P_{orb} = 6.603 h
P_{opt} = 745 s (~ P_{XMM})	P_{opt} = 745 s (~ $P_{XMM\ UV}$)
0.81 $M_\odot$ < M_{WD} < 1.2 $M_\odot$	M_{WD} = 0.97 $M_\odot$
$R_{WD} = 7 \times 10^8$ cm	$R_{WD} = 5 \times 10^8$ cm
M_R = 0.81 $M_\odot$	M_R = 0.56 $M_\odot$
R_R = 0.76 $R_\odot$	R_R = 0.68 $R_\odot$
$L_X \sim 10 \times 10^{32}$ erg s^{-1}	$L_X \sim (6.6 - 9.8) \times 10^{32}$ erg s^{-1}
$\dot{M} = 3.6 \times 10^{17}$ g s^{-1}	$\dot{M} \simeq (1 - 4) \times 10^{17}$ g s^{-1}
M_V = 5.4	M_V = 5.9
f = Rd/a = 0.2 – 0.3	f = Rd/a = 0.2
UBV Orbital modulations of continuum	UBV & UV Orbital modulations of continuum & emission lines EWs

al., 2010). Such an emission cannot be justified without the presence of an intense white dwarf magnetic field. Moreover, if SS Cyg should be a dwarf nova (non-magnetic CV) – like reported in the table of detected CVs in the former papers – why other dwarf novae are not detected with the same instruments?

Rudolf Gális (2011) discussed the X-ray and optical activity of the INTEGRAL CVs, explicitly mentioned SS Cyg as IP, making a comparison with its X-ray behaviour with those very similar of V 709 Cas, a well established IP.

Then we can assume, without reasonable doubts, that SS Cyg is an IP. What is the intensity of its magnetic field? A relationship between the strength of the high–state UV emission lines and the strength of the white dwarf magnetic field has been found by Howell et al. (1999). From the fluxes of UV emission lines (Gaudenzi et al., 1986) we derived the luminosity of C II and C IV: $L_{CII} \sim (9.9 \pm 3.3) \times 10^{30}$ erg s^{-1}, and $L_{CIV} \sim (1.3 \pm 0.3) \times 10^{31}$ erg s^{-1}, respectively.

Using these values of luminosity and the extrapolation of the line best fitting the emission line luminosity of C II and C IV from Howell et al. (1999), the magnetic field intensity of SS Cyg is $B_{CII} \simeq 2.0^{+0.5}_{-0.4}$ and $B_{CIV} \simeq 1.1^{+0.3}_{-0.6}$ MG, respectively as shown in Fig. 2, upper and lower panels, respectively.

Then a reasonable value of the white dwarf magnetic field in SS Cyg is $B \simeq 1.6 \pm 0.7$ MG. This value is in complete agreement with the evaluation made by Fabbiano et al. (1981) ($B \leq 1.9$ MG) using simultaneous X-ray, UV, and optical data.

Moreover,

v) a periodicity at 12.18 ± 0.01 m in R and I bands was detected in SS Cyg by Bartolini et al. (1985), probably the beat period between the spin period of the white dwarf and the orbital period of the system. If the rotation is direct with orbital motion $P_{spin} = 11.82 \pm 0.01$ m, corresponding to 709.2 ± 0.6 s. If the rotation is inverse $P_{spin} = 12.56 \pm 0.01$ m (753.6 ± 0.6 s). Tramontana (2007) found a periodicity of 12.175±0.539 m by using 504 images obtained in R band on October 26, 2006 with SS Cyg in outburst at the didactic telescope TACOR of the La Sapienza University. Braga (2009) by using 10 ks XMM-OM UV observations of SS Cyg found a period of 709 ± 1 s that should be the rotational period of the white dwarf, following the model of IPs developed by Warner (1986).

By using P_{spin} = 709 s and the relationship P_{spin} vs P_{orb} (Warner, 1996), SS Cyg lies in the zone of the IPs very close to the line of 1 $M_\odot$ (Fig. 3, upper panel). The mass of SS Cyg white dwarf is $0.97^{+0.14}_{-0.05}$ $M_\odot$ (Giovannelli et al., 1983).

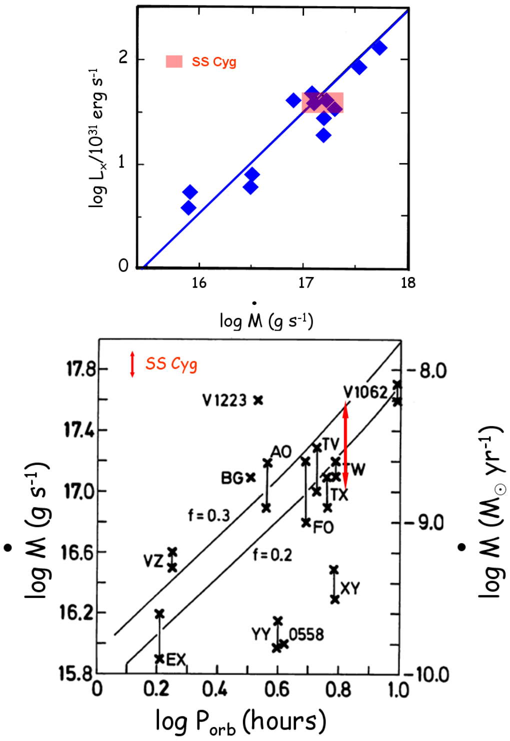

Fig. 1. Upper panel: relationship between X-ray luminosity and mass accretion rate for IPs that are indicated with x (by courtesy of Warner, 1996). Lower panel: relationship between mass accretion rate and orbital period for IPs (by courtesy of Warner, 1996). SS Cyg positions are indicated with a red rectangle and a red line in the upper and lower panels, respectively.

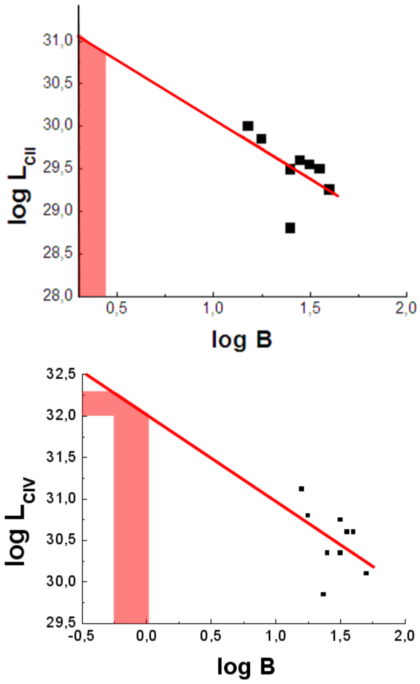

Fig. 2. Observed emission fluxes converted to luminosity for magnetic CVs (after Howell et al., 1999) are indicated with ■: C II in the upper panel, and C IV in the lower panel. SS Cyg positions are indicated with red areas. Luminosity expressed in erg s^{-1}, and B in unit of 10^6 gauss.

With B $\sim$ 1.6 MG, and the radius of the white dwarf $R_{wd} = 5 \times 10^8$ cm (Martinez-Pais et al., 1994), the magnetic moment is $\mu \sim 2 \times 10^{32}$ G cm^3. Using this value of μ and the average value of $\dot{M}$, SS Cyg lies just in the IPs region as shown in the lower panel of Fig 3.

As pointed out by Lamb & Patterson (1983), since the evolutionary time scale of CVs, $\tau_{ev} \propto \dot{M}^{-1} \sim 10^8$ yr, is greatly in excess of time–scale $\tau \sim P/\dot{P} \sim 10^6$ yr to reach the spin equilibrium, P_{eq}, it is usually accepted that the white dwarfs in IPs rotate close to their equilibrium value.

Using the formula (10) of Warner (1990), taken from Lamb & Patterson (1983), the equilibrium period for SS Cyg is P_{eq} = 780 s. This is one more indirect proof about the IP nature of SS Cyg.

Norton, Wynn & Somerscales (2004) and Norton et al. (2004a) used a model of magnetic accretion for investigating the rotational equilibrium of MCVs. Their results of numerical simulations demonstrate that there is a range of parameter space in the P_{spin}/P_{orb} versus μ plane at which rotational equilibrium occurs. Upper panel of Fig. 4 shows the P_{spin} versus P_{orb}. Triangles and squares represent polars and IPs, respectively (Norton et al., 2004b). There are 5 systems in which P_{spin} and P_{orb} differ by $\lesssim$ 2%. These are assumed to be polars that have been disturbed from synchronism by

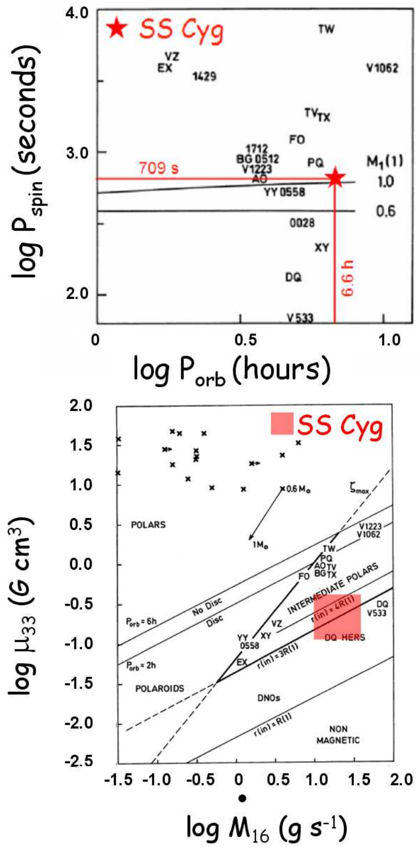

Fig. 3. Upper panel: relationship between P_{spin} and P_{orb} for IPs (by courtesy of Warner, 1996). Lower panel: relationship between the magnetic moment of the white dwarfs in CVs and $\dot{M}_{\odot}$ (by courtesy of Warner, 1996). Polars are indicated with x, and IPs with their abbreviated titles. SS Cyg positions are indicated with a red ⋆ and a red square, respectively. Magnetic moment μ is expressed in G cm^3, and $\dot{M}_{\odot}$ in unit of 10^{16} g s^{-1}.

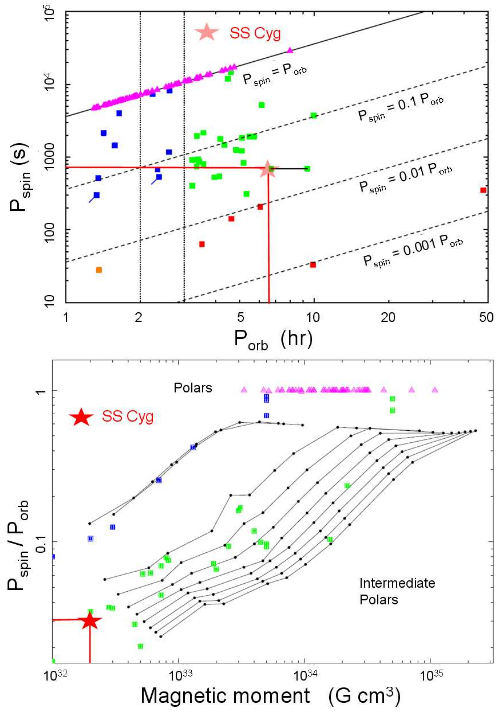

Fig. 4. Upper panel: relationship between P_{spin} and P_{orb} for MCVs. Polars and IPs are indicated by triangles and squares, respectively (by courtesy of Norton, from Norton et al., 2004). Lower panel: relationship between the P_{spin}/P_{orb} and magnetic moment μ. Each line connect 11 data points and represent the equilibrium spin periods at given orbital period. The ten lines correspond to orbital periods of 80 m, 2 h, 3 h,..., 10 h (from left to right) (by courtesy of Norton, from Norton et al., 2004b). The position of SS Cy is marked by a red ⋆ in both panels.

a recent nova explosion. Systems lie in the 'period gap' — marked with the two dotted lines — are IPs in the process of attaining synchronism and evolving into polars. There are 22 systems, classified as conventional IPs, that all have $0.01 < P_{spin}/P_{orb} < 0.25$, and $P_{orb} > 3$ hr. The two possible values of the orbital period of the IP 1RRXSJ154814.5-452845 are marked and connected by a horizontal line (Norton, Somerscales & Wynn, 2004). Lower panel of Fig. 4 shows P_{spin}/P_{orb} versus μ where the symbols are the same as in the upper panel (Norton et al., 2004b). The position of SS Cyg, marked with a star, is superimposed in both figures.

It is possible to note that virtually all the IPs have $\mu < 5 \times 10^{33}$ G cm^3, whereas virtually all the polars have $\mu > 5 \times 10^{33}$ G cm^3.

However, the magnetic moments of the WDs in IPs are mostly in the range 10^{32} G cm$^3 \lesssim \mu \lesssim 5 \times 10^{33}$ G cm^3. Norton, Wynn & Somerscales (2004) predicted that the few IPCVs with $\mu \gtrsim 5 \times 10^{33}$ G cm^3 and $P_{orb} > 3$

hr will evolve into PCVs, whilst those with $\mu \lesssim 5 \times 10^{33}$ G cm^3 and P$_{\rm orb}$ > 3 hr will either evolve into low field strength polars that are presumably unobservable, and possibly EUV emitters, or into PCVs when their fields, buried by high accretion rate, revive when the mass accretion rate reduces.

SS Cyg is an EUV emitter, with magnetic moment $\mu \sim 2 \times 10^{32}$ G cm^3 and orbital P$_{\rm orb}$ ∼ 6.6 hr.

In conclusions, we can definitively affirm that SS Cyg is an intermediate polar.

4. Discussion

LINDA SCHMIDTOBREICK: You have discussed several arguments in favour of SS Cyg being magnetic but all reflex indirect ones. What about direct measurements of optical polarization? Was done never an attempt?

FRANCO GIOVANNELLI: as far as I know, direct positive detections of optical polarization do not exist. Gnedin et al. (1995, Astr. Lett. 21, 118) performed UBVRI polarization measurements of SS Cyg. No appreciable intrinsic linear polarization was detected. However, during a radio flare simultaneous with an optical outburst, upper limits of linear polarization (3.2 ± 2.7)% and circular polarization (−3.2 ± 2.7)% have been published (Körding et al.: 2008, Science, 320, 1318).

SIMONE SCARINGI: i) hard X-ray detection of SS Cyg is NOT a proof of magnetic nature; ii) Radio emission associated with jet is NOT a proof of magnetic nature; iii) failures of spectral fits to accretion disk is NOT a proof of magnetic nature. Is there a better magnetic model fit?

FRANCO GIOVANNELLI: As I clearly discussed, the proofs I gave for supporting the magnetic nature of SS Cyg are circumstantial. However, if we consider that the circumstantial proofs are numerous, it is very reasonable to support the magnetic nature of SS Cyg. Specifically: i) only accretion onto magnetic poles (B ≈ 1 MG) justify the hard X-ray emission in quiescence (Ricketts et al.: 1979, MNRAS 186, 233; Cordova et al.: 1980, ApJ 233, 163; Heise, et al.: 1978, ApJL 63, L1). A detailed analysis of simultaneous X-ray, UV, and optical data from SS Cyg needs the presence of a magnetic field of B≤ 1.9 MG (Fabbiano et al.: 1981, ApJ, 243, 911). This conclusion is even more valid on the light of the INTEGRAL detection in a harder X-ray region. Moreover, the CVs detected by the INTEGRAL observatory are all IPs with the exception of SS Cyg (classified as dwarf Nova). Thus, if SS Cyg should be non magnetic, why INTEGRAL does not detect other dwarf novae? iii) Accretion disk models do not fit the multifrequency data of SS Cyg, that are very similar to those of AM Her (e.g. Fabbiano et al., 1981). Models with the presence of a magnetic field for SS Cyg do not exist in the literature. But this is probably the obvious consequence of considering SS Cyg, by definition, non magnetic. Some results could be available in the near future using the results of 3D MHD numerical simulations (Bisikalo & Zhilkin, these proceedings).

IRINA VOLOSHINA: You state that one of the arguments supporting the idea that SS Cyg is an IP is the detection of the 12-m period. However, I have obtained many photometric light curves of this system and none of them demonstrates the variability with the period that you report. Besides, I have not managed to find any confirmation of this period in papers published by other authors who performed photometric measurements of SS Cyg.

FRANCO GIOVANNELLI: It is true that the 12-m periodicity has not been reported by other authors. However, such periodicity has been found in the R band by Bartolini et al. (1985), and by Tramontana (2007), and in 10 ks XMM–OM UV observations by Braga (2009). On the contrary, this periodicity is not present in 10 ks XMM X-ray data analyzed by my group. However, the behaviour of SS Cyg fulfill most of the characteristics of an IP, such as orbital modulations of continuum and fluxes of emission lines, like discussed.

DMITRY BISIKALO: What are the recent estimates of the magnetic field values in SS Cyg?

FRANCO GIOVANNELLI: The variations in the mid-IR (11.7 μm) emission from SS Cyg could be due to coherent emission during flares. This would probably requires very powerful magnetic field of $\sim 10^7$ G (Dubus et al.: 2004, MNRAS, 349, 869). Our evaluation gives B = 1.6 ± 0.7 MG in agreement with the value (B≤ 1.9 MG) deduced by Fabbiano et al. (1981).

ODED REGEV: Does the decision if SS Cyg is magnetic or not have any significance on anything else, save SS Cyg?

FRANCO GIOVANNELLI: Claiming after proofs the presence of a strong magnetic field in SS Cyg is important not only for this system itself, but in general for evolutionary problems of CVs. Indeed, for instance, Norton, Wynn & Somerscales (2004, ApJ, 614, 349) investigate the rotational equilibria of MCVs. The magnetic moments of the WDs in IPs are mostly in the range 10^{32} G cm^3 $\lesssim \mu \lesssim 5 \times 10^{33}$ G cm^3. They predict that the few IPCVs with $\mu \gtrsim 5 \times 10^{33}$ G cm^3 and $P_{orb} > 3$ hr will evolve into PCVs, whilst those with $\mu \lesssim 5 \times 10^{33}$ G cm^3 and $P_{orb} > 3$ hr will either evolve into low field strength polars that are presumably unobservable, and possibly EUV emitters, or into PCVs when their fields, buried by high accretion rate, revive when the mass accretion rate reduces. SS Cyg is an EUV emitter, with magnetic moment $\mu \sim 2 \times 10^{32}$ G cm^3 and orbital $P_{orb} \sim 6.6$ hr.

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