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CHANDRA X-RAY RESULTS ON V426 OPHIUCHI

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RESUMEN

De las observaciones de 45 ks de *Chandra* de V426 Oph hemos obtenido espectros de rayos X de alta resolución con relación señal-a-ruido moderada, y una curva de luz no interrumpida de buena calidad. Los espectros se adaptan razonablemente a un modelo de flujo de enfriamiento, similar a EX Hya y U Gem. Nuestro análisis de las curvas de luz de *Chandra* y las adicionales de rayos X/óptico revela una modulación persistente a 4.2 hr desde 1988 hasta 2003, probablemente el período de giro de la enana blanca, indicando una naturaleza polar intermedia para V426 Oph.

ABSTRACT

From a 45ks *Chandra* observation of V426 Oph we have obtained high-resolution X-ray spectra at moderate signal-to-noise, and a good quality, uninterrupted lightcurve. The spectra are reasonably fit with a cooling flow model, similar to EX Hya and U Gem. Our analysis of the *Chandra* and additional X-ray/optical lightcurves reveals a persistent modulation at 4.2 hr from 1988 to 2003, likely the white dwarf spin period indicating an intermediate polar nature for V426 Oph.

Key Words: **ACCRETION, ACCRETION DISKS — STARS: INDIVIDUAL (V426 OPHIUCHI)**

1. INTRODUCTION

The cataclysmic variable V426 Oph has proven to be somewhat enigmatic, despite extensive study. First identified as a bright nova-like (V=11.5–13.4) with an emission line spectrum (Herbig 1960), a detailed spectroscopic study by Hessman (1988) revealed a K3 dwarf secondary in a 6.85 hr orbit with a white dwarf (WD), with an inclination of 53° and at a distance of 200 pc. He also concluded this was a Z Cam type of dwarf nova (DN). However, there are several observational clues that V426 Oph might harbor a magnetic WD: (i) an unusually flat flux distribution in the UV, possibly due to the truncation of a hot inner disk, (ii) the X-ray flux at quiescence is larger than for typical DNe (Szkody 1986), (iii) the emission lines show flaring activity and a phase shift from a location near the WD (Hessman 1988), (iv) quasi-periodic variability has been seen in the optical and X-ray at periods from 30 min to 4.5 hr (Szkody 1986, Szkody et al 1990, Rosen et al. 1994; but see Hellier et al. 1990). To further explore these ideas, and to try to resolve the nature of the accretion in V426 Oph, we obtained a *Chandra* observation at quiescence together with simultaneous optical photometry and a single contemporaneous spectrum. Additional photometry was later obtained (see summary in table).

UT Date	Observatory	UT Time	Notes
2002 05 30	Chandra: HETGS	21:40 – 11:02	45.15 ks
2002 05 31	BO	07:04 – 11:30	V phot
2002 05 30	CTIO: YALO	08:17 – 09:34	V phot
2002 05 31	APO: DIS	06:20 – 06:25	spectrum
2003 07 25	MRO	06:00 – 10:04	R phot
2003 07 28	MRO	04:35 – 10:51	I phot

2. DATA ANALYSIS

Chandra grating spectra and response files were extracted with `CIAO`. We performed cooling flow fits in `XSPEC` and more detailed modelling using key line fluxes. We also constructed a *Chandra* lightcurve from the PSF wings plus part of the 1st order spectrum in `CIAO` (Fig. 1). We obtained past *ROSAT* and *Ginga* data from the HEASARC archive, and supplementary optical lightcurves (some simultaneous). To search for both sinusoidal and more irregular morphology modulations we undertook period searches with Lomb-Scargle and PDM techniques and fitted sinusoids at the candidate periods.

3. IP NATURE OF V426

The classic signature of an IP is the presence of two or more coherent periodic modulations corresponding to the binary orbit, white dwarf spin and

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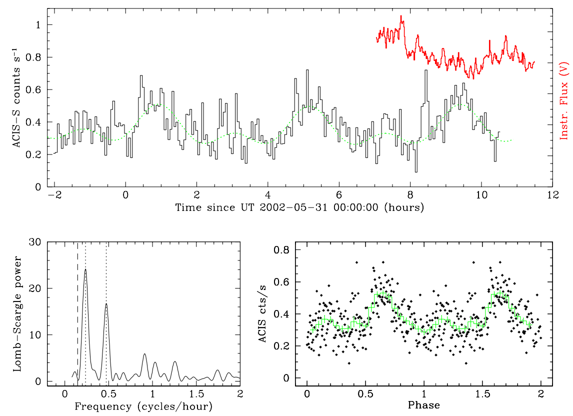

Fig. 1. Upper: Partly simultaneous lightcurve in X-rays (from *Chandra*/ACIS-S in cts/s) and optical. A double-sinusoid fit is over-plotted, with periods of 4.23 and 2.12 hrs. Lower: For the X-ray data the Lomb-Scargle periodogram and lightcurve folded on 4.23 hr are also shown.

possibly their beat. In Figure 2 we summarise all the periods reported for V426 Oph in the literature and from our own (re)analyses. The previous candidates for P_{spin} ($\sim$ 30, 60 min) we conclude are quasi-periodic and transient in occurrence. Instead, we have now finally found a much stronger candidate for the white dwarf spin period, at a surprisingly long period $\sim$ 4.2hr. This period or its first harmonic appear persistently at least from 1988 to 2003. Hence, we find that $P_{spin}/P_{orb} = 0.62$, greater than for most IPs, but similar to that of the short period system EX Hya (0.68). Here rotational equilibria is reached where $R_{in} \sim R_{co} \sim b$, and the magnetic forces dominate the motion of diamagnetic blobs of gas even at the L_1 point (King & Wynn 1999). Norton et al (2003, and these proceedings) have extended the model of magnetic accretion used to find this equilibrium to other orbital and spin periods. For the case of V426 Oph an equilibrium is possible, but for a large magnetic moment $\sim 10^{35}$G cm^3, which will only allow at most a ring of gas to exist close to R_{L_1}. Moreover, V426 Oph lies close to the dividing

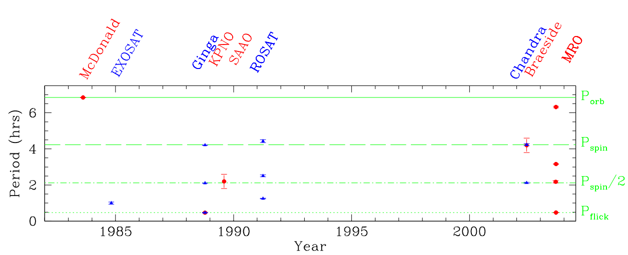

Fig. 2. Periodicities measured for V426 Oph, including published results, and those from our own (re)analyses.

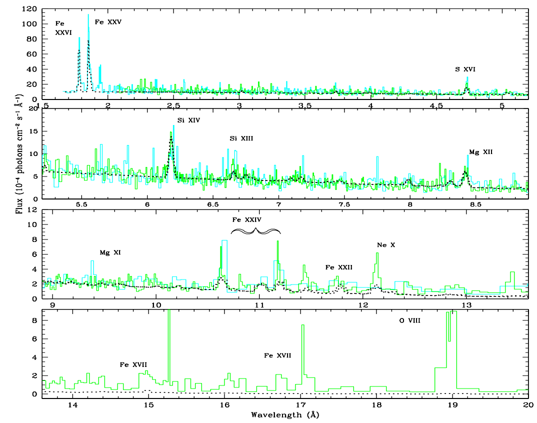

Fig. 3. *Chandra*/HETGS unfolded spectrum of V426 Oph; both HEG (solid cyan) and MEG (solid green) are shown. Overlaid is the best fit cooling flow model (dotted black).

line between Polars and IPs and may well be on the verge of synchronization (see Mason & Gray, these proceedings).

Spectroscopically, there are also similarities between EX Hya and V426 Oph. Both are better fit with a cooling flow (or shock) model than photo-excitation, and have $T_{max} \sim 20$ keV (Fig. 3). We have also experimented with a radiative shock wave code (Raymond 1979), modelling key line fluxes only. We find that the match is far from perfect, but it is close enough to indicate that the shock structure is basically correct, lending further support to the magnetic CV interpretation.

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REFERENCES

Hellier, C. et al., MNRAS, 242, 32P
Herbig, G. H. 1960, ApJ, 131, 632
Hessman, F. V. 1988, A&AS, 72, 515
King, A. R. & Wynn, G. A. 1999, MNRAS, 310, 203
Mukai, K. et al. 2003 ApJ, 586, L77
Norton, A. J. et al. 2003 ASP C. Ser., (astro-ph/0301351)
Raymond, J. C. 1979, ApJS, 39, 1
Rosen, S. R. et al. 1994, MNRAS, 269, 913
Scargle, J. D. 1982, ApJ, 263, 835
Stellingwerf, R. F. 1978, ApJ, 224, 953
Szkody, P. 1986, ApJ, 301, L29
Szkody, P., Kii, T., & Osaki, Y. 1990, AJ, 100, 546