Observing Variable Stars Using Large Telescopes

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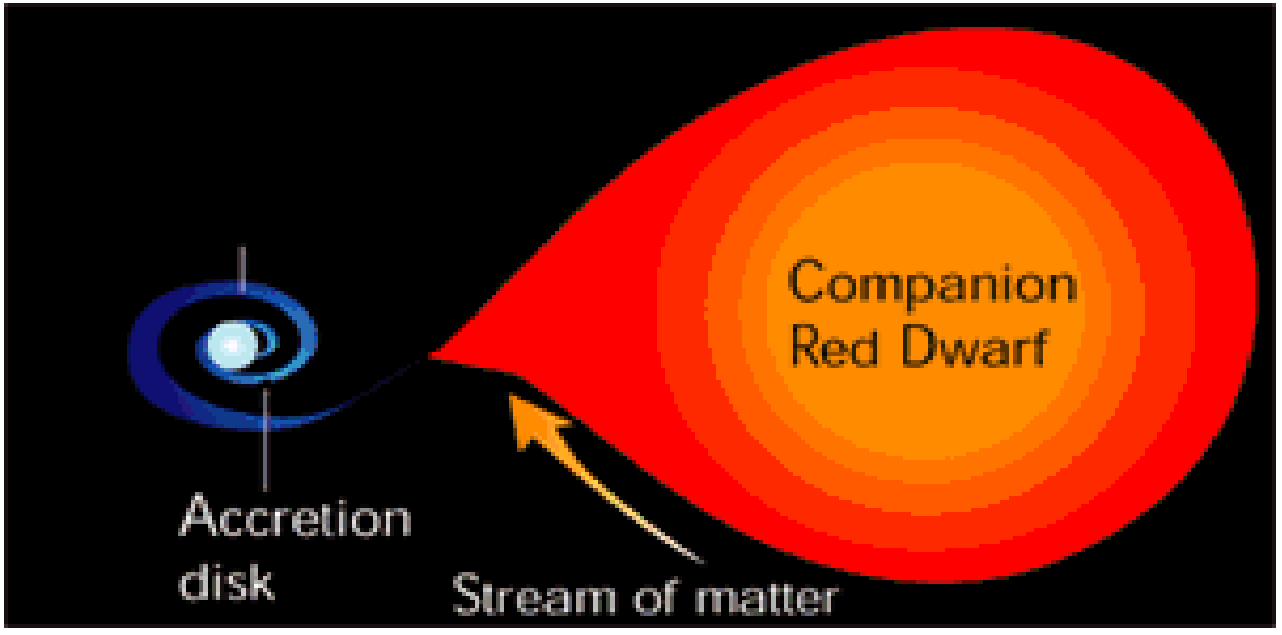
EuroVS 2013 – The 2nd European Variable Star Observers' Meeting, 27th April 2013 in Helsinki

What kind of Variable stars to stydy and why?

-Cataclysmic Variables:
Binary star systems in which the separation of the components is comparable to the diameter of the stars.



What are the cataclysmic variables?

-Compact, semi-detached binaries

-a white dwarf and a red dwarf pair

-red dwarf is filling its Roche lobe

Why the cataclysmic variables?

-very short orbital period systems (few hrs), in AM CVs (double degenerate systems) only 10-20 minutes!

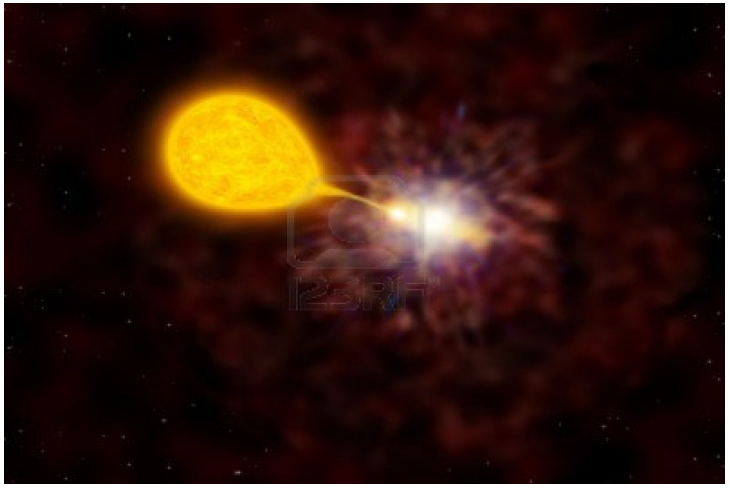
-strong X-ray, UV-, infrared and optical emission sources (among strongest X-ray sources in the whole galaxy)

-***accretion physics "laboratories"***

-strong magnetic fields in some objects

- **Classical novae**:
- have very large outbursts, of 6 mag to 19 mags.

-An outburst of a classical nova is a result of a thermonuclear runaway in the matter accreted onto the surface of a white dwarf, which ejects an expanding envelope.



Classical novae:

-Maximum visual brightness occurs when the pseudo-photosphere reaches its maximum radius.

- After the ejection, the hydrogen remaining on the white dwarf continues burning near the Eddington limit for several weeks to several years

-Recurrent novae: outbursts of several magnitudes, repeating every 10 to 80 years. Example light curve T Pyx (AAVSO light curve).

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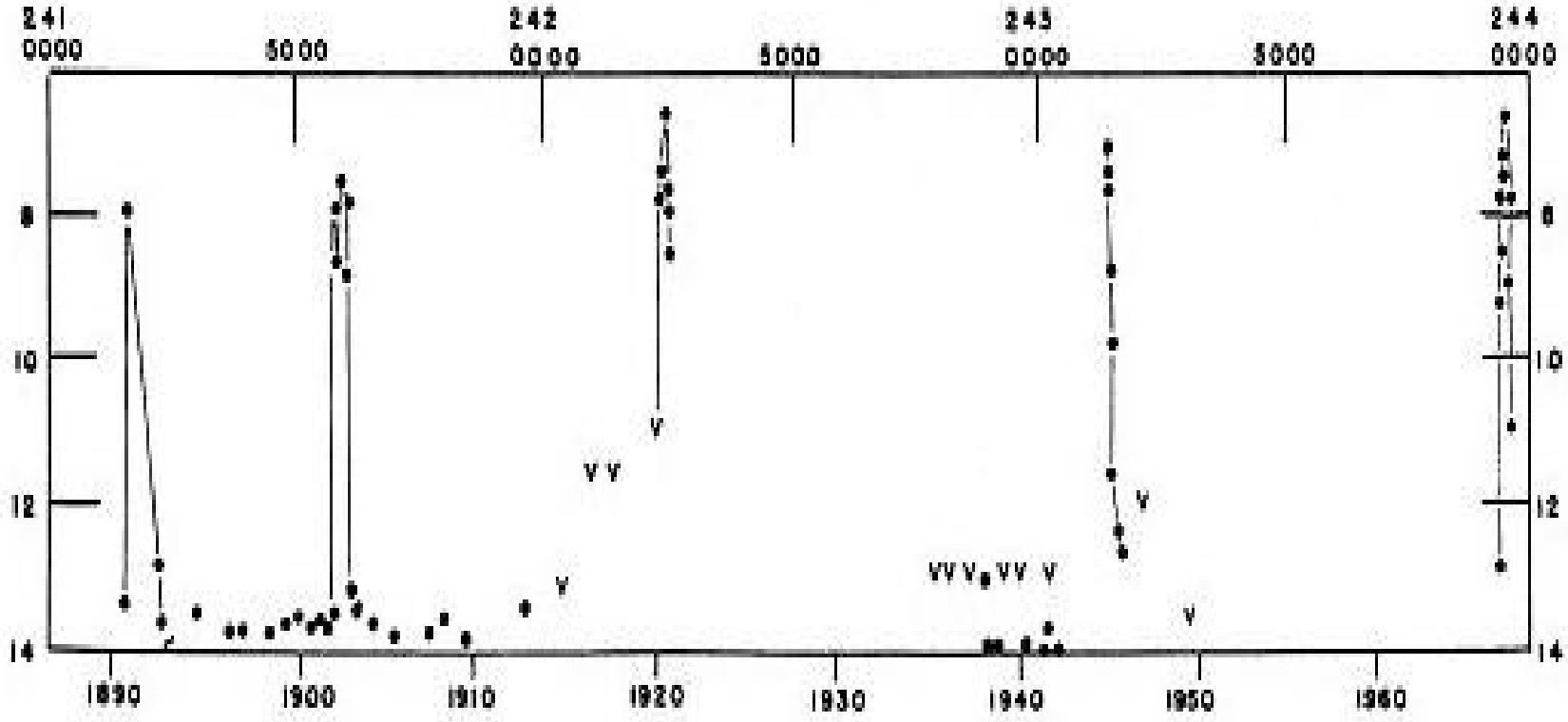


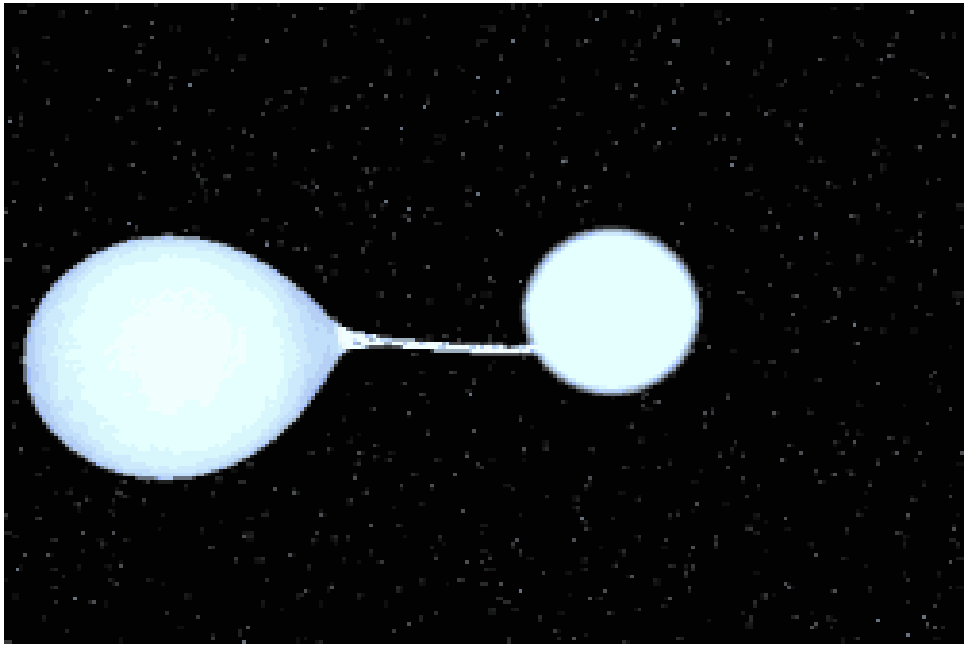
090031 T PYXIDIS — 5 MAXIMA

Some interesting subclasses among CVs:

- Polars
- Intermediate Polars
- AM Cvn stars

-AM Canun Venaticorum stars:

both components are white dwarfs; the accretion disk is composed primarily of helium, very short orbital periods, range in known systems (24) is from 5 minutes to 40 minutes!



Magnetic CVs:

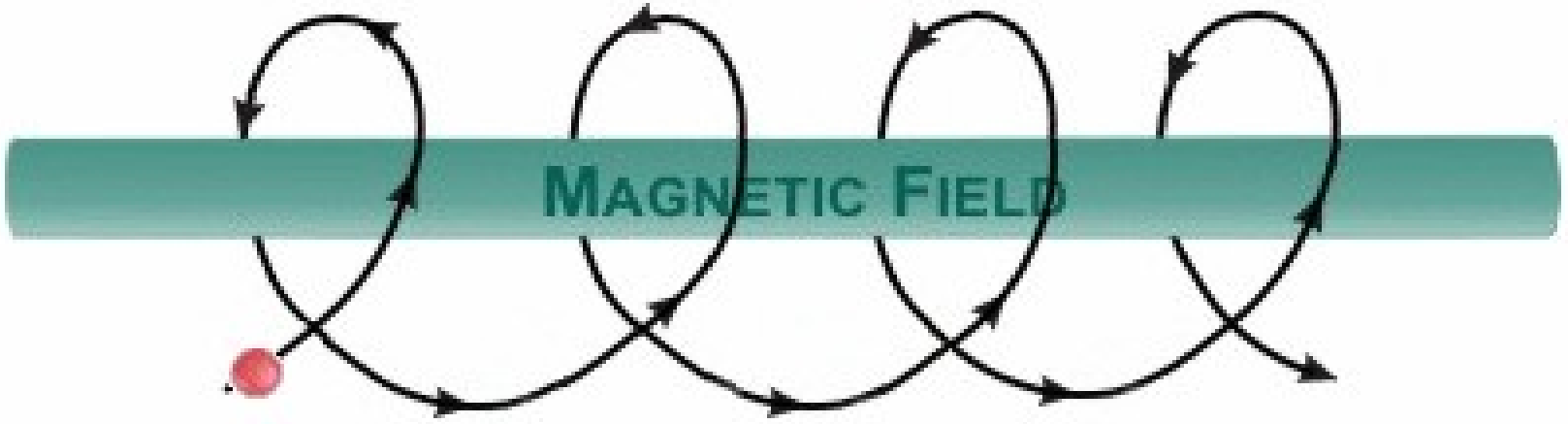
Polars have synchronized spin to orbital period due to high magnetic field

- Accreting streams / accreting disks: ***strong field objects*** (Polars) -> accretion along field lines, ***no disk***
- Magnetic fields in Polars stars: from few MG up to 200 MG
- Magnetic fields in IPs: up to few MGs (supposed)

- In Cataclysmic Variables plasma is decelerated from supersonic speed of 5000 km/s to subsonic speeds, and **matter is thus heavily heated and then cooled...**

- ...what we observe in mCVs is mostly **products of different cooling processes**

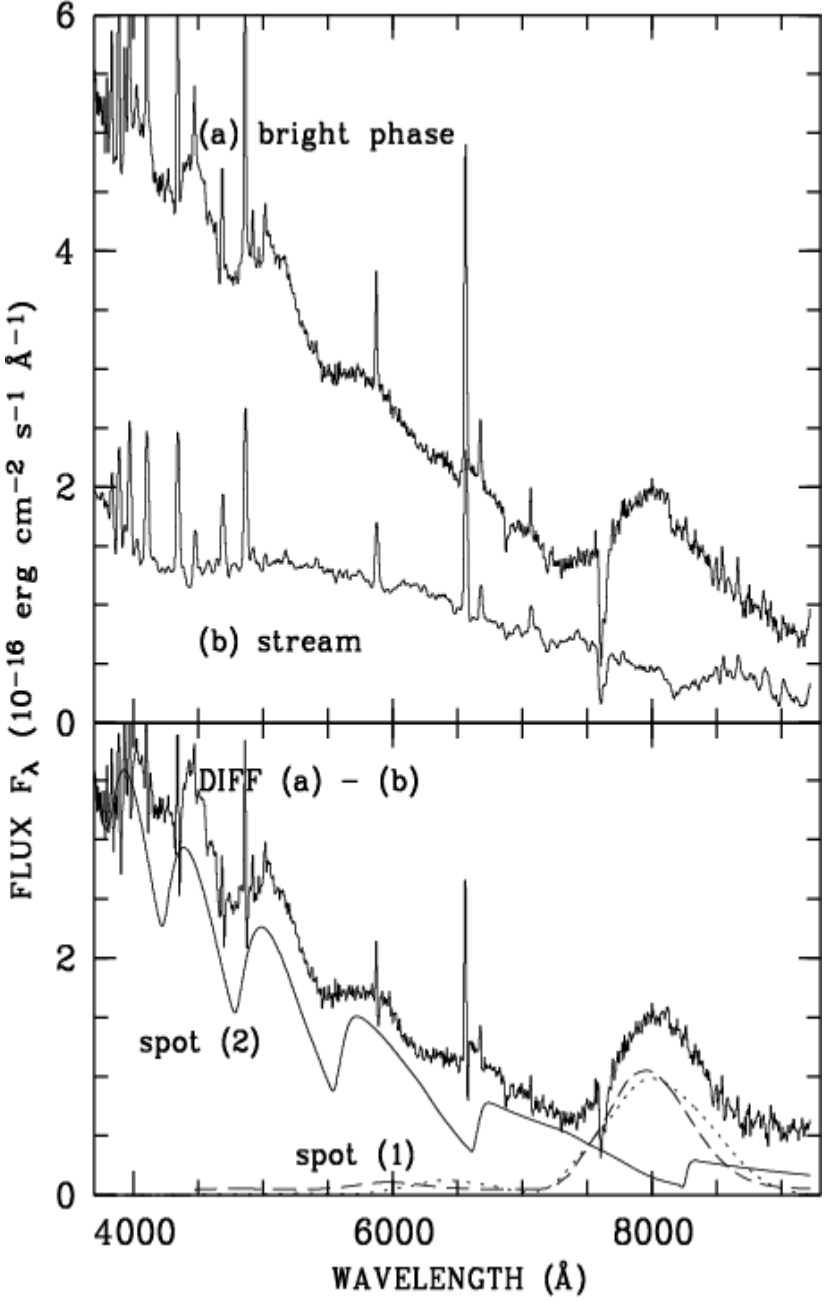
CYCLOTRON EMISSION

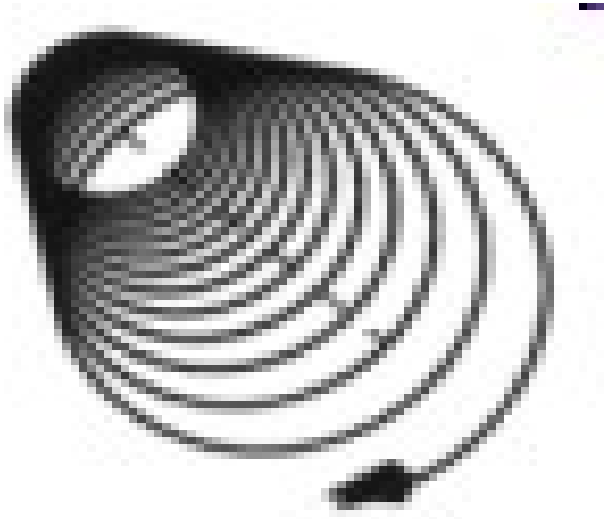


An example of the cyclotron spectrum:

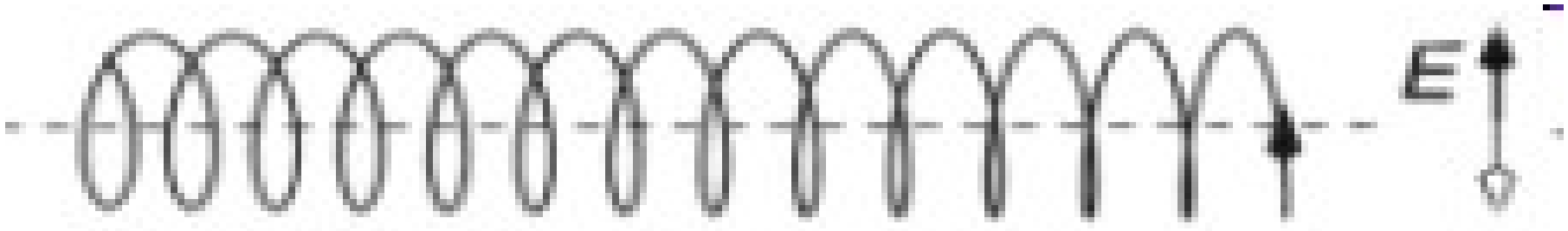
In the upper panel a high-state, bright phase spectrum of a mCV (RBS0206). Lower panel shows the difference spectrum, which is regarded as of pure cyclotron origin.

(*from Schwope et al., 2002, A&A 396, 895-910)*



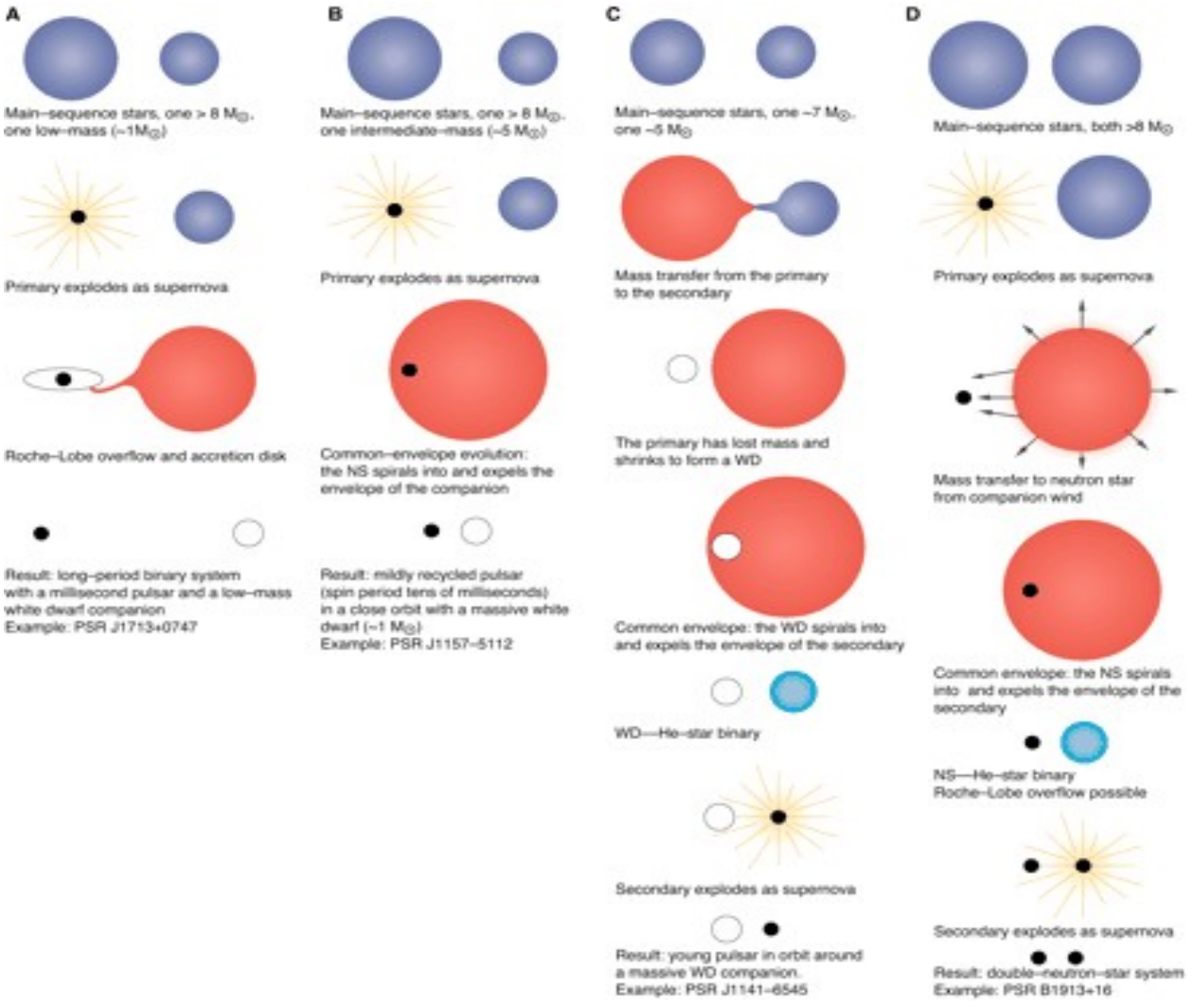


- When we look directly at a field line, the apparent motion is circular, producing circularly polarized photons. *(Image credit: Hellier 2001)*



- When the field line is seen side on, an electron spiraling around the field line will appear to be oscillating perpendicularly to the field line... and the light is *linearly polarized*. *(Image credit: Hellier 2001)*

The final evolution...??????

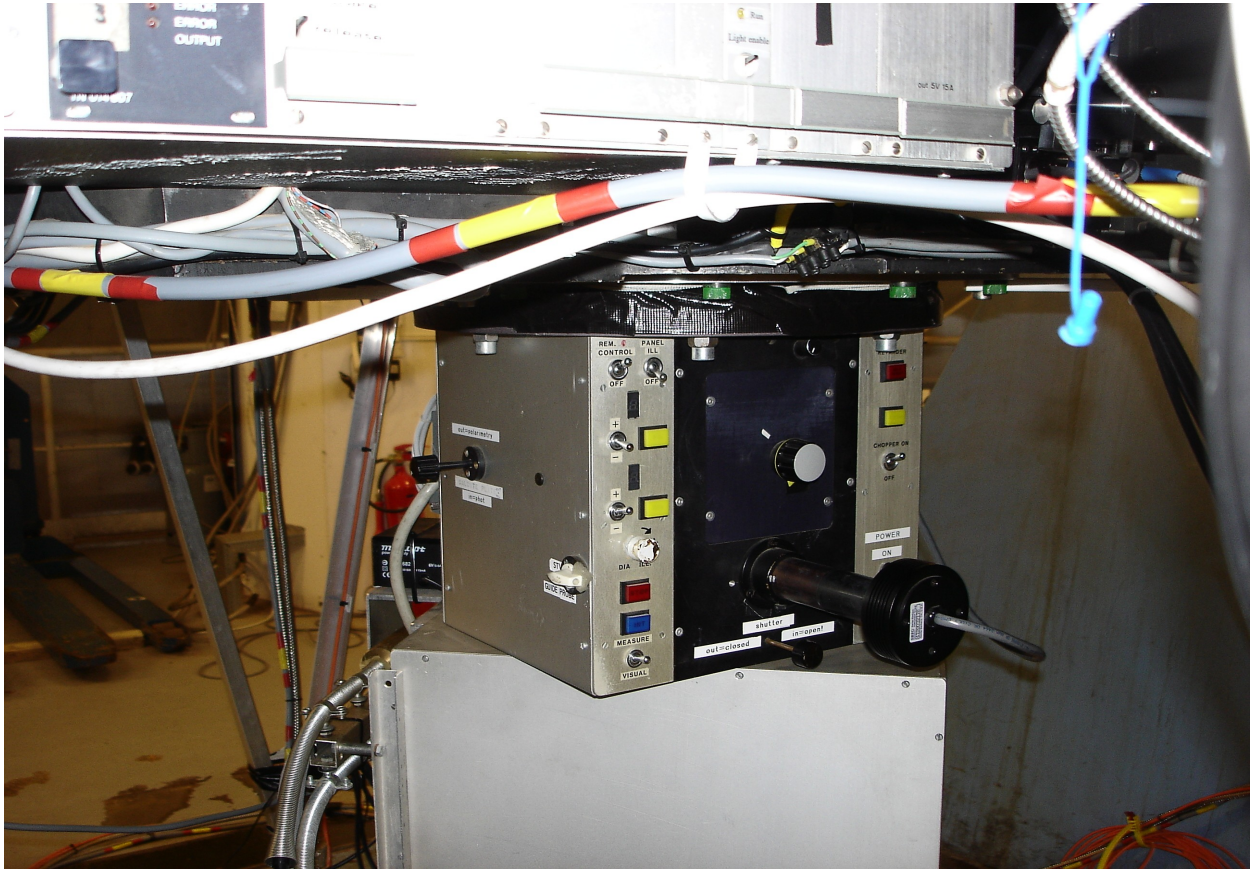


SN Ia ....or not?

Polarization as a tool..

- Magnetic field **B** strength est.,
- location and size of the accretion region on the surface of the WD
- orbital inclination accurate measurements
- Can reveal spin period of the WD...

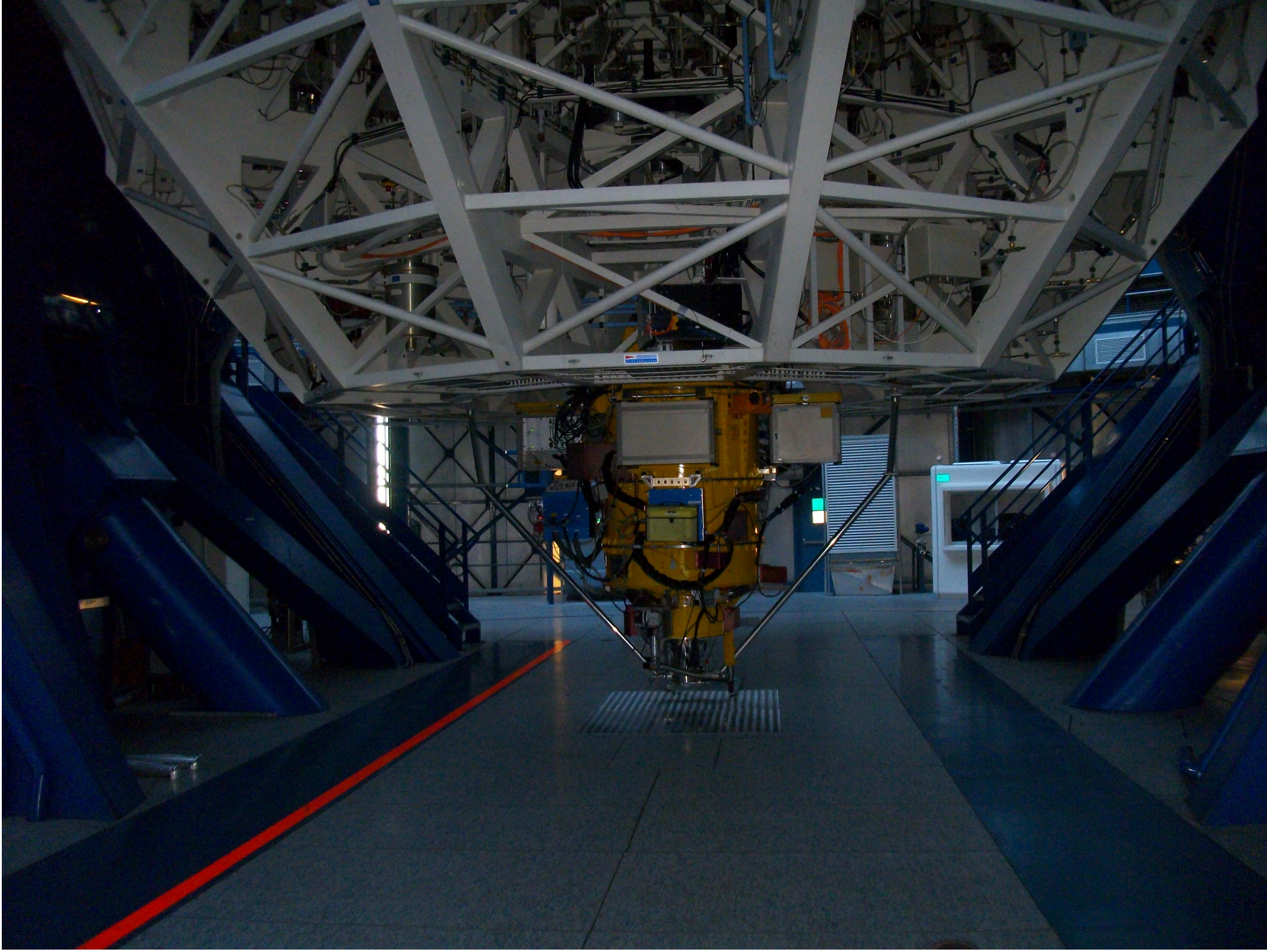
Tools for magnetic CV astronomy



- **UT 1 (Antu): FORS2:**

-A multi mode (imaging, polarimetry, long slit and multi-object spectroscopy) optical instrument mounted on the UT1 Cassegrain focus. FORS2 works in the wavelength range 330-1100 nm.

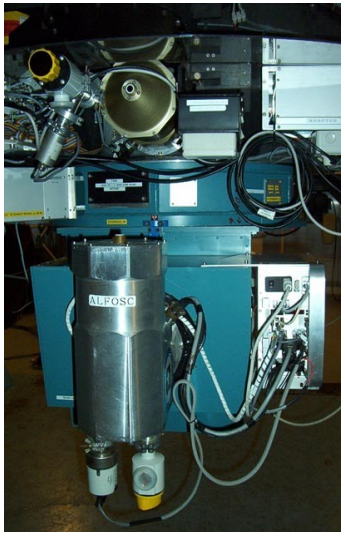
- lambda/2- or lambda/4-plate in front of the Wollaston prism.

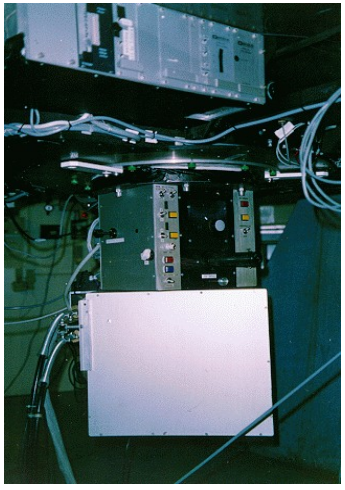


Nordic Optical Telescope, ORM, La Palma:

- **Turpol (Turku Polarimeter)**,

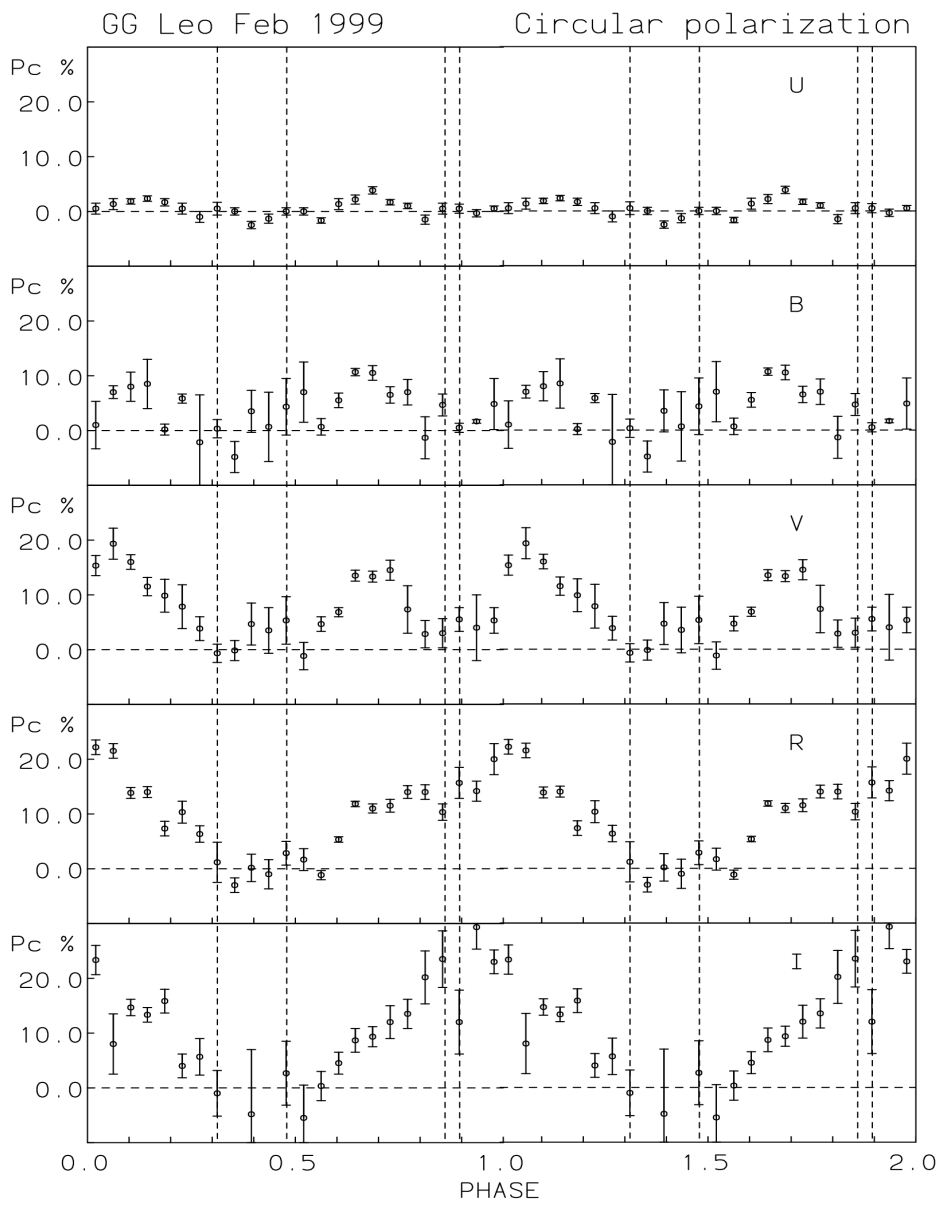
ALFOSC (Andalucia Faint Object Spectrograph and Camera):

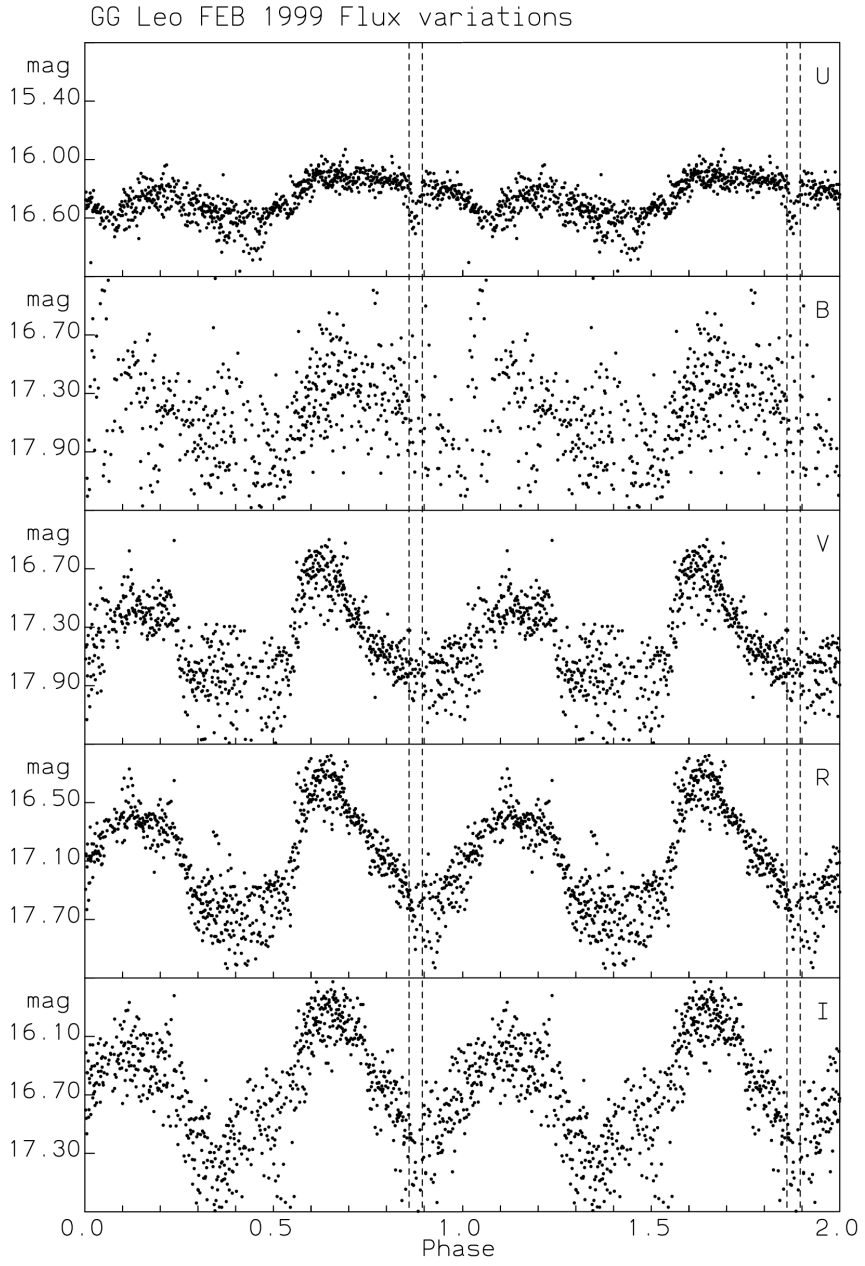


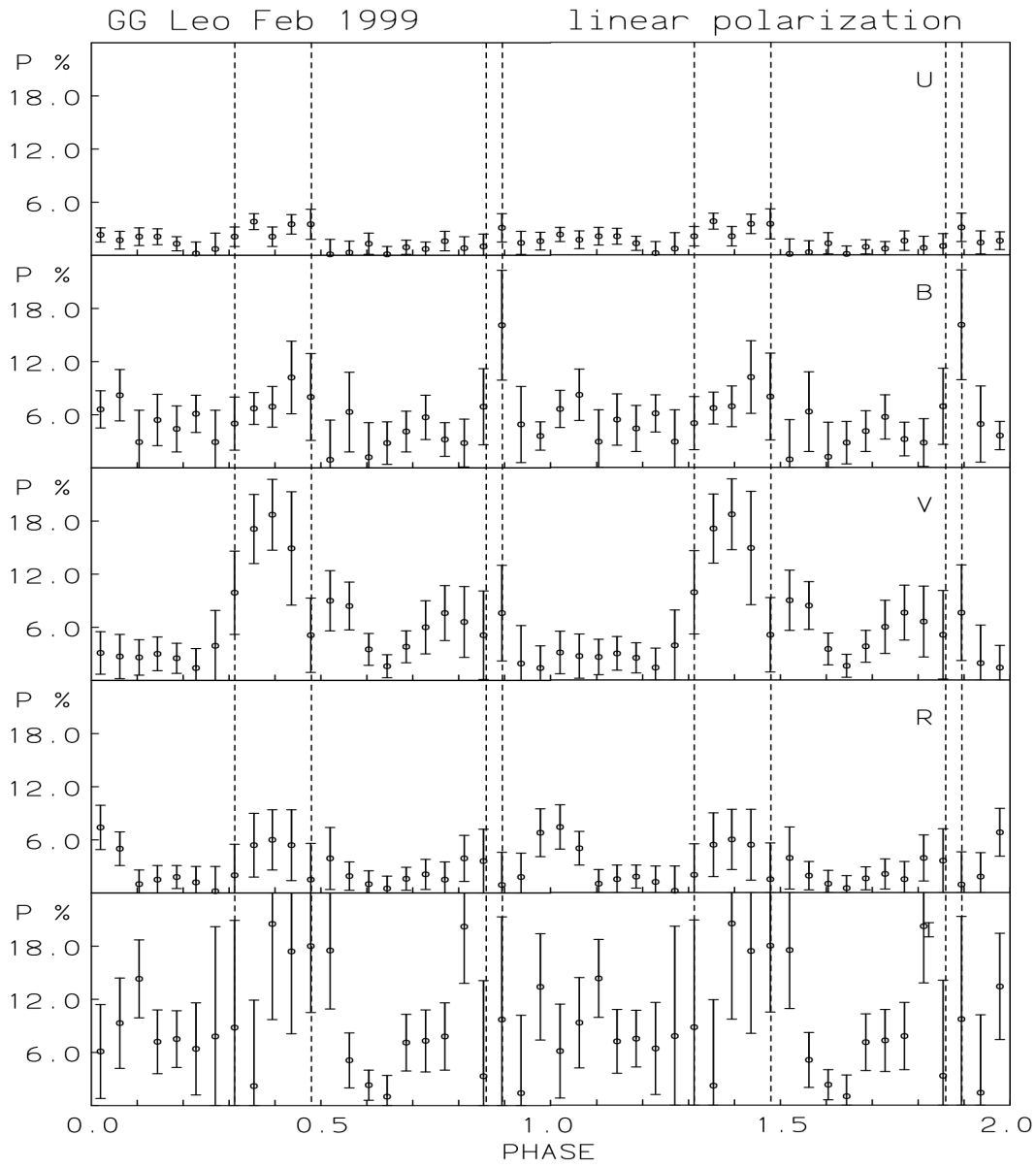


Polarimetry of magnetic CVs

- **RX J1015.5+0904 (GG Leo)**
- Orbital period is 79.88 min (close to the CV minimum orbital period)


GG Leo Feb 1999
Circular polarization
Pc %
20.0
10.0
0.0
U
B
V
R
I
0.0
0.5
1.0
1.5
2.0
PHASE

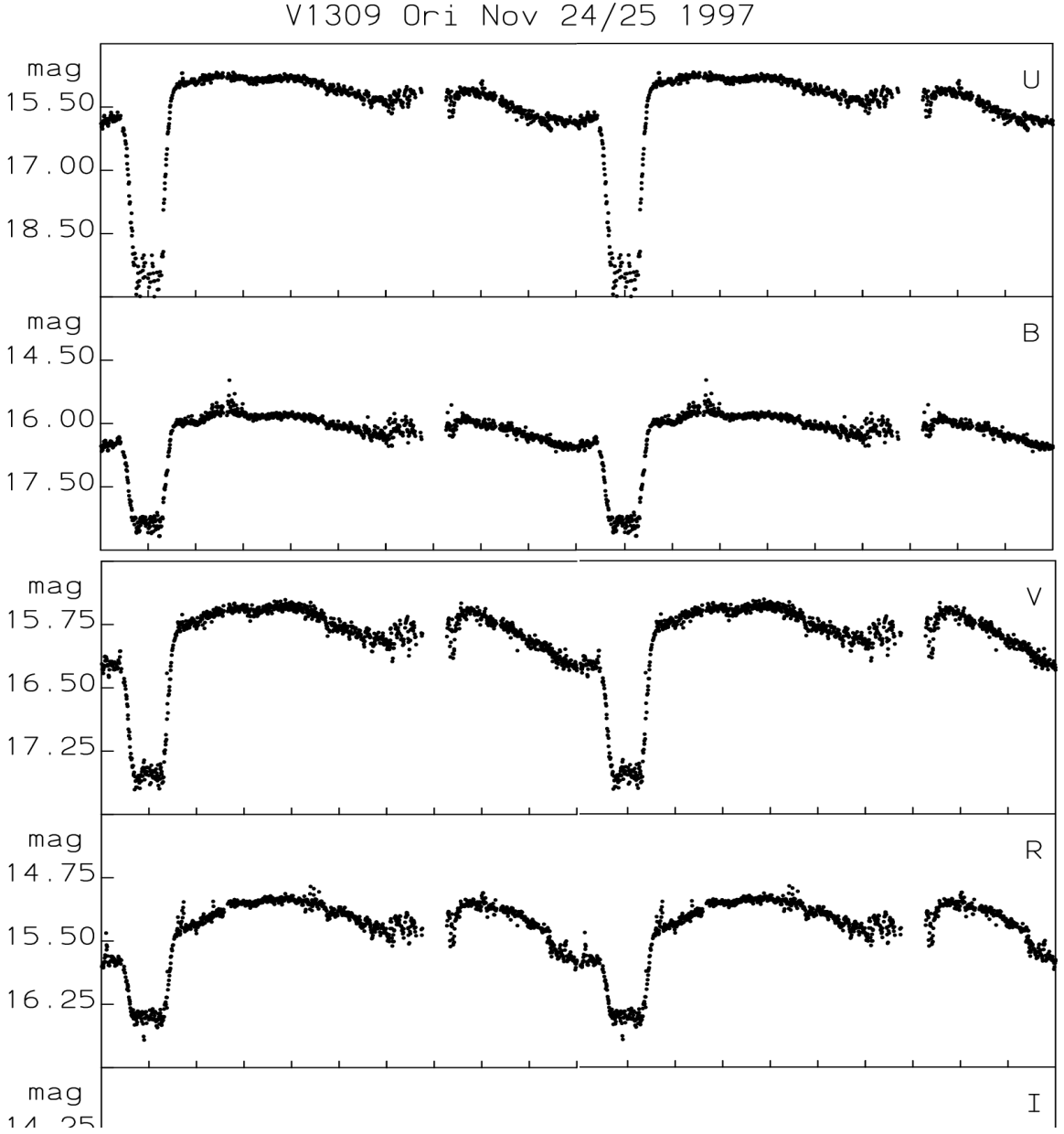

GG Leo FEB 1999 Flux variations
mag
15.40
16.00
16.60
U
mag
16.70
17.30
17.90
B
mag
16.70
17.30
17.90
V
mag
16.50
17.10
17.70
R
mag
16.10
16.70
17.30
I
0.0
0.5
1.0
1.5
2.0
Phase

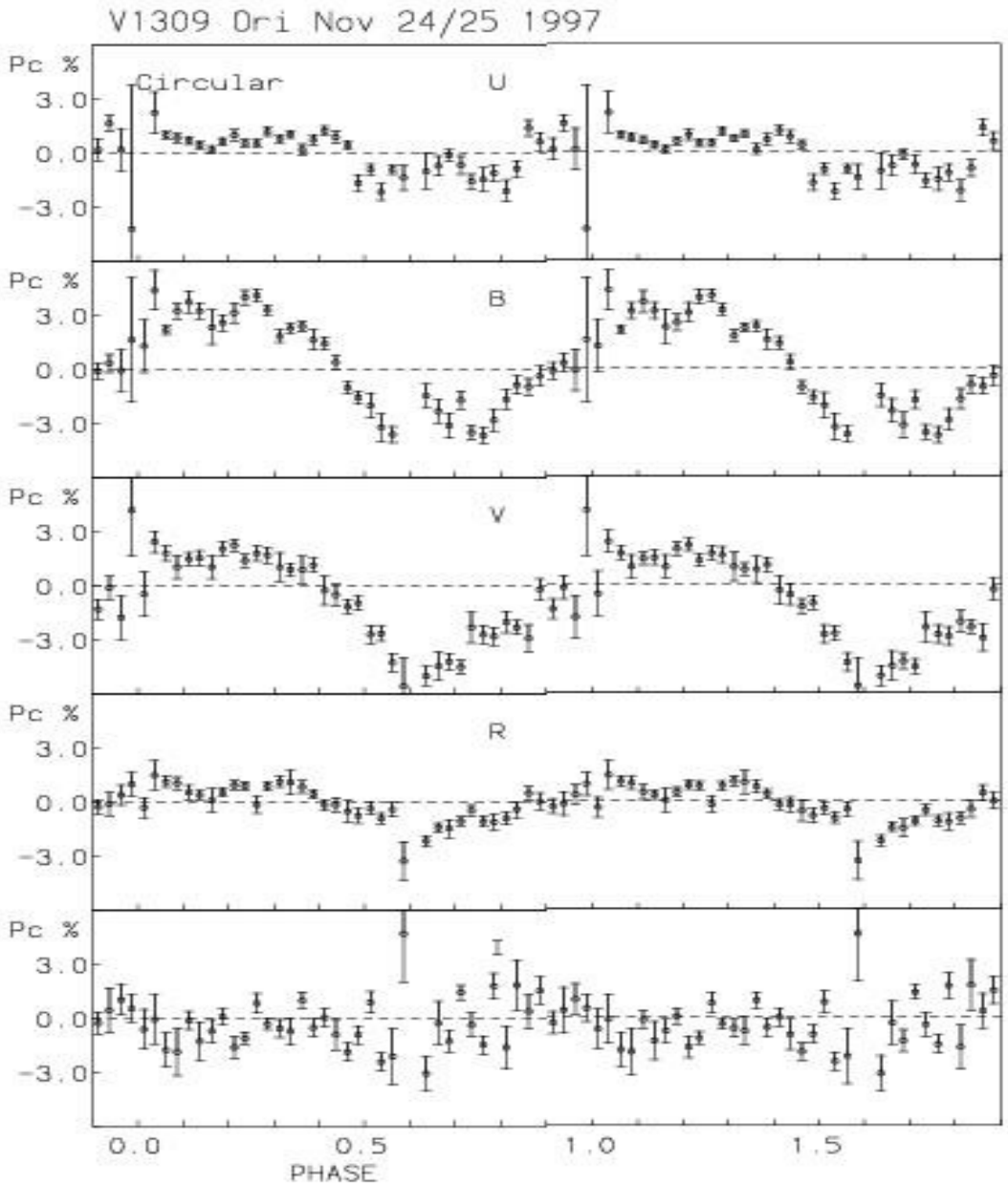

GG Leo Feb 1999
linear polarization
P %
18.0
12.0
6.0
U
B
V
R
I
0.0
0.5
1.0
1.5
2.0
PHASE

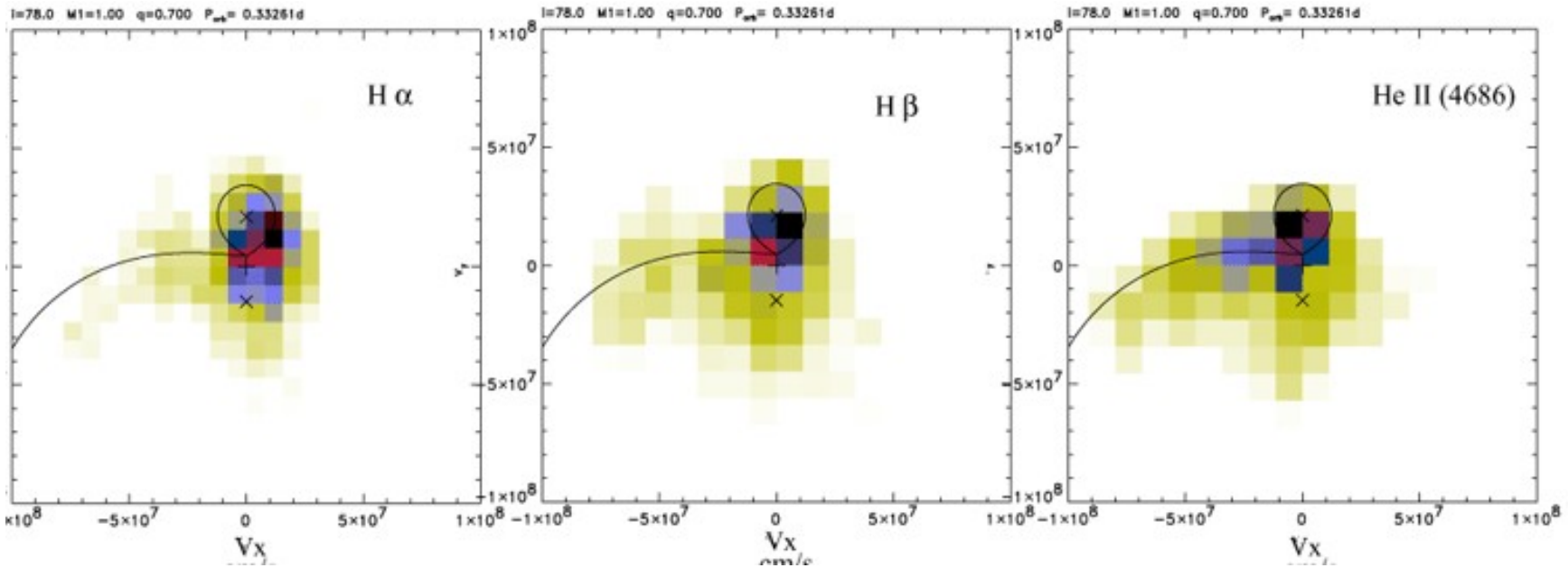
- in the RX J1015.5+0904 **B=25-30 M*G*, orbital inclination 70 degree (+-5 deg),**
- **The most part of the cyclotron emission originates from one accretion region, which is located in the colatitude range 26- 30 deg and longitudinal extension of 40 deg**

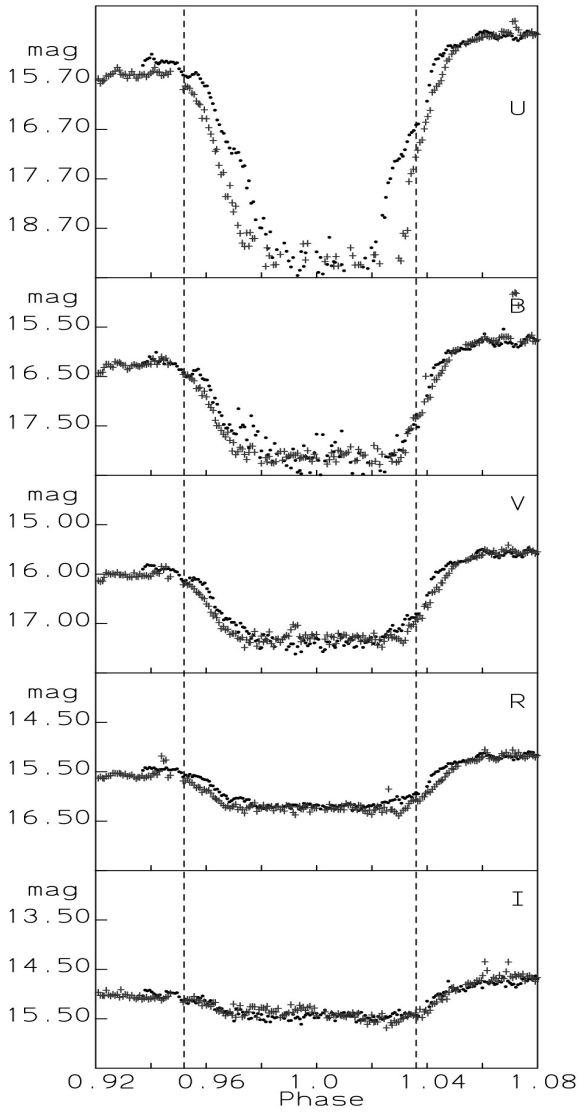
Another example: eclipsing magnetic CV: V1309 Orionis

- 7.98 hrs long orbital period eclipsing Polar (magnetic CV)
- Long orbital period → young system
- Test for synchronization degree,
- Polarization observations over several yrs timescale gives upper limit 0.002 % for the difference of the WD spin and orbital period (=well synchronized system!)

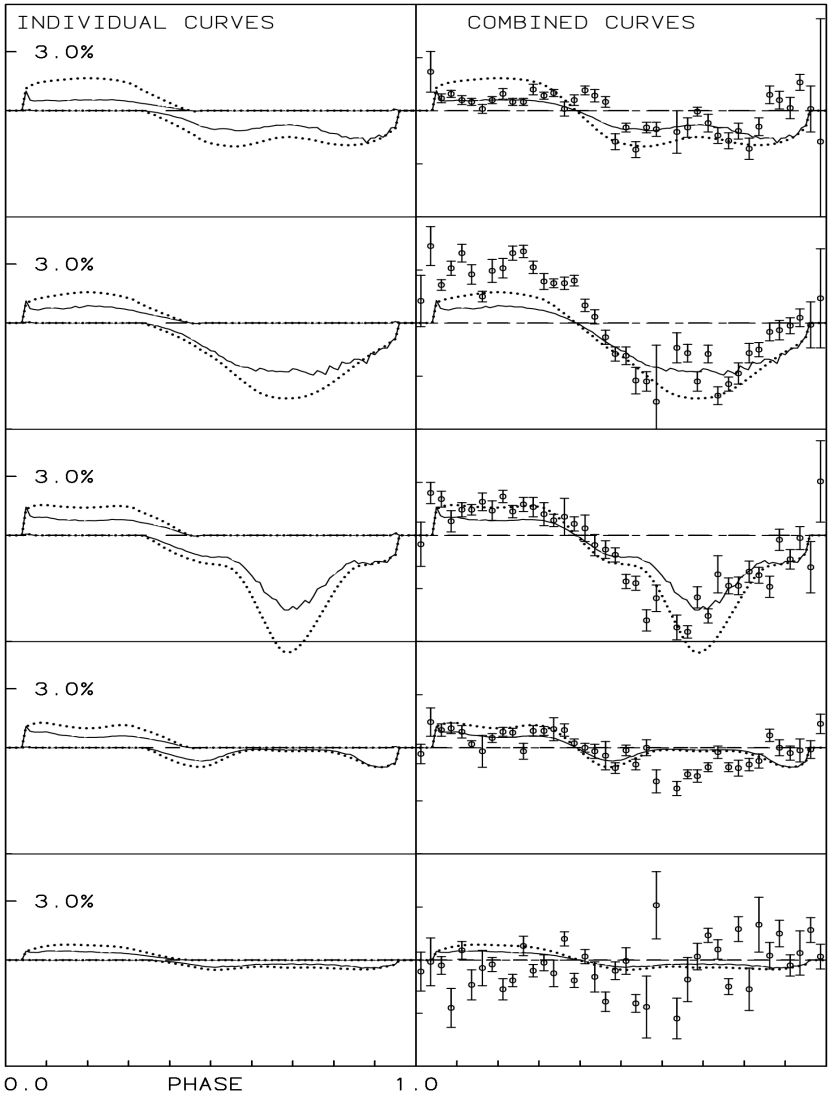

V1309 Ori Nov 24/25 1997
mag
15.50
17.00
18.50
U
mag
14.50
16.00
17.50
B
mag
15.75
16.50
17.25
V
mag
14.75
15.50
16.25
R
mag
I


V1309 Ori Nov 24/25 1997
Pc %
Circular
U
B
V
R
I
3.0
0.0
-3.0
0.0
0.5
1.0
1.5
PHASE

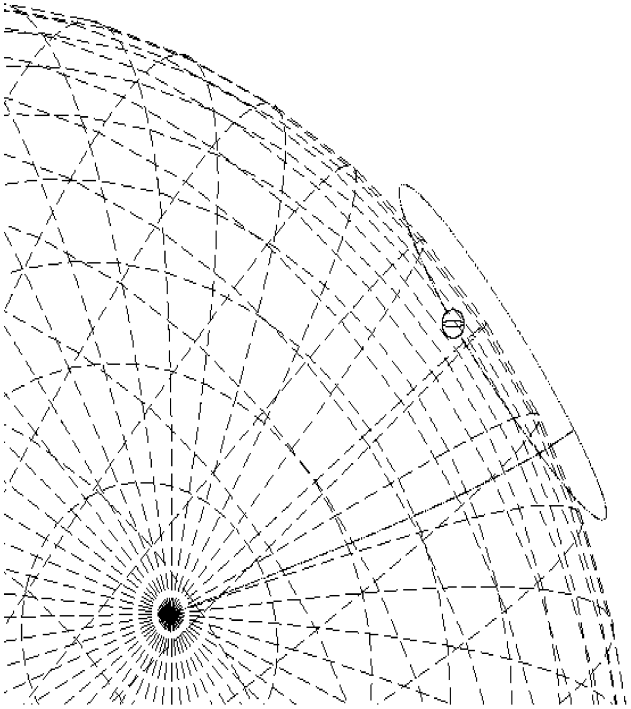

i=78.0 M1=1.00 q=0.700 P_orb= 0.33261d
H α
H β
He II (4686)
1×10^8
5×10^7
0
−5×10^7
−1×10^8
Vx

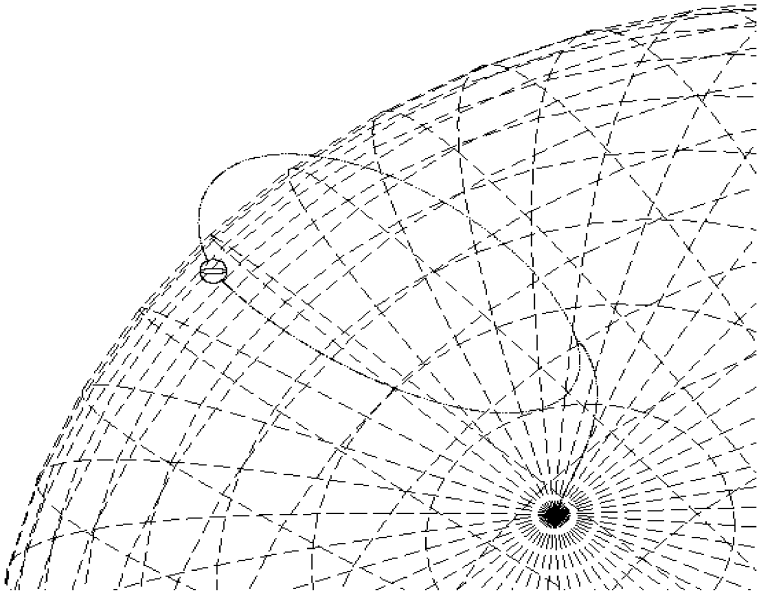

mag
15.70
16.70
17.70
18.70
U
mag
15.50
16.50
17.50
B
mag
15.00
16.00
17.00
V
mag
14.50
15.50
16.50
R
mag
13.50
14.50
15.50
I
0.92
0.96
1.0
1.04
1.08
Phase

CALC. CIRCULAR POLARIZATION:



- V1309 Ori: In the left pict. WD is just eclipsed by the secondary, but the tall accretion streams are still seen and they are eclipsed gradually. In the right picture, the accretion streams are seen well before the egress.





Modelling of cyclotron emission in V1309 Ori

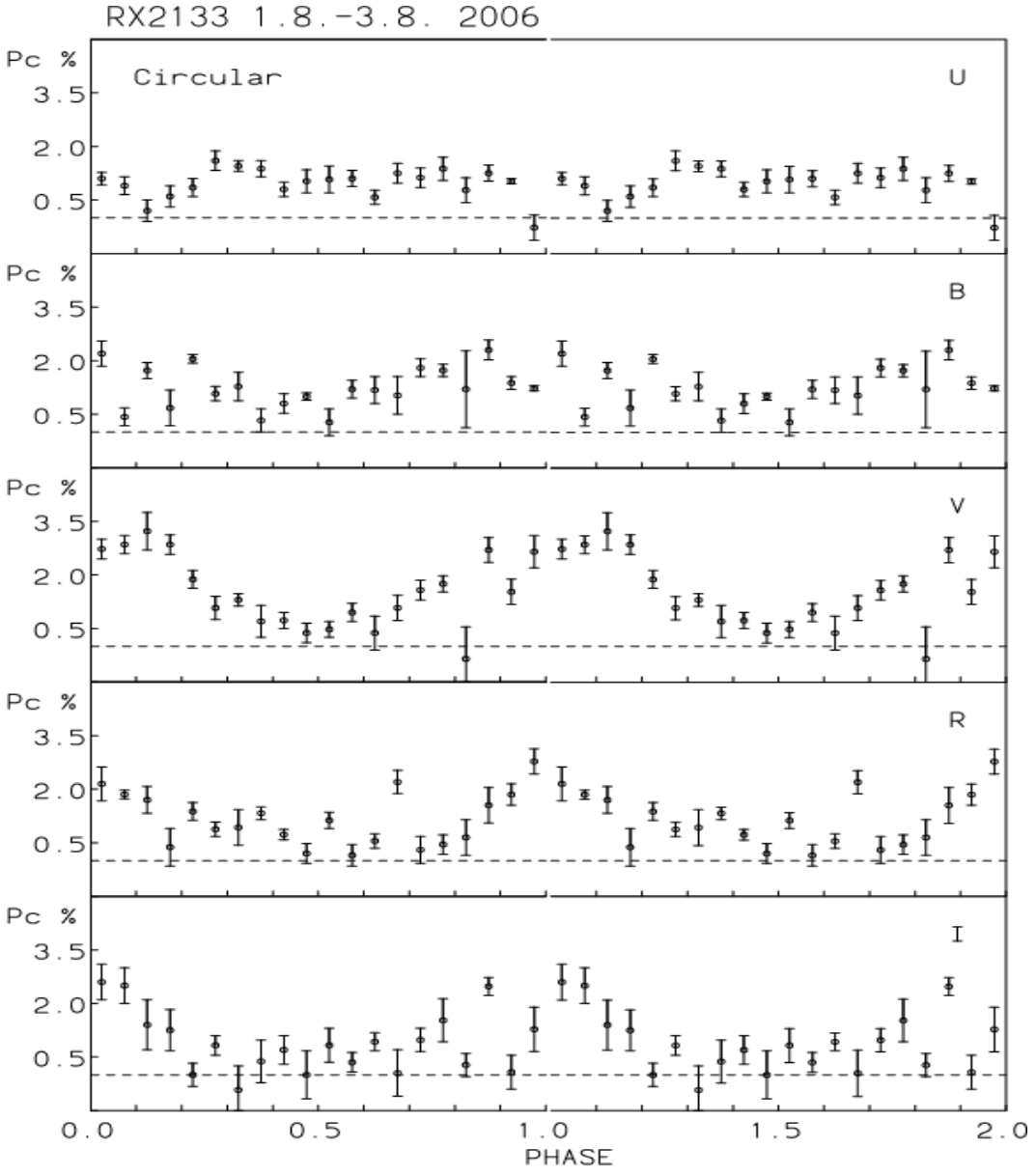
B=50-60 M*G*,

- **orbital inclination 78 degree (+-2 deg),**
- **The cyclotron emission originates from two accretion region, which are located in the colatitude range 35 deg and 145 deg and longitudinal extension of 30 deg**

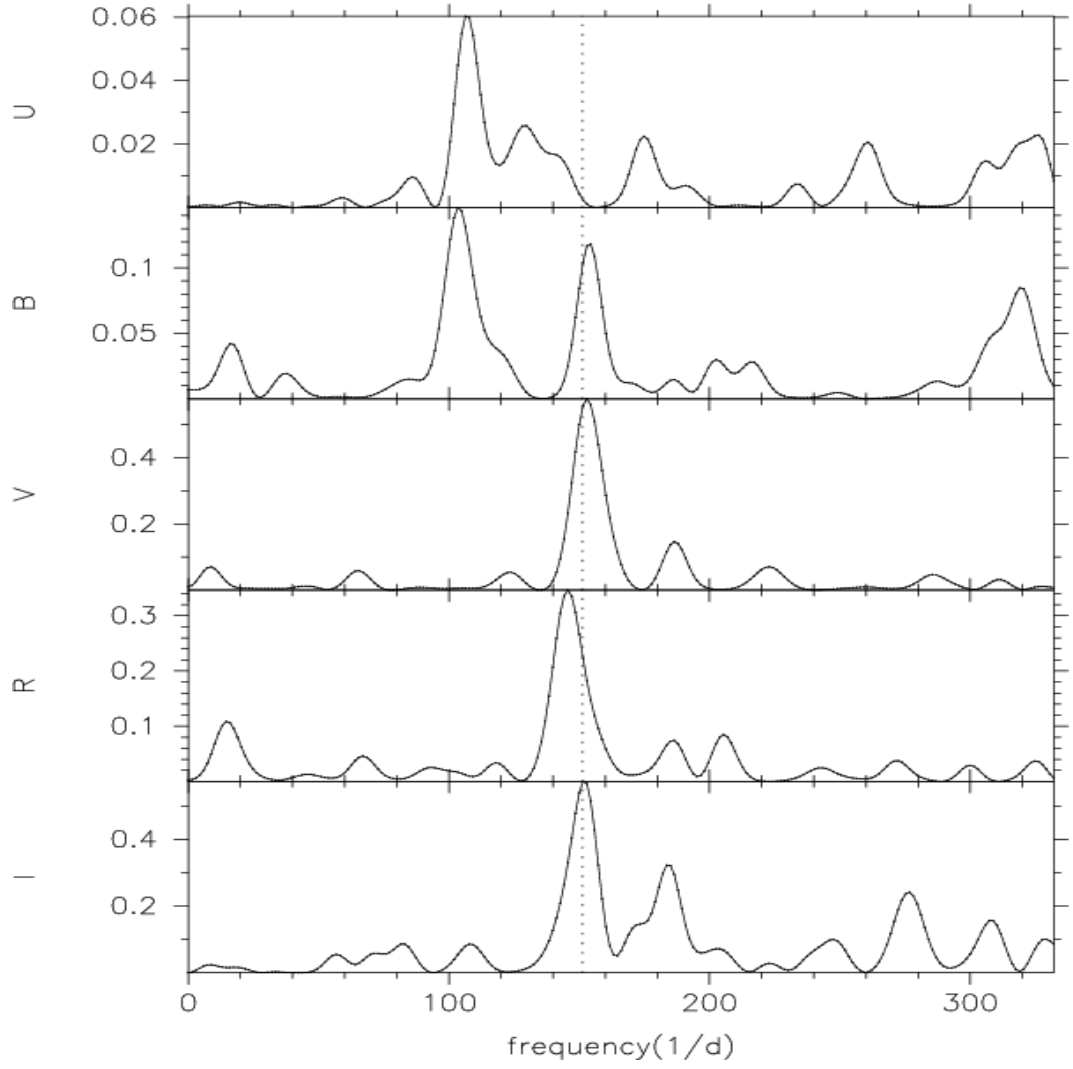
Magnetic field strengths in Intermediate Polars…?

Question: Are Intermediate Polars progenitors for Polars?....Do they evolve as Polars when their orbital period is enough short, and will they be synchronized?

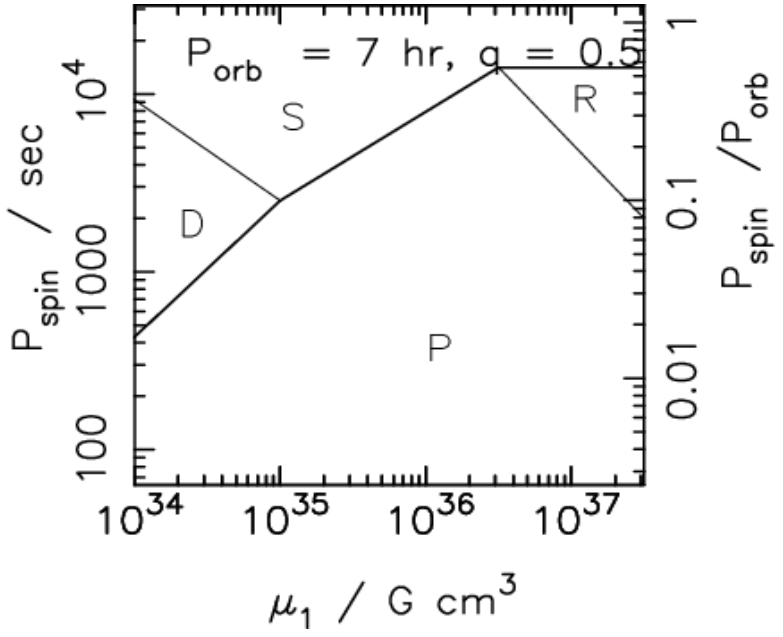
- **RX J2133.7+5107 (Katajainen et al. 2007)**
- emits circularly polarized light in all UBVRI bands (up to 3%).
- The highly asynchronous rotation of RX J2133.7+5107 (the spin to orbital period ratio is 0.022), suggests that it has only recently come into contact and it is likely to evolve into a polar (**B=20-30 MG**)


RX2133 1.8.-3.8. 2006
Pc %
Circular
U
B
V
R
I
3.5
2.0
0.5
0.0
1.0
1.5
2.0
PHASE

CLEANed periodogram of the polarization curves of RX J2133.7+5107 observed during the night of 2006 July 31/August 1. The spin frequency of the white dwarf is 152 cycles per day.

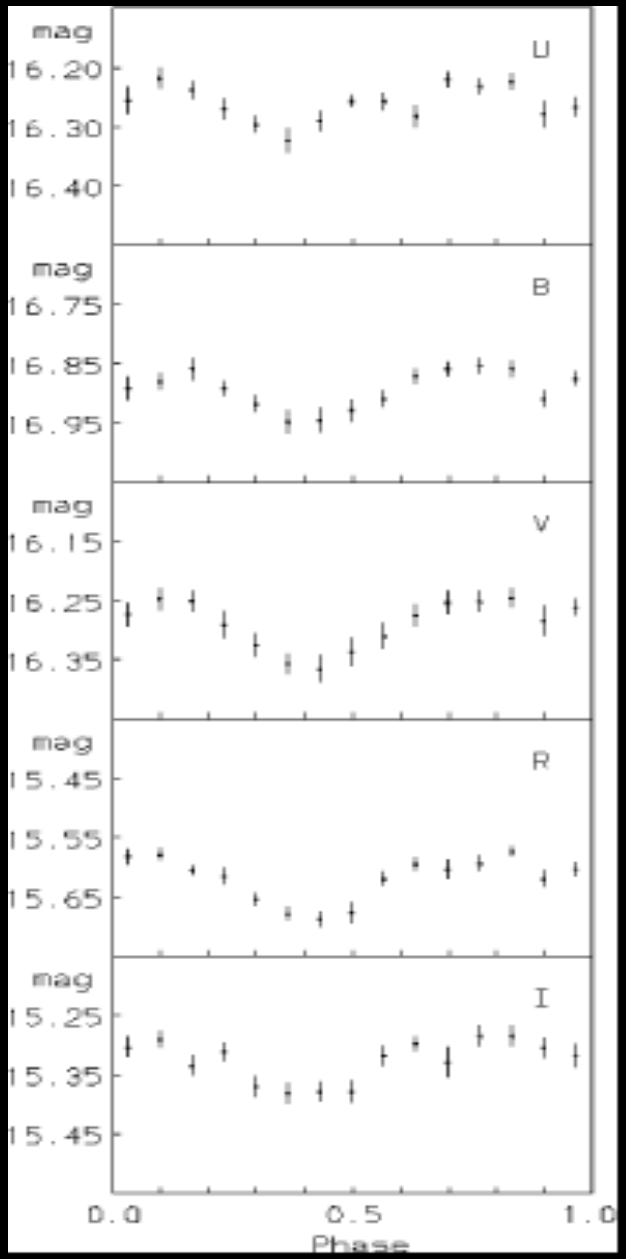


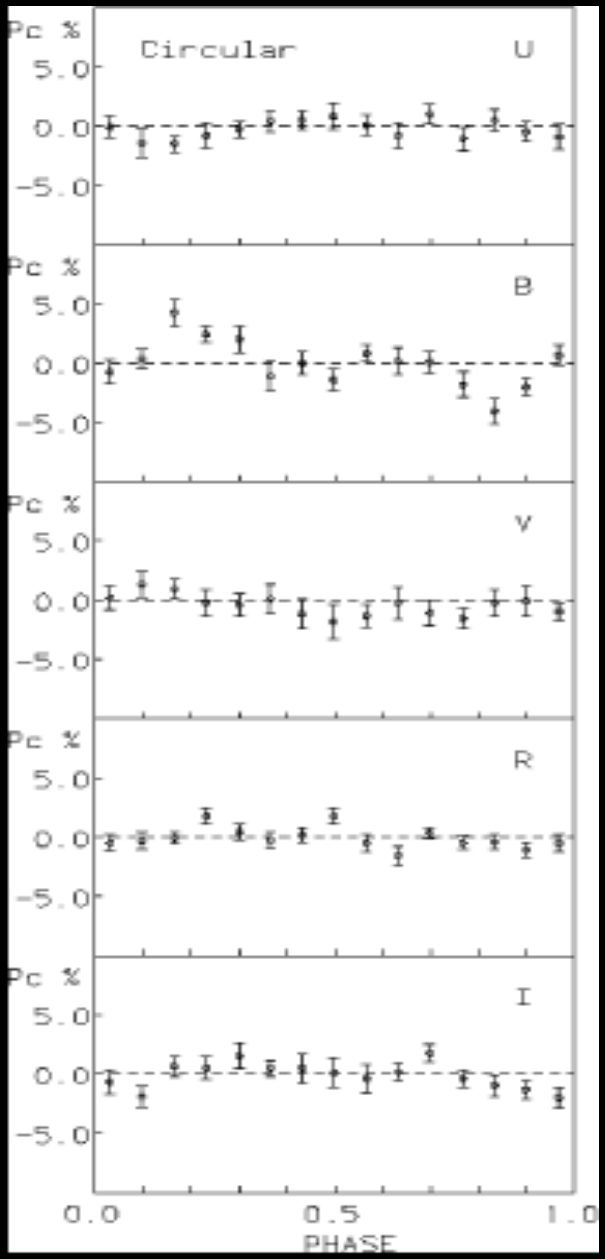
Spin period vs. magnetic moment diagram for a mass ratio of 0.5 and an orbital period of 7 h (adapted from Norton et al. (2007). The letters "S'', "P'', "D'' and "R'' indicates regions of the parameter space in which a stream-like, propeller-like, disc-like and ring-like flow respectively may be seen. In spin equilibrium, systems tend toward the line which divides disc-like and stream-like flows from propeller-like and ring-like flows.



IGR J17303-0601 = 1RXS J173021.5-055933

- Intermediate polar
- Magnetic CV system with a spin period of 128 s
- Orbital period 15.4 hrs
- Circularly polarized!

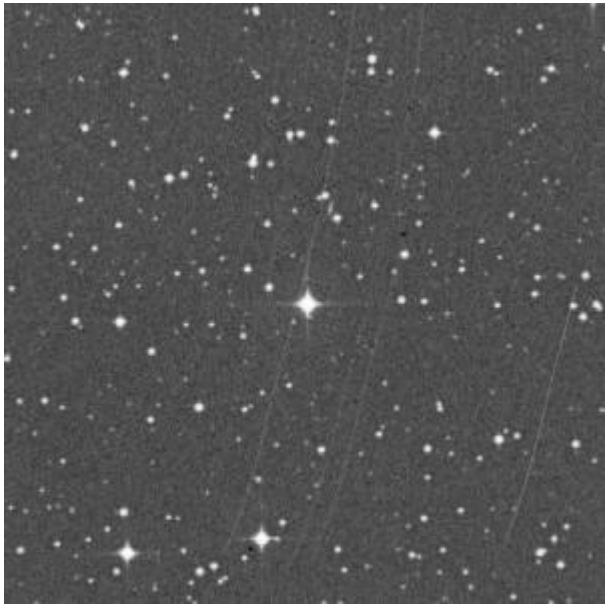

mag
16.20
16.30
16.40
U
mag
16.75
16.85
16.95
B
mag
16.15
16.25
16.35
V
mag
15.45
15.55
15.65
R
mag
15.25
15.35
15.45
I
0.0
0.5
1.0
Phase


Pc %
Circular
U
5.0
0.0
-5.0
Pc %
B
Pc %
V
Pc %
R
Pc %
I
0.0
0.5
1.0
PHASE

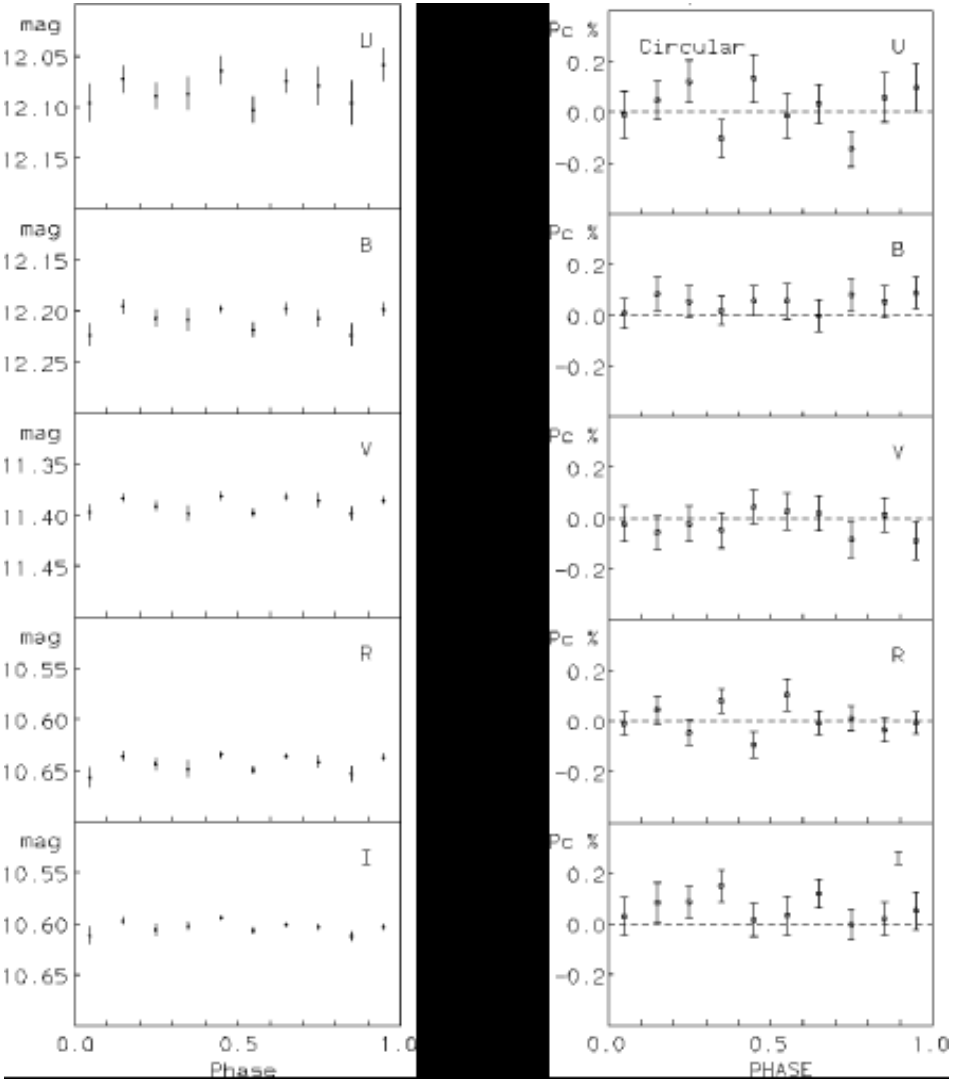
One of the strangest and most peculiar CV systems of all: AE Aqr

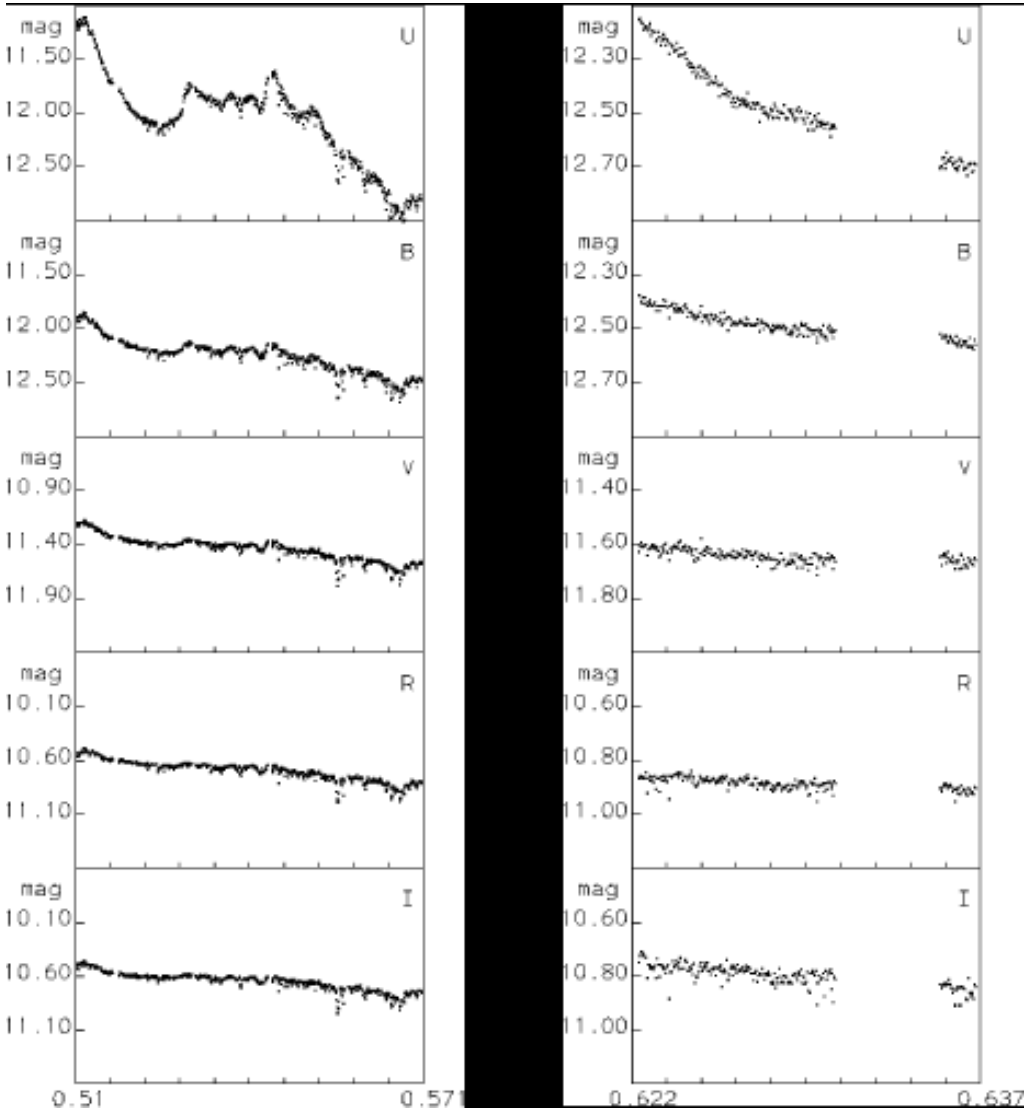
Spin of the WD only 33.062 s

- fastest spinning WD so far
- Intermediate Polar CV



Butters, Katajainen, Norton, Lehto, Piirola, 2009, A&A 496, 891




mag
11.50
12.00
12.50
U
mag
11.50
12.00
12.50
B
mag
10.90
11.40
11.90
V
mag
10.10
10.60
11.10
R
mag
10.10
10.60
11.10
I
0.51
0.571
mag
12.30
12.50
12.70
U
mag
12.30
12.50
12.70
B
mag
11.40
11.60
11.80
V
mag
10.60
10.80
11.00
R
mag
10.60
10.80
11.00
I
0.622
0.637

EXAMPLES OF VLT use in CV studies:

UU Columbae

Intermediate Polar,

V=18 mag target

863.5 ± 0.7 s spin period and a 3.45 ± 0.03 hr orbital period.

S. Katajainen et al. 2010 ApJ 724 p. 165

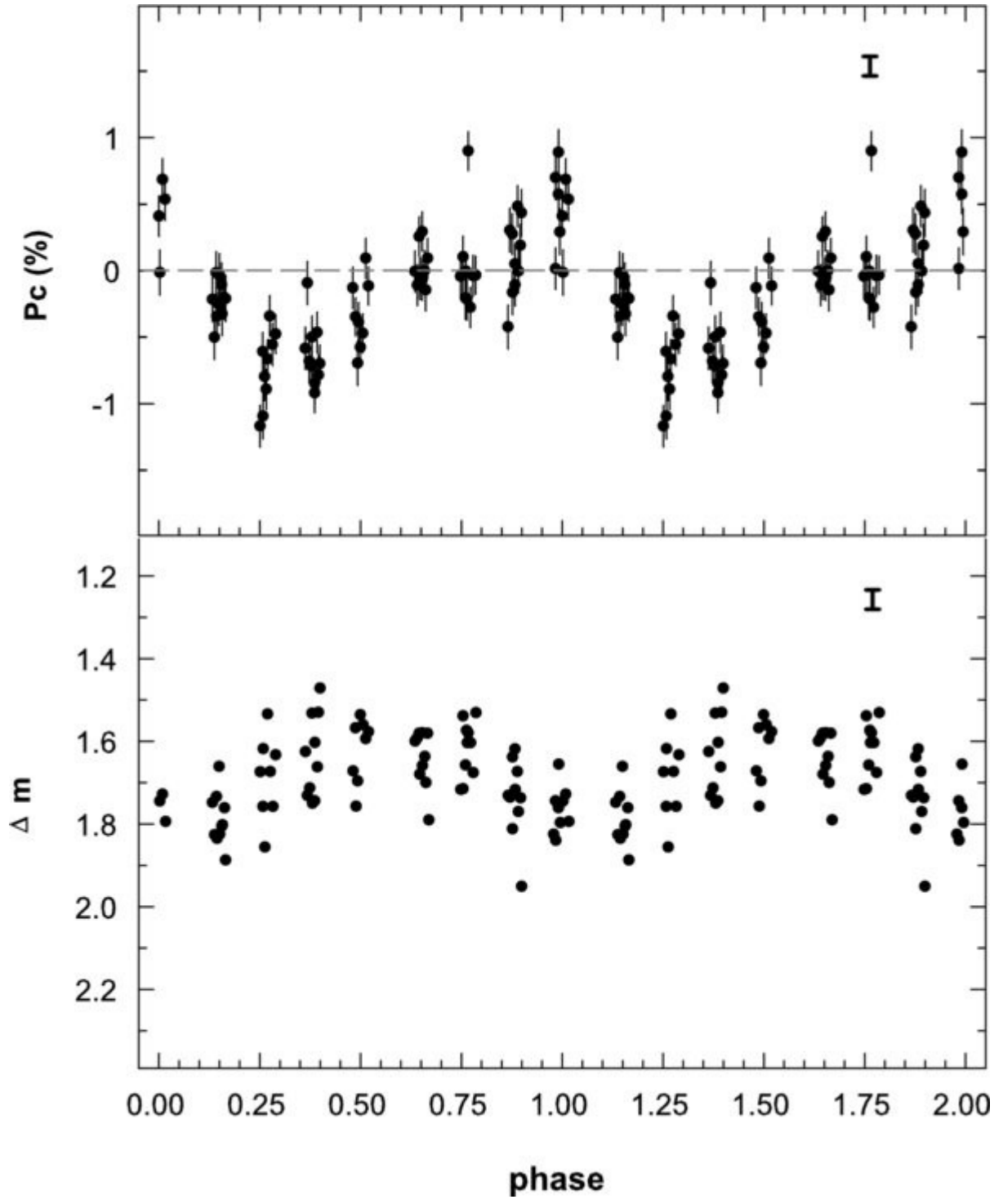
DISCOVERY OF POLARIZED EMISSION FROM TWO SOFT X-RAY-EMITTING INTERMEDIATE POLARS: UU Col AND NY Lup

In the next page:

VLT FORS-data

Top: unbinned circular polarization of UU Col in the I band from 2006 March. The error bars are calculated from photon noise statistics and correspond to ±1σ uncertainties.

Bottom: unbinned differential photometry of UU Col in the I band from 2006 March.


I
1
0
-1
Pc (%)
I
1.2
1.4
1.6
1.8
2.0
2.2
Δ m
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
phase


Thank You for your attention! Mille Grazie!