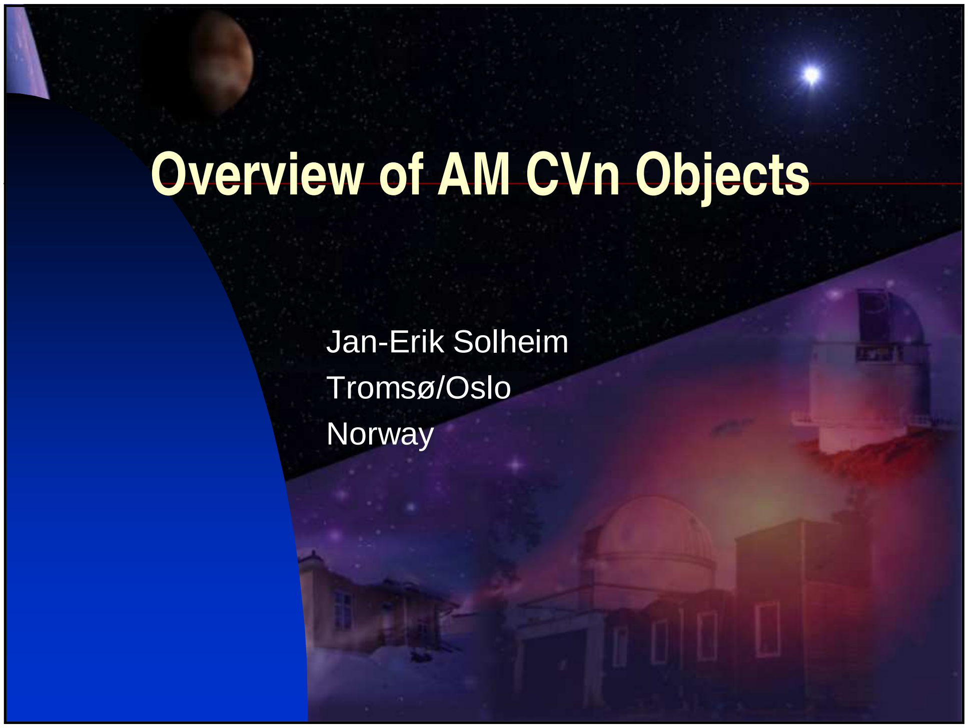
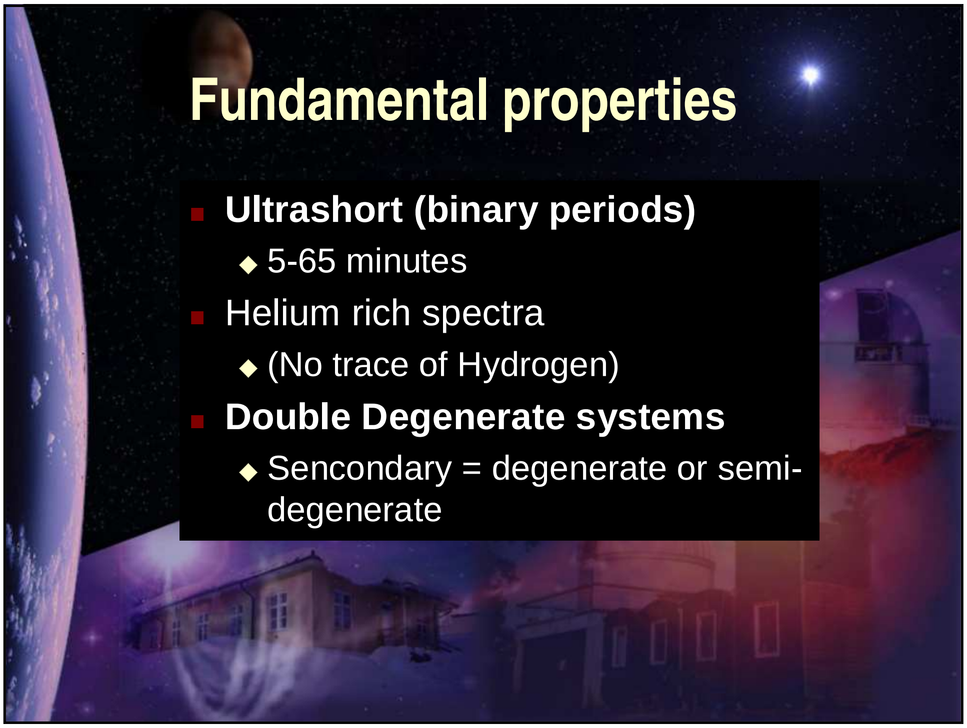
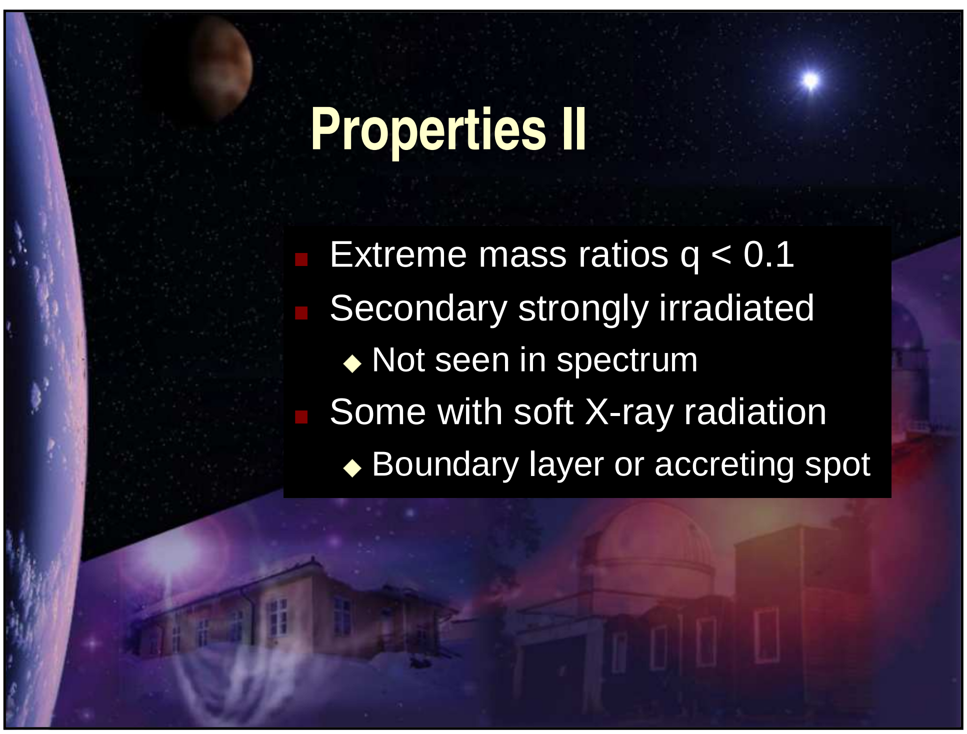
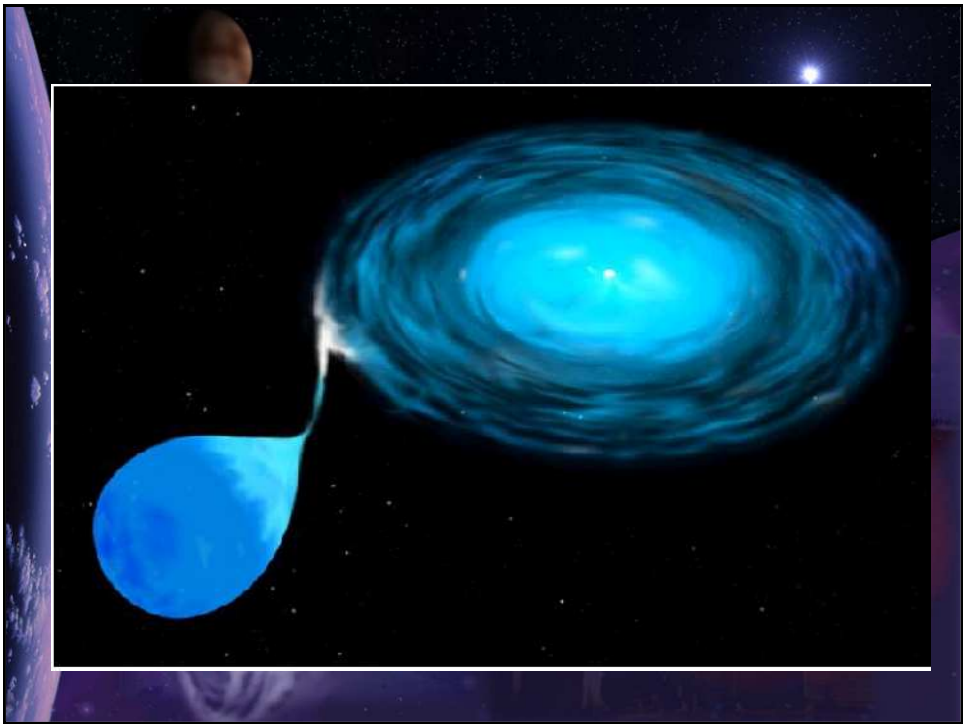

Overview of AM CVn Objects
Jan-Erik Solheim
Tromsø/Oslo
Norway


Contenth
Definitions
Fundamental Properties
History of discovery
More General properties

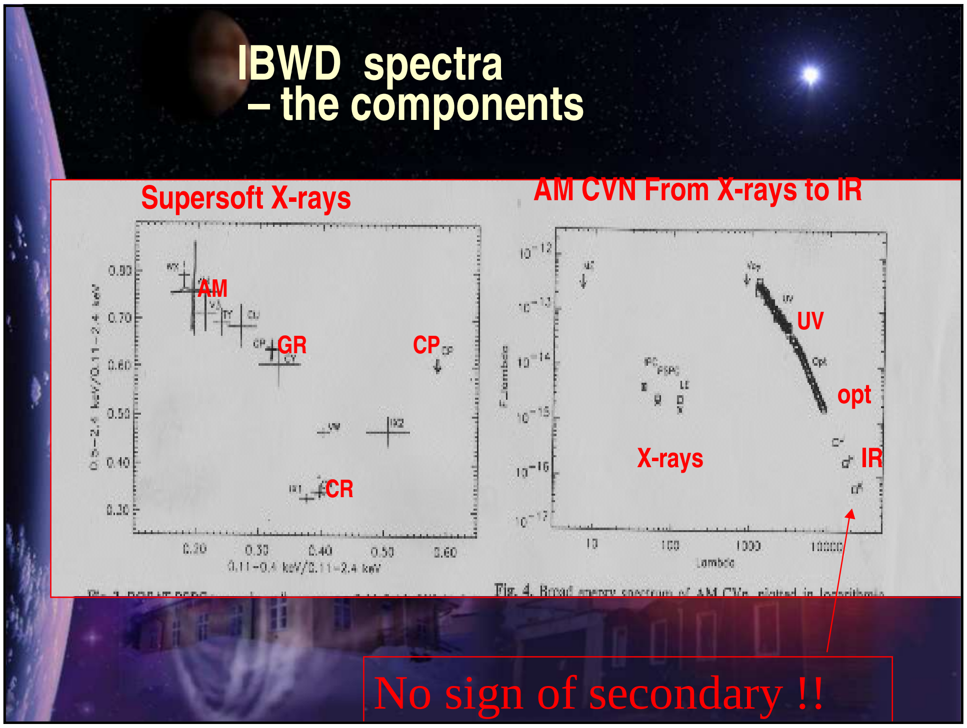

Fundamental properties
Ultrashort (binary periods)
5-65 minutes
Helium rich spectra
(No trace of Hydrogen)
Double Degenerate systems
Sencondary = degenerate or semi-degenerate

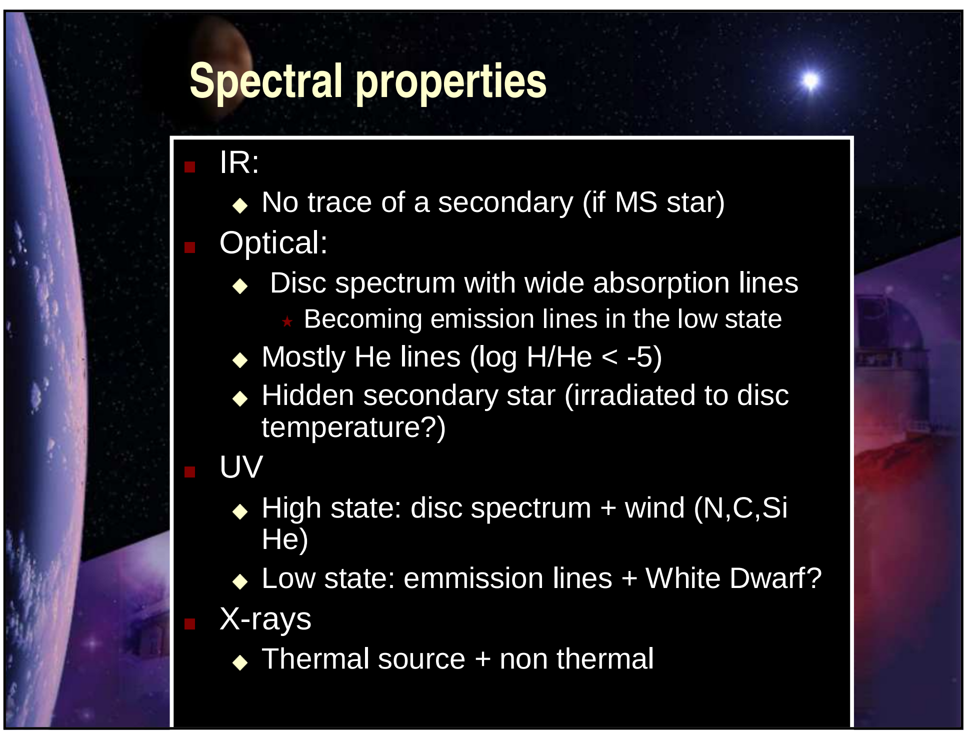

Properties II
Extreme mass ratios q < 0.1
Secondary strongly irradiated
Not seen in spectrum
Some with soft X-ray radiation
Boundary layer or accreting spot

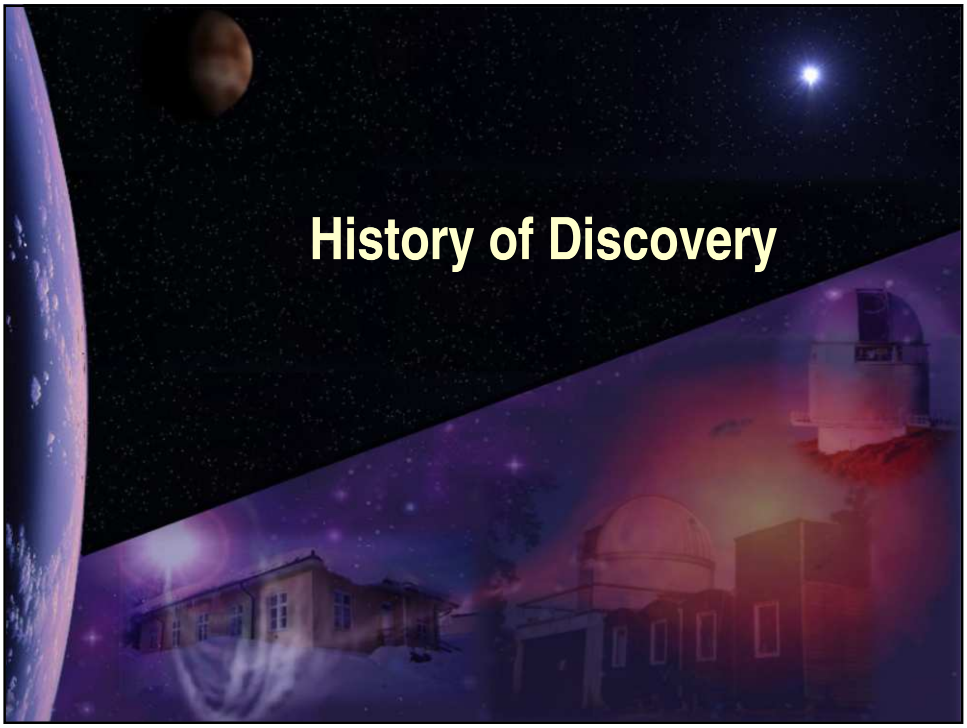


Helium Cataclysmics

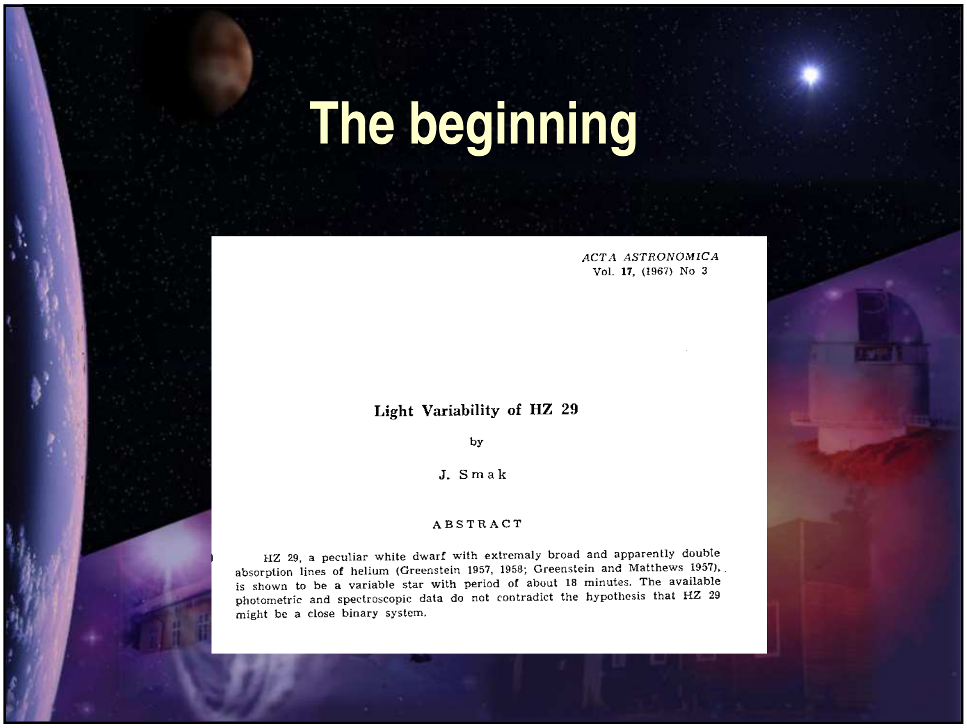
- Mass transfer'
  - High or Low
  - Nova like or SU UMa like
- Systems with Discs
  - Stable or Unstable discs
  - Excentric discs
  - Superhumps
  - Density waves, Sprial structure
- Disc-less systems
  - Direct mass transfer, or magnetic field locked

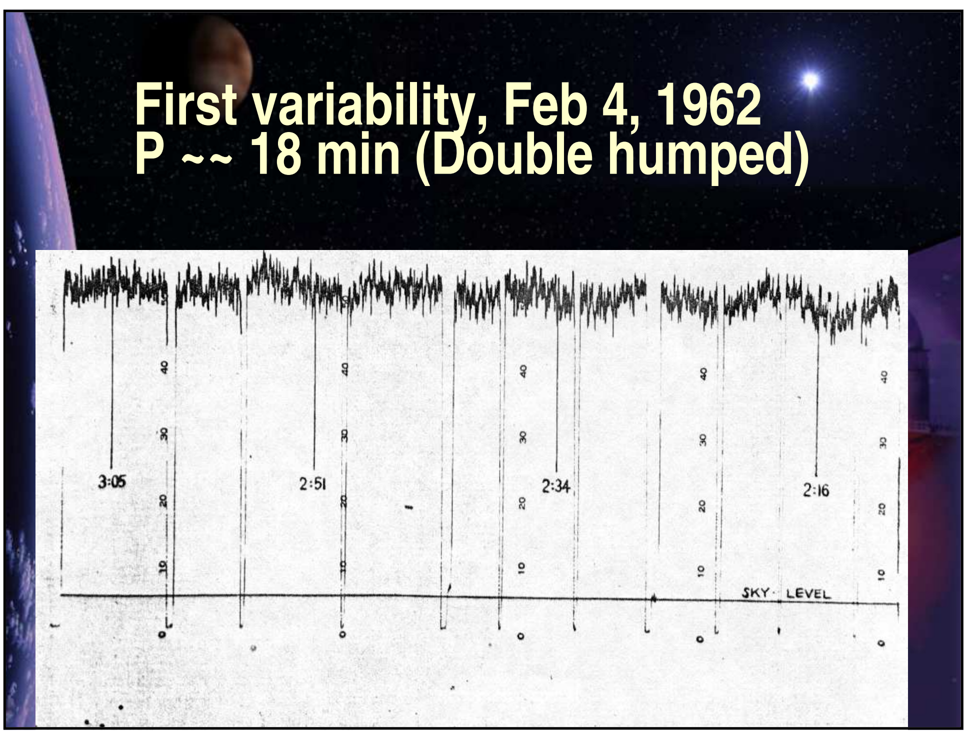

IBWD spectra
– the components
Supersoft X-rays
AM
GR
CP
CR
0.11–0.4 keV/0.11–2.4 keV
AM CVN From X-rays to IR
UV
opt
X-rays
IR
Lambda
No sign of secondary !!

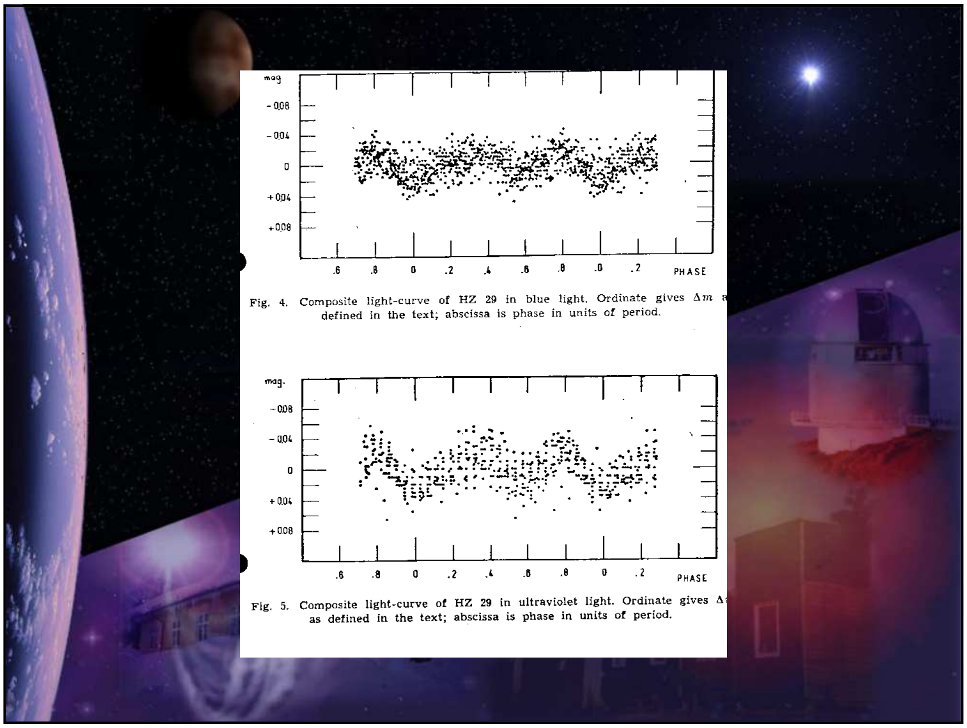

Spectral properties
IR:
No trace of a secondary (if MS star)
Optical:
Disc spectrum with wide absorption lines
Becoming emission lines in the low state
Mostly He lines (log H/He < -5)
Hidden secondary star (irradiated to disc temperature?)
UV
High state: disc spectrum + wind (N,C,Si He)
Low state: emmission lines + White Dwarf?
X-rays
Thermal source + non thermal

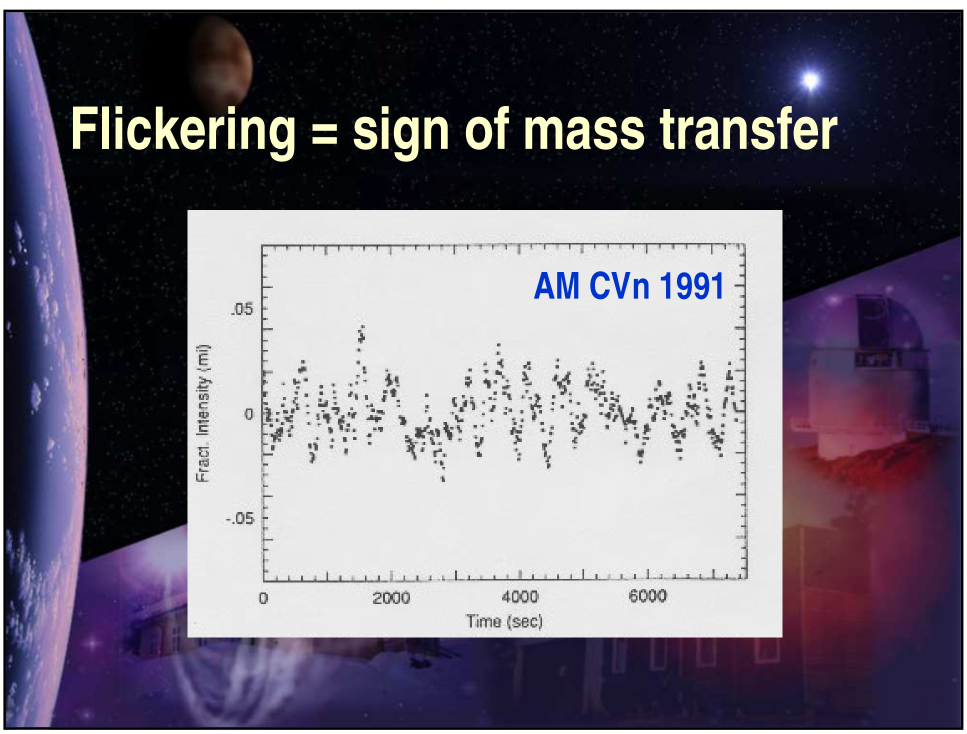


1.AM CVn (HZ 29)	1967	Smak
2. GP Com (G61-29)	1972	Warner
3. CR Boo (PG1346+082)	1985	Nather
4. V803 Cen (AE 1)	1985	Robinson
5. CP Eri	1992	Abott et al.
6. HL Lib (EC 15330-1403)	1994	O'Donoghue et al
8. RX J1914+2456	1998	Cropper et al
9. CE 315	2001	Ruiz et al.
10. ES Cet (KUV 01584-0939)	2002	Warner & Woudt
11. RX J0806+1525	2002	Ramsay et al.


The beginning
ACTA ASTRONOMICA
Vol. 17, (1967) No 3
Light Variability of HZ 29
by
J. Smak
ABSTRACT
HZ 29, a peculiar white dwarf with extremaly broad and apparently double absorption lines of helium (Greenstein 1957, 1958; Greenstein and Matthews 1957), is shown to be a variable star with period of about 18 minutes. The available photometric and spectroscopic data do not contradict the hypothesis that HZ 29 might be a close binary system.


First variability, Feb 4, 1962
P ~~ 18 min (Double humped)
3:05
2:51
2:34
2:16
SKY LEVEL


mag
-0.08
-0.04
0
+0.04
+0.08
PHASE
Fig. 4. Composite light-curve of HZ 29 in blue light. Ordinate gives Δm a
defined in the text; abscissa is phase in units of period.
mag.
-0.08
-0.04
0
+0.04
+0.08
PHASE
Fig. 5. Composite light-curve of HZ 29 in ultraviolet light. Ordinate gives Δ
as defined in the text; abscissa is phase in units of period.


Flickering = sign of mass transfer
AM CVn 1991
Fract. Intensity (mi)
.05
0
-.05
0
2000
4000
6000
Time (sec)

The Dwarf Nova Model (FFW--1972)

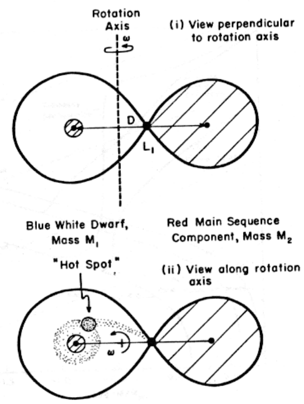
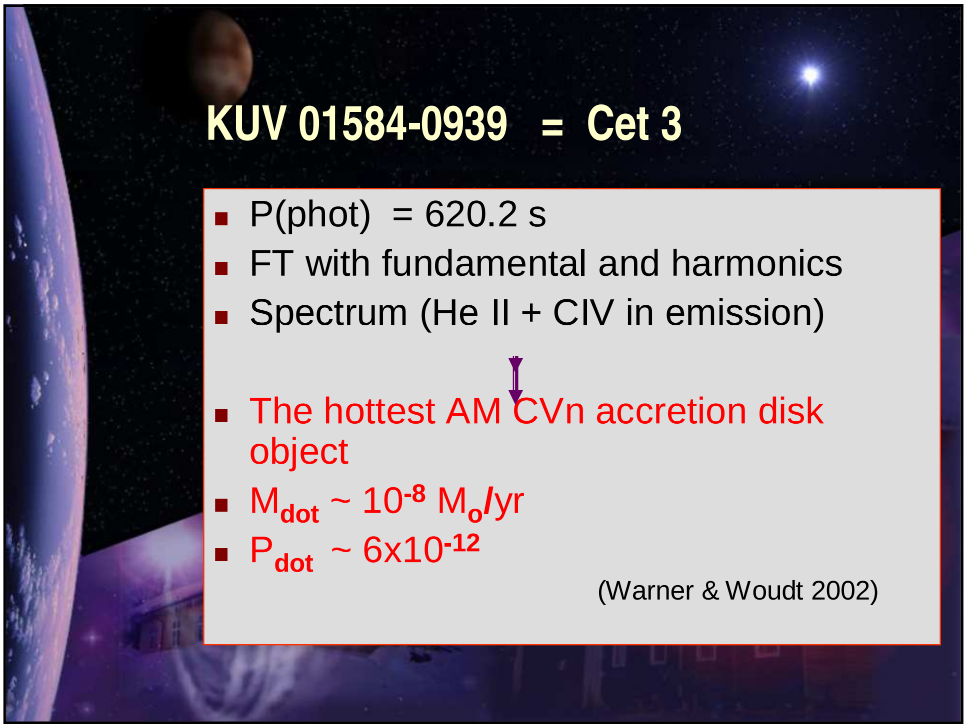
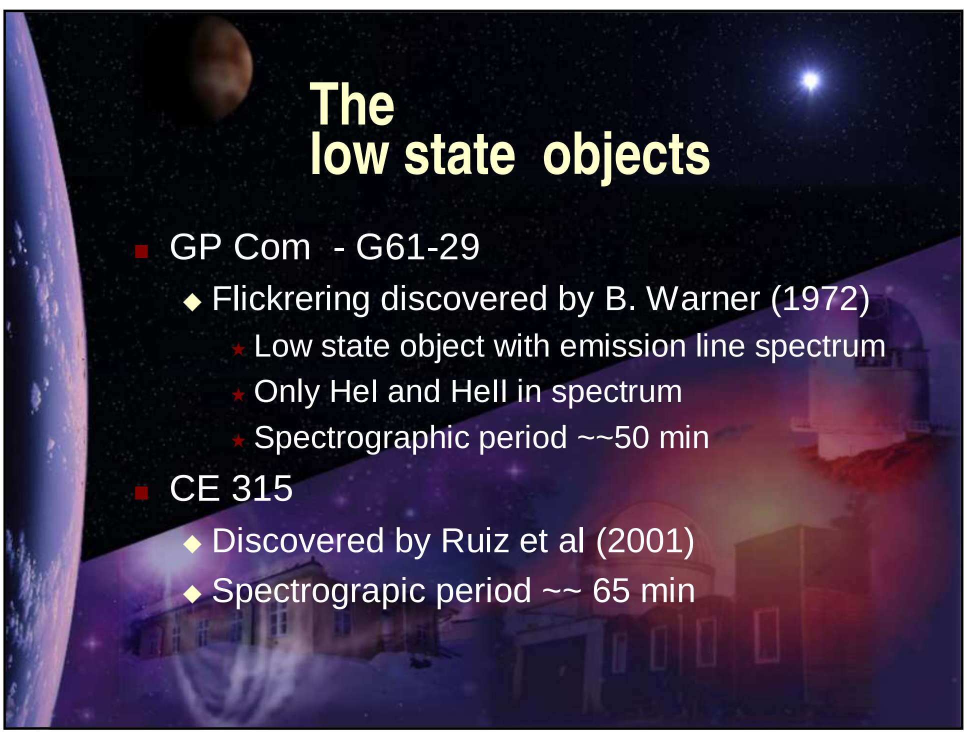


FIG. 1.—The typical dwarf nova. As pointed out in the text, the main-sequence component may con tain a small helium core, which will be revealed after sufficient mass transfer. In later stages, as propose for AM CVn, the main-sequence component is replaced by a degenerate, receding system, mass transf still proceeding as shown.

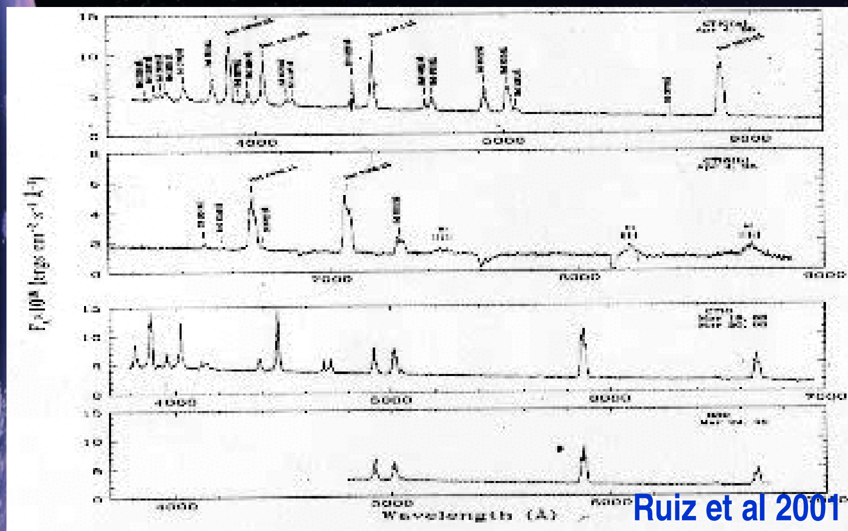
Short History of AM CVn

- J.Smak (1965) discovers photometric variablility with period ~18 min
- Paczynski (1967) proposes semi-detached pair of degenerate dwarfs, -- mass transfer driven by loss of angular momentum due to Gravitational Radiation (GR)
- Warner and Robinson (1972) discover flickering in the light curve -→ propose it as a Cataclysmic Variable
- Tutukov and Yungelson (1979,81) model common envelope evolution creating two white dwarfs, which are brought into semi-detached phase due to GR
- Iben and Tutukov (1991) Helium star Cataclysmics
- Patterson et al (1993) Precession period in spectra
- Nelemans (2001) Tomography – disc structure


KUV 01584-0939 = Cet 3
P(phot) = 620.2 s
FT with fundamental and harmonics
Spectrum (He II + CIV in emission)
The hottest AM CVn accretion disk object
M_{dot} ~ 10^{-8} M_o/yr
P_{dot} ~ 6×10^{-12}
(Warner & Woudt 2002)


The
low state objects
GP Com - G61-29
Flickrering discovered by B. Warner (1972)
Low state object with emission line spectrum
Only HeI and HeII in spectrum
Spectrographic period ~~50 min
CE 315
Discovered by Ruiz et al (2001)
Spectrograpic period ~~ 65 min

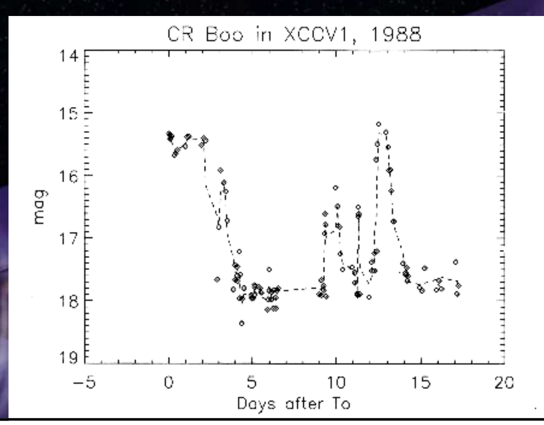
Tne second low state object CE 315

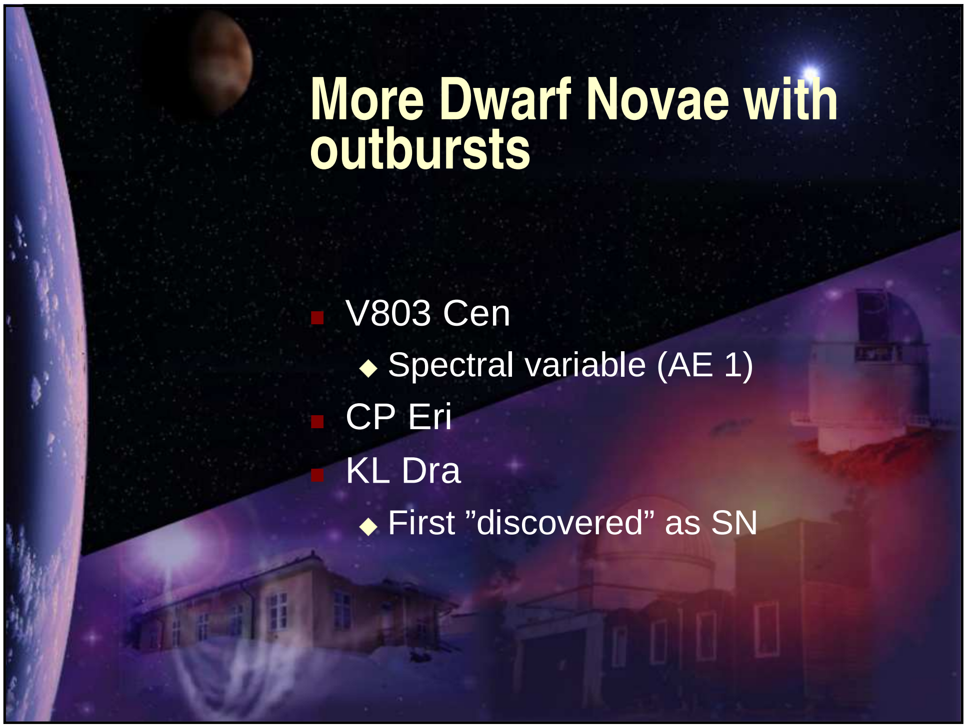


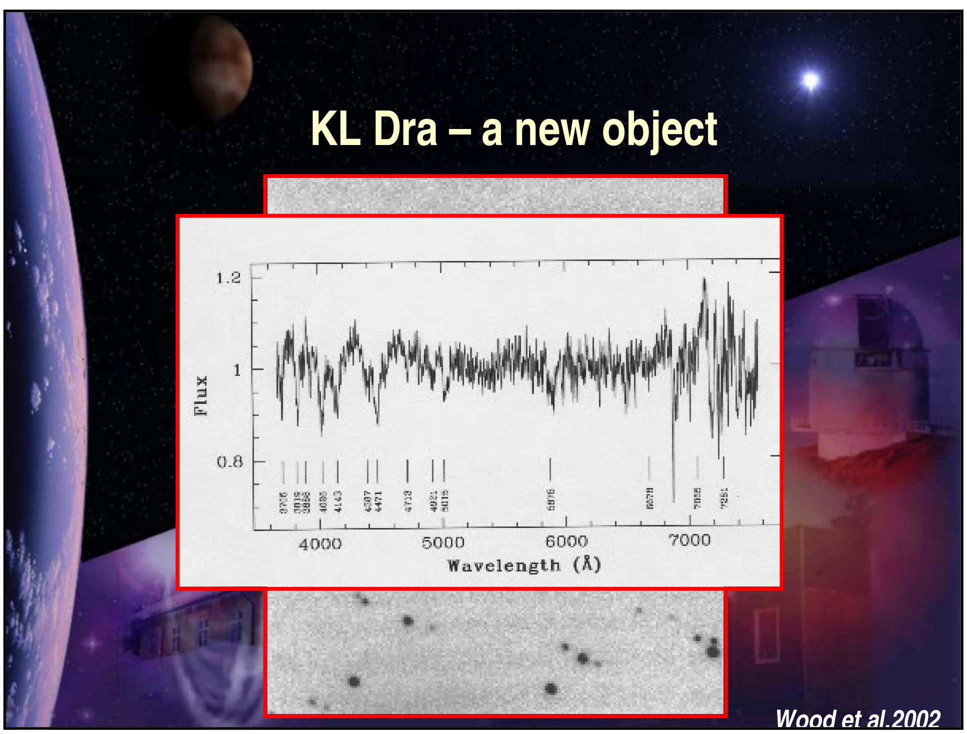
Ruiz et al 2001

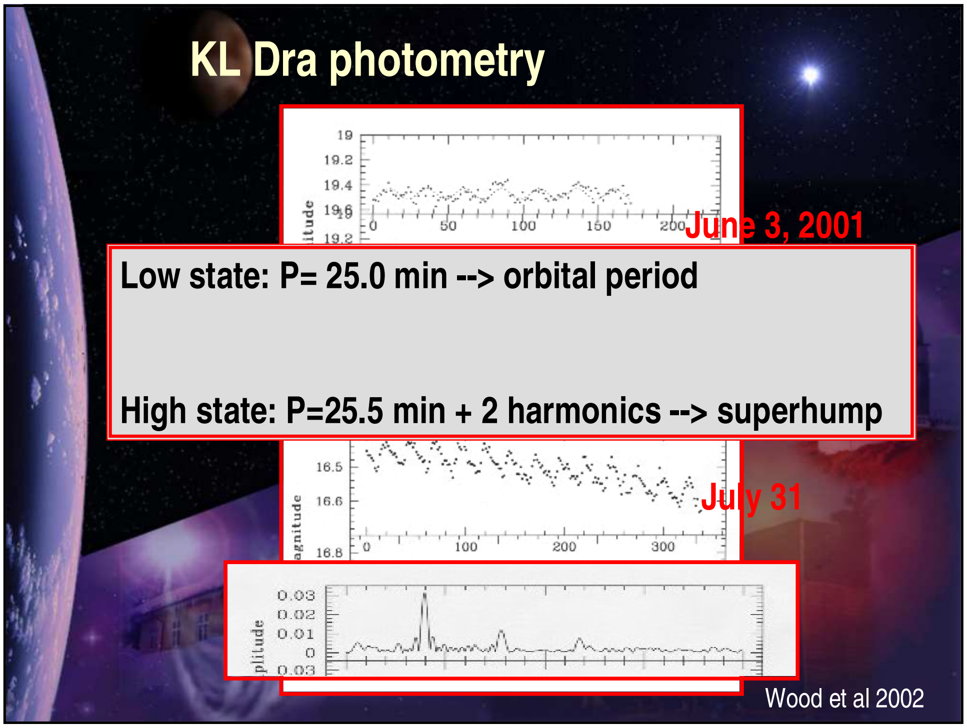
CR Boo – Dwarf Nova

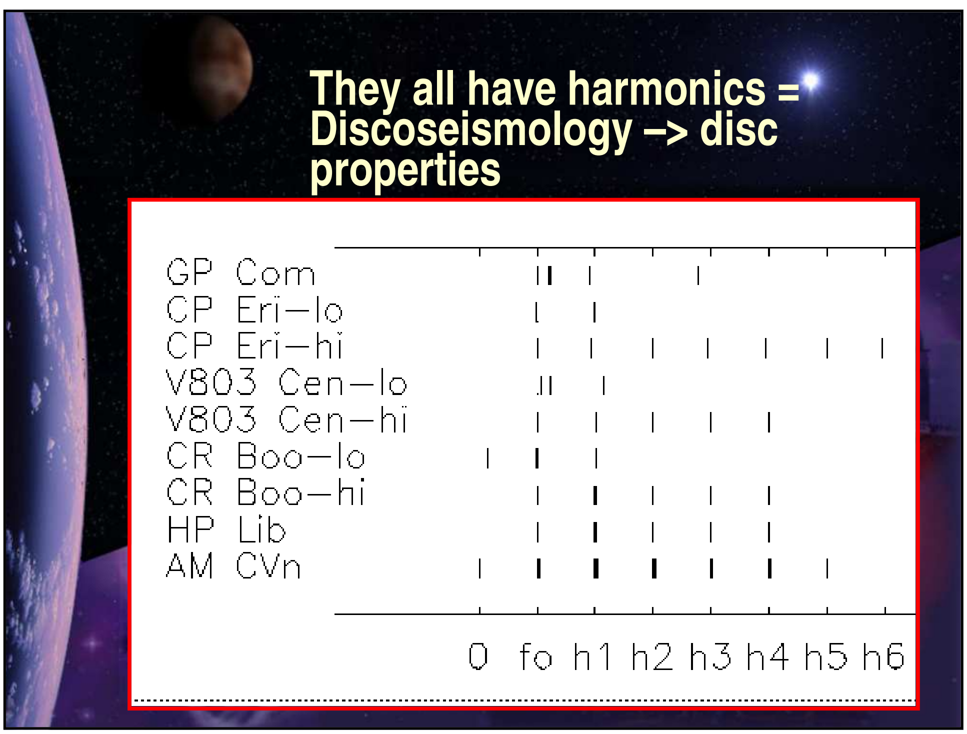
- Helium ER Uma: very frequent short maxima
- Helium Z-Cam: standstill slightly below maxium
- Helium SU Uma



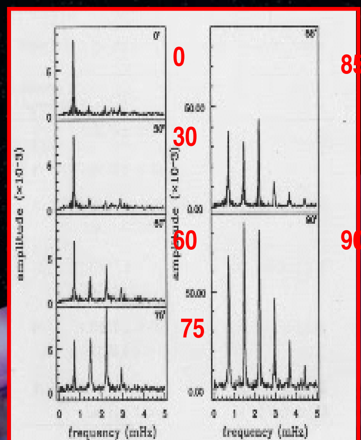

More Dwarf Novae with outbursts
V803 Cen
Spectral variable (AE 1)
CP Eri
KL Dra
First "discovered" as SN


KL Dra – a new object
1.2
1
0.8
Flux
4000
5000
6000
7000
Wavelength (Å)
Wood et al.2002


KL Dra photometry
June 3, 2001
Low state: P= 25.0 min --> orbital period
High state: P=25.5 min + 2 harmonics --> superhump
July 31
Wood et al 2002


They all have harmonics = Discoseismology --> disc properties
GP Com
CP Eri-lo
CP Eri-hi
V803 Cen-lo
V803 Cen-hi
CR Boo-lo
CR Boo-hi
HP Lib
AM CVn
0 fo h1 h2 h3 h4 h5 h6

Why do we see harmonics ?



- NON-Cicular shape of disc with spiral arms
- Harmonics of superhump frequency
  - Higher amplitudes at higher angles
  - Mixed with harmonics of orbital period at exteme angels

Wood & Simpson 1995

The AM CVn family today

Object	V-mag	States
AM Cvn	14.1-14.2	High-superhumper (SH)
Hp Lib	13.6	High-superhumper
ES Cet	16.9-17	High-superhumper
CR Boo	13.0-18.0	High/low: Dwarf Nova(SH)
HL Tau	16.4-20	DN-SH
V803 Cen	13.2-17.4	DN-SH
CP Eri	16.5-19.7	DN-SN
GP Com	15.7-16	Low
CE 315	16.5	Low
RX J1914+24	>19.7	Polar or Algol
RX J0806+15	21.1	Polar or Algol

Comparison with CVs

- 3 Nova Like – with high mass transfer rate
  - AM CVn, HP Lib, ES Cet
- 6 Dwarf Novae
  - CR Boo, V803 Cen, CP Eri, HL Tau, GP Com,CE 315
- 2 Magnetic
  - Polars or Intermediate Polars or Algols
    - RX J1914+2456,RX J0806+1527

Orbital and Superhump periods

Object	P(superhump) s	P(orbit) s
RX J0806+15		321
RX J1914+24		570
KUV 01584-939	620	
AM CVn	1051	1028
HP Lib	1119	1103
CR Boo	1488	1471
KL Dra	1531	1502
V803 Cen	1643	1611
CP Eri	1716	1701
GP Com		2790
CE 315		3906

Mass determination

- Kepler orbits
- Superhump and binary orbital periods (Hirose-Osaki)
  - Superhump period from photometry (harmonics)
  - Orbital period from photometry & tomography
- Equation of state for the secondary object
  - Degenerate
  - Semi-degenerate

Masses from superhumps if degenerate secondary

Object	$q=M_2/M_1$	M_2	M_1
AM CVn	0.080	0.044	0.49
HP Lib	0.056	0.040	0.71
CR Boo	0.045	0.030	0.67
KI Dra	0.079	0.030	0.38
V803 Cen	0.075	0.028	0.37
CP Eri	0.033	0.026	0.78
GP Com	0.02*	0.016	0.8
CE 315	0.022*	0.011	0.38

* From spectroscopy

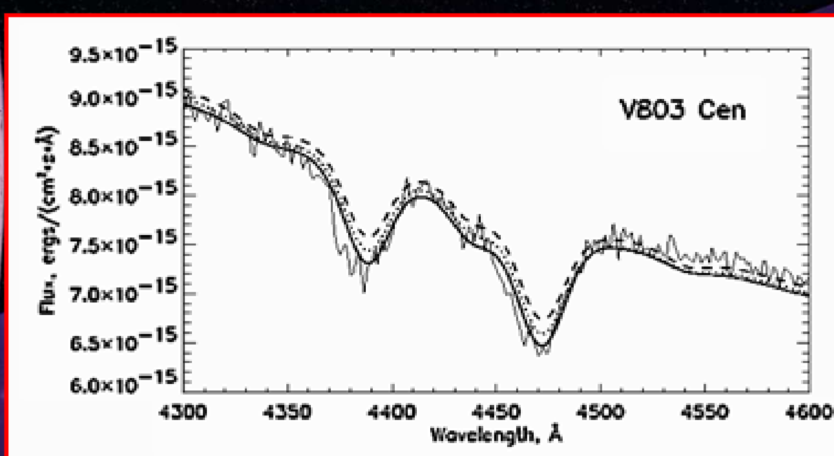
Masses from superhumps if semi-degenerate secondary

Object	$q=M_2/M_1$	M_2	M_1
AM CVn	0.080	0.114	1.06
HP Lib	0.056	0.099	1.51
CR Boo	0.045	0.062	1.31
KI Dra	0.079	0.060	0.73
V803 Cen	0.075	0.054	0.70
CP Eri	0.033	0.049	1.51
GP Com	0.02*	0.021	1.0
CE 315	0.022*	0.012	0.55

* From spectroscopy

IBWD objects spectroscopy

Low resolution spectra from the Nordic Optical Telescope (NOT) and theoretical spectra calculated with the TLUSDISC (I. Hubeny)

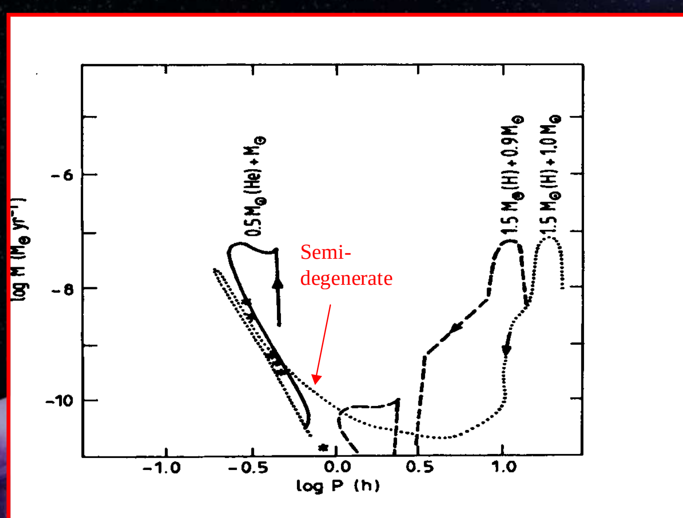


Parameters determined from disc spectra

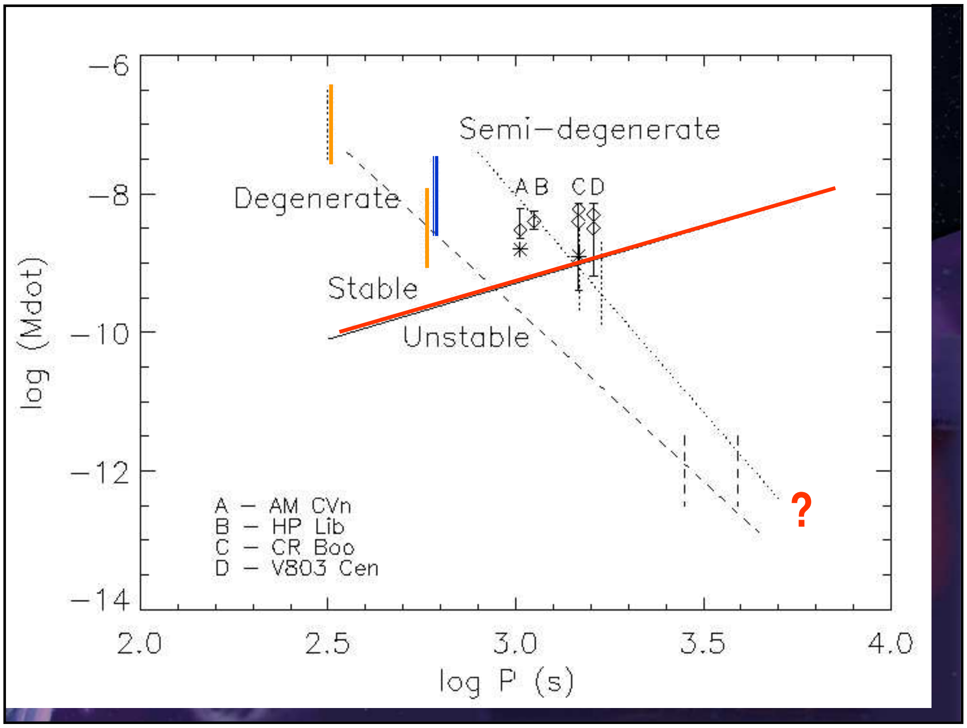
Object	M_1/M_o	Log M(dot) (M_o/yr)	inclination
AM CVn[1]	0.84	-8.8	45°
AM CVn[2]	1.1	-8.5	45°
HP Lib[2]	1.1	-8.4	28°
CR Boo[1]	0.94	-8.9	44°
CR Boo[2]	1.0	-8.4 to –8.2	30°
V803 Cen[2]	1.2	-8.5 to –8.3	5°

Notes:1. El-Khory & Wickramasinghe (2000), 2. Nasser 2001

Evolution and mass transfer

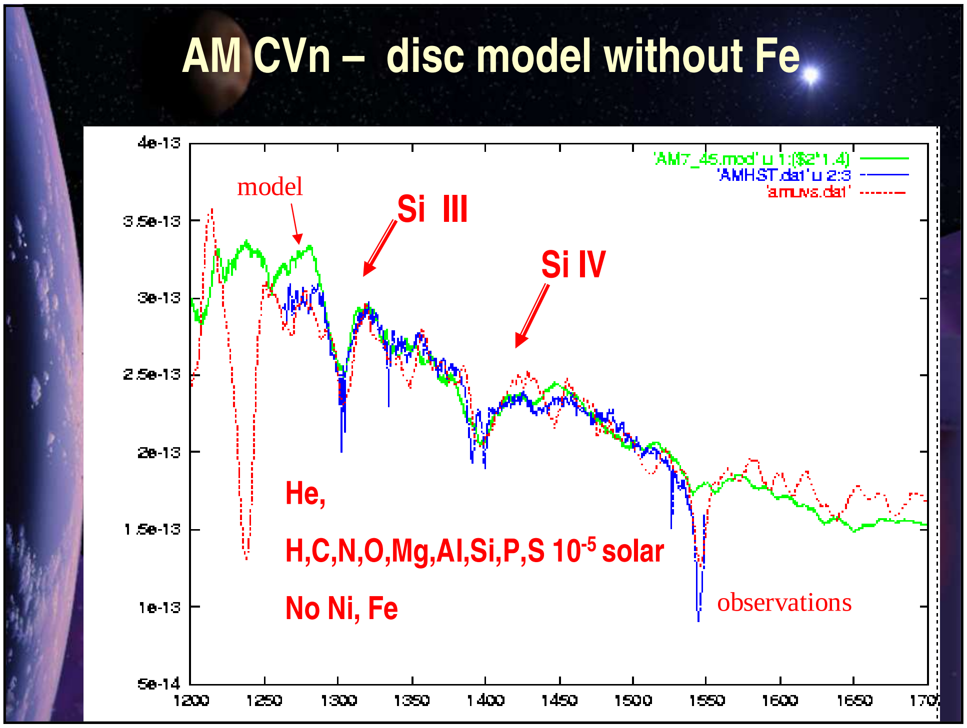


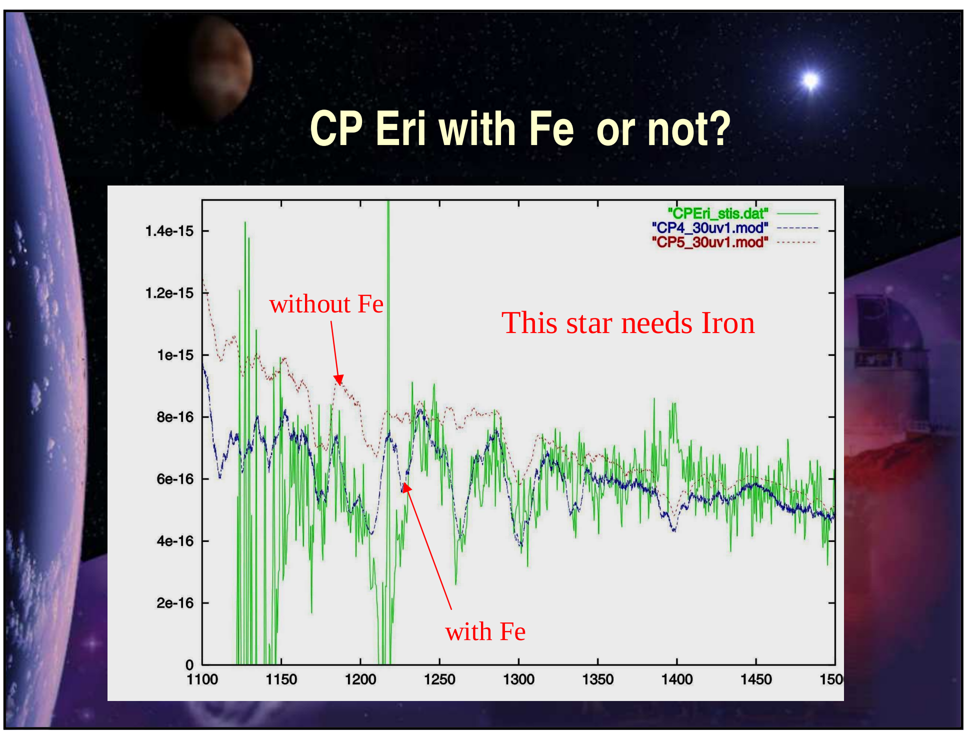
Iben and Tutukov 1991

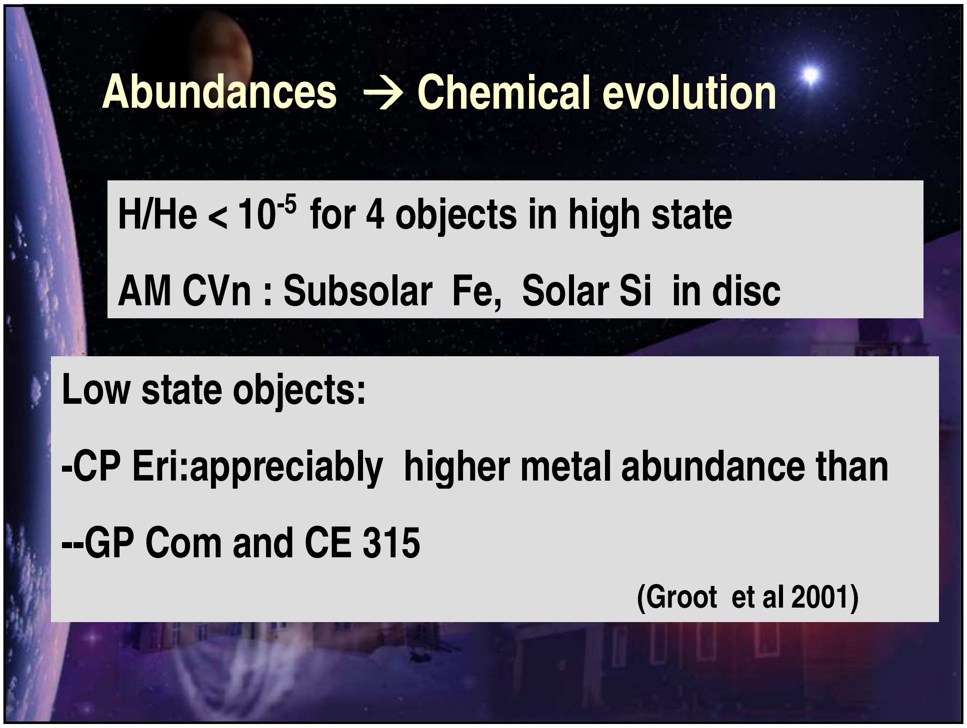


Conclusion - masses

- The mass loss rate observed favours semi-degenrate secondary
  -- incomplete He burning when mass transfer starts
- Photometric masses:
  - M_1 =0.55 –1.5 M_o
- Spectroscopic masses:
  - M_1 =0. 8 --1.2 M_o


AM CVn – disc model without Fe
'AM7_45.mod' u 1:($2*1.4)
'AMHST.dat' u 2:3
'amuvs.dat'
model
Si III
Si IV
He,
H,C,N,O,Mg,Al,Si,P,S 10-5 solar
No Ni, Fe
observations
4e-13
3.5e-13
3e-13
2.5e-13
2e-13
1.5e-13
1e-13
5e-14
1200
1250
1300
1350
1400
1450
1500
1550
1600
1650


CP Eri with Fe or not?
"CPEri_stis.dat"
"CP4_30uv1.mod"
"CP5_30uv1.mod"
without Fe
This star needs Iron
with Fe
1.4e-15
1.2e-15
1e-15
8e-16
6e-16
4e-16
2e-16
0
1100
1150
1200
1250
1300
1350
1400
1450


Abundances → Chemical evolution
H/He < 10^-5 for 4 objects in high state
AM CVn : Subsolar Fe, Solar Si in disc
Low state objects:
-CP Eri:appreciably higher metal abundance than
--GP Com and CE 315
(Groot et al 2001)