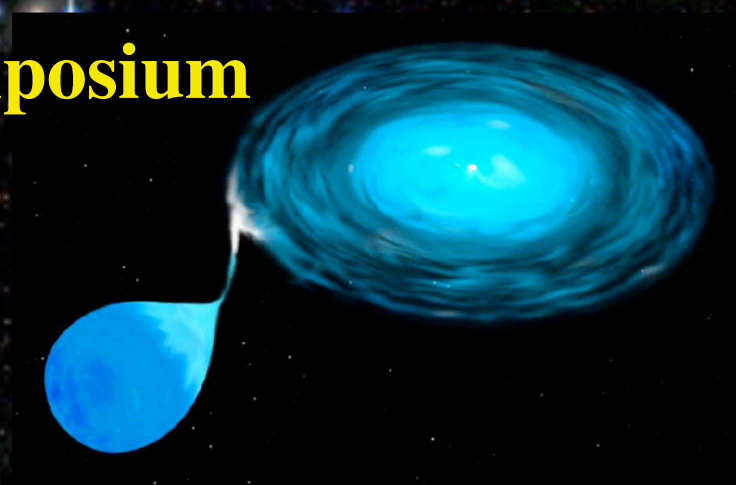
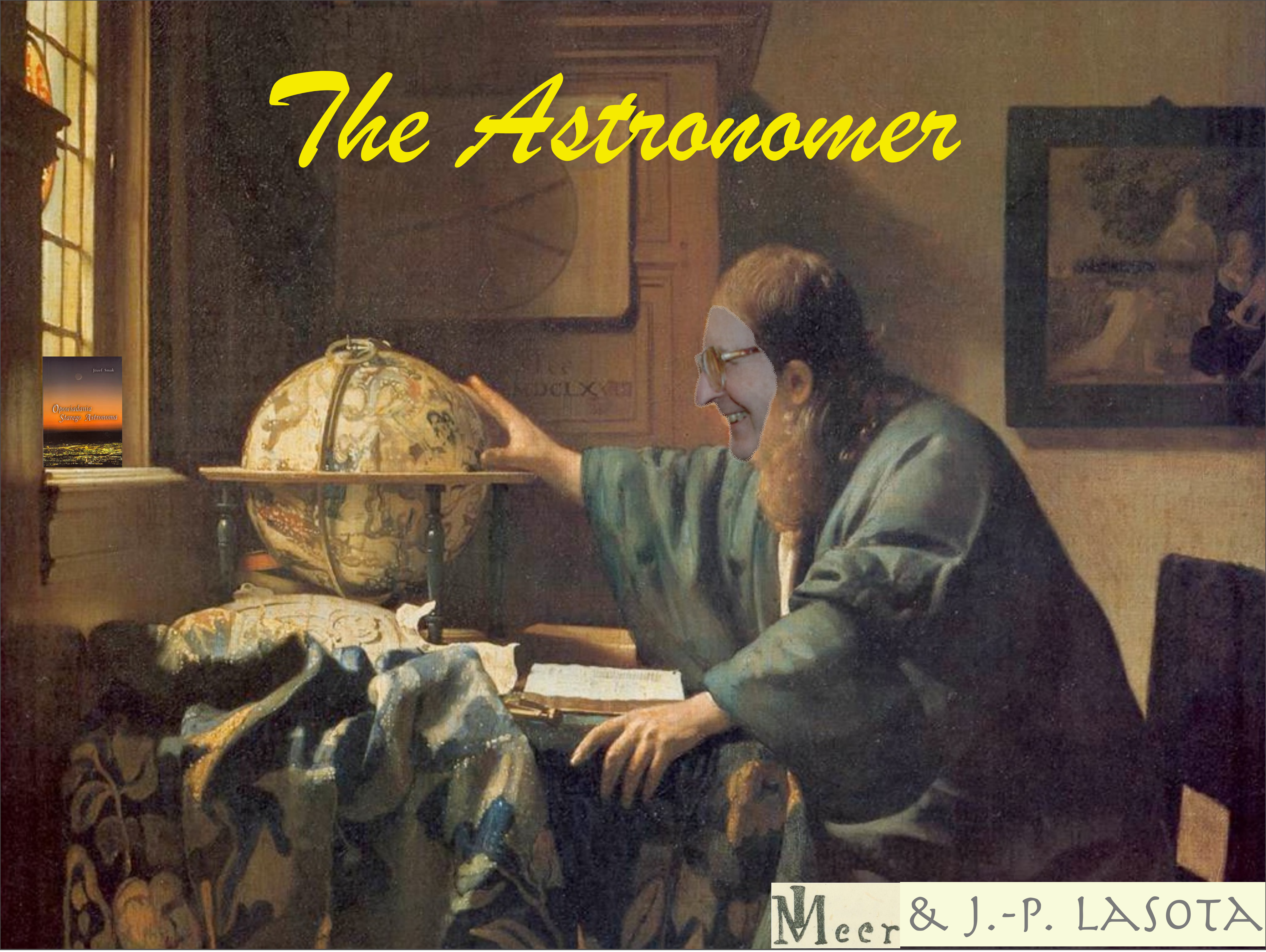
Accretion flow instabilities:

30 years of the thermal-viscous disc instability model

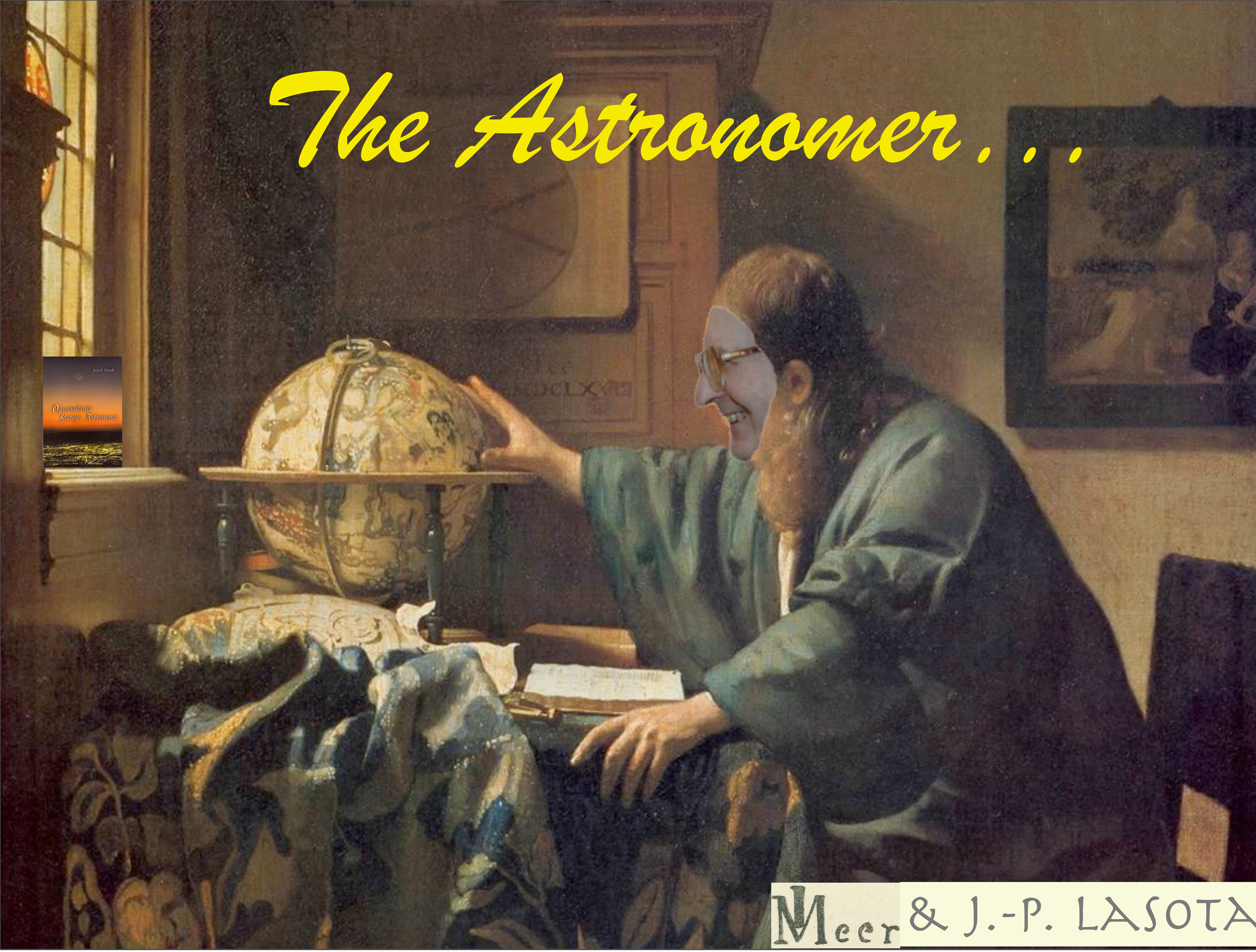
3rd NCAC Symposium



Warsaw, Poland, 4-7 September 2012



The Astronomer
Józef Smak
Opowiadania Starego Astronoma
Meer & J.-P. LASOTA


The Astronomer . . .
Józef Smak
Opowiadania
Starego Astronoma
Meer & J.-P. LASOTA

... or some outstanding problems in close binary star astronomy

... or some outstanding problems in close binary star astronomy

- Evolution of close binaries

... or some outstanding problems in close binary star astronomy

- Evolution of close binaries
- Stream-disc interaction

. . . or some outstanding problems in close binary star astronomy

- Evolution of close binaries
- Stream-disc interaction
- Accretion disc structure

... or some outstanding problems in close binary star astronomy

- Evolution of close binaries
- Stream-disc interaction
- Accretion disc structure
- Accretion disc emission lines

. . . or some outstanding problems in close binary star astronomy

- Evolution of close binaries
- Stream-disc interaction
- Accretion disc structure
- Accretion disc emission lines
- Origin of disc «viscosity»

- Political astronomy

Political astronomy

149 1993Urani..64...66S 1.0000 3/1993
Smak, J. AM CVn - a variable star that threatened the political system of the Soviet Union.

Political astronomy

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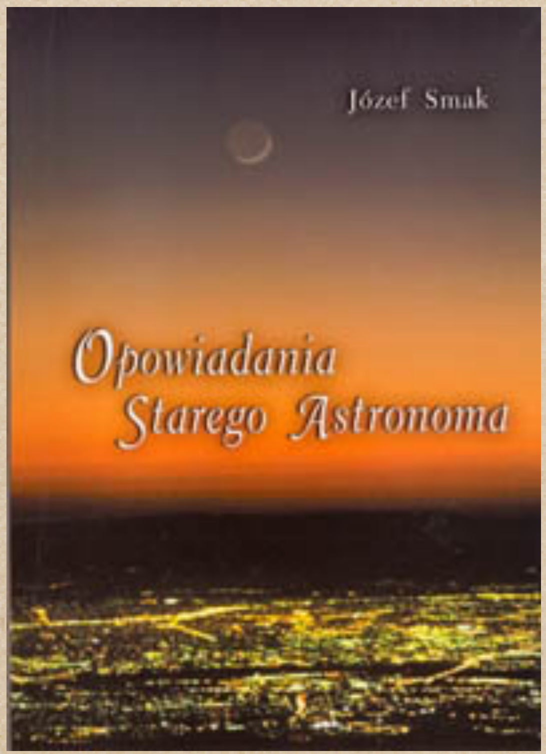

Political astronomy

149 1993Urani..64...66S 1.0000 3/1993
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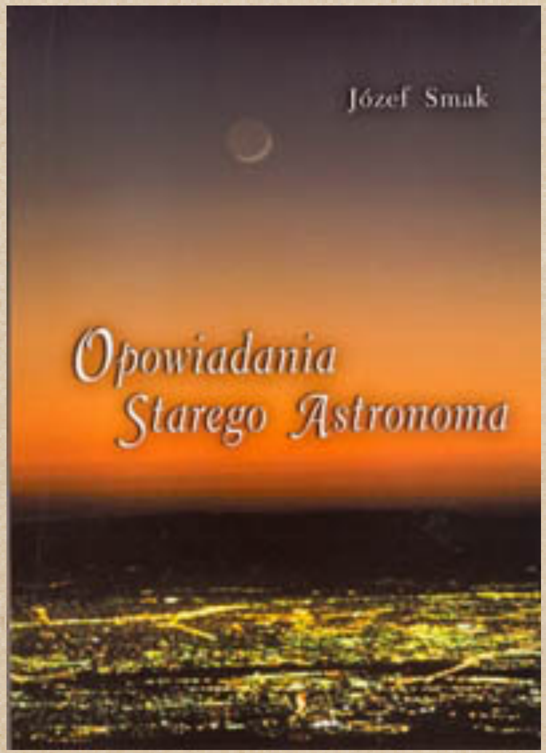
29 1982SvA....26..558V 1.000 10/1982A C S
Vojkhanskaya, N. F. A model of AM Canum venaticorum

30 1982AZh....59..925V 1.00010/1982 C
Vojkhanskaya, N. F. A New Model of Am-Canum



Political astronomy

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Vojkhanskaya, N. F. A New Model of Am-Canum

HZ 29 (AM CVn)

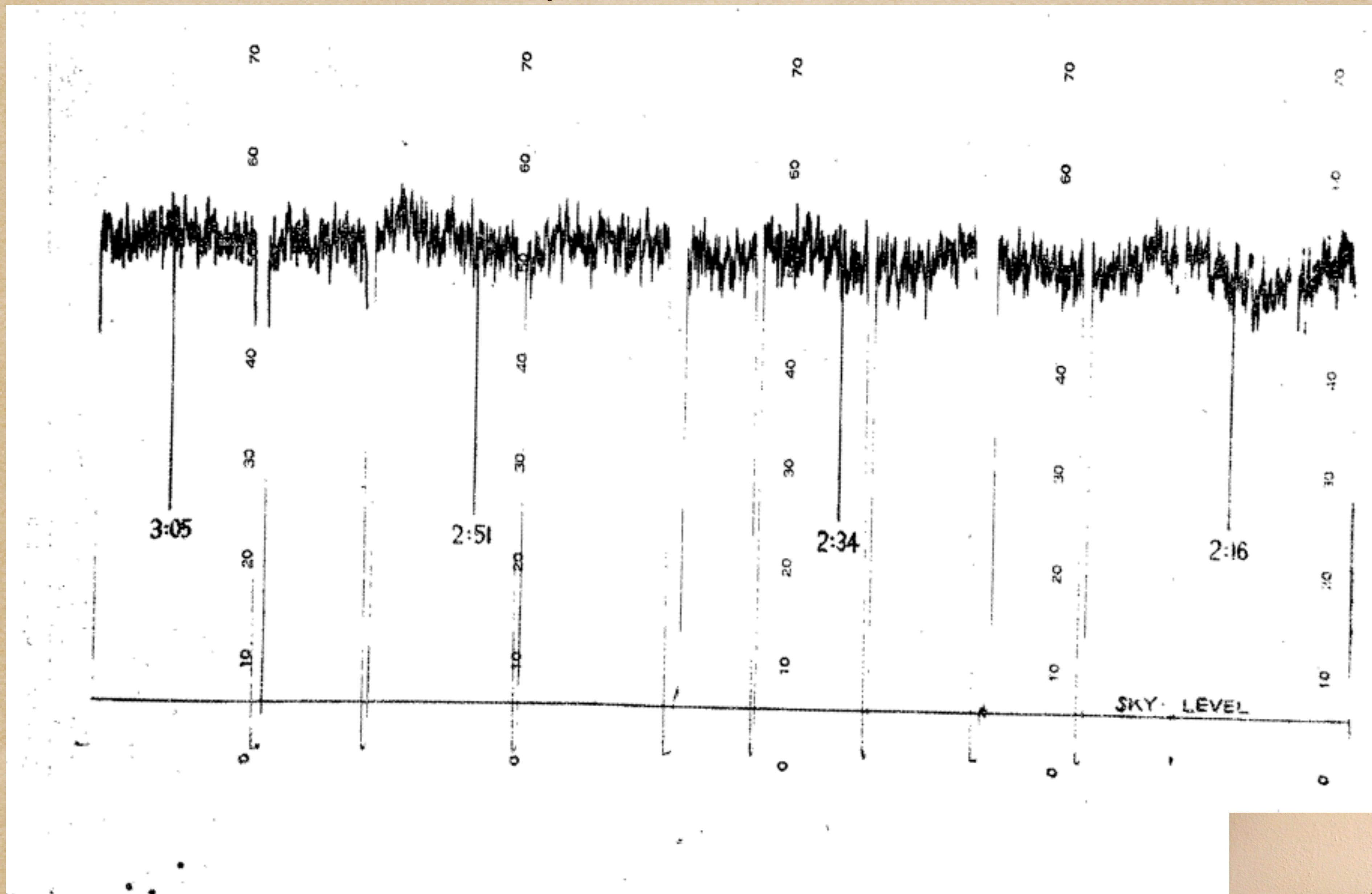
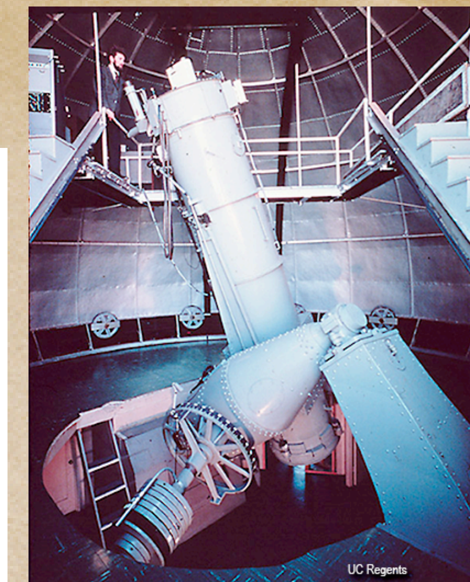


Fig. 2. Section of Brown recorder sheet showing observations of HZ 29 made in ultraviolet light with the Crossley reflector on February 4 UT, 1962 (Run 1). The observations shown cover an interval of about 57 minutes. (The time-marks are in uncorrected PST; the time correction was + 9 sec.).



P_{orb} = 17.28 min

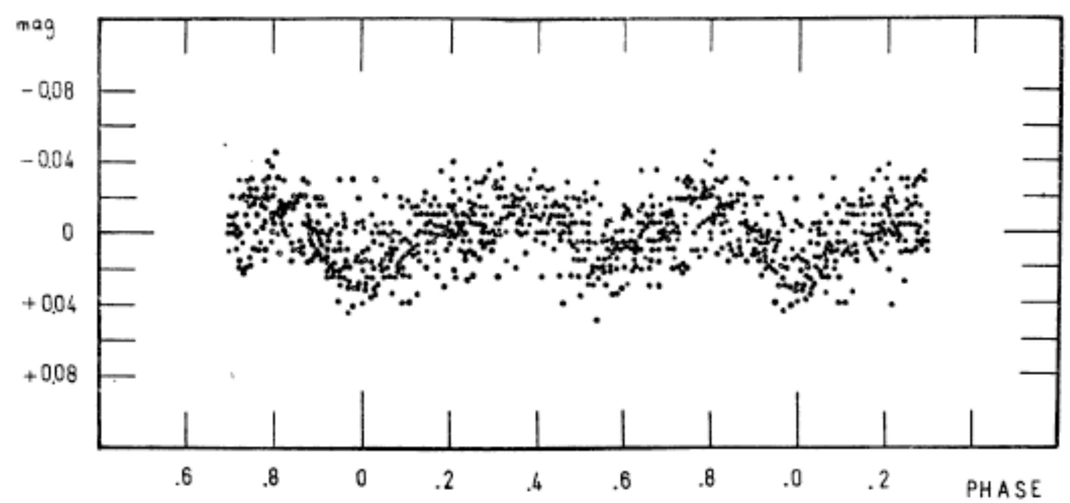


Fig. 4. Composite light-curve of HZ 29 in blue light. Ordinate gives Δm as defined in the text; abscissa is phase in units of period.

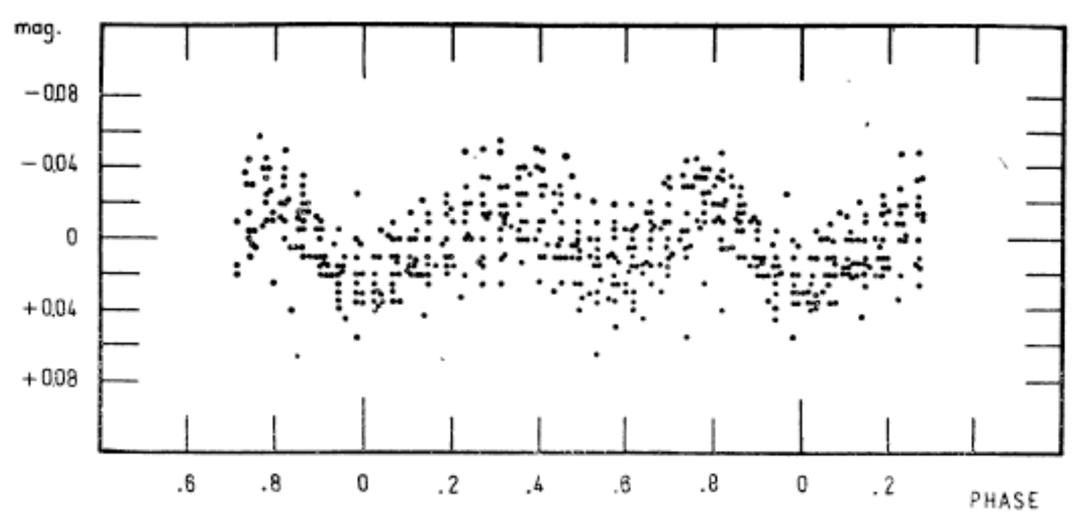


Fig. 5. Composite light-curve of HZ 29 in ultraviolet light. Ordinate gives Δm as defined in the text; abscissa is phase in units of period.

Shortest period known HM Cnc (RX J0806.3+1527) ; P_{orb} = 5.3 min

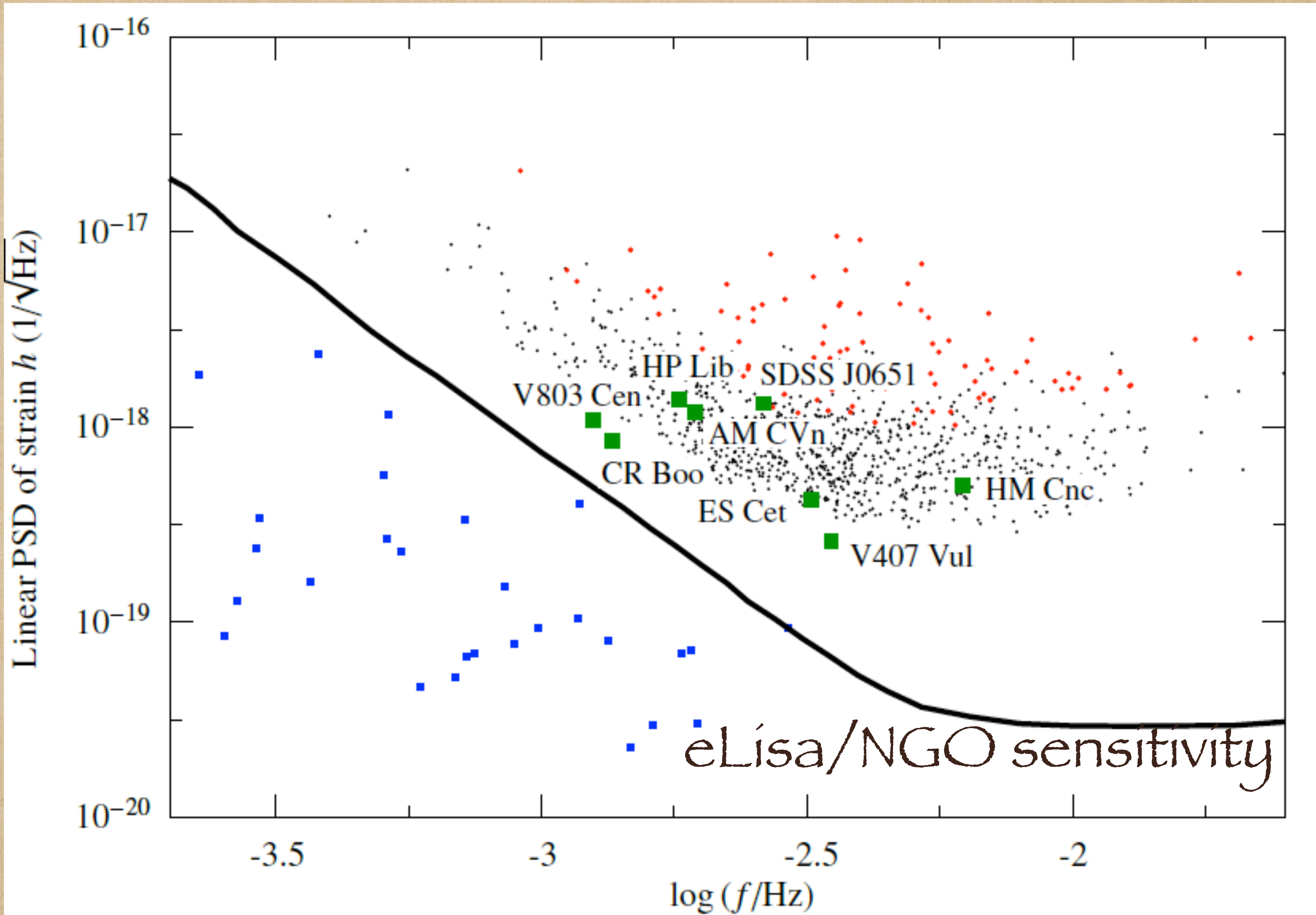
AM CVn

One final comment can be added here. If HZ 29 turns out to be a binary it may soon provide a decisive test for the existence or non-existence of the gravitational waves, assuming of course that all other, intrinsic changes of period could properly be eliminated.

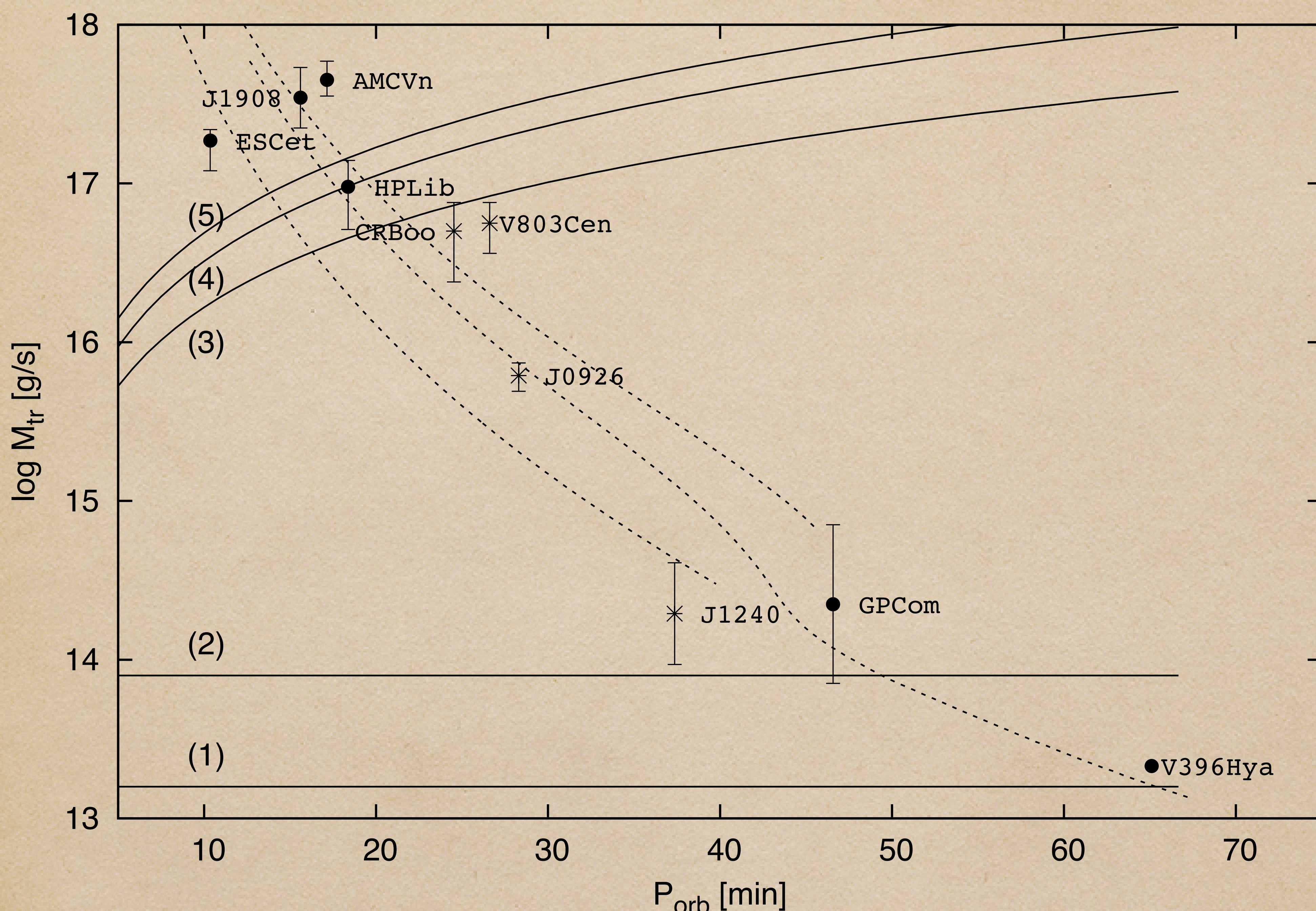
1967

Models of the vertical structure of helium accretion disks show thermal instability in the temperature range corresponding to the helium ionization. The critical effective temperatures, $\log T_e = 4.1$ and 3.95, are higher than in the case of hydrogen-rich disks. Of the two known helium cataclysmic binaries, AM CVn avoids the instability due to a high accretion rate, while GP Com – most likely – due to a very low accretion rate. Evidence is also presented to suggest that in GP Com the accretion pattern is modified by the magnetic field of the white dwarf.

1983

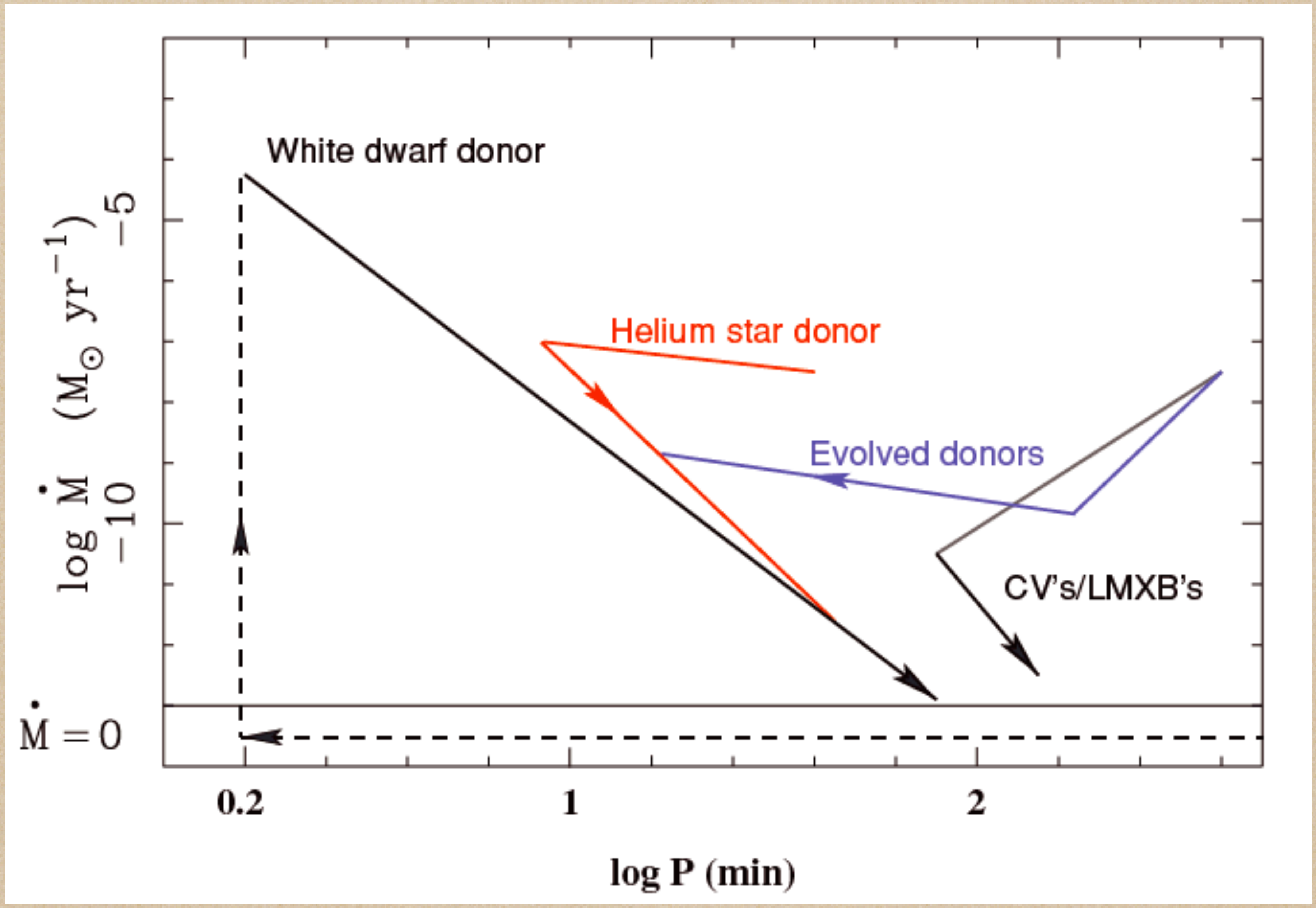


10^{-16}
10^{-17}
10^{-18}
10^{-19}
10^{-20}
Linear PSD of strain h $(1/\sqrt{\text{Hz}})$
-3.5
-3
-2.5
-2
log (f/Hz)
HP Lib
SDSS J0651
V803 Cen
AM CVn
CR Boo
ES Cet
HM Cnc
V407 Vul
eLisa/NGO sensitivity



Kotko, Lasota, Dubus & Hameury 2012

Evolutionary paths to AM CVn stars



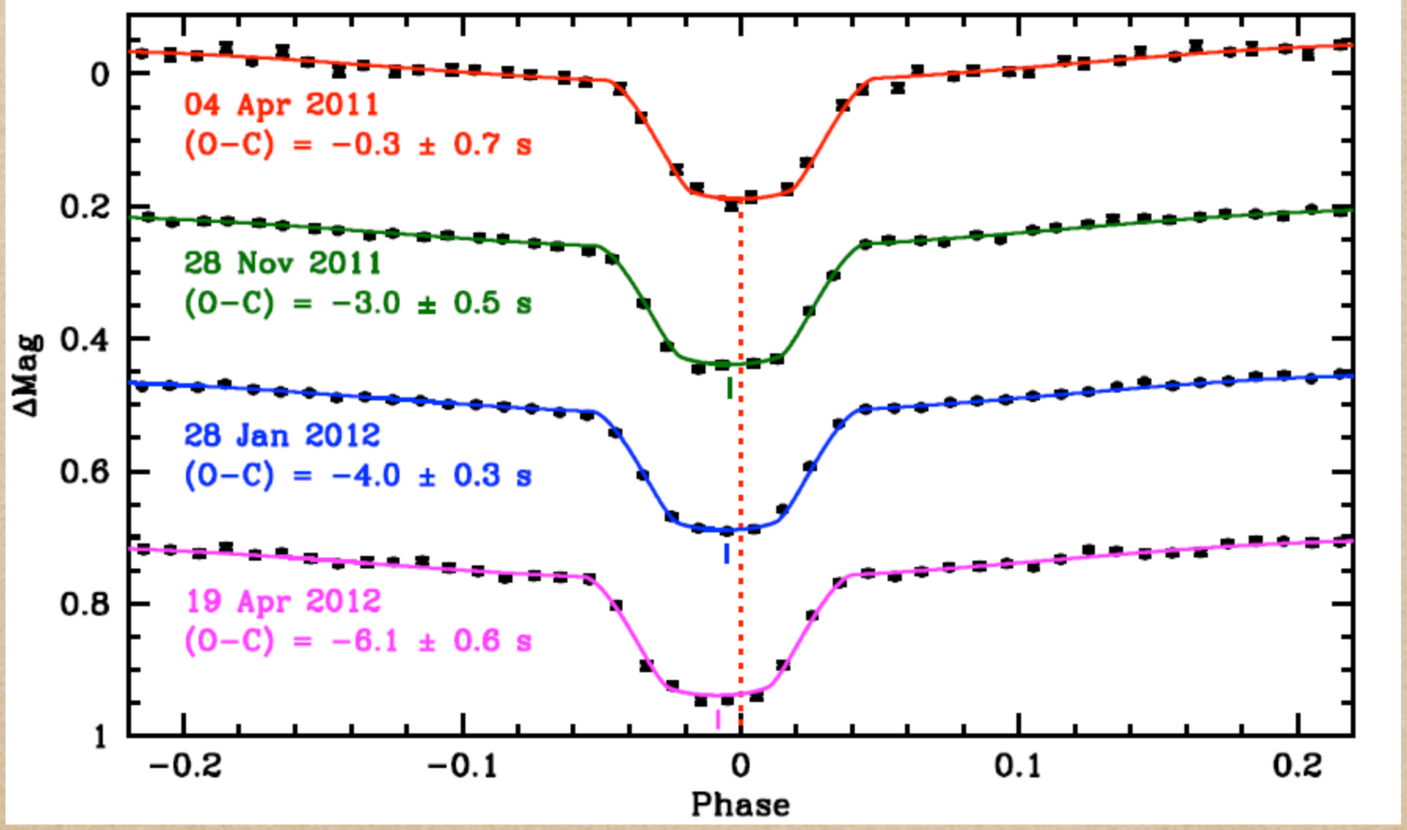
Detached WD binary

SDSS J065133.338+284423.37

P_{orb} = 12.75-min

Orbit's decay rate: -0.31 +/- 0.09 ms/yr

GR: -0.26 +/- 0.05 ms/yr



Hermes et al. 2012

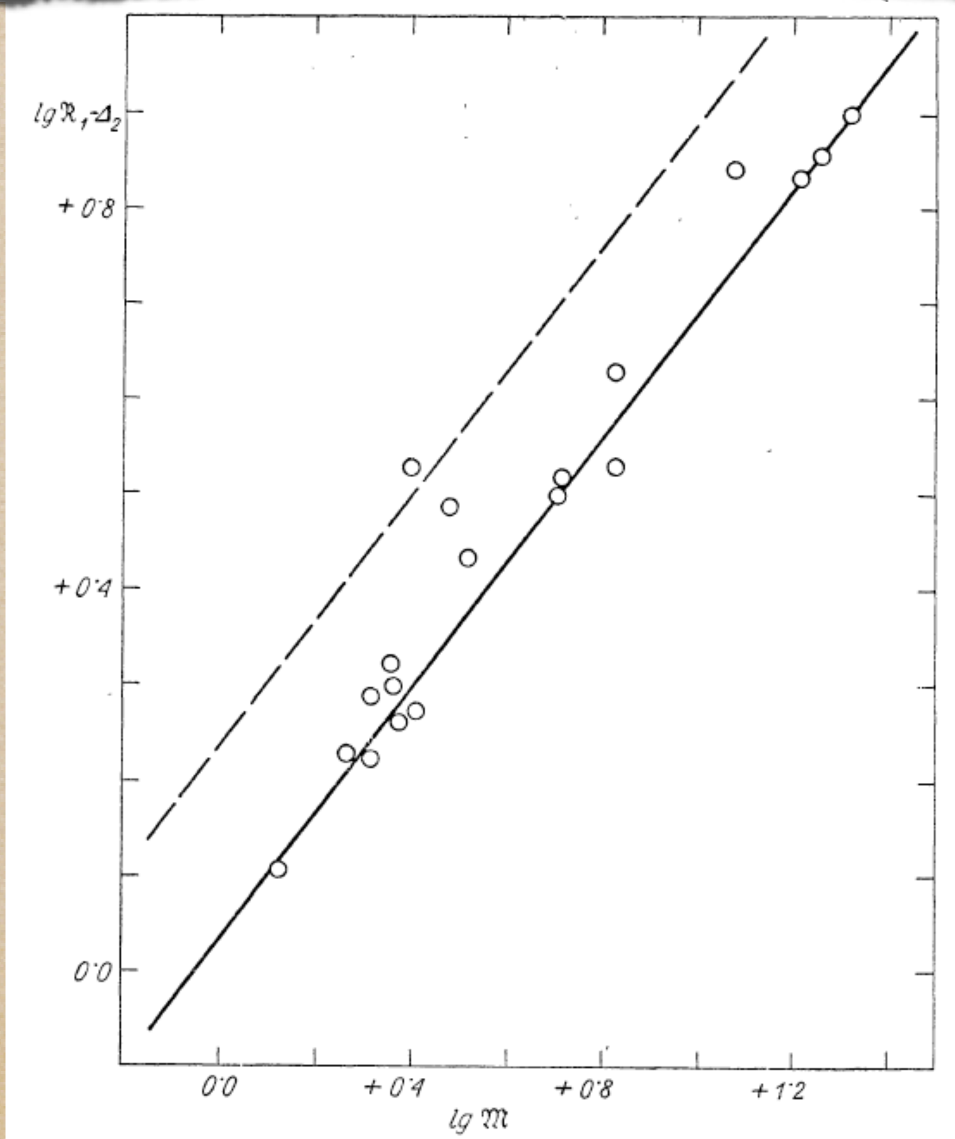
Note on the Evolution of Close Binaries

by

J. Smak

SUMMARY

The mass — radius relation for eclipsing binaries is discussed. The primary components are systematically greater than the secondaries of the same mass, in agreement with the theory of stellar evolution.



XZ Sge not an R CMa.
DN Or also not helium burning

1959

Stellar evolution and the Algol paradox

The observed values of masses of R CMa stars together with a reasonable assumption that their initial masses were greater than $1\mathfrak{M}_\odot$ lead to the conclusion that the evolutionary mass loss in these objects exceeds 90% of the initial mass.

1961

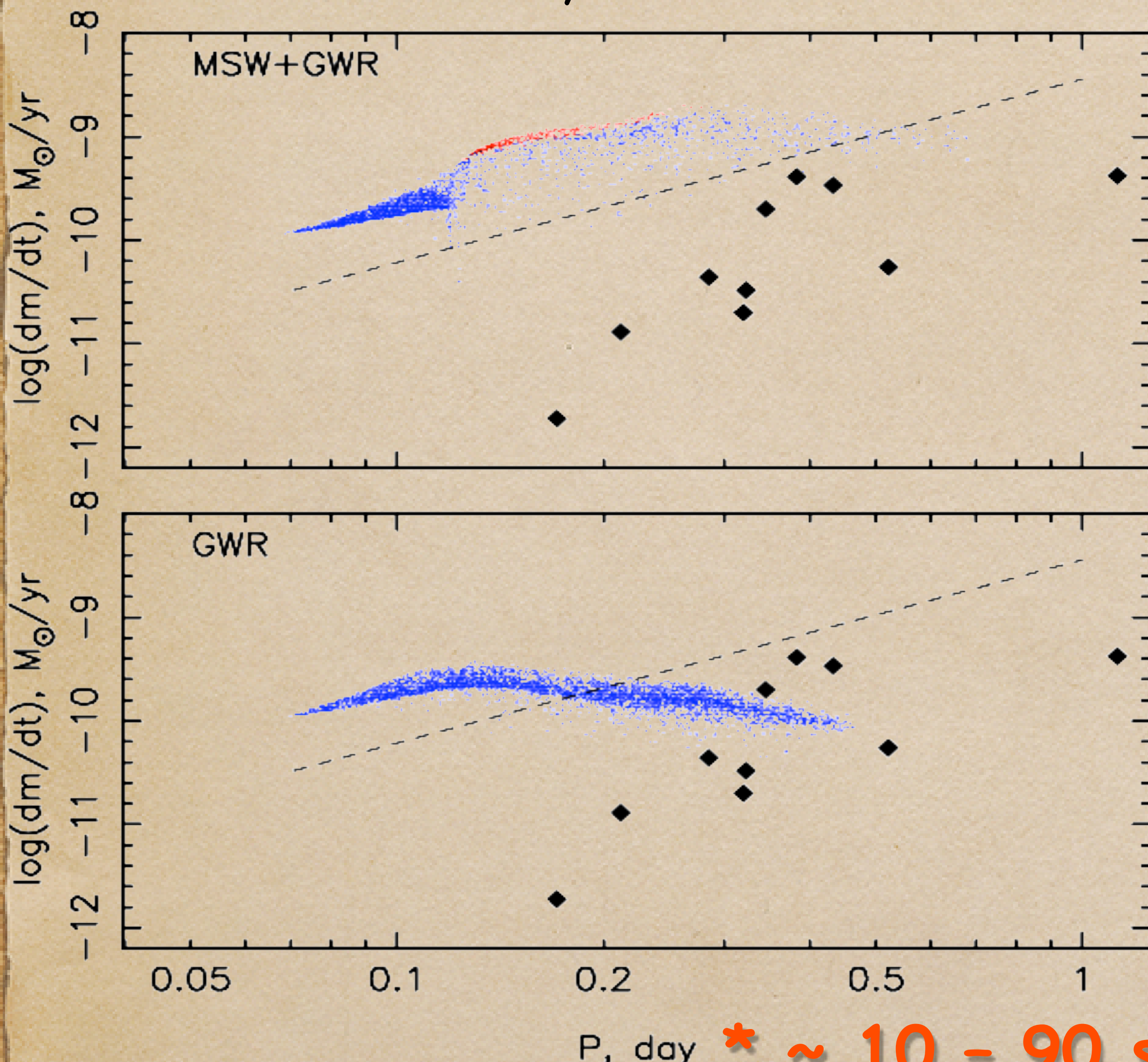
The observational mass-luminosity relation suggests then that the components of R CMa systems are helium-burning stars.

1961

1962: Kelvin & nuclear time instabilities

Evolution of BH LMXBs

Blue - unstable, red - stable



13737 binaries 367 bright & stable*, 2905 transients

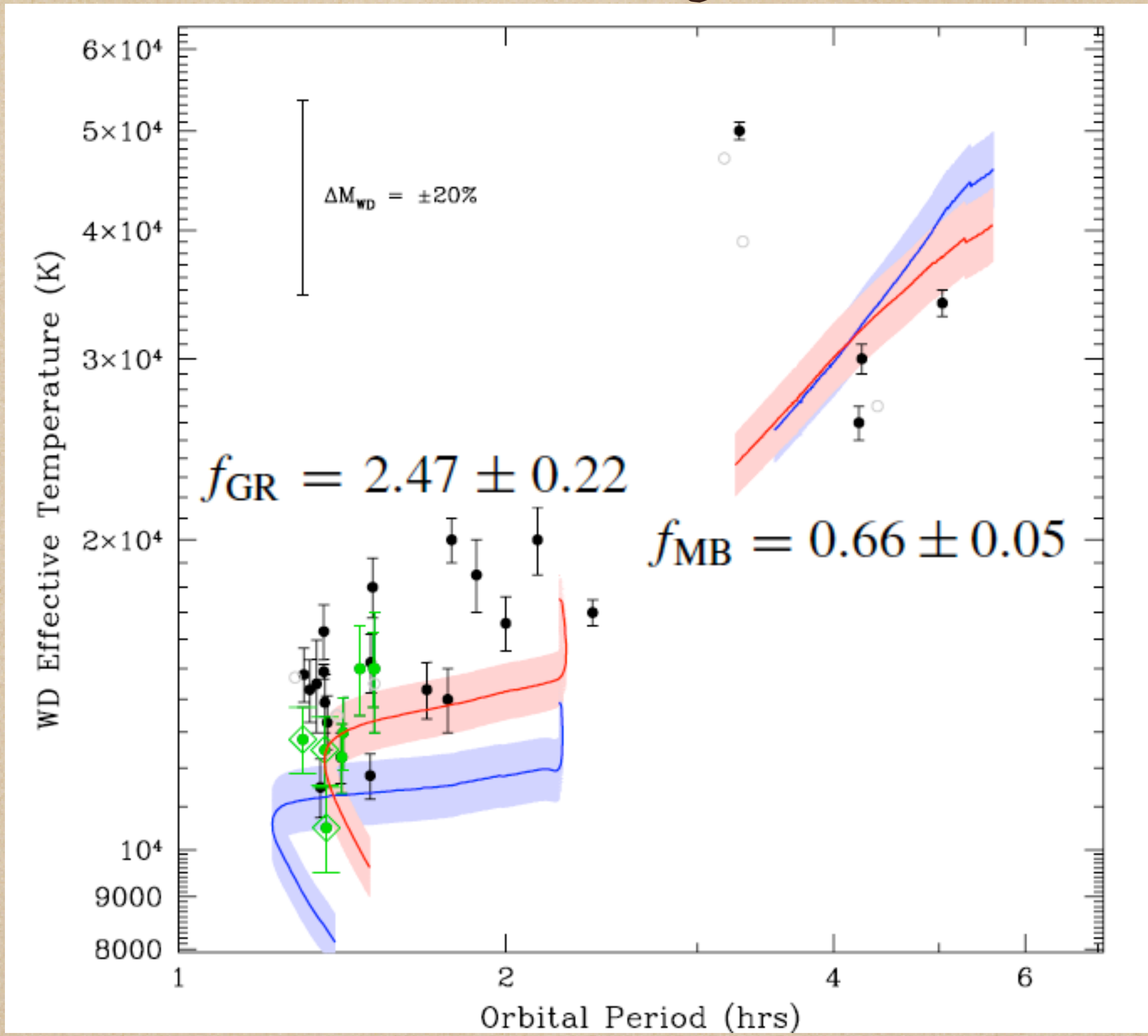
12089 binaries 0 stable, 5074 transients

*** ~ 10 - 90 should be observed - they are not.**

Therefore: <u>no magnetic braking when RLOF</u>

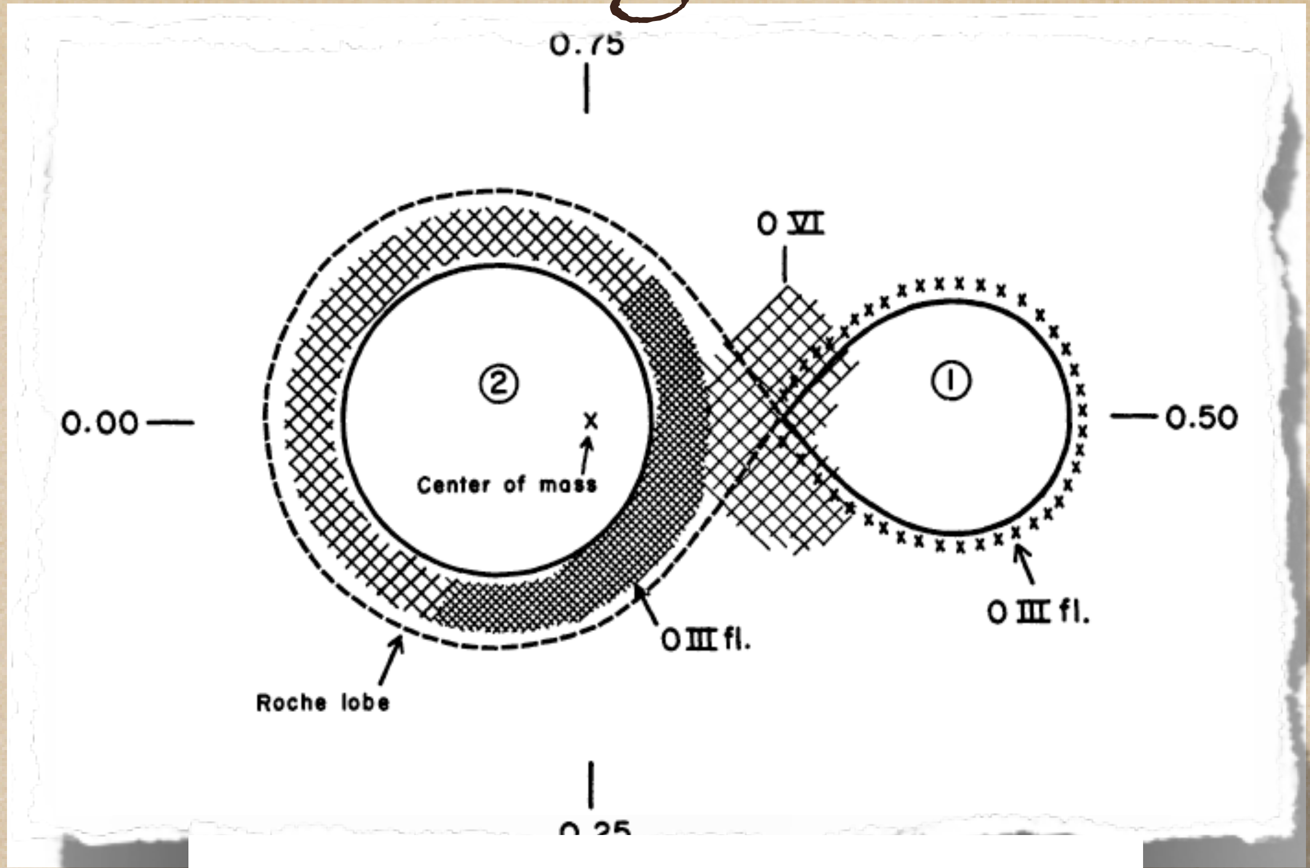
Yungelson, Lasota, Nelemans, Dubus, van den Heuvel, Dewi & Portegies Zwart 2006;
Yungelson & Lasota 2008, 2009

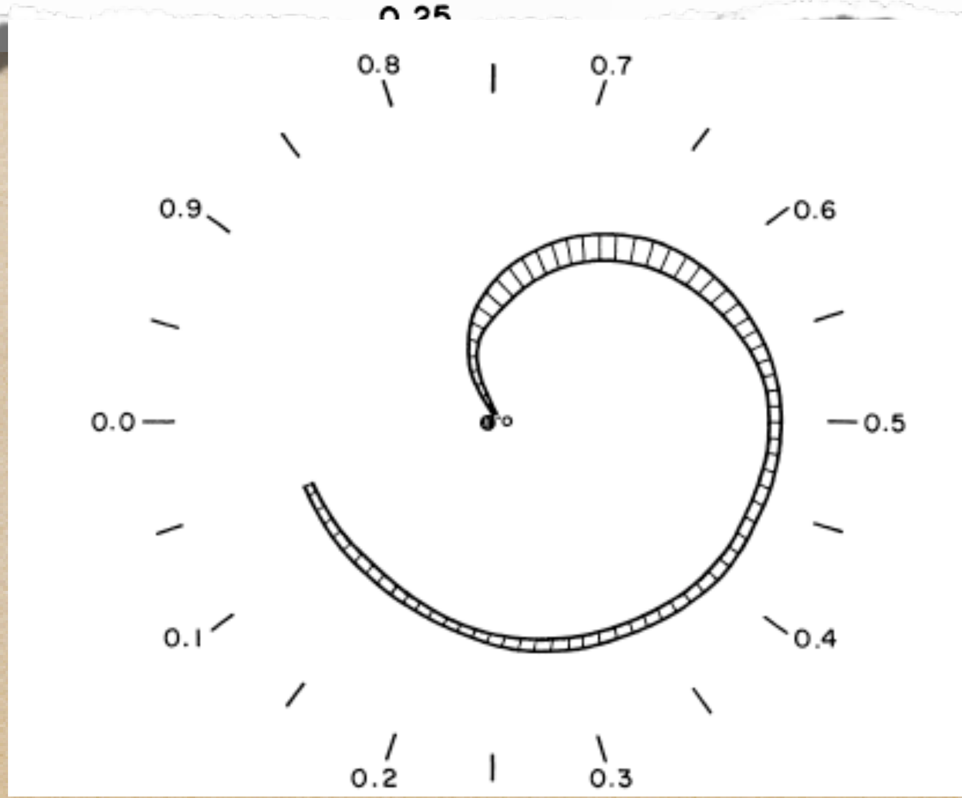
Evolution of cataclysmic binaries



Knigge, Baraffe & Patterson 2011

V Sge





Herbig, Preston, Smak & Paczyński 1965

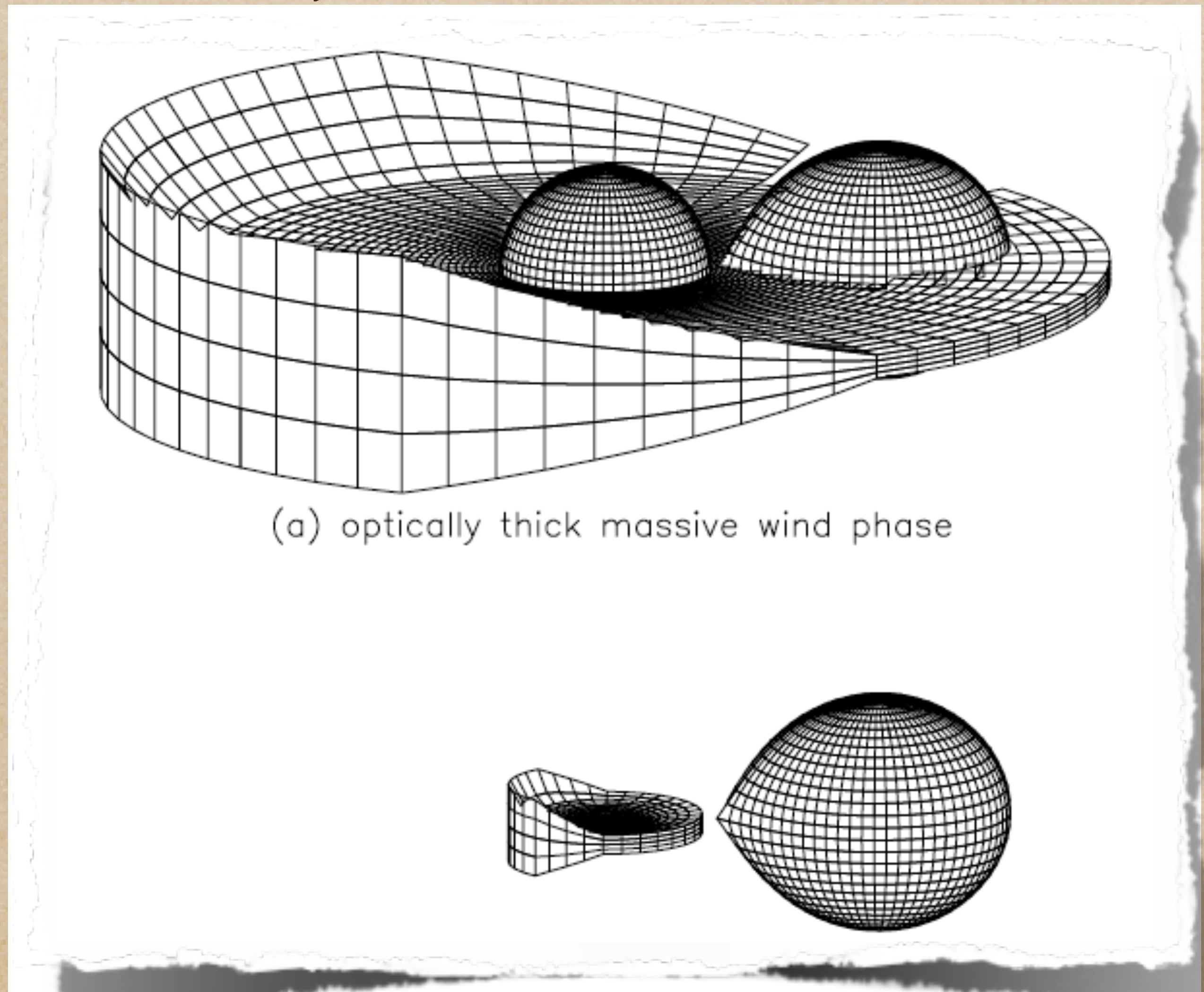
V Sge: a Hot, Peculiar Binary System

2001

Józef I. Smak, K. Belczyński & S. Zoła

Models with an accretion disk around the white dwarf primary (or a very massive neutron star secondary) fail completely to reproduce the shapes of the observed light curves.

A supersoft X-ray source ?



Hachisu & Kato 2003

ON THE COLORS OF T TAURI STARS AND RELATED OBJECTS

J. SMAK†
Lick Observatory, University of California

1964

ON THE COLORS OF T TAURI STARS AND RELATED OBJECTS

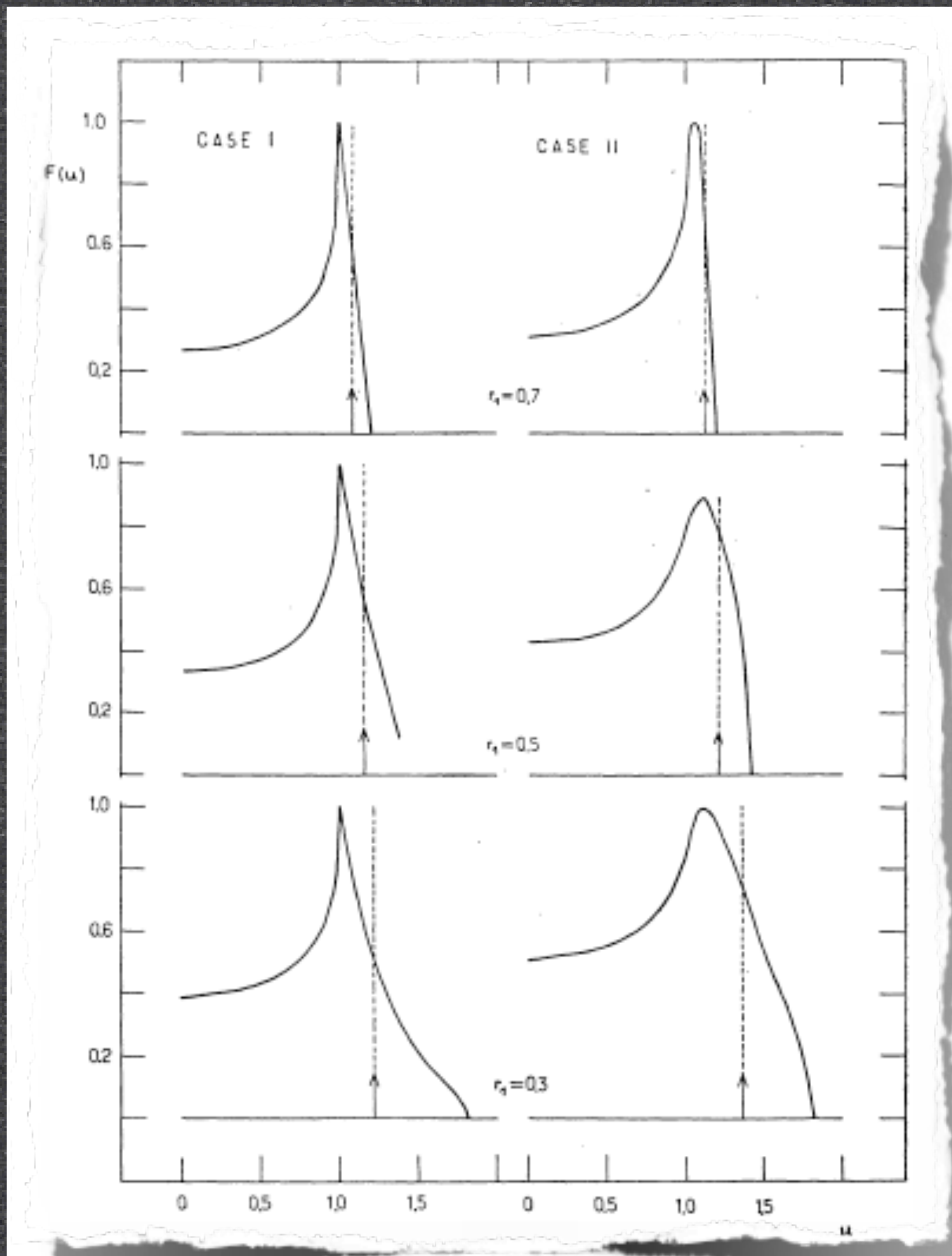
J. SMAK†

Lick Observatory, University of California

1964

T Tauri stars have considerable UV continuum emission compared to a main sequence stellar photosphere with the same spectral type (..Smak, 1964...). Because this 'veiling' is an extra source of continuum emission, it fills in stellar absorption lines. Together with analyses of IR excesses, measurements of stellar veiling have led to detailed accretion disk models and fairly robust estimates of accretion rates from the disk onto the star. (Kenyon et al . 2008)

Emission lines from «gaseous rings»



1969

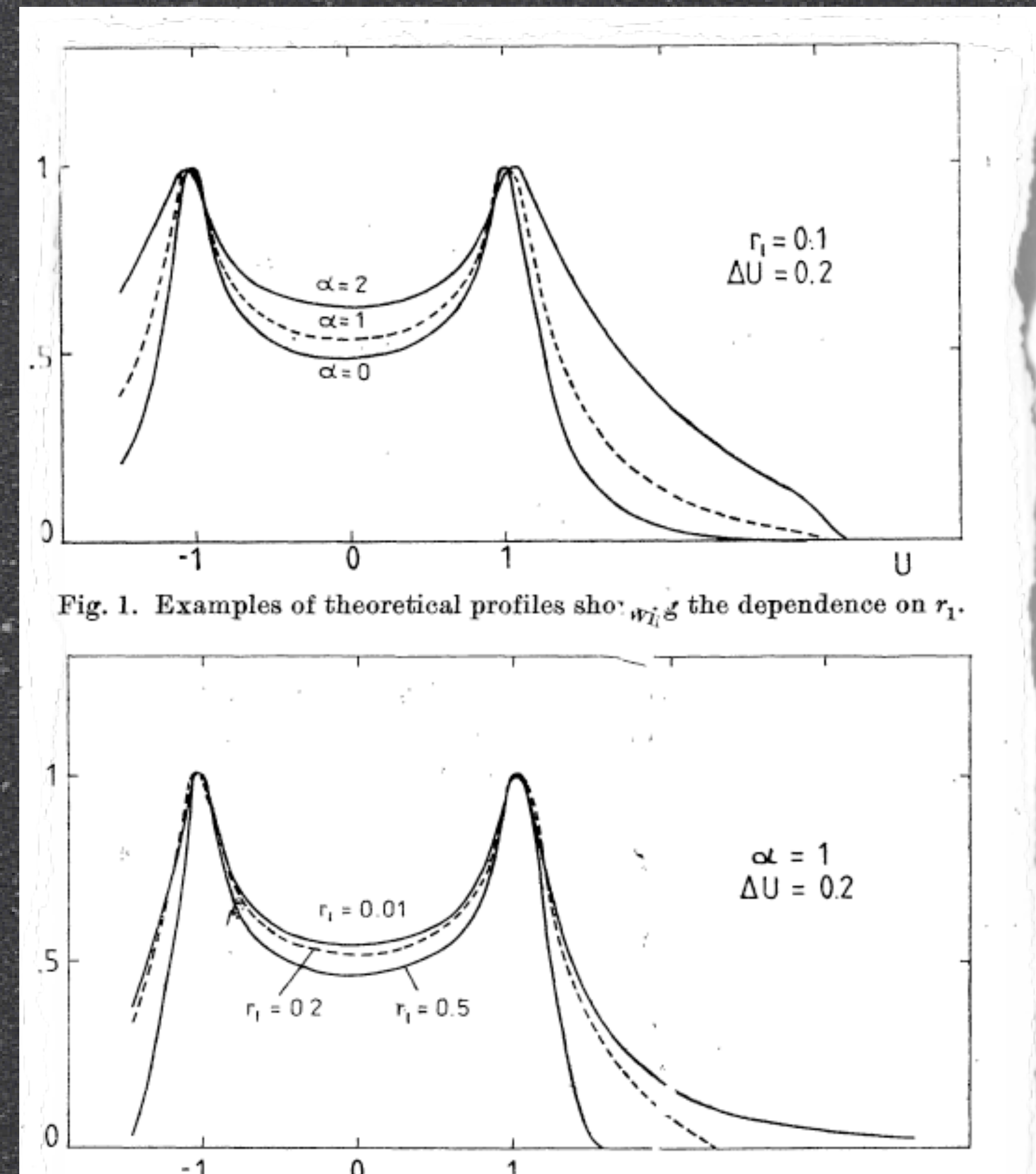


Fig. 1. Examples of theoretical profiles showing the dependence on r_1.

Fig. 2. Examples of theoretical profiles showing the dependence on α.

1981

Disc irradiation (by hot white dwarfs)

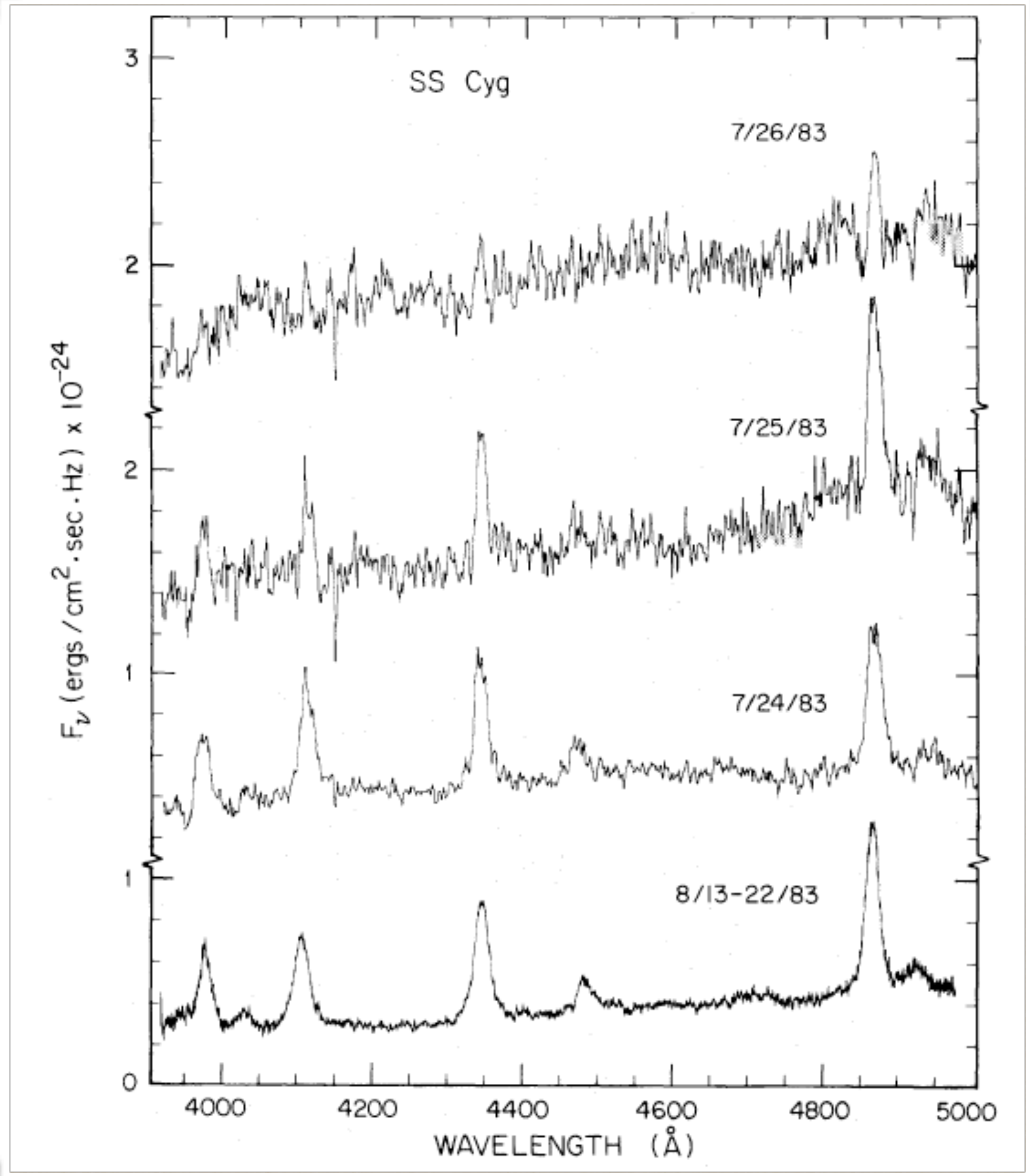
Temperatures and Luminosities of White Dwarfs in Dwarf Novae

1984

On the Irradiation of Disks in Cataclysmic Binaries

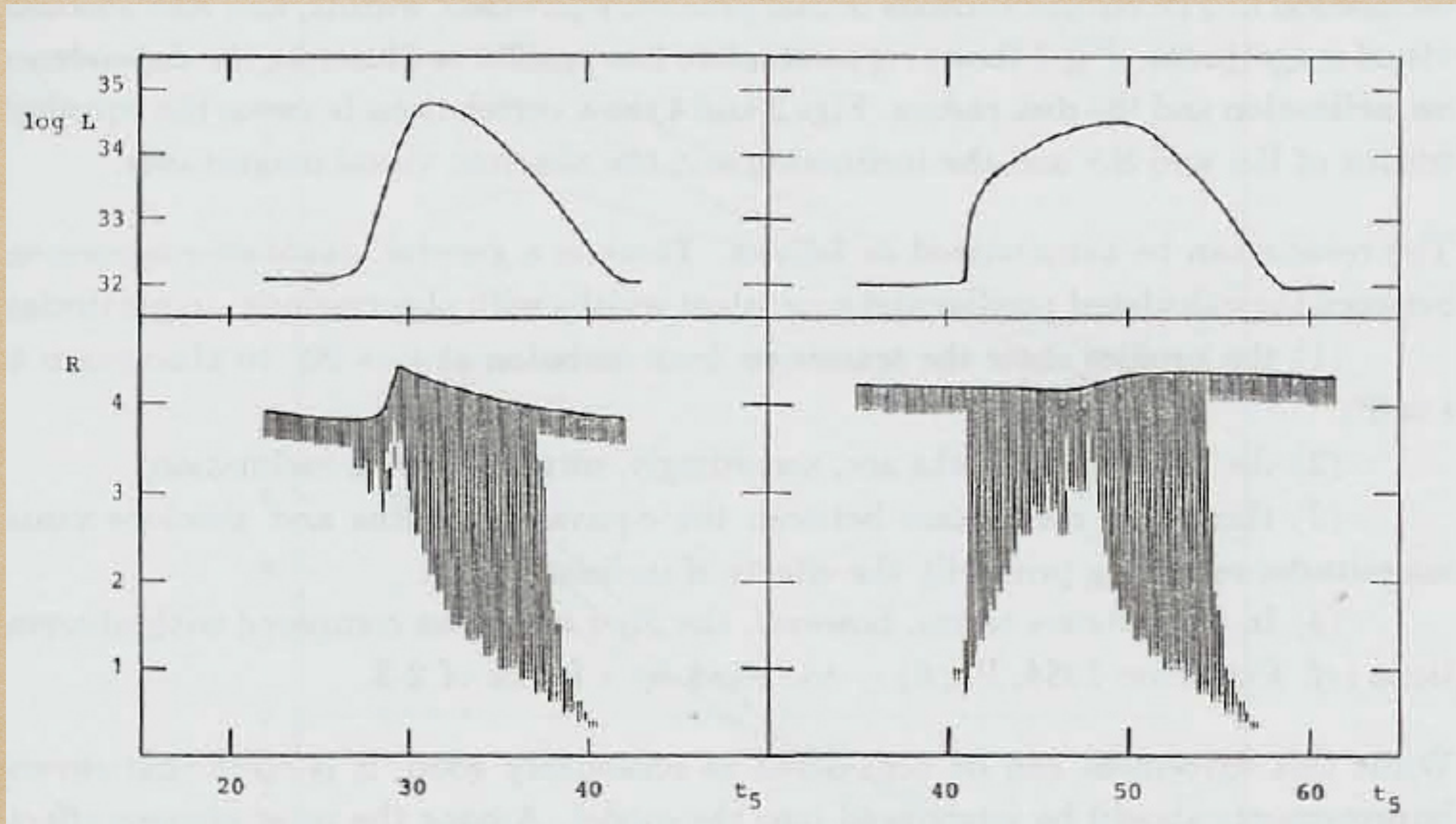
1989

Radiation from white dwarfs is likely to be the source of excitation of the emission lines from disks. It is also argued that the heating by the white dwarf can significantly modify the structure of the innermost parts of the disk and, particularly, inhibit the incidence of thermal instability in that region.

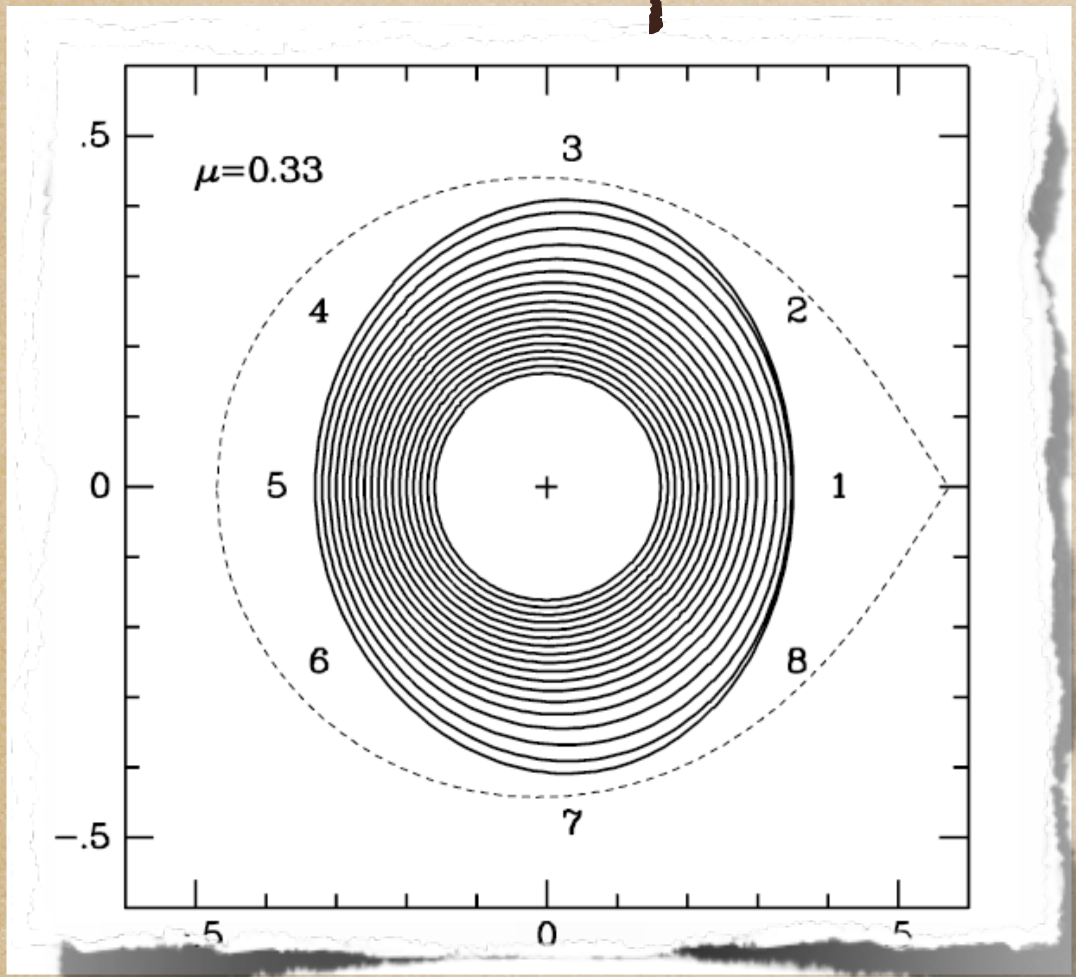


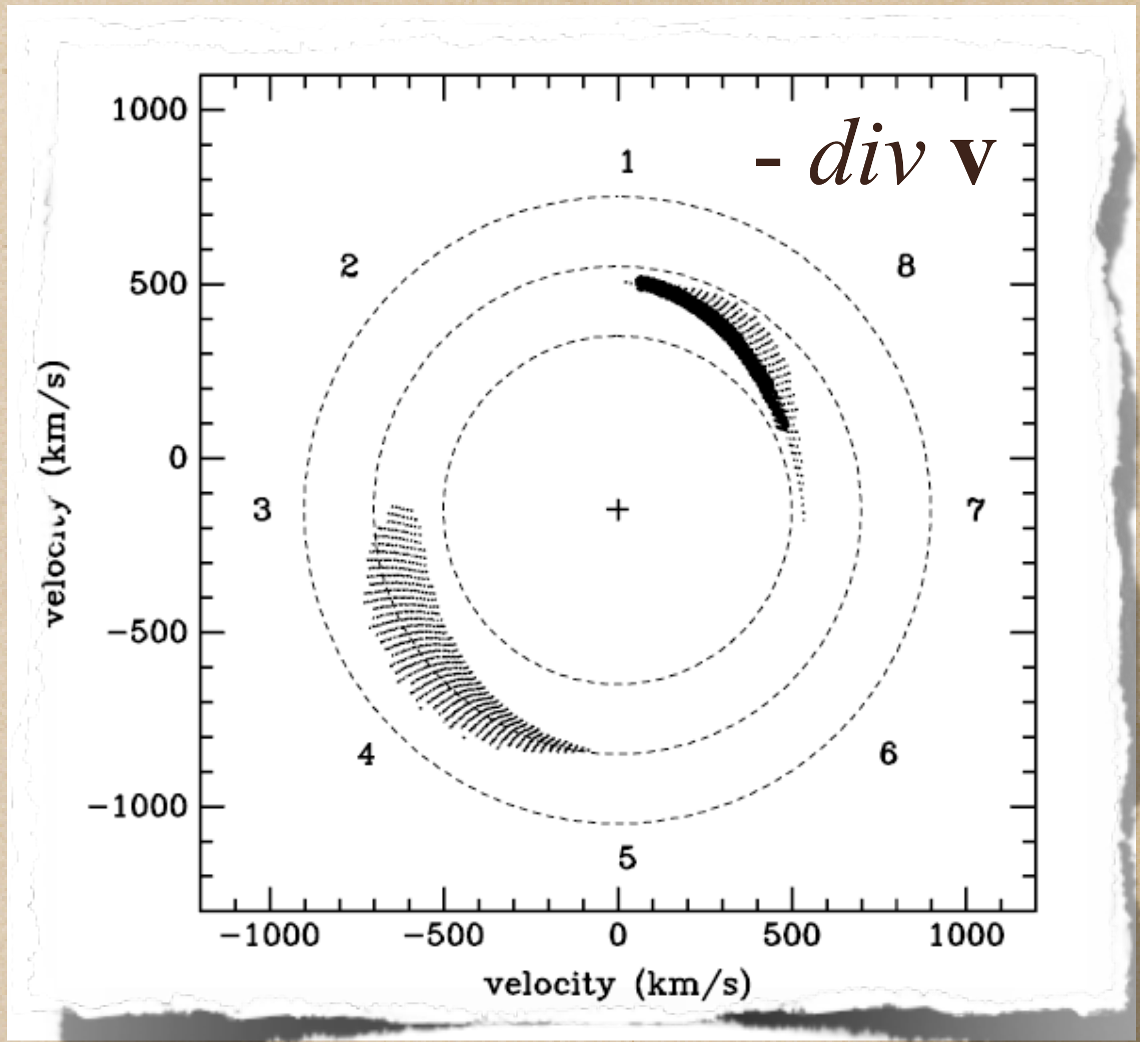
Clarke, Capel, Bowyer 1984

Smak 1991: emission lines by irradiation; variability through screening of outer disc regions:



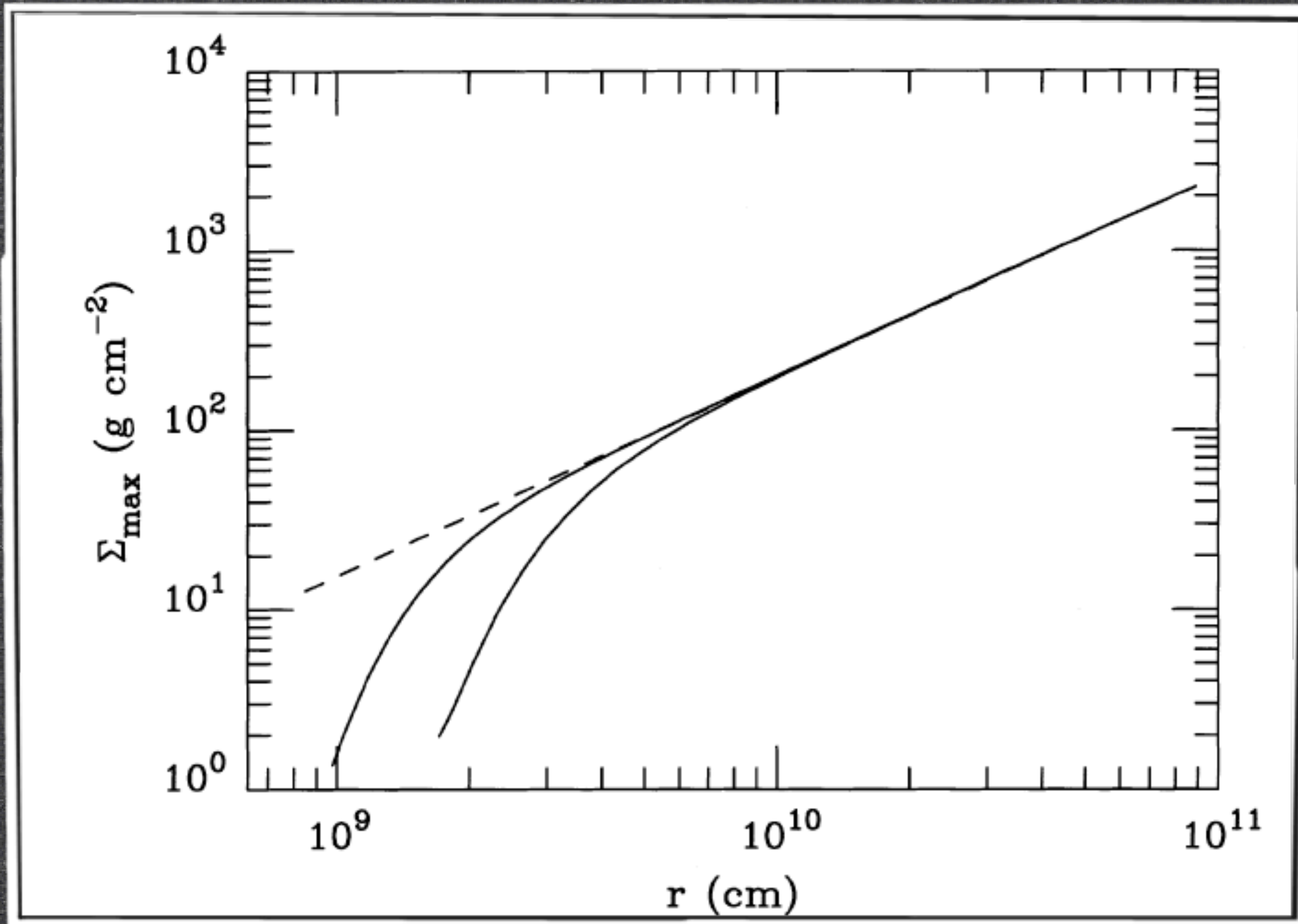
2001 «Spiral arms» in discs





Three-body effect; lines produced by irradiation.
«Arm» 187 stronger than 345.

Effect of inner disc irradiation

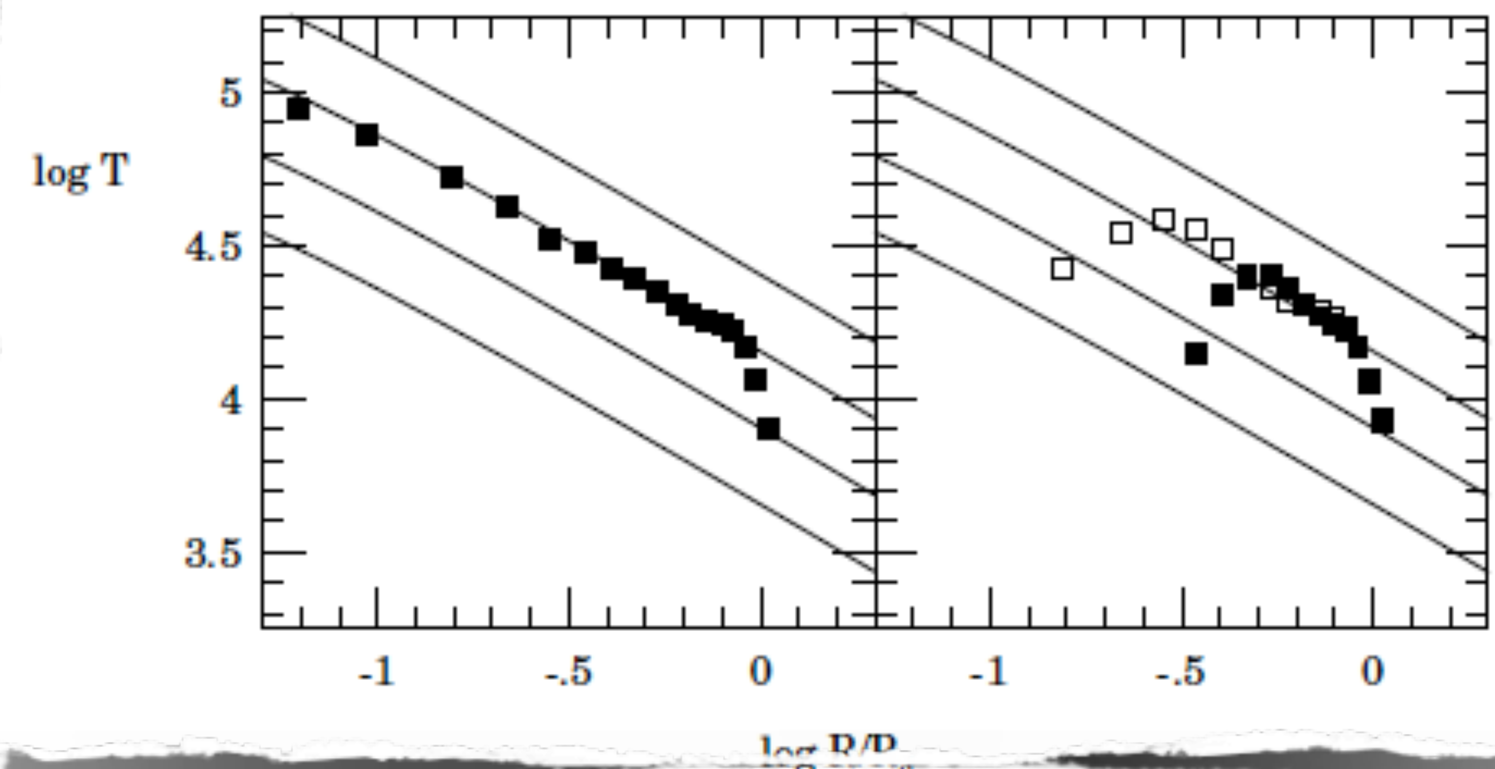


Destabilising by lowering Σ_{max} .

Hameury, Lasota & Dubus 1999

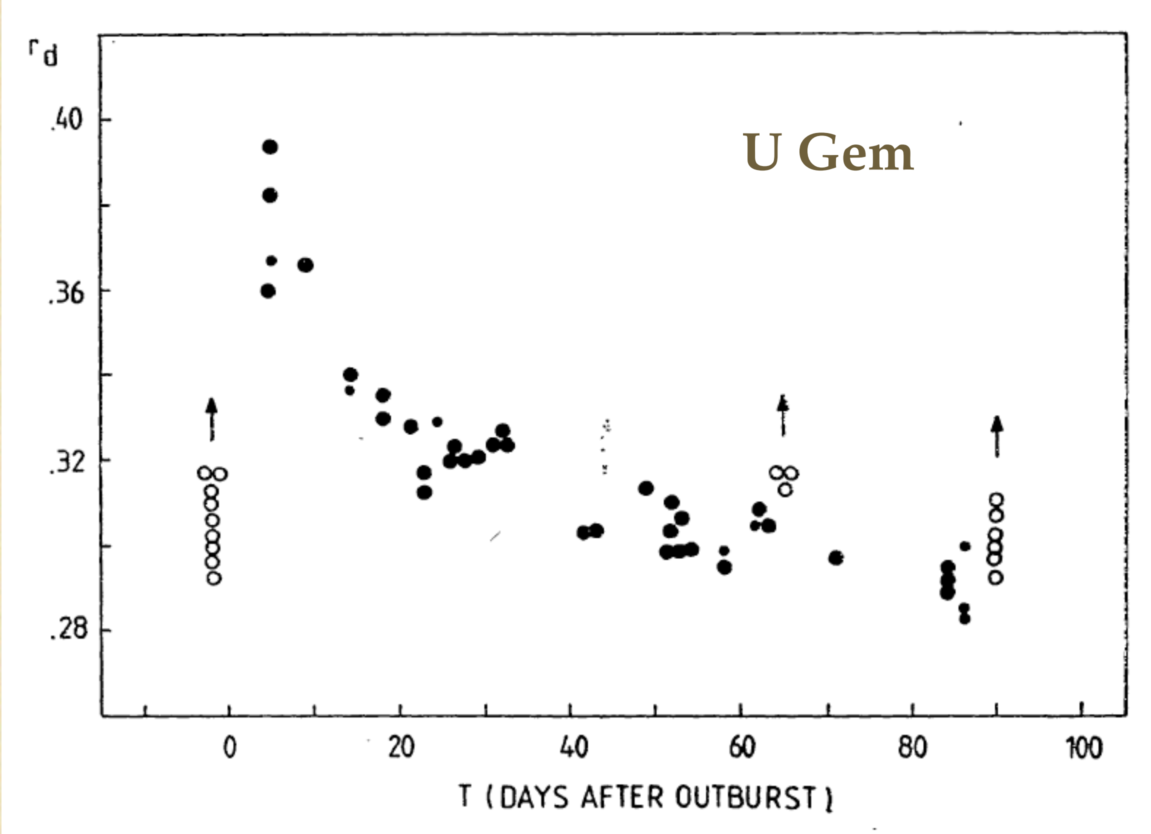
Eclipses in Cataclysmic Variables with Stationary Accretion Disks.
IV. On the Peculiar T(R) Distributions

1994

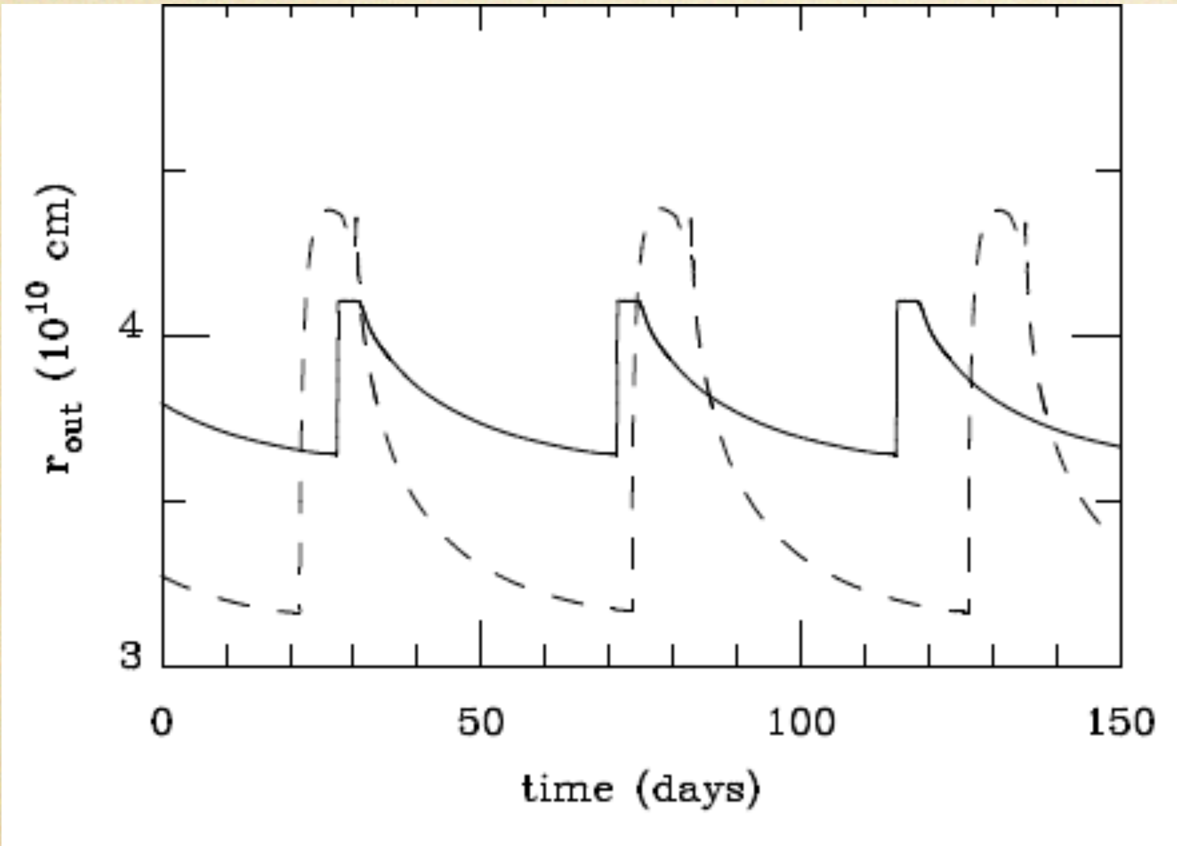


When a disc is truncated the chopped-off part does not radiate!

Disc-radius variations



Smak 1984

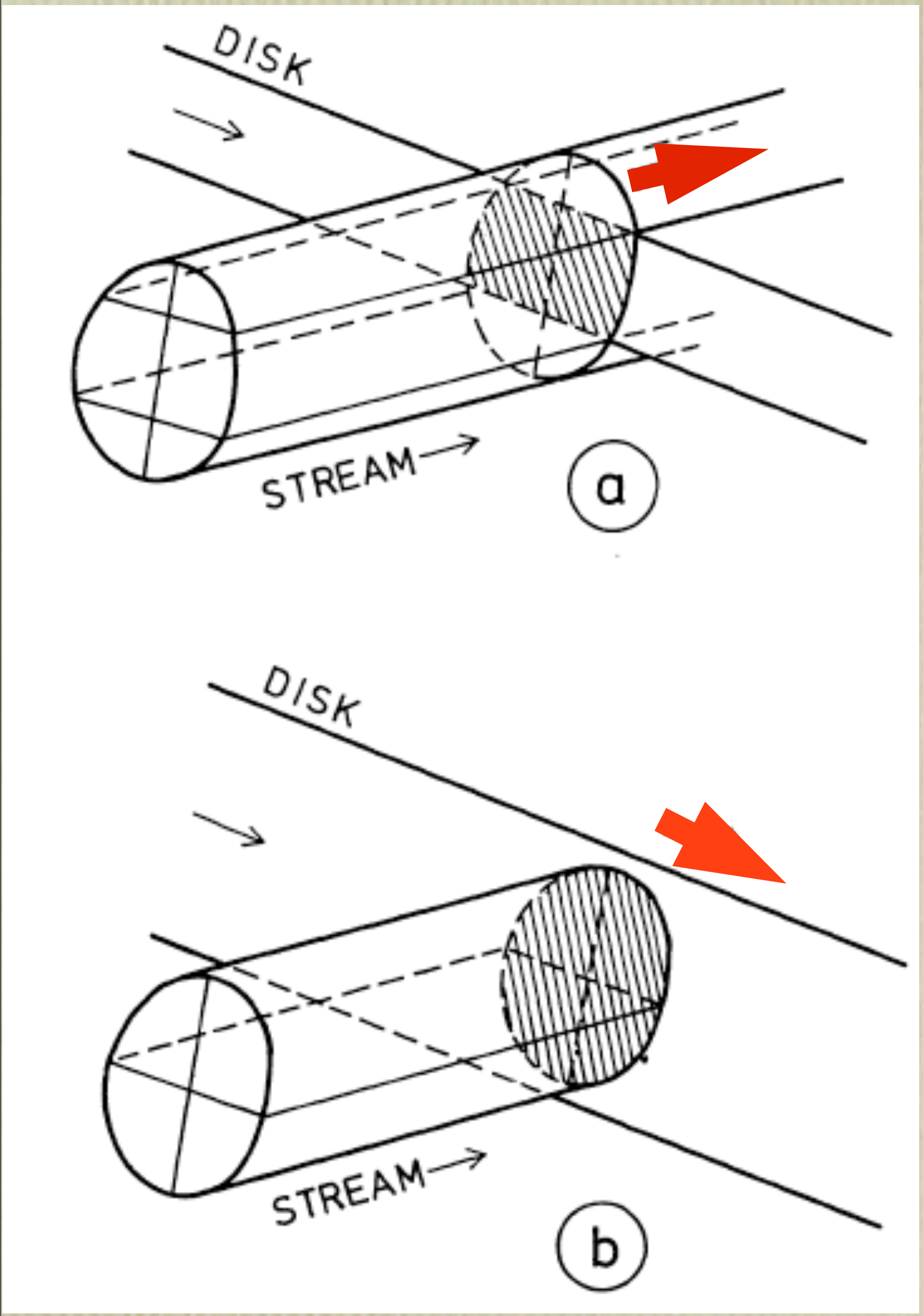


- - - - $T_{tid} = c\omega r \nu \Sigma \left(\frac{r}{a}\right)^n$

_____ $T_{tid} \propto \exp((r - r_{tid})/10^8 \text{ cm})$

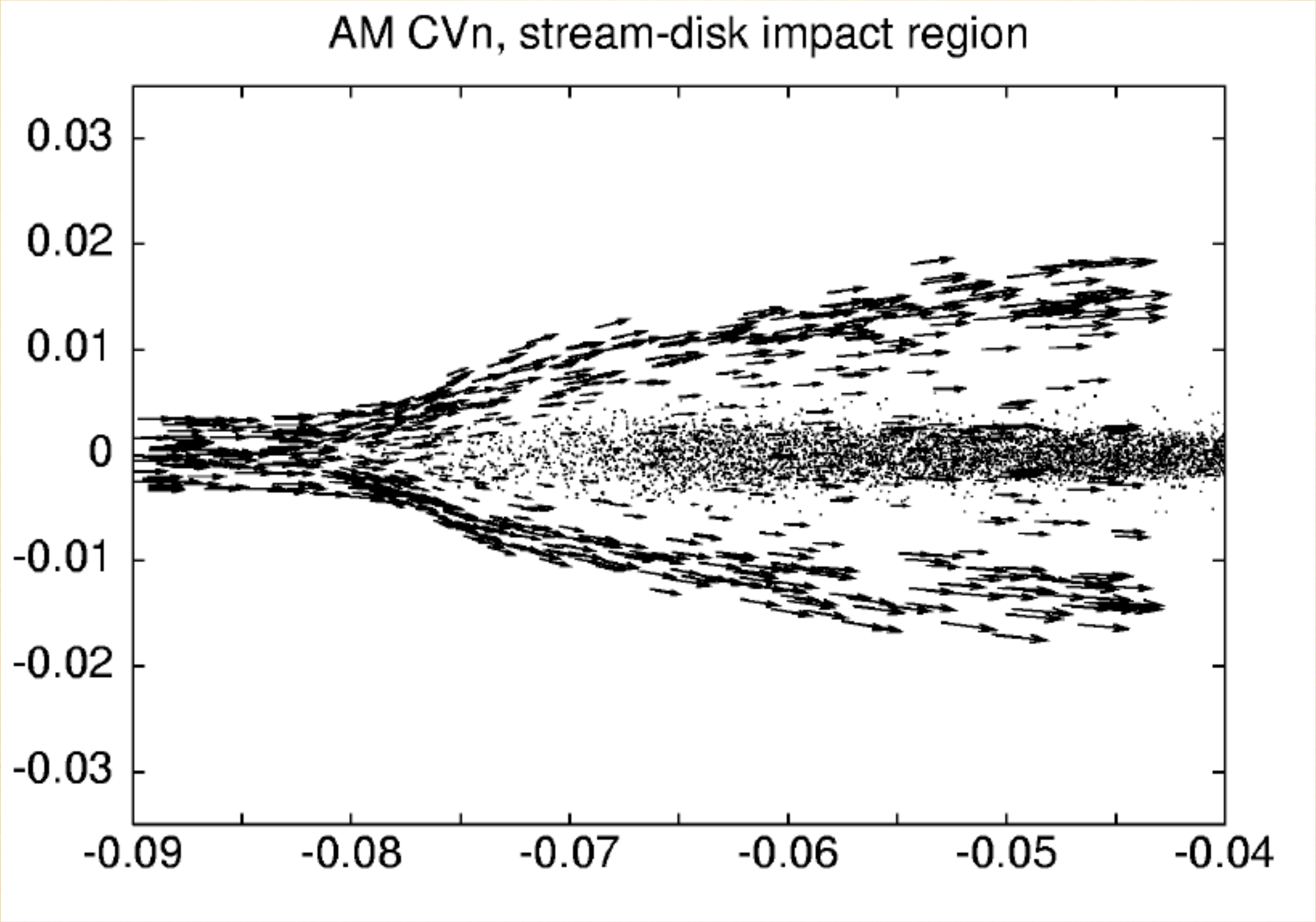
Hameury & Lasota 2005

1985: Hot spots



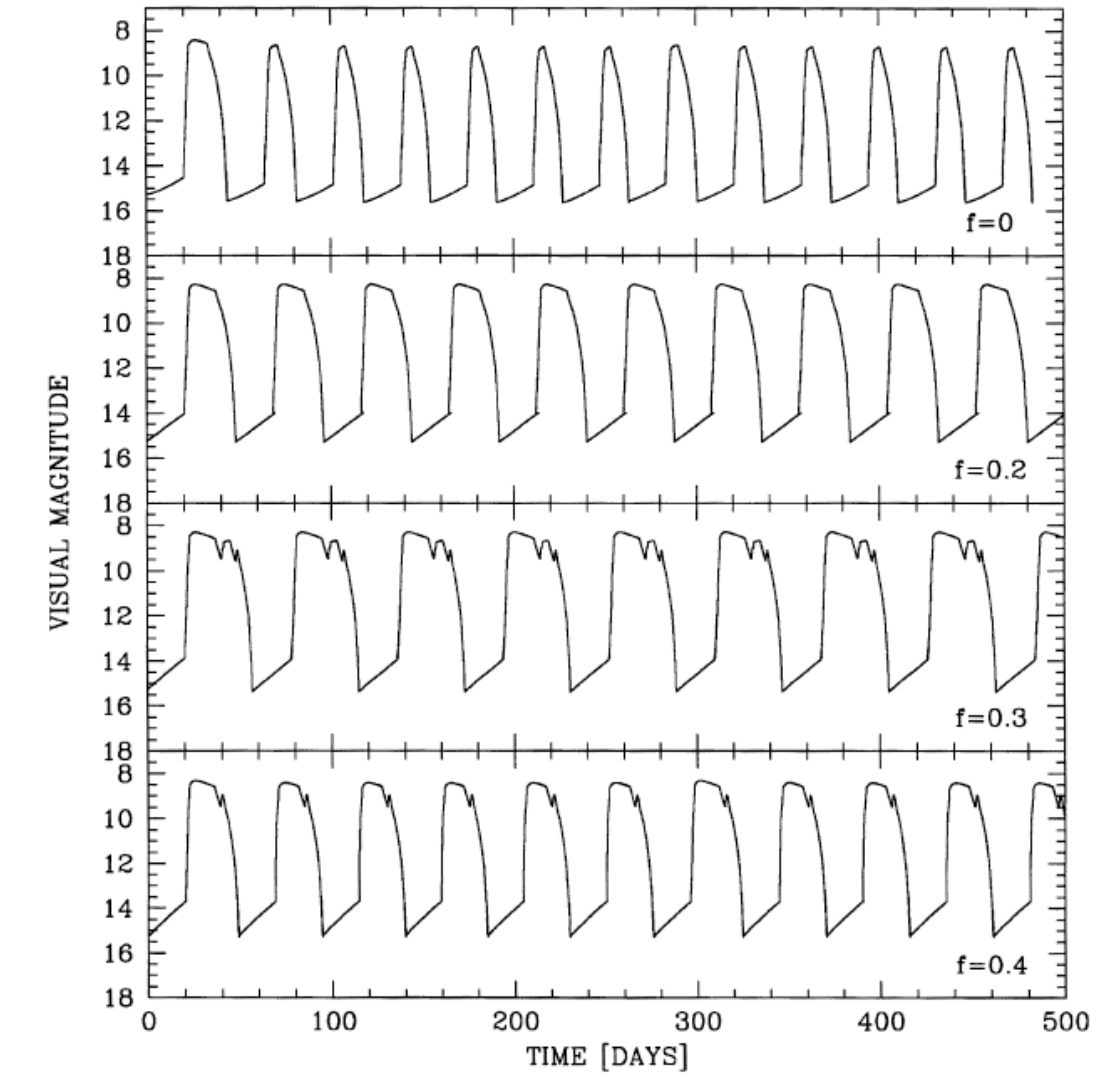
Low state:
S-wave velocities≈stream velocity

High state:
S-wave velocities≈outer disc velocity

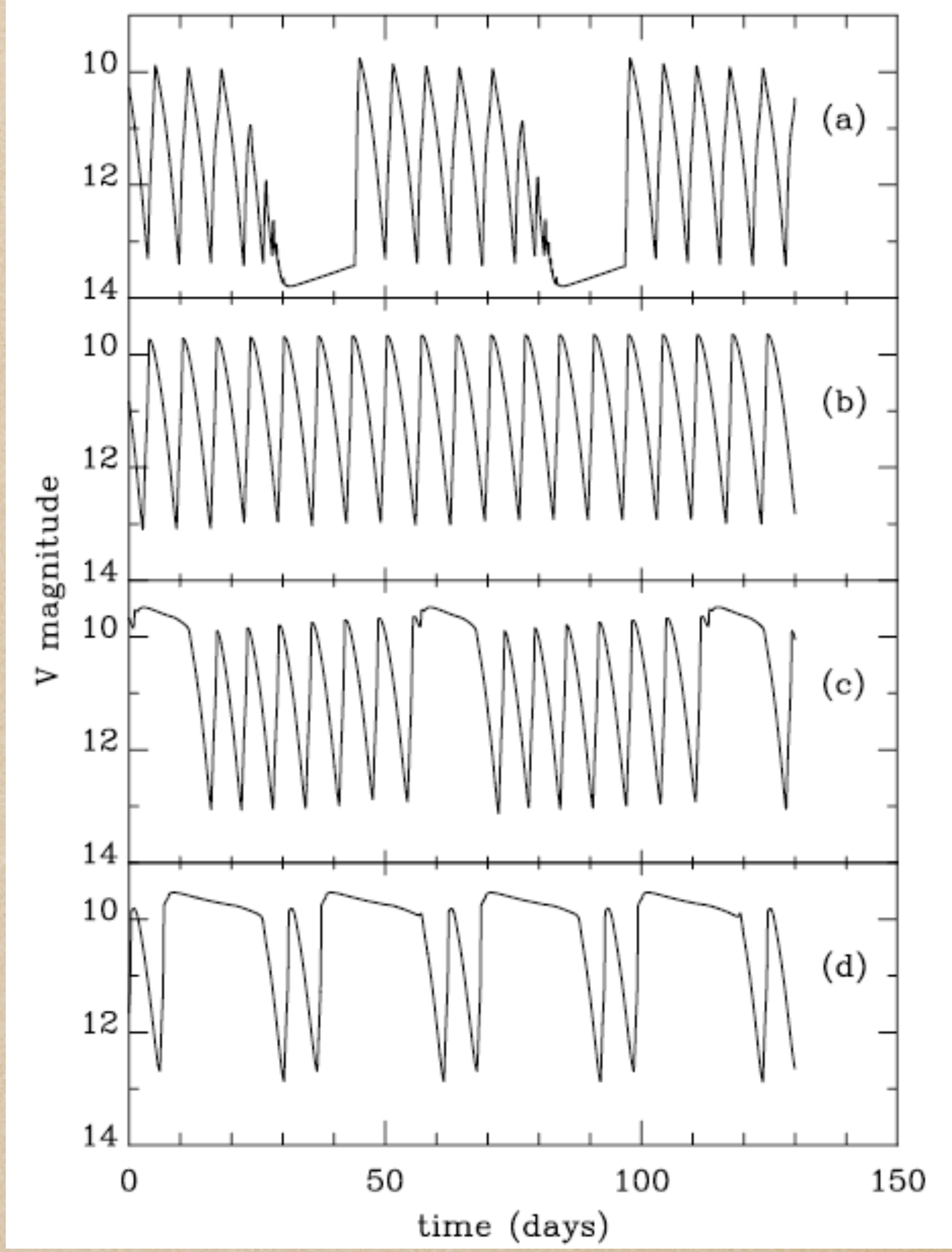


R. Speith and S. Kunze 2002

Stream overflow & the disc instability model



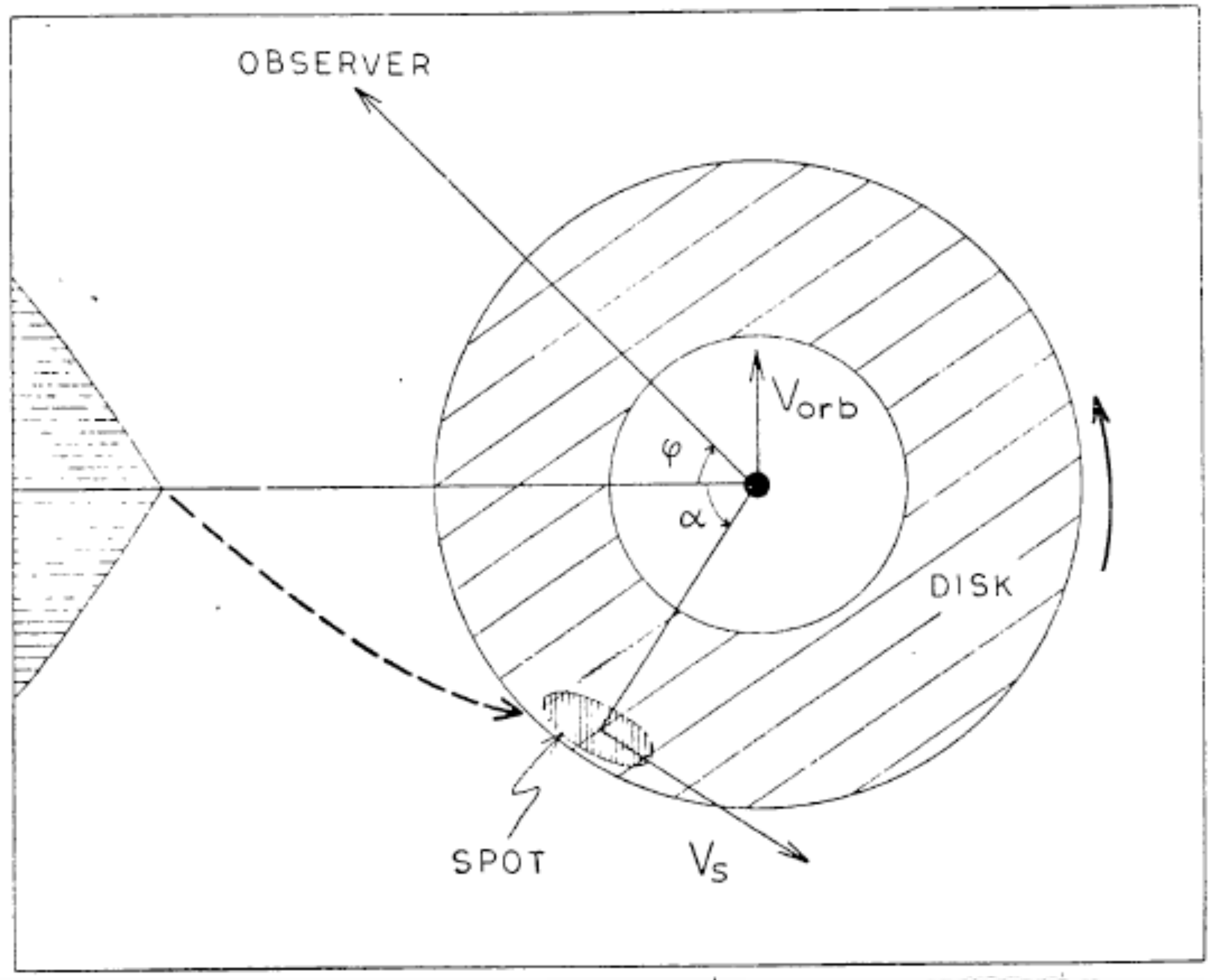
Schreiber & Hessman 1998



Hameury, Lasota & Warner 2000

1970

Eruptive Binaries. I. Hot Spots and Distortions of the Radial Velocity Curves



Arguments pointing to the location of a hot spot in the disk around the primary (blue) component rather than on its surface are reviewed.

Hot spots

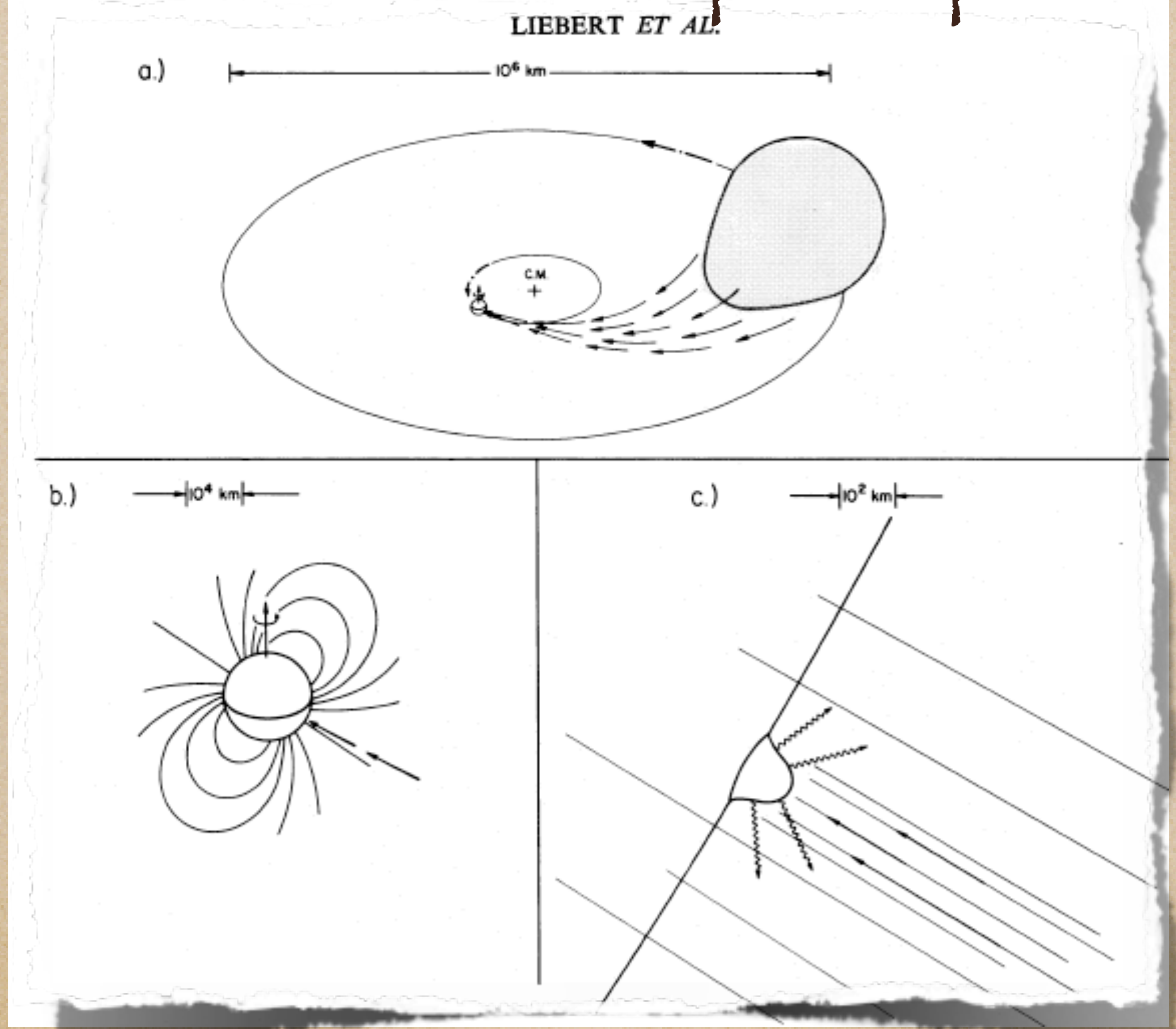
Two examples are considered. In VV Pup the observed amplitude is nearly identical with that of the orbital motion. In Z Cam, where variations of the observed amplitude and the phase shift are probably due to the variable contribution from the spot, the true amplitude is about 200 km/sec instead of the (mean) observed one of 144 km/sec.

, + 1971 on VV Pup

Hot spots

Two examples are considered. In VV Pup the observed amplitude is nearly identical with that of the orbital motion. In Z Cam, where variations of the observed amplitude and the phase shift are probably due to the variable contribution from the spot, the true amplitude is about 200 km/sec instead of the (mean) observed one of 144 km/sec. , + 1971 on VV Pup

but in 1978: VV Pup is a polar

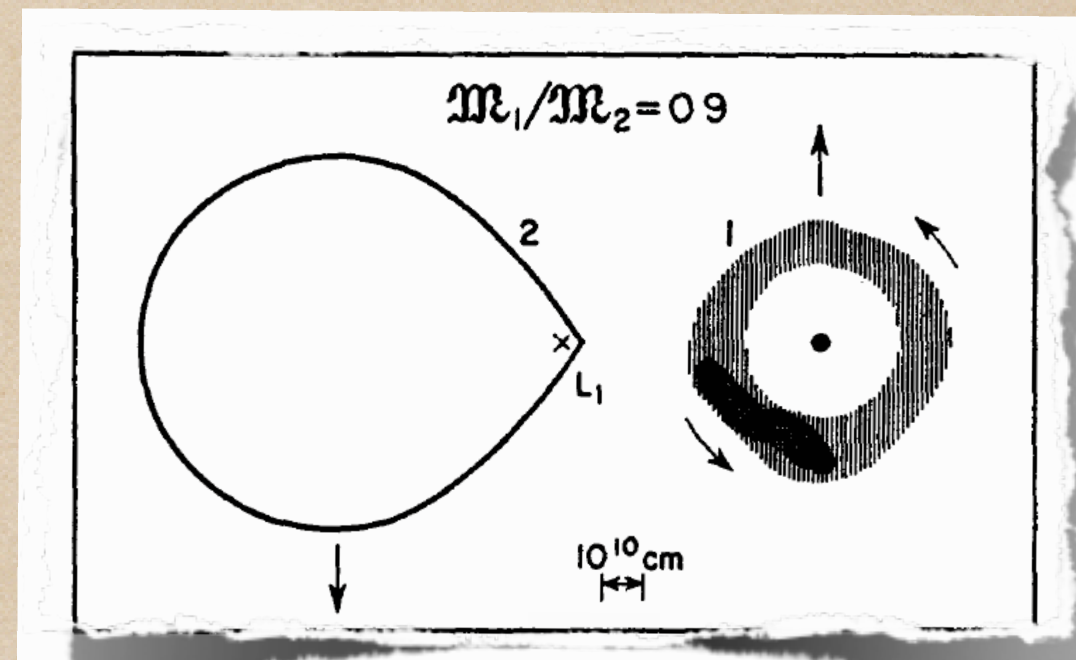


U Gem

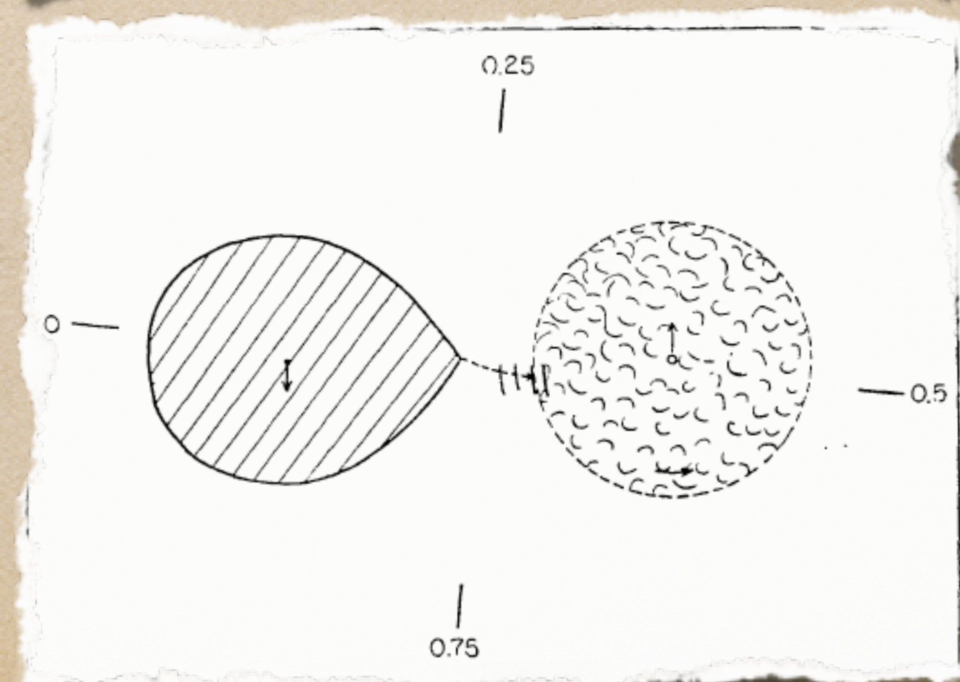
Where is the hot spot? Where is the outburst ?

Krzemiński 1965

(The secondary component responsible for outburst. Also Smak 1969 for SS Cyg.)



Smak 1971



1971

Eruptive Binaries. II. U Geminorum

The outburst of U Gem involves at least two, probably related phenomena. The luminosity increases due to the brightening of the central parts of the disk; shortly before maximum these are extensive enough to be partly eclipsed and a shallow, broad minimum is then observed with a characteristic phase shift of its central phase. The brightness of the spot either remains constant or changes only very slightly so that its eclipses are detectable during the initial rise and during the decline but not during the maximum. Simultaneously the dimensions of the disk increase considerably; this increase, as measured by the increase of the radius-vector of the spot, amounts to about 30 percent. During the declining light the disk contracts. Its contraction continues at a much slower rate until the next outburst.

Drs. Nather and Warner are particularly to be thanked for a preliminary copy of their paper on U Gem.

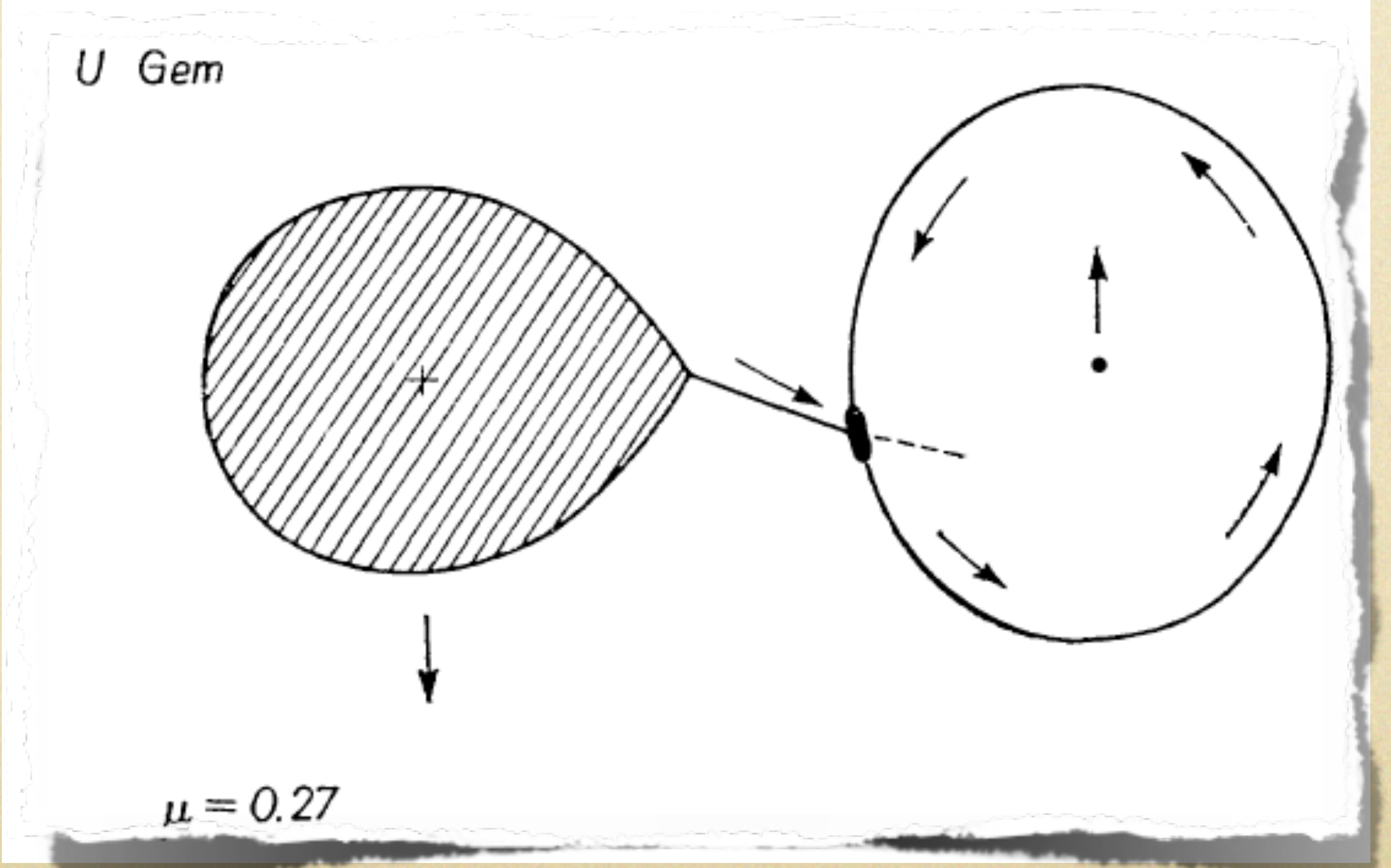
(nebulous ring)

1976

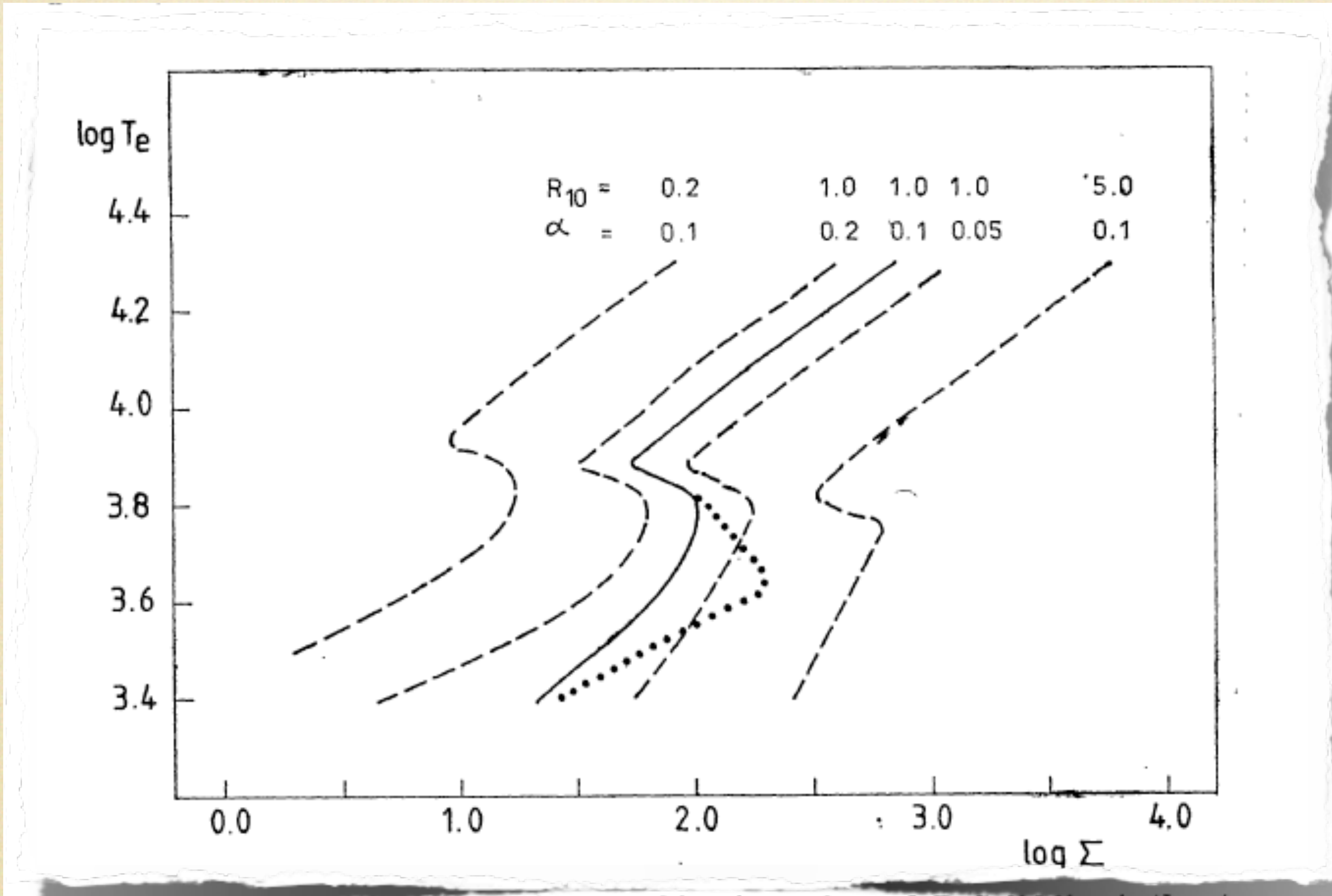
Eruptive Binaries VI. Rediscussion of U Geminorum

The relatively high luminosity of the hot spot (compared to the luminosity of the disk) is shown to exclude the possibility that a stationary accretion from the disk onto the white dwarf could take place between the outbursts. Thus the material coming from the secondary component must be accumulated in the disk. Its sudden accretion can provide more than enough energy for a typical outburst of U Gem.

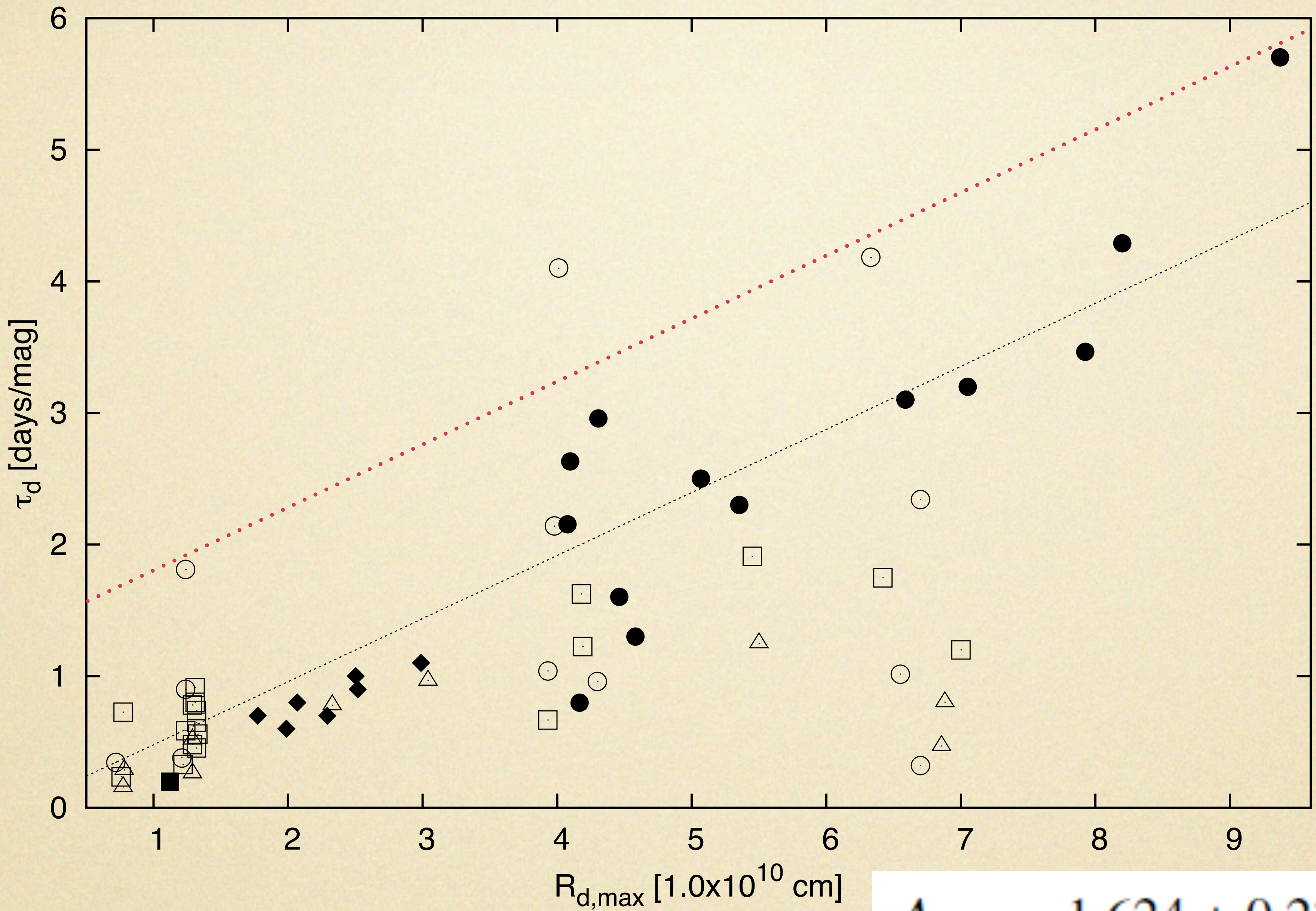
(Osaki 1974, Paczyński 1974)



1983/84: $\alpha_{hot} > \alpha_{cold}$



Hot disc viscosity: $\alpha_h \gtrsim 0.1$



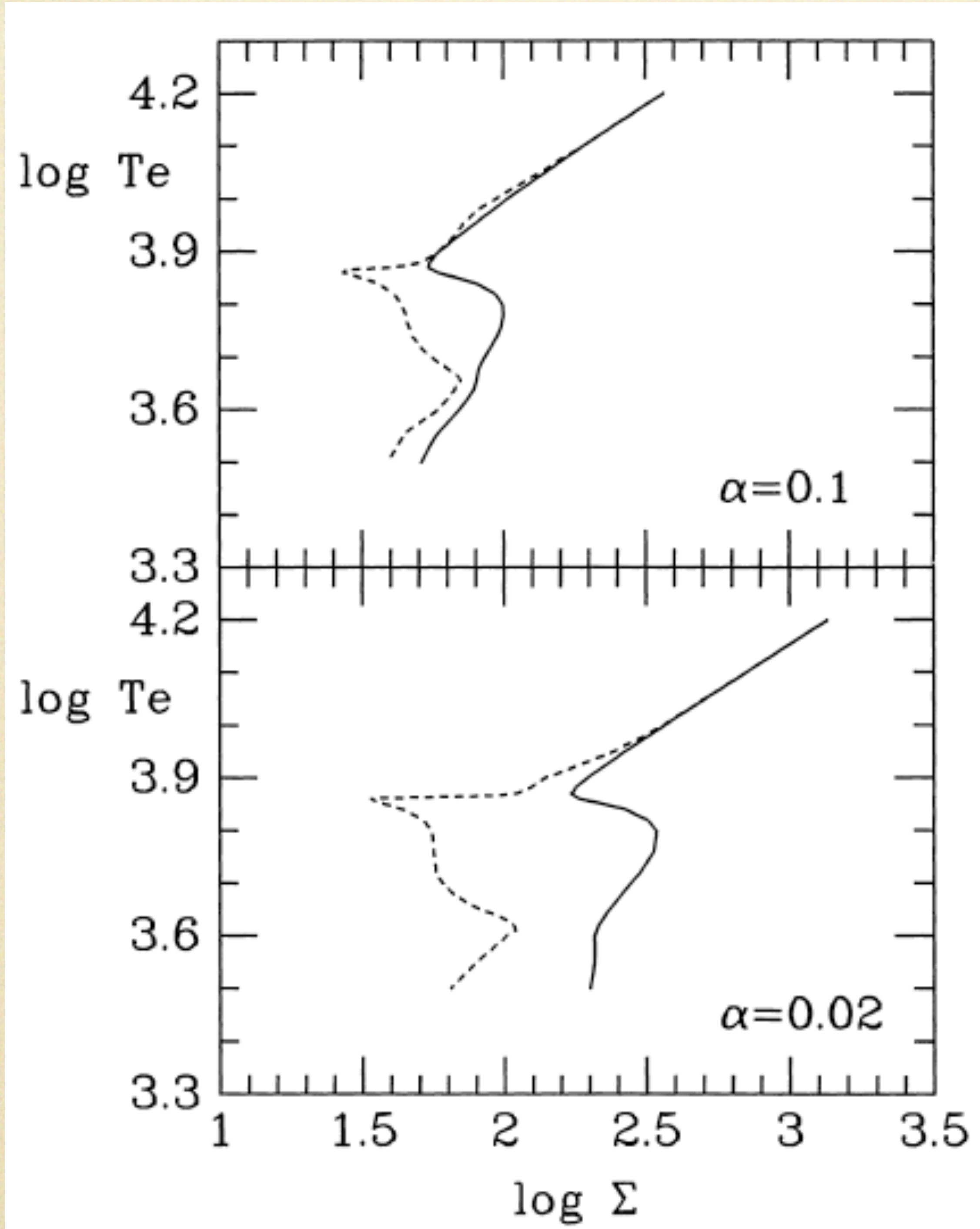
$A_{obs} = 0.48 \pm 0.03$

$$\tau_d = A \cdot R_{d,max}$$

$A_{0.05} = 1.624 \pm 0.235$ for $\alpha_h = 0.05$
$A_{0.1} = 0.525 \pm 0.128$ for $\alpha_h = 0.1$
$A_{0.2} = 0.338 \pm 0.036$ for $\alpha_h = 0.2$
$A_{0.3} = 0.151 \pm 0.031$ for $\alpha_h = 0.3$.

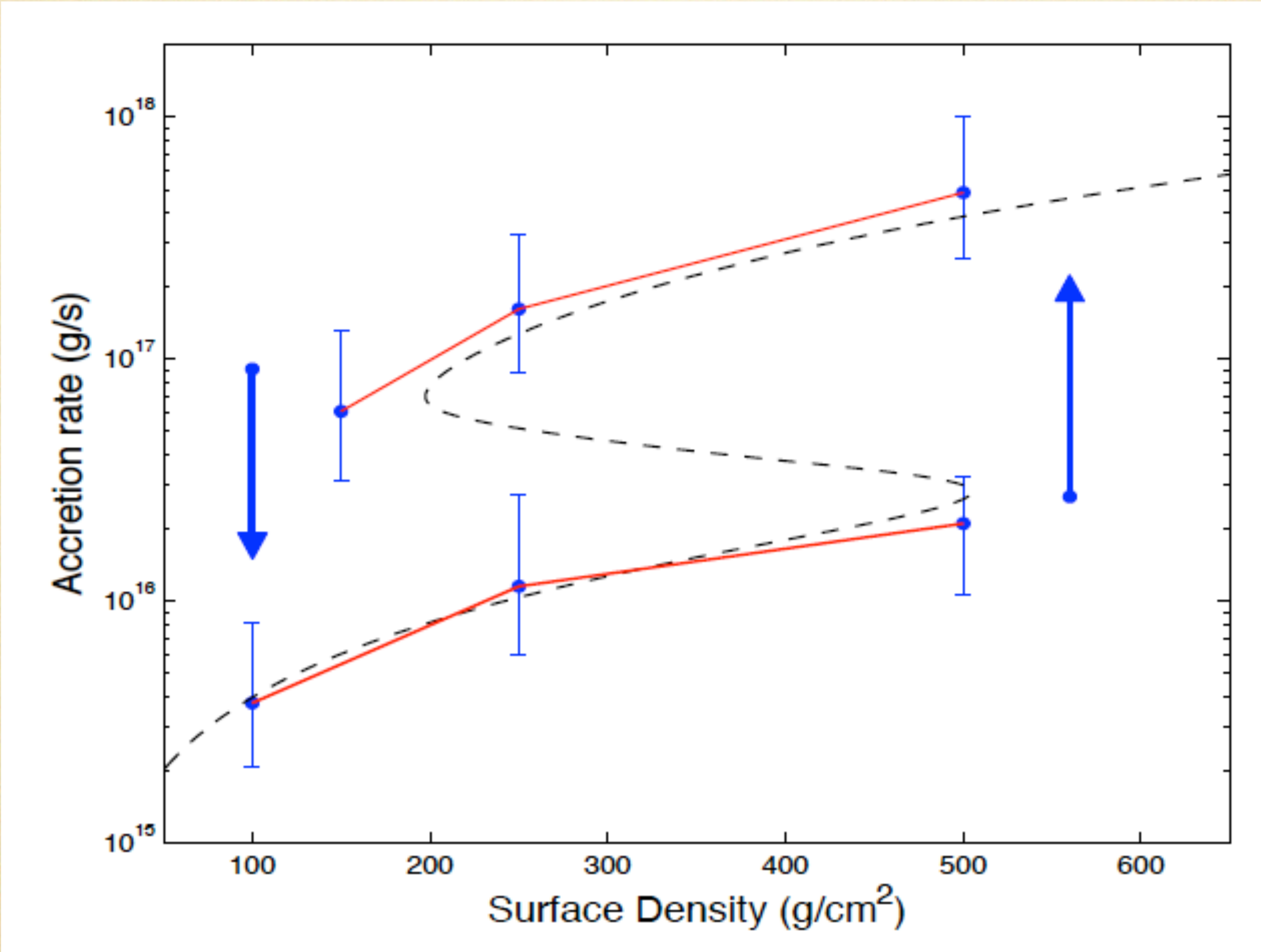
Smak 1999; Kotko & Lasota 2012

Convective viscosity ?



1997

MRI plus cooling law



Latter & Papaloizou 2012

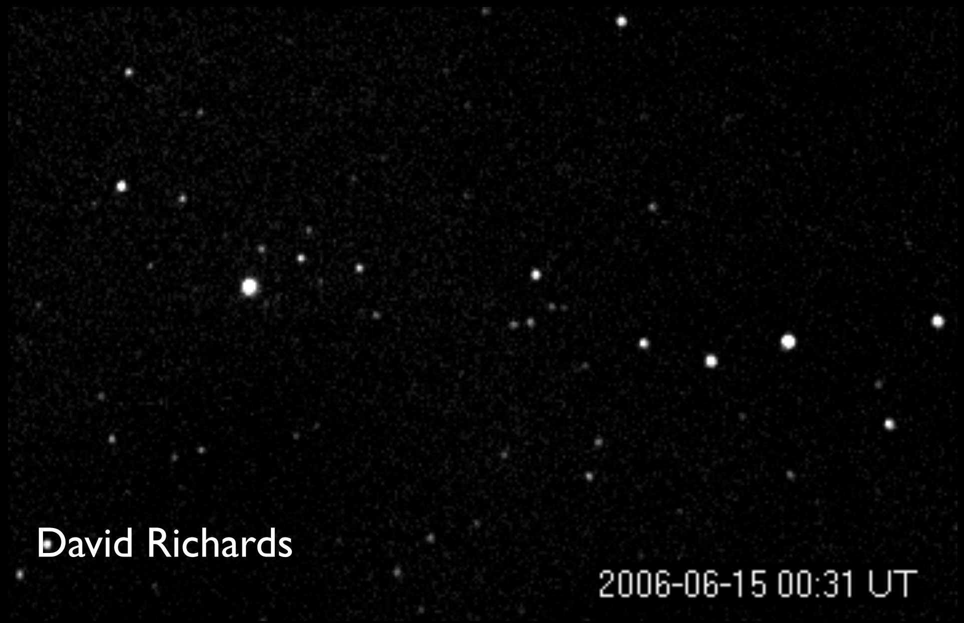
My contribution to Joe Smak's research

Note added after the Colloquium. Jean-Pierre Lasota, in his review talk, brought to the attention of those present at the *Colloquium* a very important fact concerning the occurence of superoutbursts (which, strangely enough, remained largely unknown!): In 1985 October/November U Gem underwent a *superoutburst* lasting for 45 d (Mason et al. 1988). For the models of superoutbursts, which were tailored *specifically* to explain their occurence *exclusively* in the very short period, very low mass ratio dwarf novae of the SU UMa subtype, the superoutburst of U Gem (unless it can be explained as a completely different kind of event) implies that *all of them may actually be wrong!*

(Keele conf. 1996)

Dear Joe:

Niech Ci gwiazdka pomyślności nigdy nie zagaśnie !



(English translation: MANY HAPPY RETURNS !)