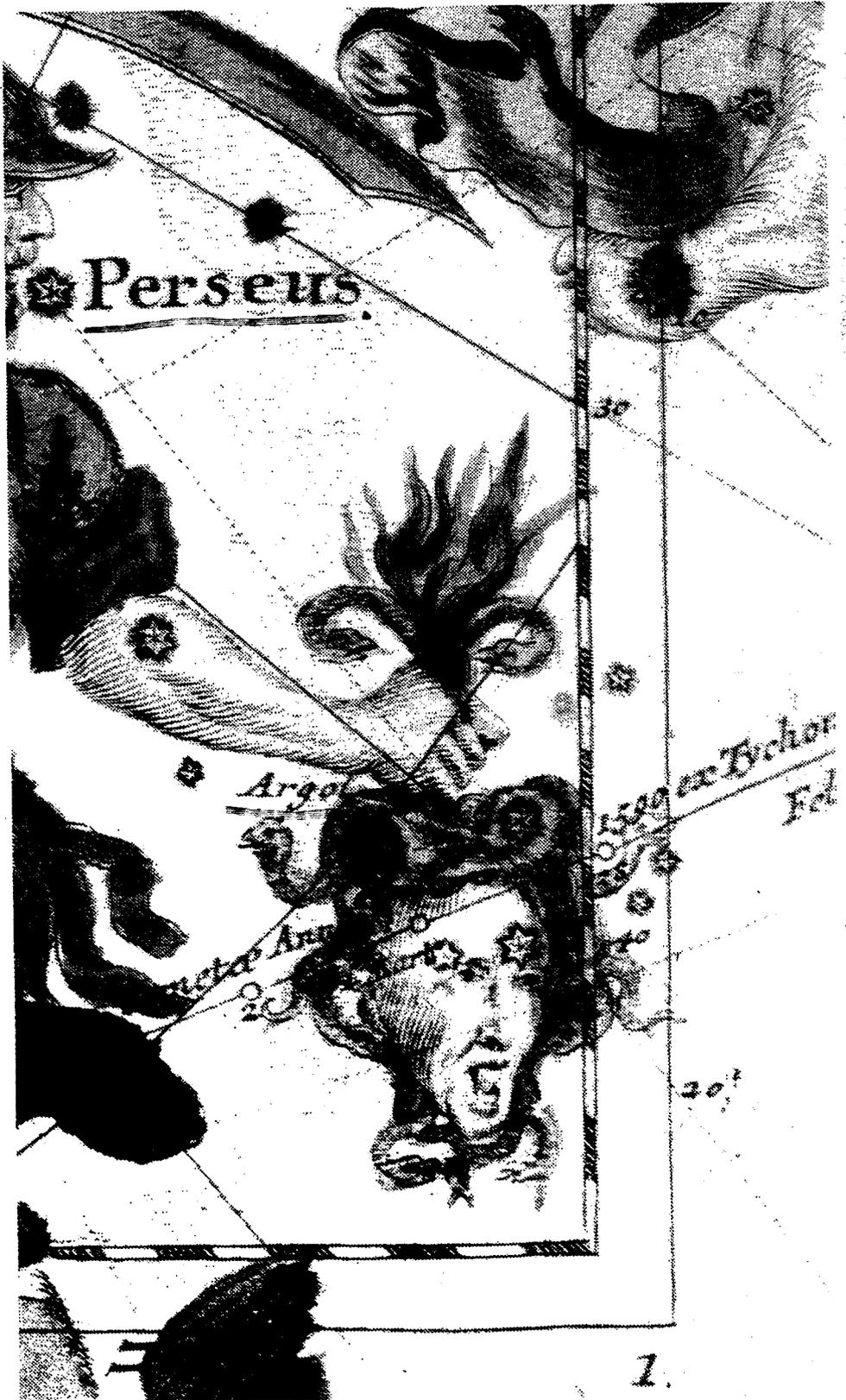


# A Closer Look at Evolved Binary Stars

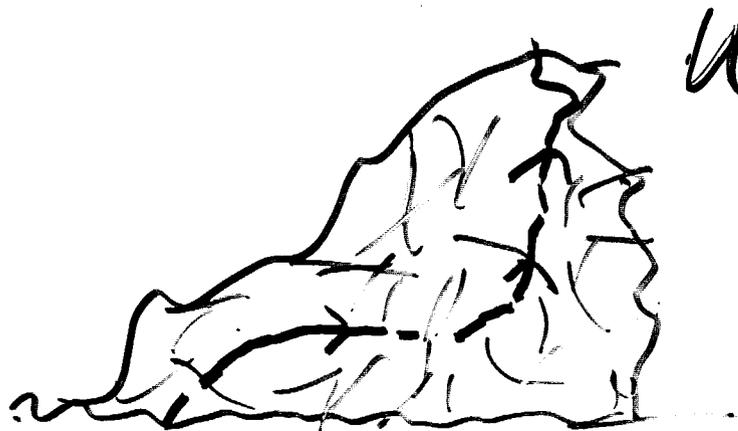
Virginia  
Trimble

Physics:  
UC Irvine

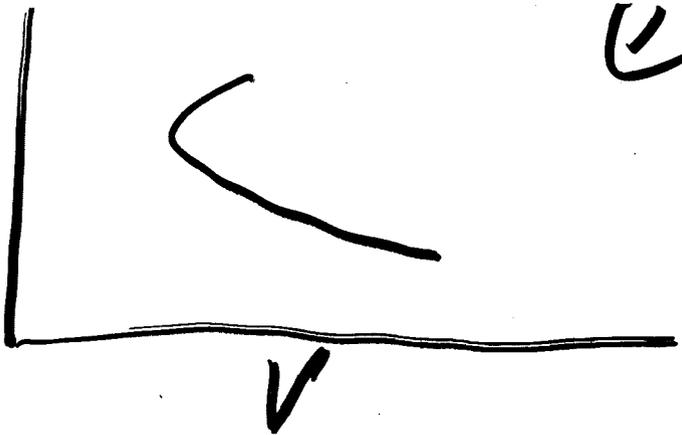
Astronomy:  
U Maryland



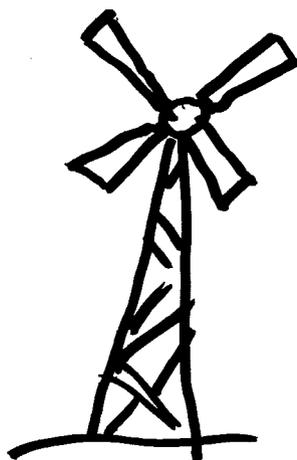
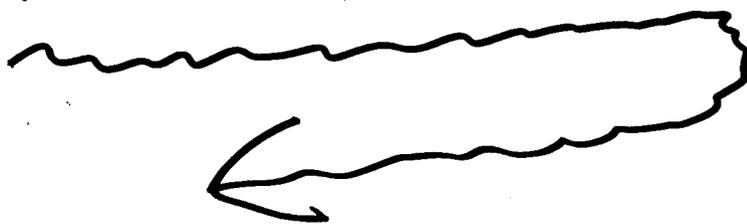
# Interferometry



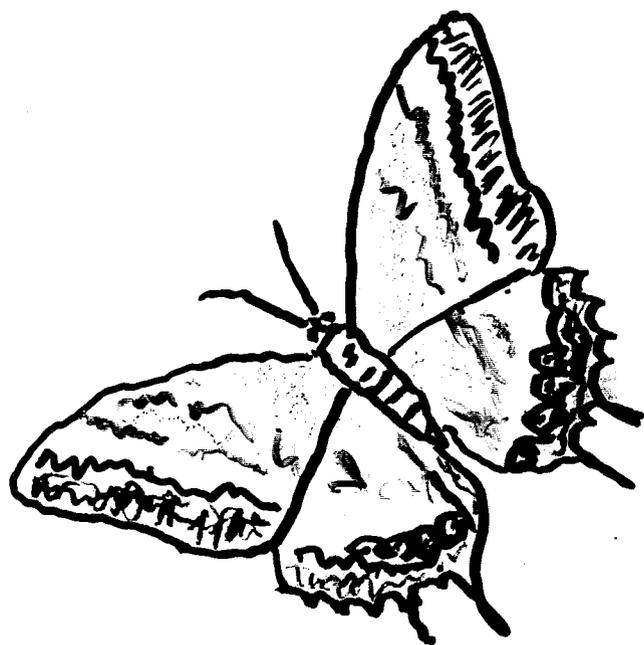
u



# Adaptive Optics



# NGST



(LSMFT?)

We shall never understand [ $\beta$  Lyrae]  
until we find a net and  
fetch the thing down

Henrietta S. Leavitt given  
by Anthony Maury quoted by Cecilia M-G  
quoted by Dorrit Hoffleit

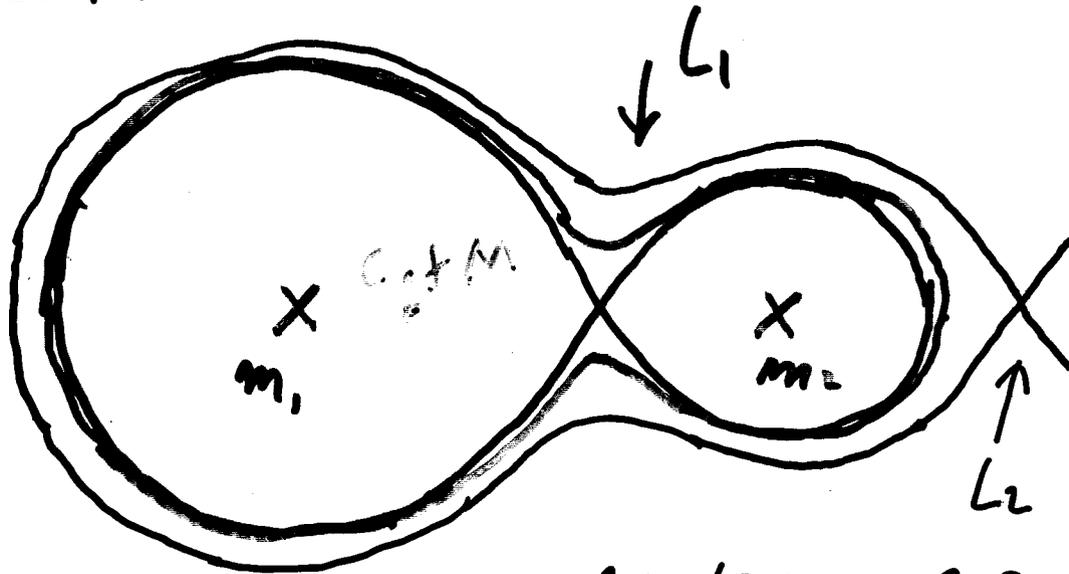
First conf on  
interacting binaries  
IADC 6 Sept 69  
Elsinore DK

Last (?) conf. on  
full topic 1995  
NATO ASI Camb UK



# Core goal of CBS Research L3

$N(m_1, m_2, a, e, t)$   $\xrightarrow{\text{evolve}}$  Full RANGE of types in correct proportions  
 $J, B, \text{comp}$   $\nearrow$  environmental effects  
 all of single  $\nearrow$   
 $\&$  evolve



Roche geometry: equipotentials of  
 The restricted three-body problem  
 in co-rotating coordinates

Expected results: mass transfer at  $L_1$   
 mass loss at  $L_2$  — also, of course,  
 tr/loss of ang. mom. of  $J/m \Rightarrow$  average

# The Zoo

→ mass

⌊

time

WUMa1 + SV Cen (contact)

Ap 1Bp, blue stragglers, SX Phe, LRV<sup>+</sup> (7 Cir)

RS CVn<sup>+</sup> 5 Aur, VV Cen h

R Arae → W Serp → GG Car → β Lyrae → V453 Sco  
→ U Cen<sup>h</sup> → A Per

~~AlgoL + hi M analogs~~

AlgoL + hi M analogs

5 Aur? FK Comae (EB phases - V Hya?)

WR + Of, OBN, He A<sup>+</sup> (Not WN 8, 9 =  
Thorne - Zytkov: 11)

5 stars (+ Ba, CH subg, dwarf carbon,  
with no Te Yellow SG<sup>s</sup>

PN binary nuclei → V471 Tau

CV types - NL, classed Ne, RNe, DNe,

Symbiotic, polars, DQ, AM Nov types ....

AM CVn

Xray bin<sup>+</sup> - LM, Be, HM, BH... SS 433, He A<sup>+</sup>

AIC?

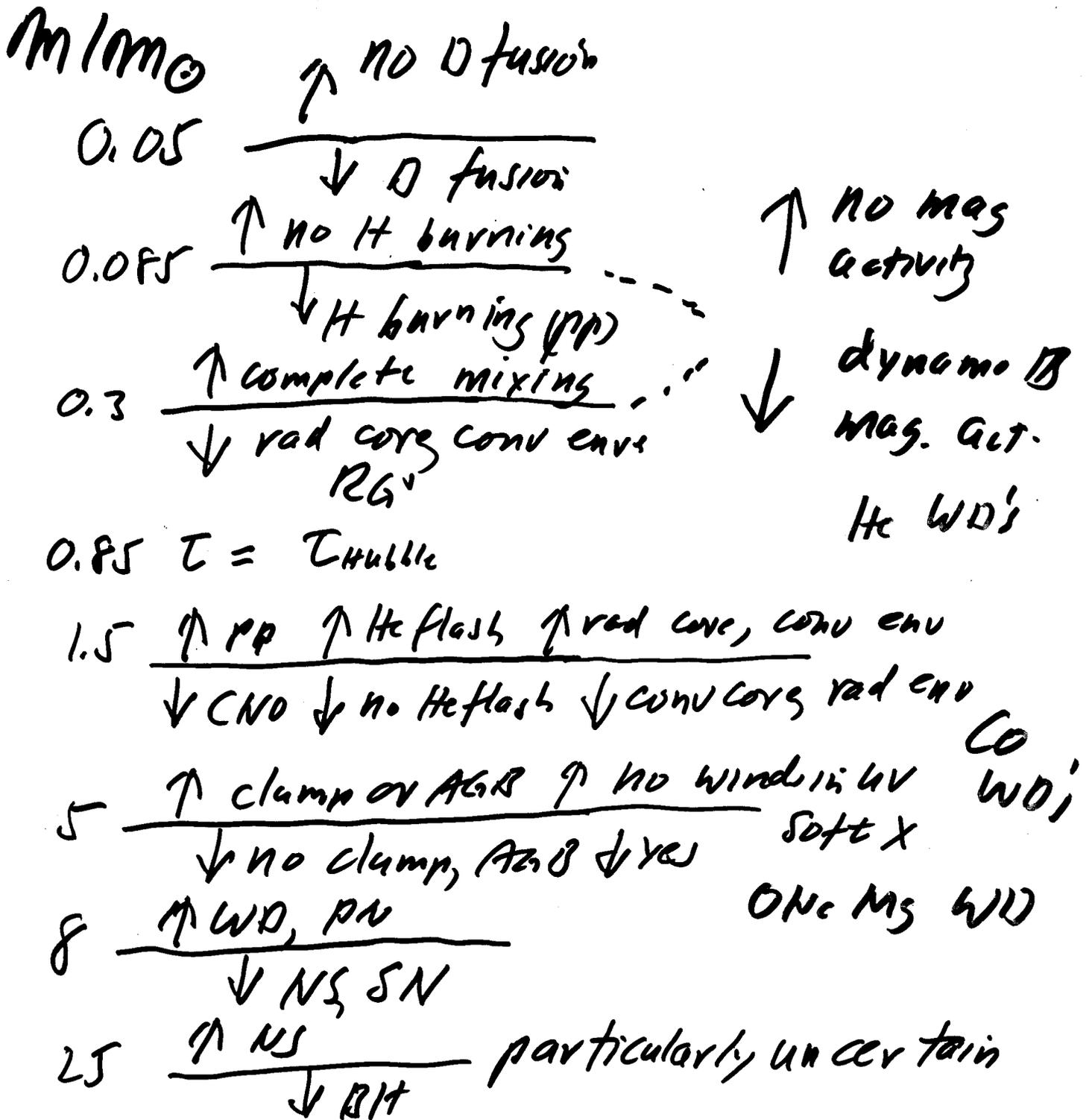
binary + msec puls

GRB<sup>s</sup> (some)

Binary BH - Interferom  
probably not useful

# Single Critical Points

7



CBS effects - all critical  $m_i$ ; ↑ (mass loss)

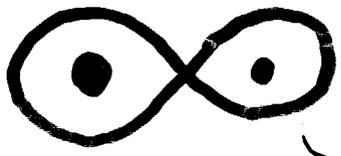
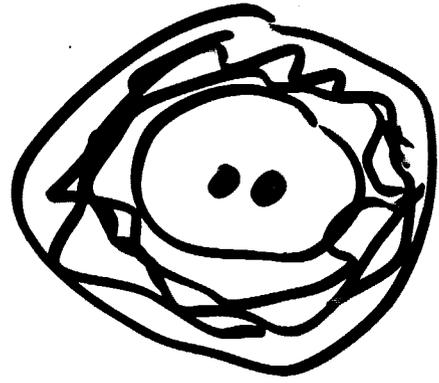
- synchronized vortices → activity persists
- GPE available at several stages

CBJ evoln (precis of pictures) ⑥

pre MS



OV



OR



W UMa ch



J loss due to magnetized wind

Some feeding in  $\sim 10^5$  yr



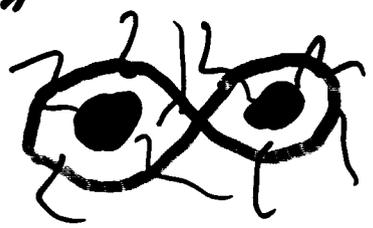
OV



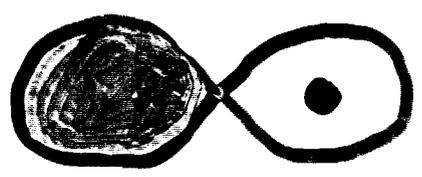
FH Comae

bl. str.

Nuclear evolution



$M_1 \sim M_2 =$   
RS CVn



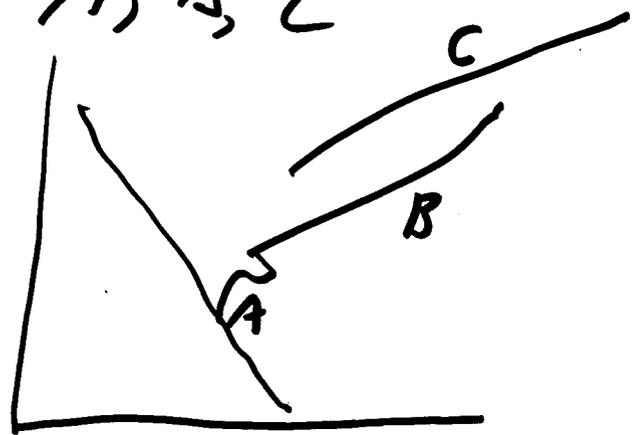
CEB possible

$\Delta(J/m) \gg$  average system stride

# 1st RLOF, Cases A, B, C 12

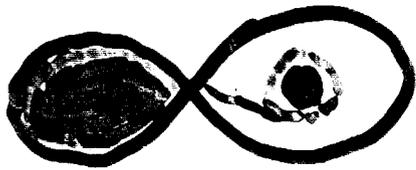
$M_1 > M_2 \therefore$

Lobe 1 shrinks as  
 $A'$  move together



Mass transfer on H-H time scale  
 (Serpentis?  $\beta$  Lyrae? ...)

When  $M_1' < M_2'$  Lobe expands



Algol: mass transfer on

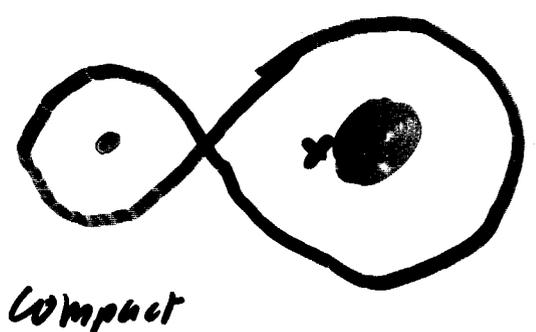
nuclear time scale, stream,  
 disk, hot spot - resolve them?

- $M_1'$  → WD binary PUN → V471 Tau  
 do they look different?
- $M_1'$  → NS wind fed HMHBG (Vela X-1)  
 unbinding possible
- $M_1'$  → BH wind fed BH XRB (Cyg 1)

$a <$  initial  $v_1 + v_2 =$  CER sign.

$M_2'$  erosion by radio/xrays from  $M_1'$  (WD  
 possible (1957) + 20 etc)

OR: Kick velocity in NS/BH case, ~~OR~~  
 → runaway OB, WR... binary  $7^{th}$



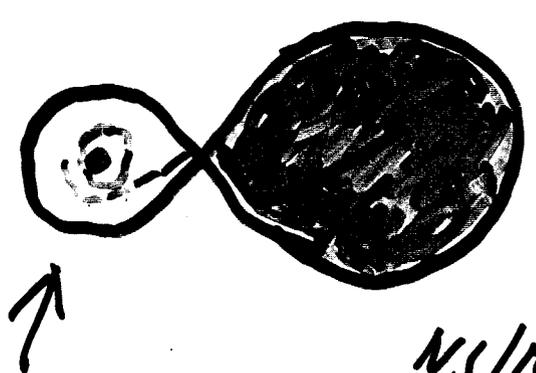
renewed detachment

MS, post MS

2<sup>nd</sup> RLOF, A, B, or C

WO → CV type

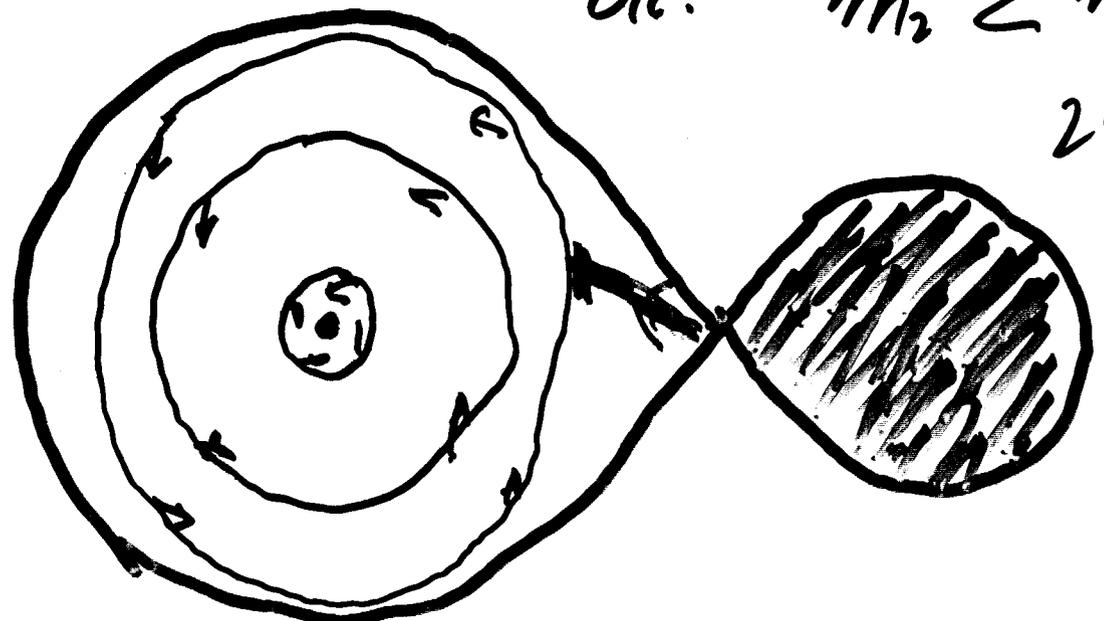
NS/BH → LMXRB



NS/BH + OB - gashed?

disk, stream, hot spot

OR:  $M_2 \ll M_1$



2<sup>nd</sup> reversal of mass ratio

note non-circ disc stream lines

Possible outcomes:

CEB (mass + J loss) — single PBG — Thorne Zytka  
 — single BH hi alm

$m_2 \rightarrow$  WD  
 $m_2 \rightarrow$  NS  
 $\downarrow$  BH

SN Ibc if stripped  
 unbinding more likely  
 if  $m_2'' > m_1''$

|       |          |         |        |
|-------|----------|---------|--------|
| seen? |          | $m_1''$ |        |
|       | WD       | NS      | BH     |
| WD    | many (1) | Yes     | NO (3) |

|         |        |        |                  |        |
|---------|--------|--------|------------------|--------|
| $m_2''$ | NS     | Yes    | 1913 + 11<br>Yes | NO (2) |
| BH      | NO (4) | NO (3) |                  | NO (5) |

- (1) none of  $P < 1d$   $m_{tot} > Ch.$  (2) expect when  $\exists$  10-20 NS x 2  
 (3) expected (4) not expected  
 (5) detection difficult  $\exists$  no psr x 2

What do we MOST want to see? <sup>(9)</sup>

angular momentum loss - collimated jets?  
- Spatter in disks?? (like YSOs)  
(AGN jets)

mass loss - imaging in lines?? radio  
rims of  
assoc. of these with  $\Delta P$   $\beta$  Lyrae

composition of stuff shed - Colliding  
imaging spectroscopy | wind,  
WR stars

nb NOT clear that maxsec will  
help enormously

Second best

see shape of RLOF  $A^*$  - R  $A_{gr}$  is not  
circle + has  $v \propto v(\lambda)$  w/ HST

see disk (continuum), stream, hot spot <sup>(lms)</sup>

in Algols, CVs, XPER<sup>s</sup>.....

current data = time resolved spectra

Some what more tractable

# Third best

Colliding wind confirmation (coronal lines,  
see magnetic braking as spot cycle  
corr. of DP (Doppler tomography))

Shapes and structures of PNC from

a. single  $A'$       b. wide  $bn'$

c. PNV of orbit  $P \sim$  few hours

eg  $4U\text{Sc} = \text{Abell } 63$  ( $\sim$  square)

Sign. for rotation of ejecta 2))

Catch really early like

SAO 85766 (A5  $\rightarrow$  B0 1940-99)

+ He 1357

Additional ubiquitous problem:

dynamic range

Concl: if I were going There, I

wouldn't start from here