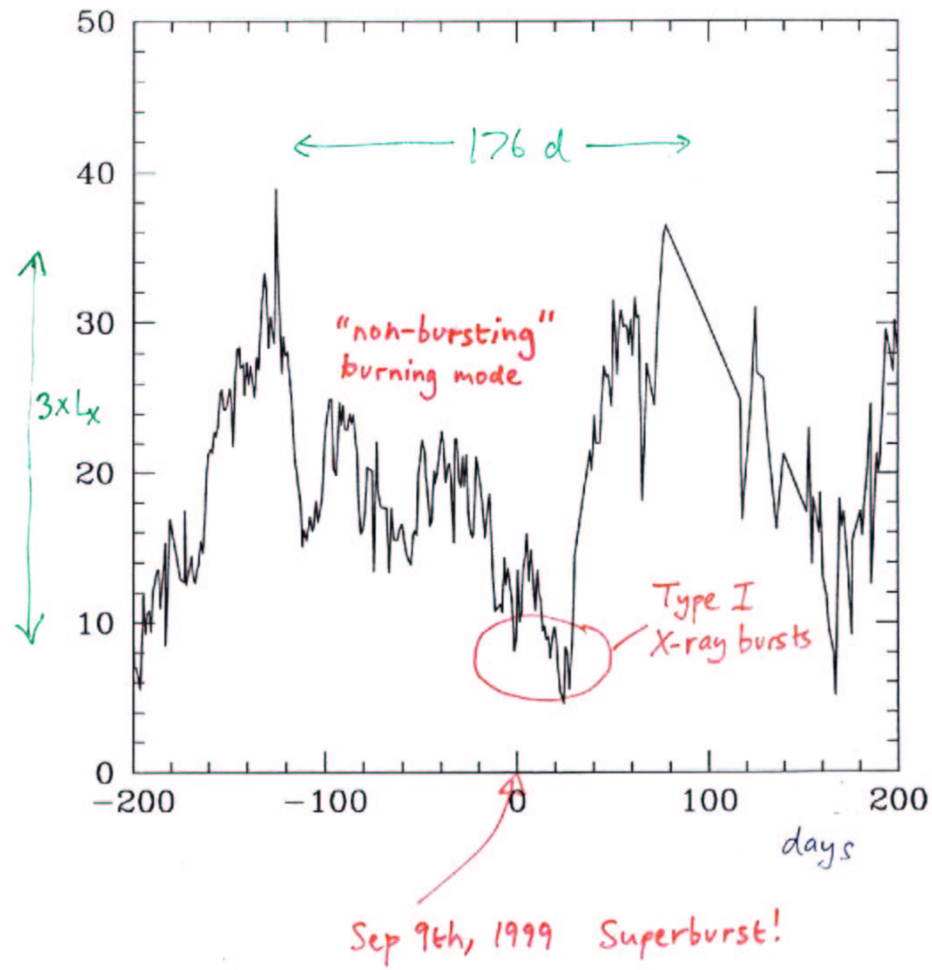
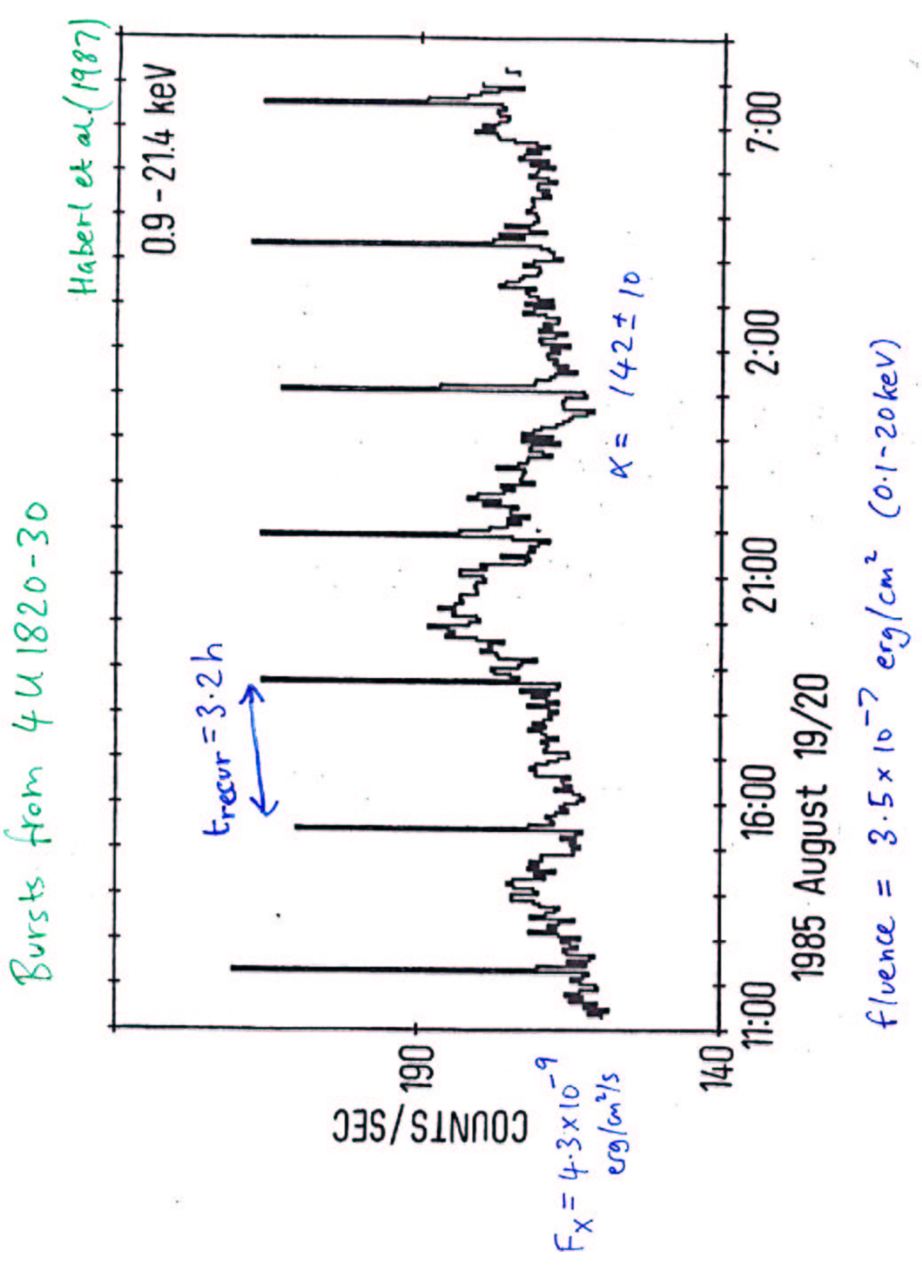
Constraining Evolutionary Models of 4U1820-30 using Type I X-ray bursts

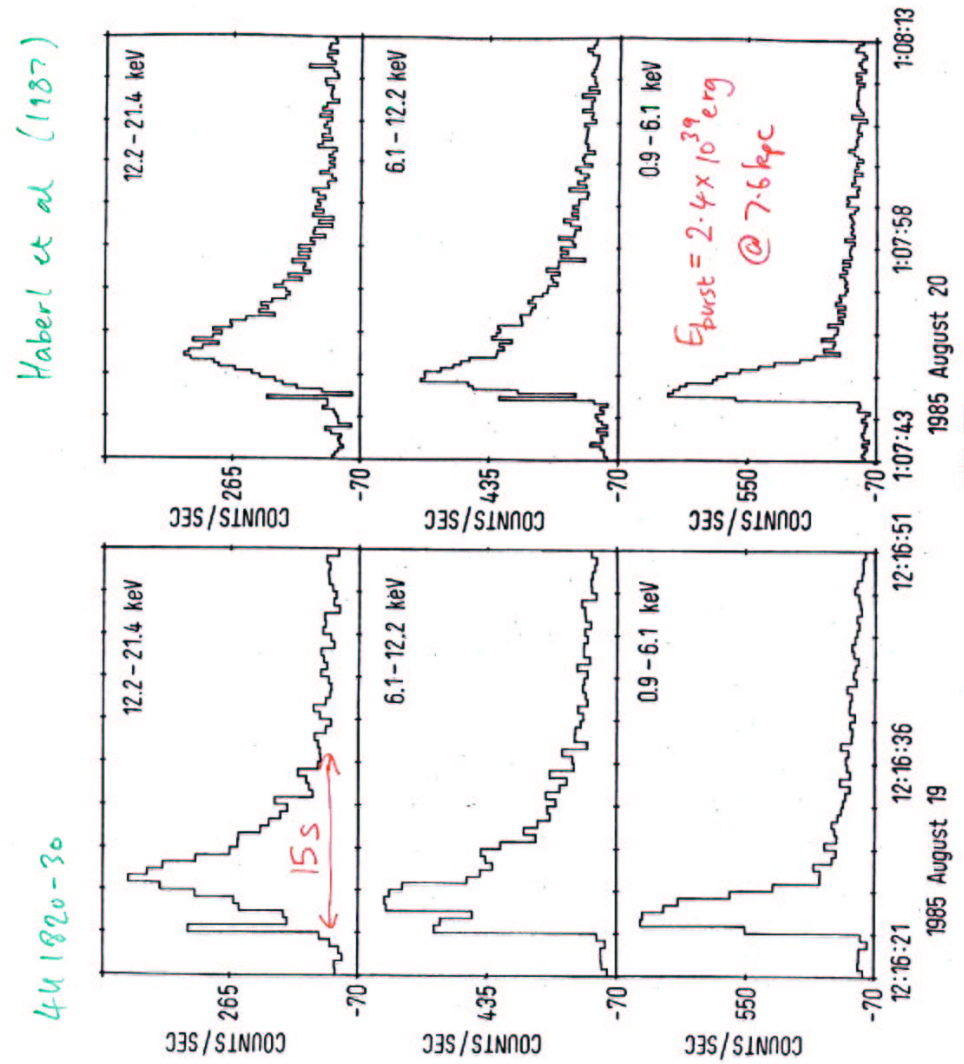
Andrew Cumming
UC Santa Cruz

ASM lightcurve for 4U 1820-30



$L_X \approx (3-9) \times 10^{37}$ erg/s (@7.6 kpc)


Bursts from 4U 1820-30
Haberl et al (1987)
0.9 - 21.4 keV
t_recur = 3.2h
α = 142 ± 10
COUNTS/SEC
190
140
11:00
16:00
21:00
2:00
7:00
1985 August 19/20
fluence = 3.5 x 10^-7 erg/cm² (0.1-20 keV)
F_x = 4.3 x 10^-9 erg/cm²/s


Haberl et al (1987)
4U 1820-30
12.2 - 21.4 keV
6.1 - 12.2 keV
0.9 - 6.1 keV
E_burst = 2.4 x 10^39 erg
@ 7.6 kpc
15s
COUNTS/SEC
265
435
550
-70
1:07:43
1:07:58
1:08:13
1985 August 20
12:16:21
12:16:36
12:16:51
1985 August 19

Some numbers

inferred accretion rate

$$\dot{M} = \frac{(4\pi d^2) F_X}{(GM/R)} = 2.4\times 10^{-9}\, M_\odot/yr$$

$$\langle \dot{M} \rangle \approx 2\dot{M} \approx 5\times 10^{-9}\, M_\odot/yr$$

energetics

$$\alpha = \frac{\text{persistent fluence}}{\text{burst fluence}} \approx 140$$

for pure He burning $Q_{nuc} \approx 1.6$ MeV/nucleon

$$\Rightarrow \alpha \sim \frac{200}{1.6} \sim 125$$

ignition mass

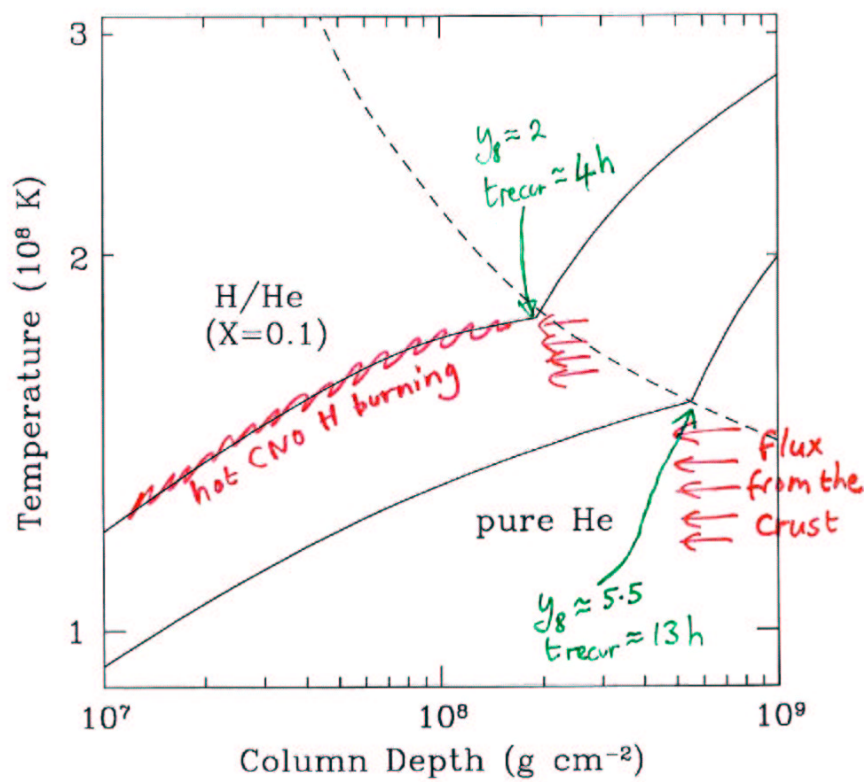
energy $= 2.4\times 10^{39}$ erg @ 7.6 kpc

if $Q_{nuc} = 1.6$ MeV/nuc $\simeq 1.6\times 10^{18}$ erg/g

$\Rightarrow$ $\Delta M = 1.5\times 10^{21}$ g

in 3.2 h, the mass accreted is 1.8×10^{21} g

Ignition models at $\dot{m} = 1.2\times 10^4\, g/cm^2/s$



I take $Q_{crust} = 0.1$ MeV/nucleon

ignition models Cumming & Bildsten (2000)

How much hydrogen do you need?

requiring $F_{CNO} > F_{crust}$

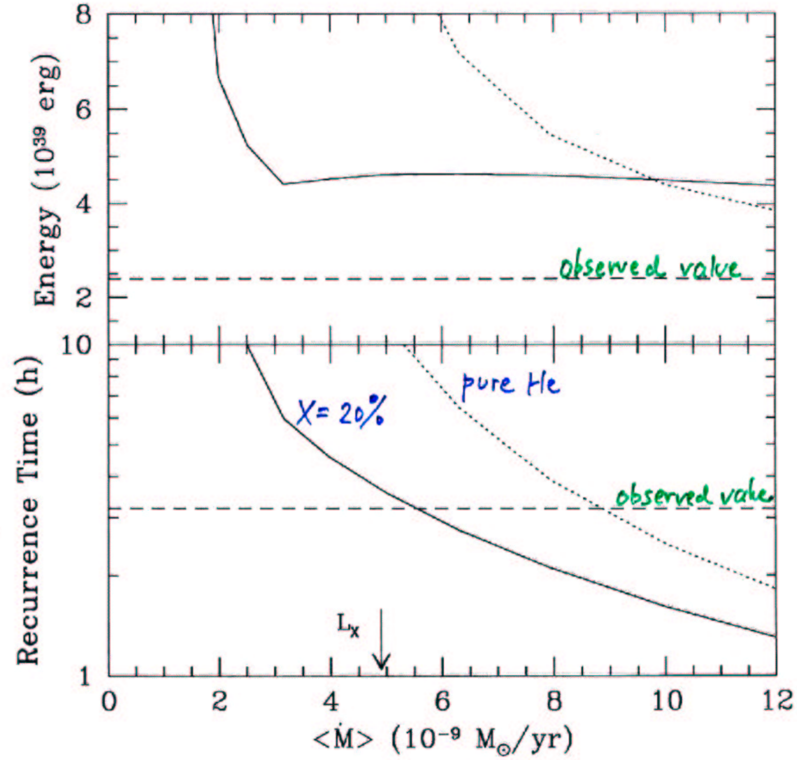
gives

$$X \gtrsim 0.03 \left(\frac{Q_{crust}}{0.1\,\mathrm{MeV}}\right)\left(\frac{\langle\dot{M}\rangle}{2\dot{m}}\right)$$

$$Z_{CNO} \gtrsim 3\times10^{-3} \left(\frac{Q_{crust}}{0.1\,\mathrm{MeV}}\right)\left(\frac{t_{recur}}{3\,\mathrm{h}}\right)$$

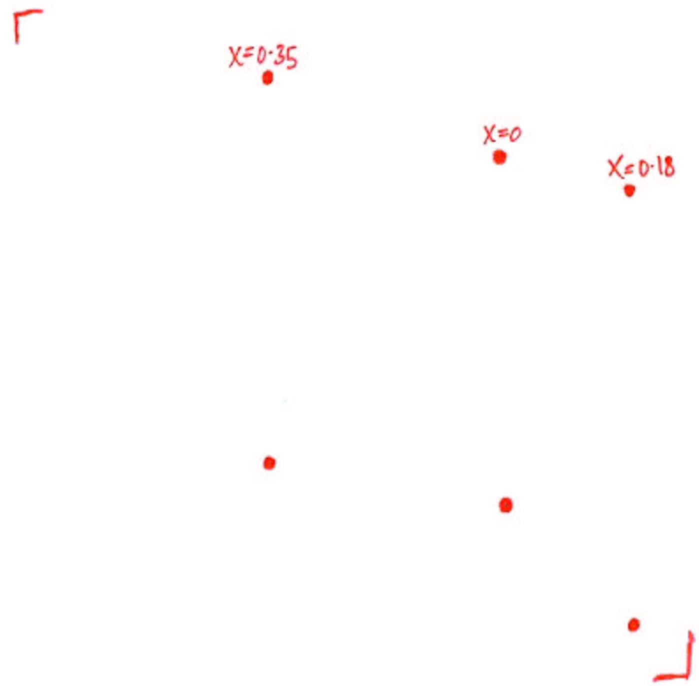
evolutionary models give $X \approx 0.1-0.35$
(Podsiadlowski et al)
Fedorova & Ergma

NGC 6624 is metal rich, $[Fe/H] \sim -0.4$



instantaneous $\dot{M} = \frac{\langle\dot{M}\rangle}{2}$

Podsiadlowski et al. evolutionary models



Superburst

- for the pure He case

  if $\dot{M} \approx 2\times$ higher

  recurrence time is ≈ 1 yr

  rather than >10 yr (as found by Strohmayer & Brown 2002)

- if H is present

  it will affect carbon production

  $$3\alpha \rightarrow {}^{12}C$$
  $${}^{12}C + 2p \rightarrow {}^{14}O$$

  2 protons per carbon $\Rightarrow$ $X = \frac{2}{7}$

Summary

- basic energetics points to burning of (almost) pure He
- hydrogen helps to get short recurrence times (even a little bit $X \gtrsim 3\%$, $Z_{CNO} \gtrsim \frac{1}{10}$ solar)
- not possible to say definitively H is present

  particular evolutionary models ($\dot{M}, X$) can be excluded
- other effects

  Superburst : Carbon production
  recurrence time

  Type I burst duration as a fn. of H fraction