Formation and Evolution of Black–Hole X–Ray Binaries

High–Mass companions

Persistent emission

(3)

- ☆ Black- Hole formation
  - masses
  - progenitors
  - asymmetric kicks

Low–Mass companions

Transient emission

(14)

- ☆ X- Ray Binary formation
  - stellar companions
  - orbital periods

- ☆ Black- Hole X- Ray Binary evolution ☆
  - conservative or not ?
  - persistent or transient ?
  - luminosity evolution ?

Observed Properties:

- Black- Hole masses: 3 - 18 M_o
- Orbital Periods: 0.2 - 35 days
- Donor masses: <1- 2 M_o , 6.5 M_o
  spectral class: most V, a few III and IV

Main evolutionary phases:

- BH progenitor and companion
- Common- Envelope and spiral- in
- BH formation
- Roche- lobe overflow and mass transfer

Black–Hole Masses

? ? peaks and gaps and maxima ? ?

current observations:

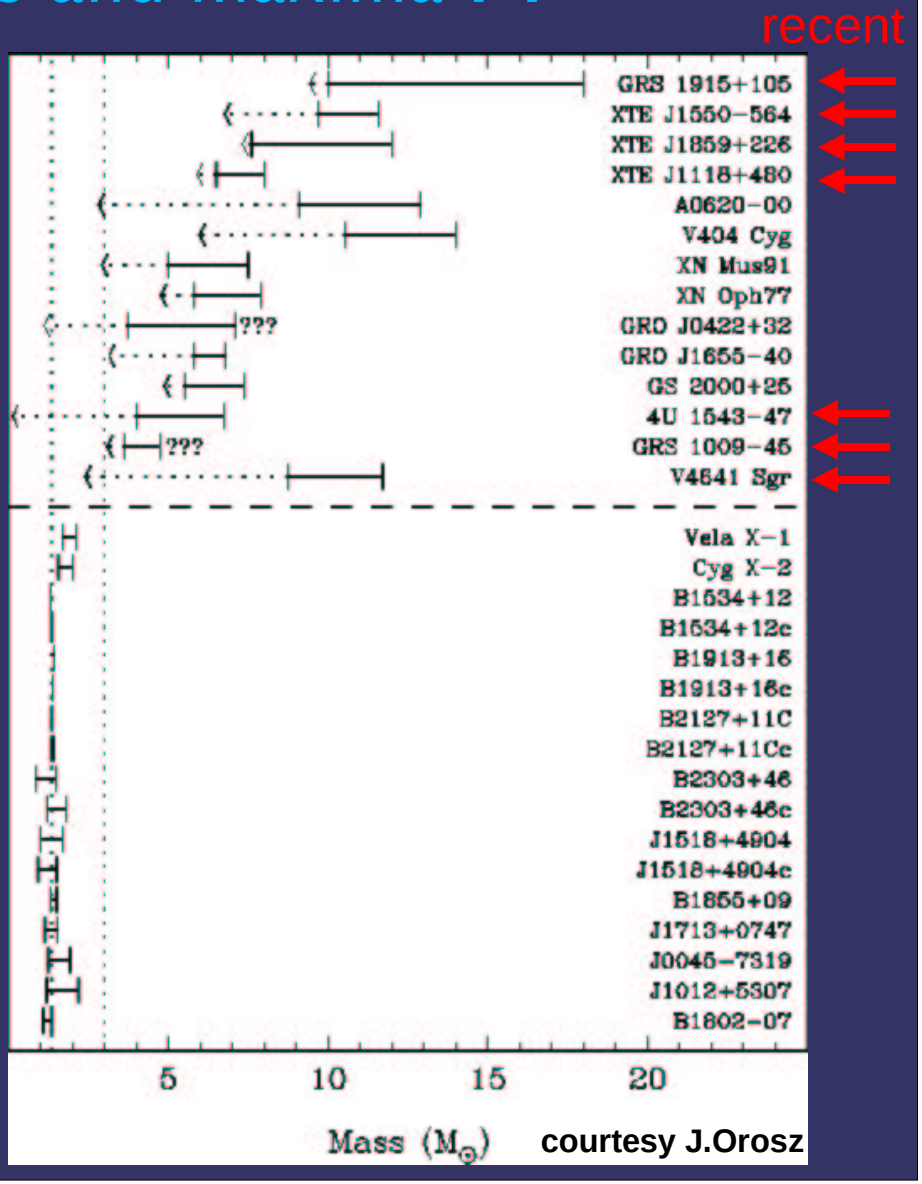
Bailyn et al. 1998
peak at ~7 M_o
(at 50% C.L.)

Bailyn 2001
no peak
maybe a gap
at 3–5M_o ?

Maximum BH mass ?

V404 Cyg : 10–14 M_o

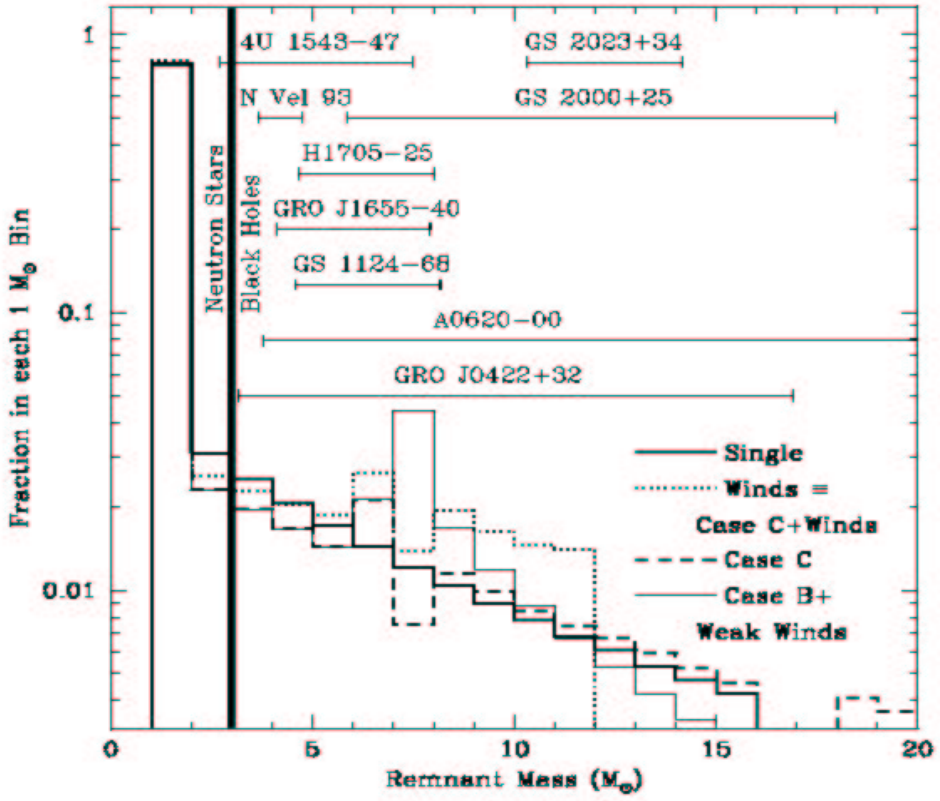
1915+105 : 14 ± 4 M_o



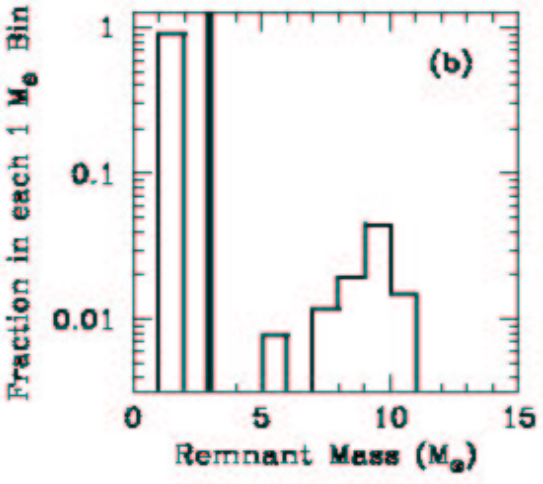
Black Hole mass distributions "in theory":

continuous and roughly flat
when effects of stellar winds and
binary evolution are included

with current understanding of
the dependence of SN explosion energy
on progenitor mass



with an artificially induced step in
the dependence of SN energy
on progenitor mass

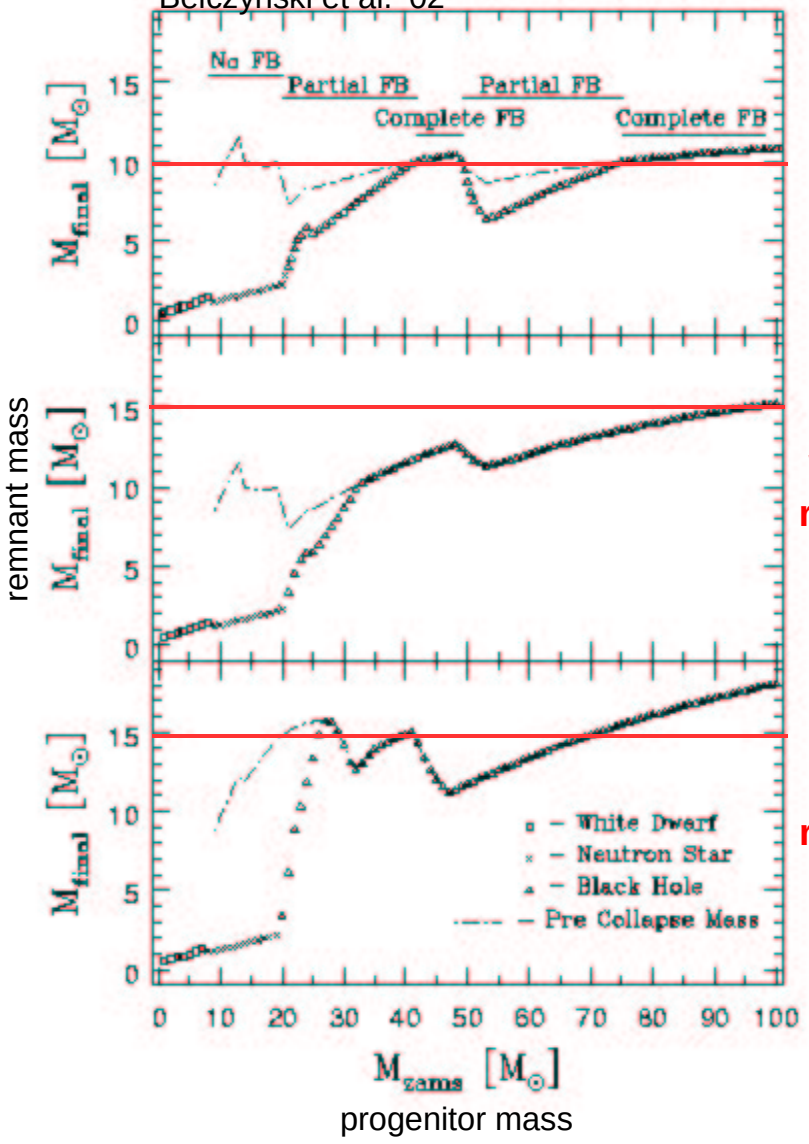


Fryer & Kalogera '01

Maximum BH mass

from single−star evolution:

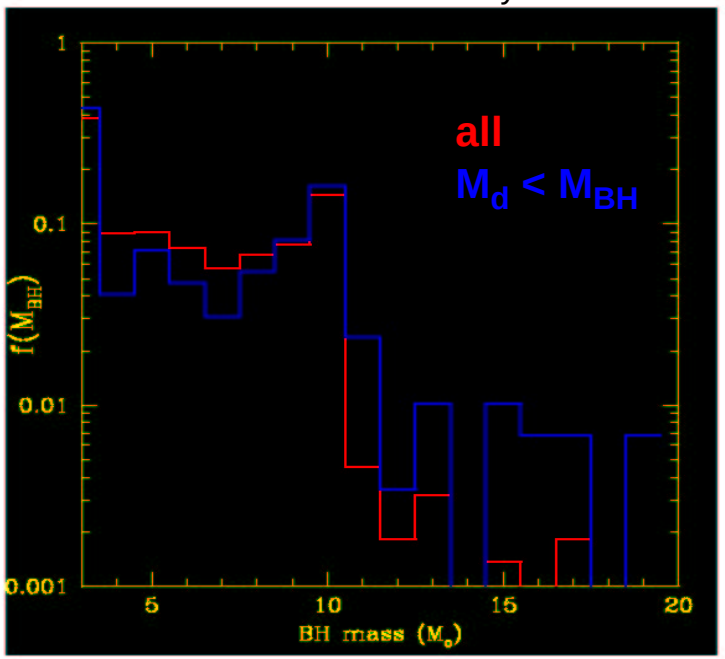
Belczynski et al. ’02



W−R winds reduced by 2

all winds reduced by 2

Belczynski & VK ’02



BH masses in X−ray binaries at the onset of mass transfer

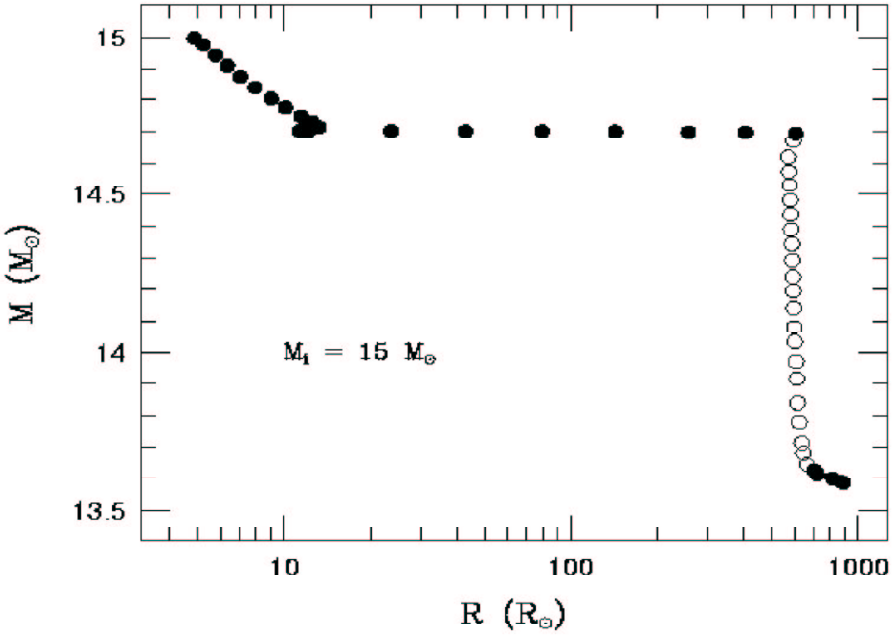
massive BH more common among BH−LMXB ?

Determination of BH mass distributions:

- Progenitor - remnant mass relationship
  SN mechanism
  mass loss (Fryer et al. '02)
  angular momentum
- Timing of common- envelope episode and He- core exposure
  before or after core He burning ?
  (case B) (case C)
- Strength of stellar winds

Case B or Case C mass transfer ?

Schaller et al. '92



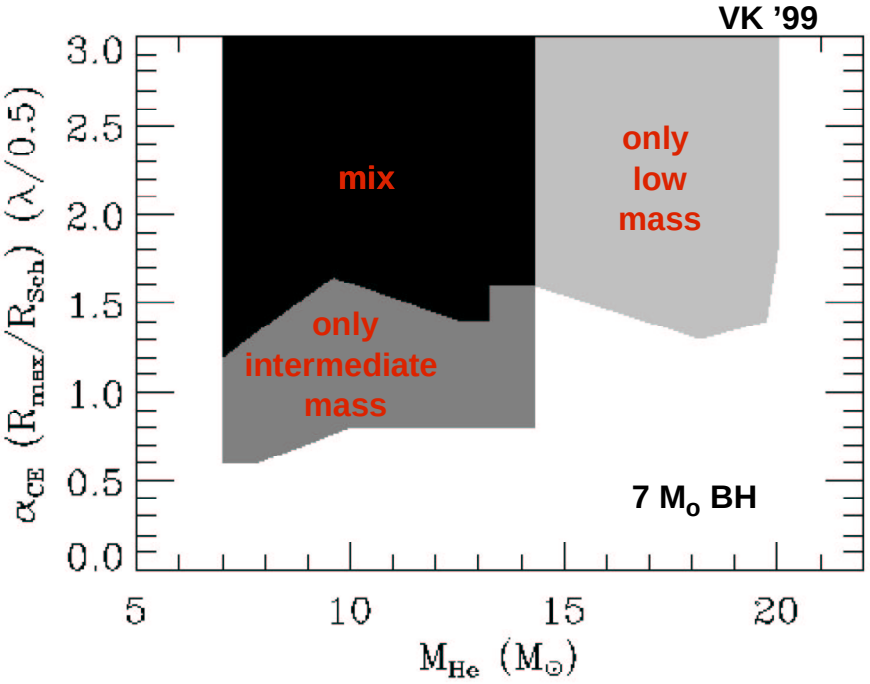
- M > 25−30M_o : no radial expansion after core He burning
- Case B: He core masses smaller
- Case B: CE survival more difficult > high CE efficiencies
- Case B: He−star winds important > weak winds

see Portegies Zwart et al. 97; Ergma & vdHeuvel 98; VK 99; Nelemans & vdHeuvel 01

BH Companions and Orbital Periods

Three years ago

SXT majority: low–mass donors $< 1–2\ M_o$
short orbital period < 1 day



He–star mass just after C E phase

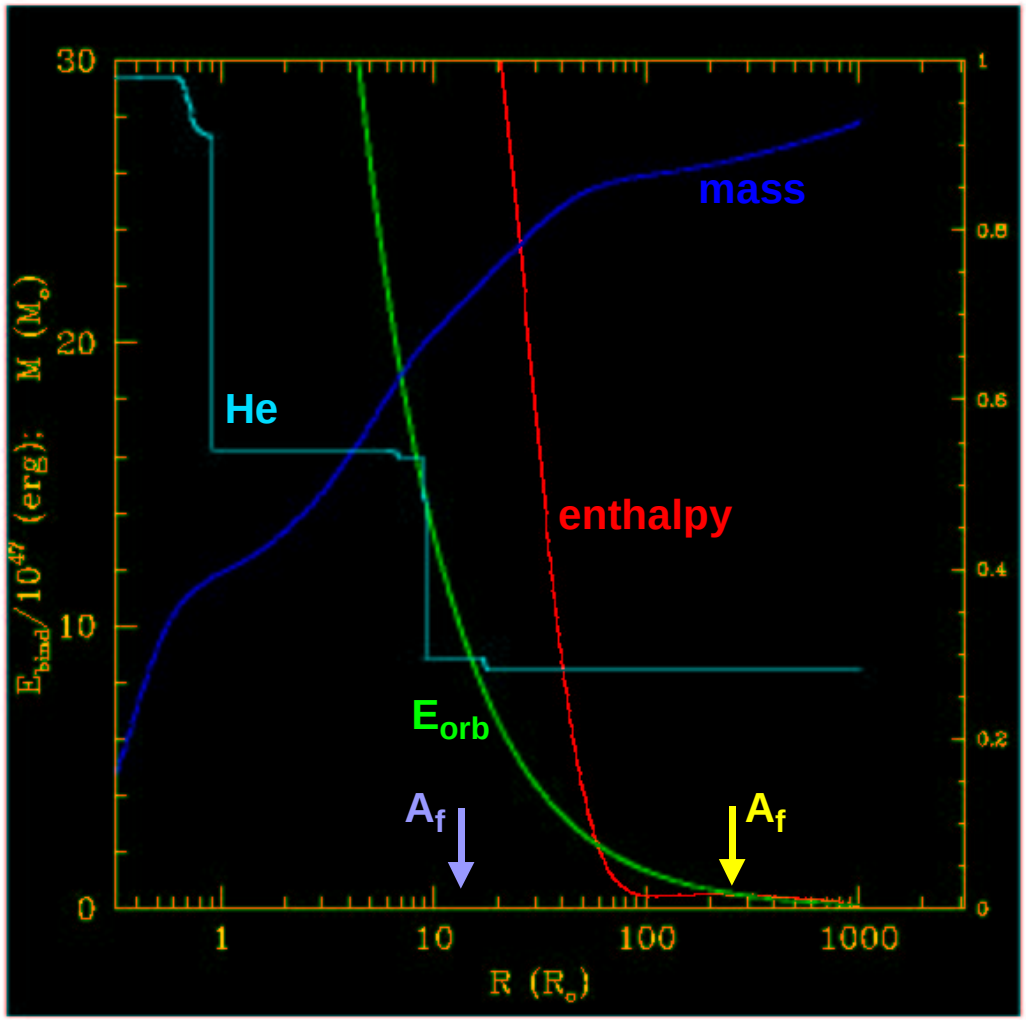
If this is representative of the true population:

- limited mass loss in winds and BH formation (< 50%)
- high CE efficiency ($a\lambda \sim 1$)

BUT ...

Common Envelope Outcome

Ivanova et al. 02



$$\alpha_{CE}(E_{orb,f} - E_{orb,i}) = -\frac{G M_p M_e}{R}$$

Stellar structure models are needed even with the 'simple' energy balance argument

BH Companions and Orbital Periods

'Missing' population:

except V4641 Sgr!

higher donor masses
short orbital periods

and **longer orbital periods**

evolutionary link

Q: **are they formed or not ?**
how do they evolve ?
are they transients ?

? BH kicks ?

BH formation: symmetric → asymmetric
direct → SN + fallback

White & van Paradijs '98: space distribution of BH XRBs
no or very small kicks

Podsiadlowski et al. '99: GRO J1655−25 radial velocity
Fryer & VK '02: small kicks necessary

Nelemans et al. '00: reanalysis of radial velocities
marginal agreement without kicks

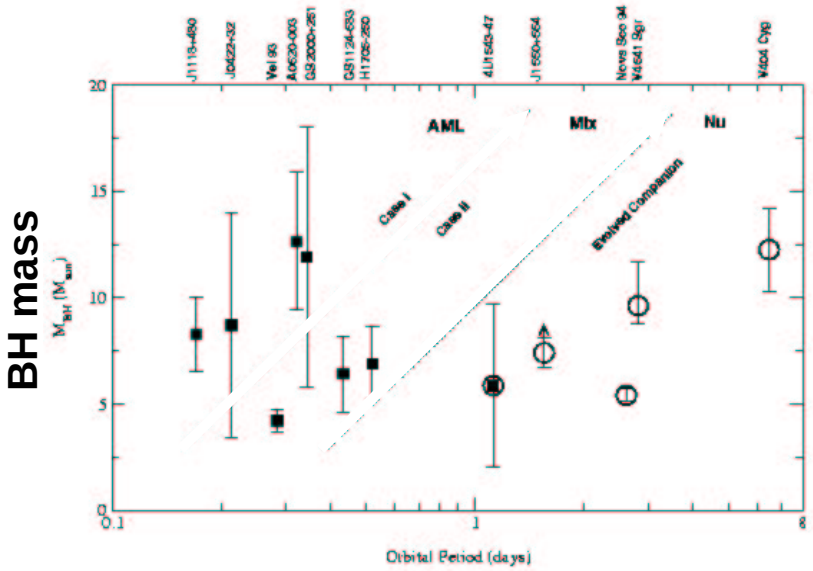
→ XTE J1118+480 Mirabel et al. '01
orbital dynamics reconstruction possible
peculiar orbit > motion in the Galactic potential

→ sample of proper motion measurements
- kicks: necessary or not ?
- BH kick magnitude relative to NS kicks
- kick − BH mass correlation ?

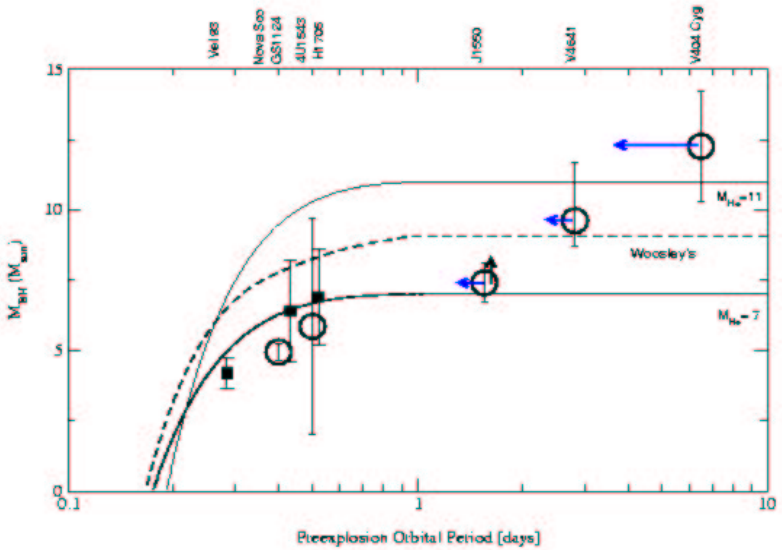
BH Masses and Orbital Periods

? correlation ? effects of angular momentum ?

Lee et al. ’01



Observed orbital period



Orbital period before BH formation

reconstruction:

- pre−collapse orbit
- mass transfer
- magnetic braking
- tidal coupling of high−mass helium stars

hard to tell ...

How about the next three years ?

account for XRB *evolution* to use *observed* systems to understand BH XRB *formation*

- mass transfer calculations for black hole binaries
- dynamical evolution in the Galactic potential
- detailed treatment of the CE phase

- can a gap at low BH masses be induced by mass transfer?
- what are the relative lifetimes of persistent and transient emission phases for various initial binary properties?
- are BH kicks necessary to explain the observed kinematic properties?