The Effect of Common Envelope Evolution on the Formation of High Mass X-Ray Binaries

Tim Linden

With much thanks to:

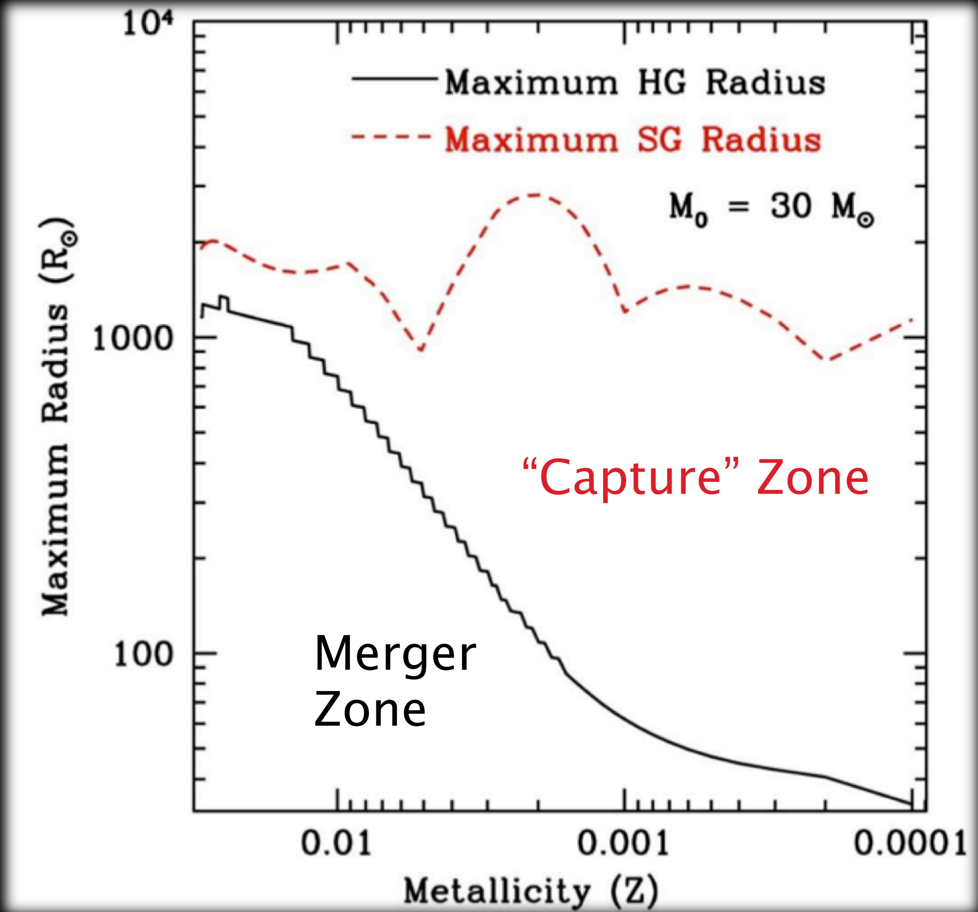
Vicky Kalogera, Jeremy Sepinsky, Andrea Prestwich, Andreas Zezas, Jay Gallagher

Outline

- Creating a High Mass X-Ray Binary population through Common Envelope Evolution
  - Concentrating on the effect of metallicity
- Ultra-Luminous X-Ray sources as an template to study HMXB pathways

The Ingredients
Creating an HMXB through Common Envelopes

- Large primary/secondary mass ratio
- Initial periastron separation larger than the Roche Lobe of the primary as a Hertzsprung Gap Star
- But smaller than the Roche Lobe of the primary as a supergiant star

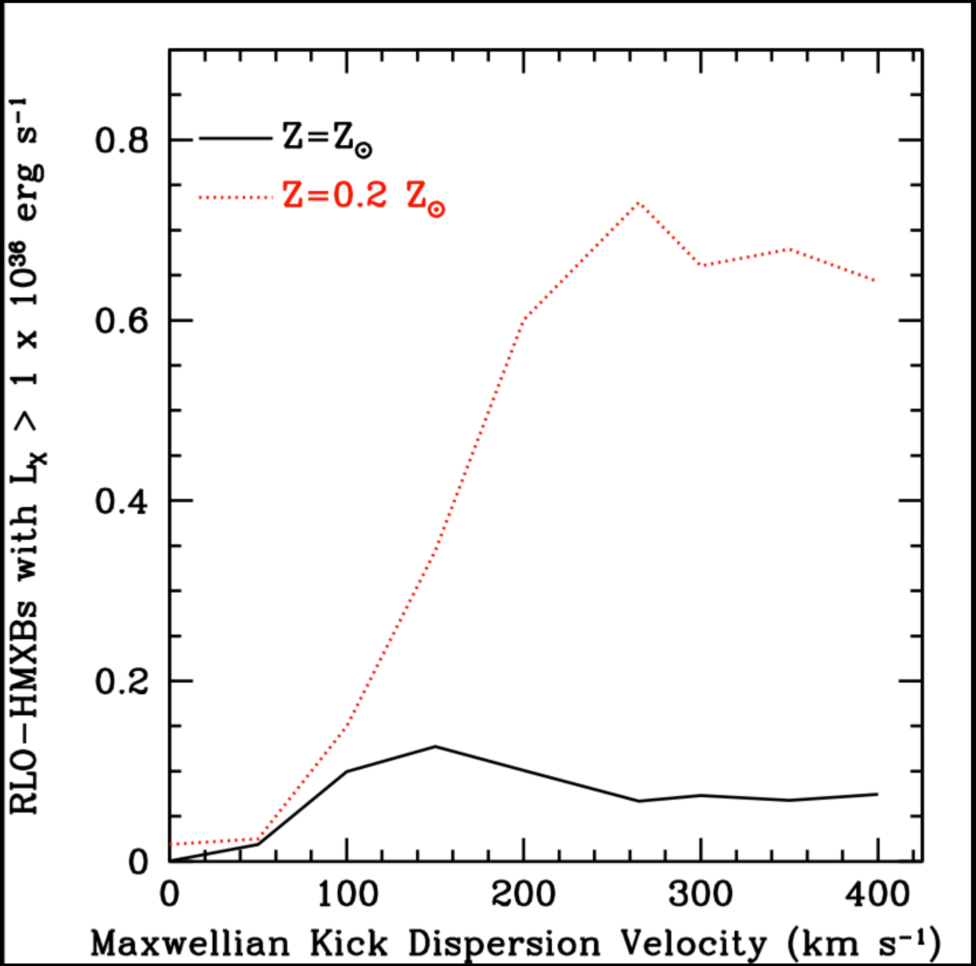


Simulation using SSE (Hurley et al. 2000)

The Ingredients
Creating an HMXB through Common Envelopes

- The Energy in the binary orbit must exceed the envelope binding energy (Webbink, 1984)

- Additionally, to create an RLO-HMXB, a natal kick imparts an eccentricity – causing a second RLO



Similar result for LMXBs (Kalogera & Webbink 1998)

Simulation using StarTrack (Belczynski et al. 2008)

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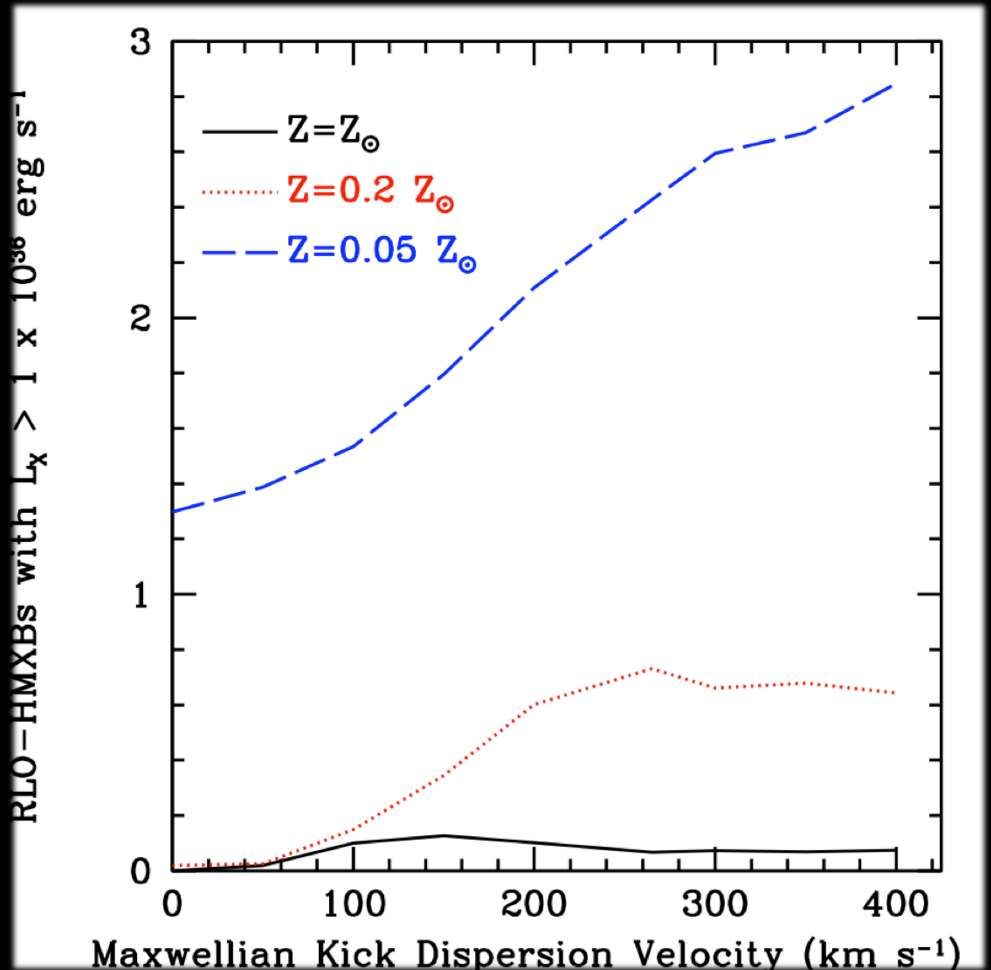

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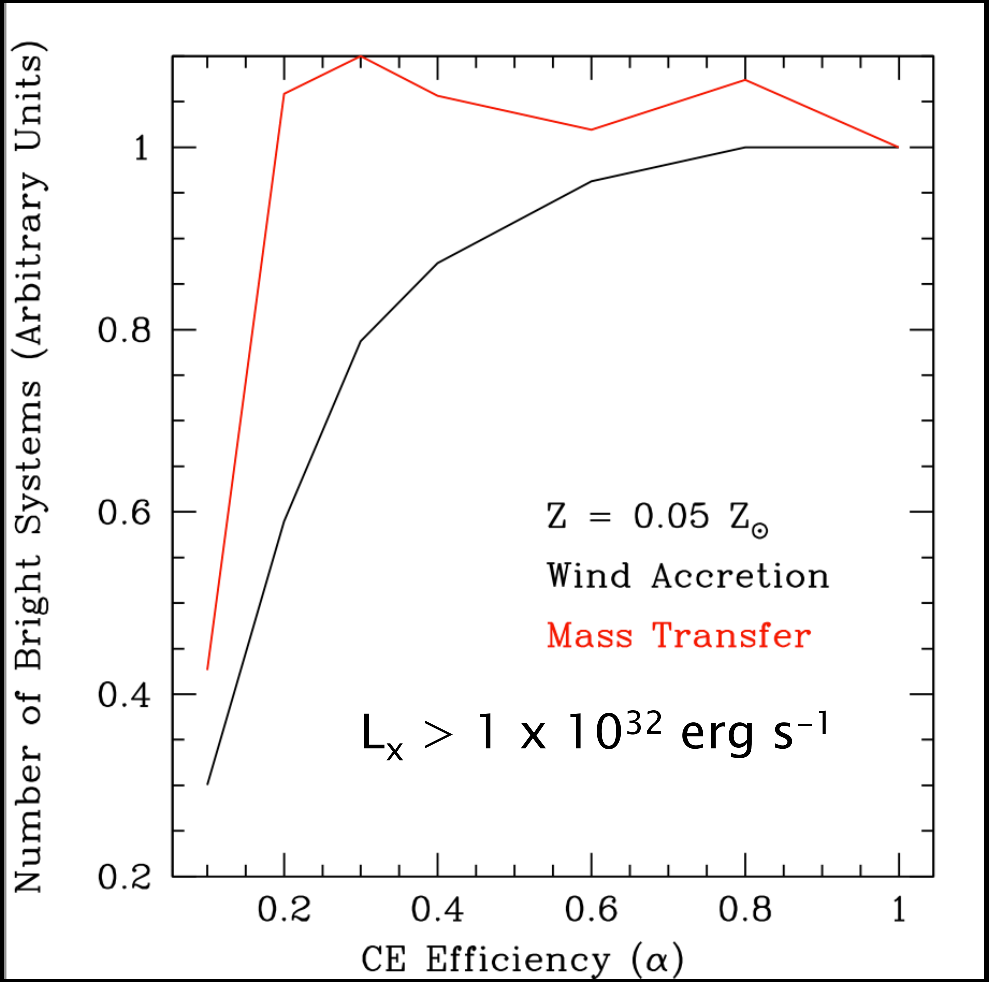
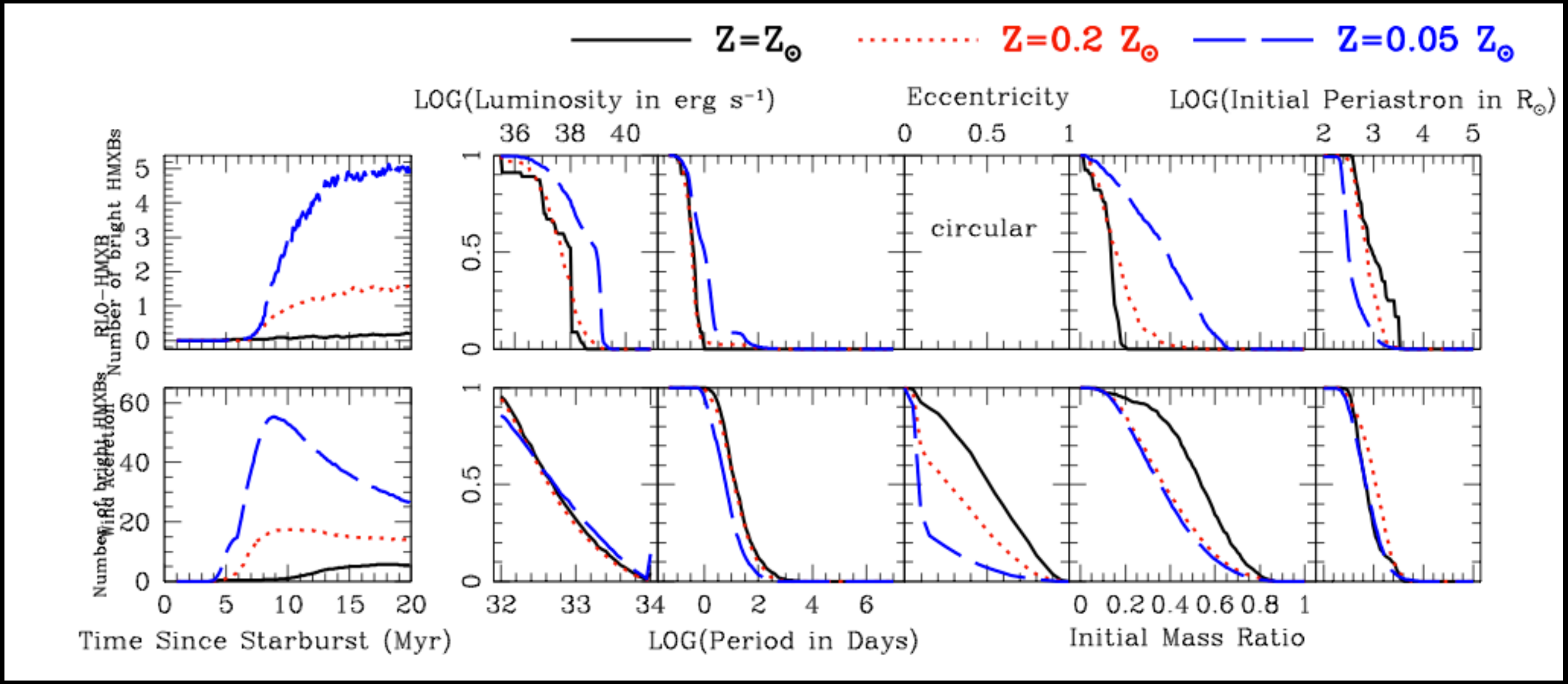


Simulation using StarTrack (Belczynski et al. 2008)

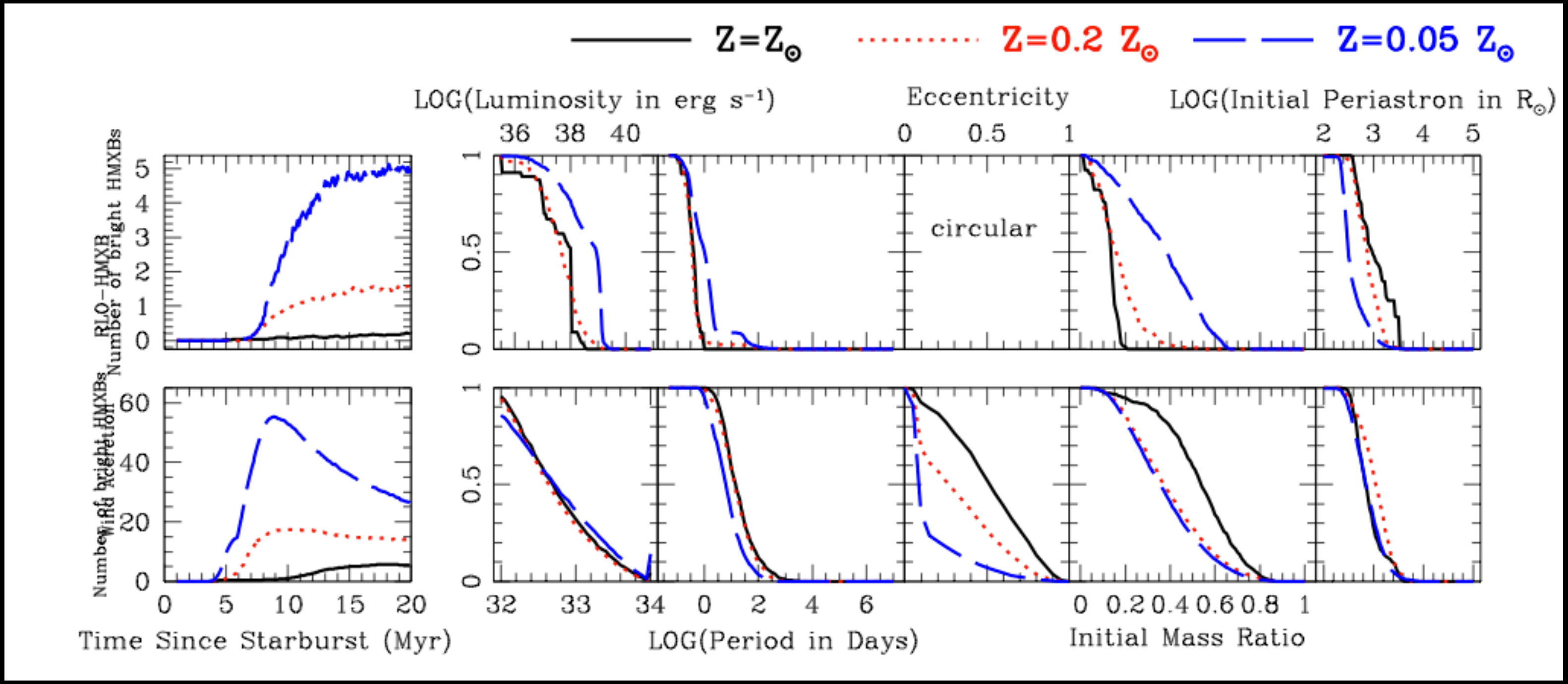
The Product (CE driven HMXBs)



- The Surviving HMXB has:
  - A Mass Ratio Near Unity
  - A short orbital period (<10 days for RLO, <100 days for wind)
  - Main sequence donor

Simulation using StarTrack (Belczynski et al. 2008)

The Product (CE driven HMXBs)



- Metallicity does not influence the observable characteristics of systems which evolve through CE pathways.

- Instead, metallicity controls the number of systems which move through the CE pathway (strong preference for low metallicity)

Simulation using StarTrack (Belczynski et al. 2008)

Ultra-Luminous X-ray Sources

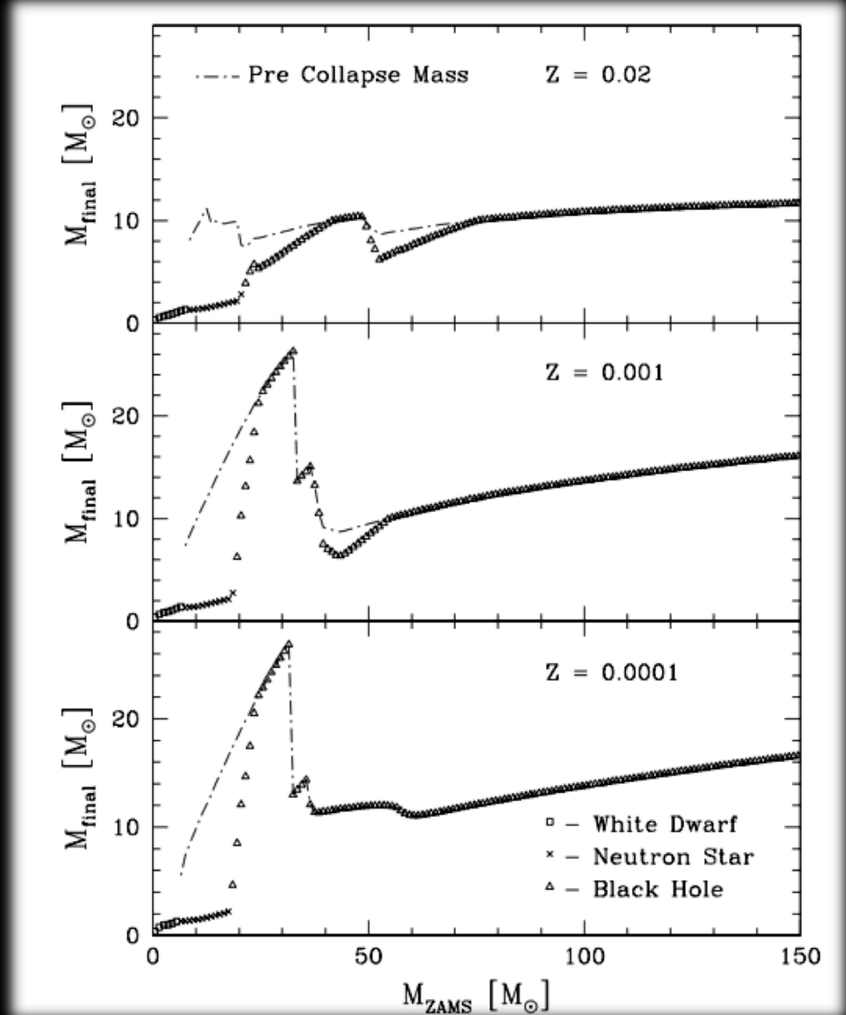
- Two effective pathways for the creation of ULX with spherical winds
  - Roche Lobe Overflow (based on Common Envelope)
  - Wind accretion with red-supergiant donor

- Roche-Lobe overflow pathways require common envelope evolution, while SG-HMXBs are prohibited from common envelope phases

- Observations find a strong metallicity effect in ULX/SFR (Pakull & Mirioni 2002, Zampieri et al. 2004)

Ultra-Luminous X-ray Sources

- Is this effect correlated to BH mass? (Mapelli et al 2009, 2010) (Zampieri et al 2010)
- Large BHs require much less super-Eddington accretion to explain ULX population



Belczynski et al (2004)

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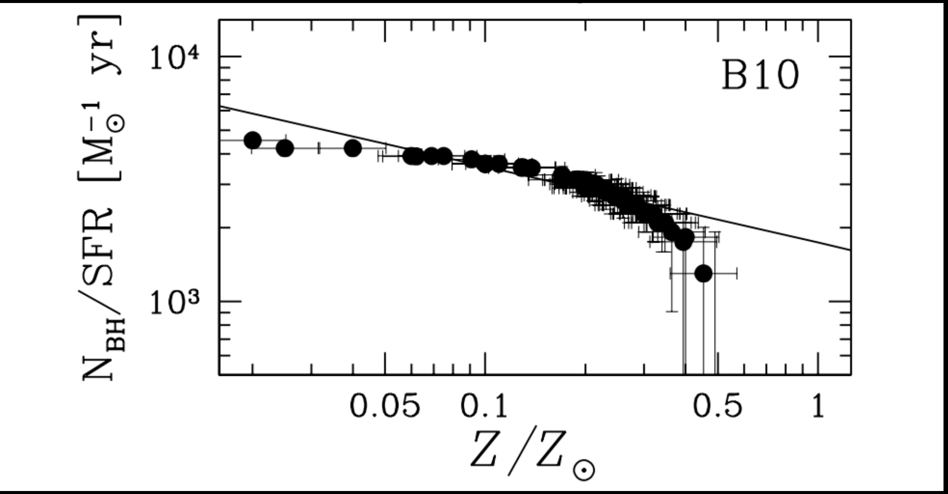
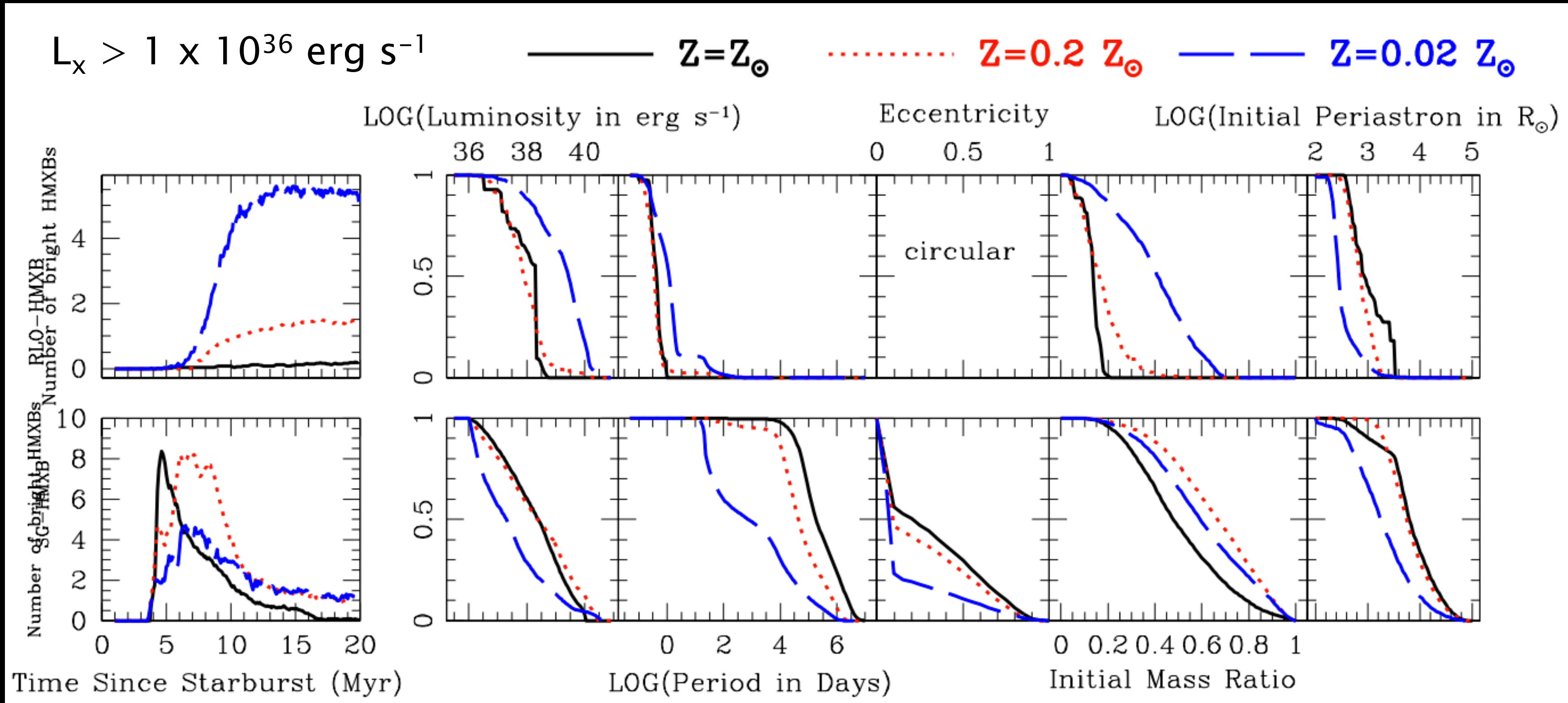


Mapelli et al (2010)

HMXB Pathways



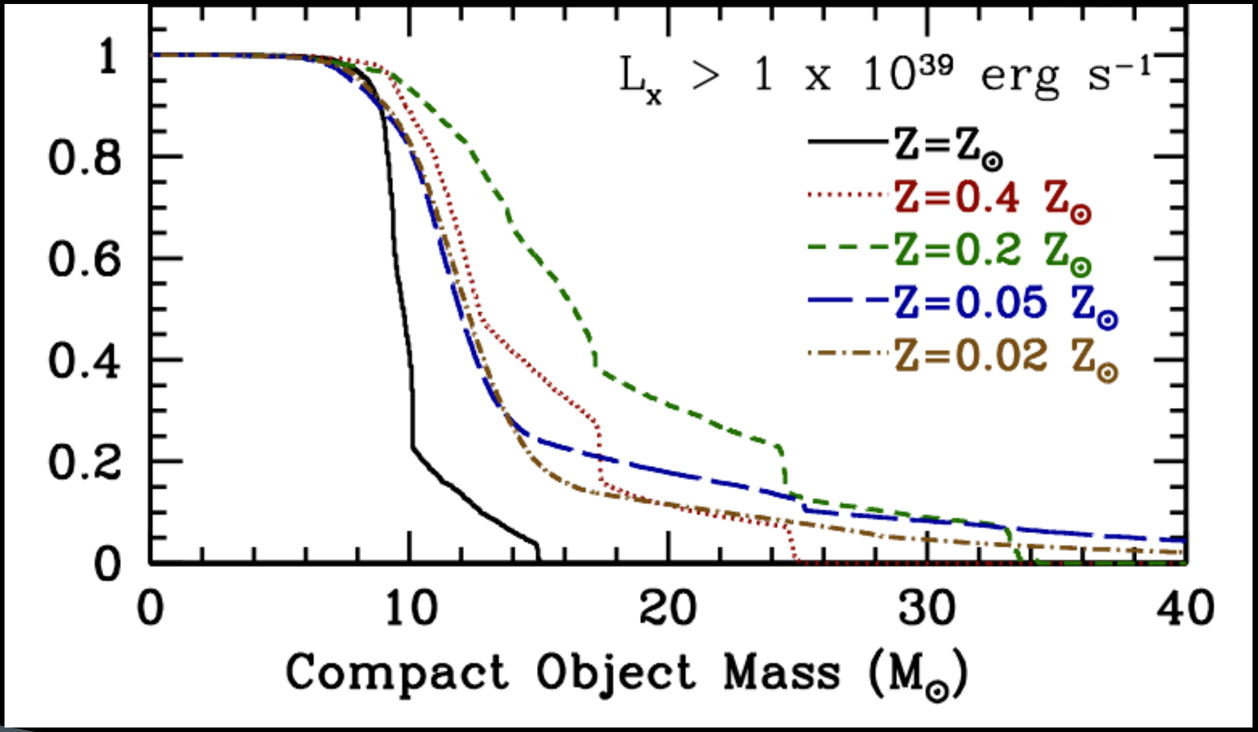
RLO systems dominant at low metallicity

Supergiant background important especially at medium to solar metallicity

Simulation using StarTrack (Belczynski et al. 2008)

What do the pathways tell us?

- Despite the propensity of low metallicity environments to create more massive BHs -- we do not see significantly more massive BHs in the ULX in our models

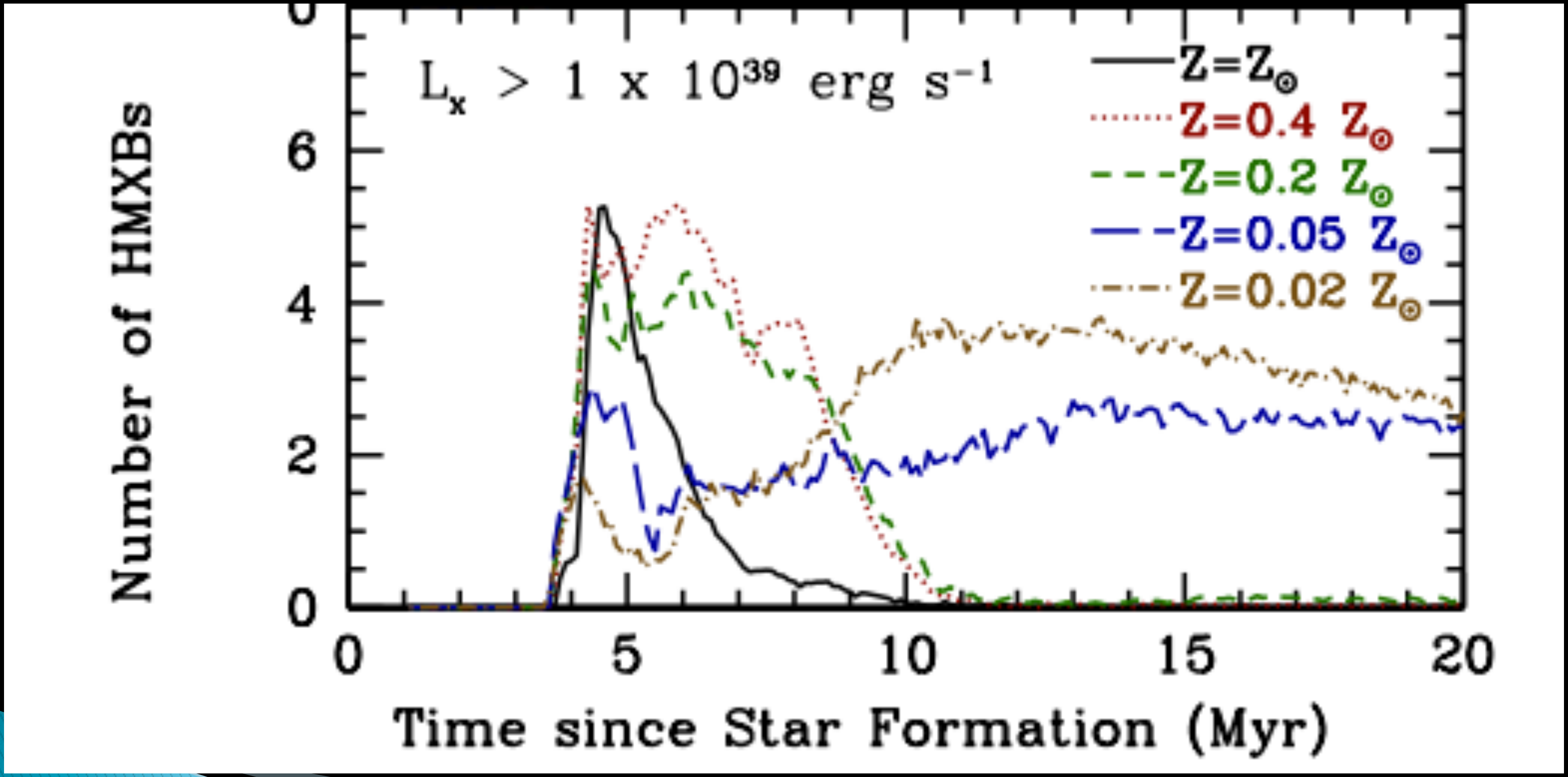


Two Models for ULX

- Usual Model: Low metallicity stars lose less mass – becoming more massive BHs (Mapelli et al 2009, 2010, Zampieri et al. 2010)
- New Model: Low metallicity stars have more survivable common envelopes
  - In Fact, the most massive stars will not move through the supergiant stage (LBV) and will not form ULX at all

What do the pathways tell us?

- These scenarios are observationally testable!



Conclusions

- Common envelope phases greatly influence:
  - The characteristics of systems which become HMXBs
  - The observable characteristics of HMXBs
  - The effect of metallicity on HMXB development

- The effect of common envelope phases can be observed directly in several model systems

Bonus Tracks

Can CE evolution solve other puzzles?

- Quick discussion of Be-HMXBs vs background systems

- Be-HMXBs are typical of systems which do not go through CE evolution

The StarTrack Modeling Code

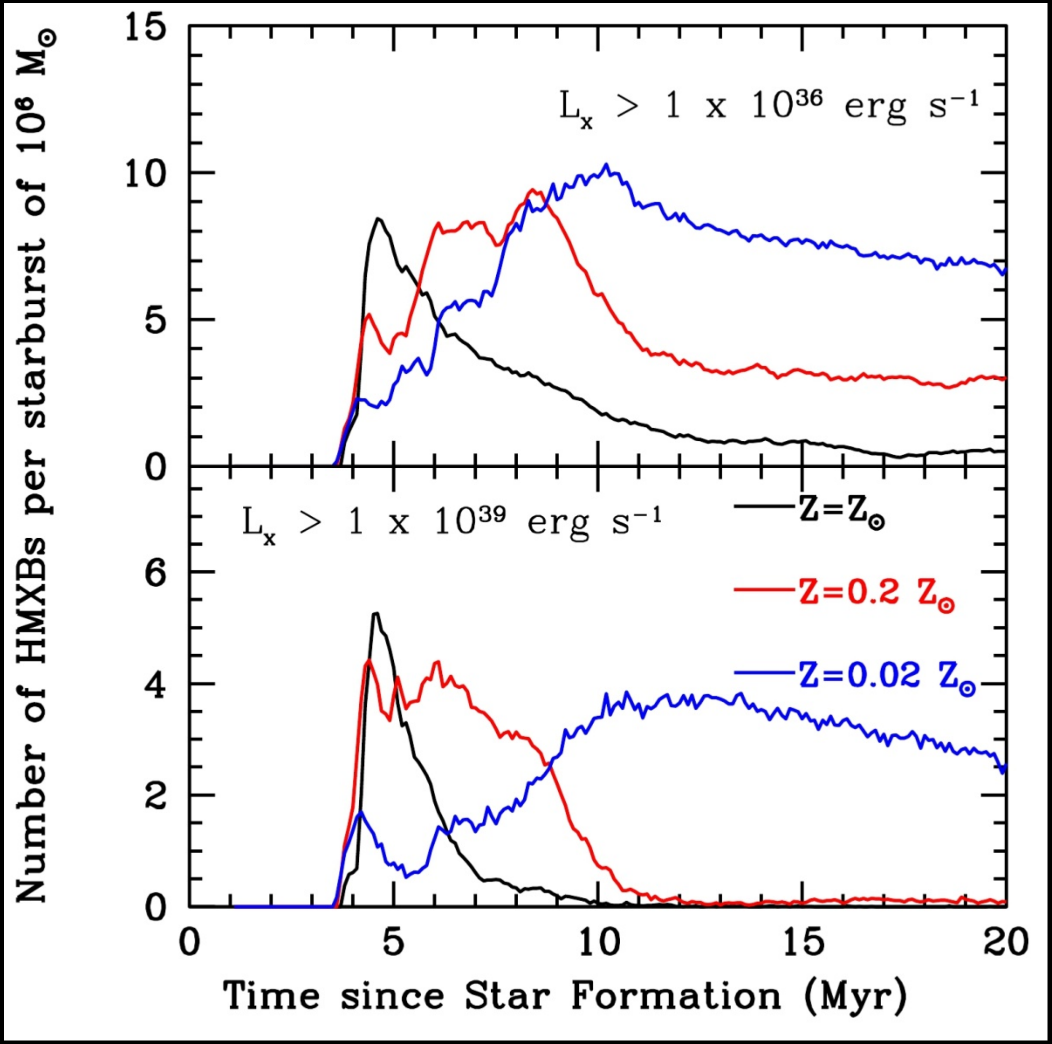
- Developed by Chris Belczynski (Belczynski et al. 2002, 2008) to determine the populations of X-Ray binaries, NS-NS binaries, etc.

- In this research, we simulate a delta function starburst of 10^6 solar masses and follow it for 20 Myr.

- We employ standard prescriptions for common envelope efficiencies, X-Ray luminosities, Roche Lobe overflow, etc.

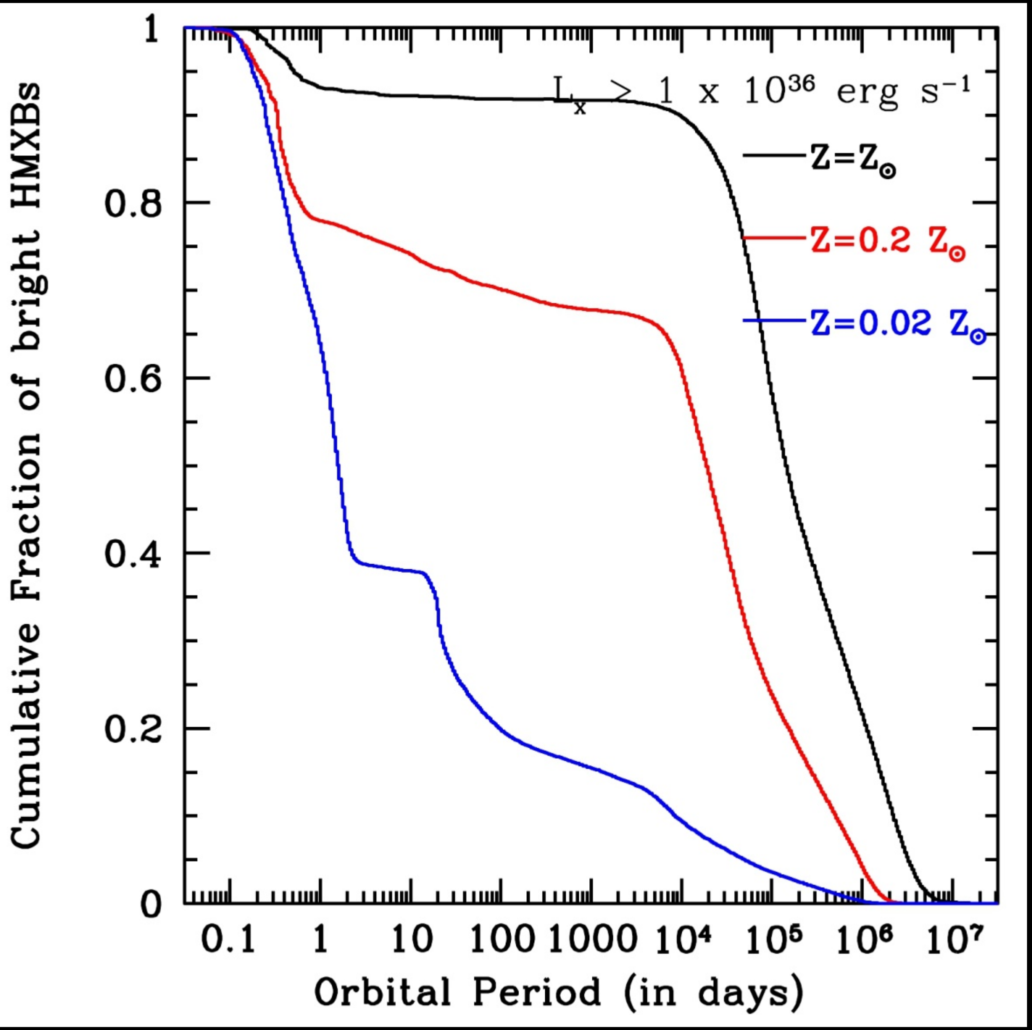
The Young HMXB Population

- Low metallicity HMXBs are preferred by a factor of 3.5 at the low luminosity cutoff and 5.0 at the ULX cutoff.
- HMXB number peaks earlier at high metallicity and decays much faster.

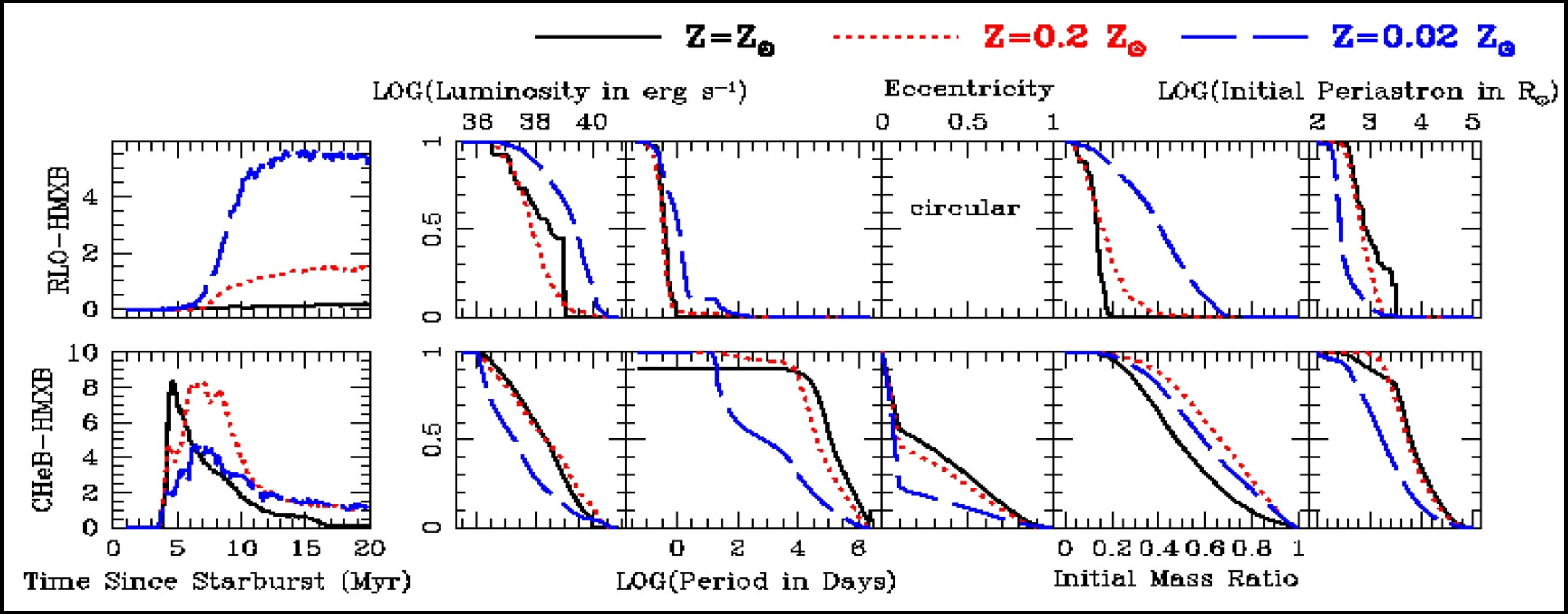


The Smoking Gun

- Orbital period data clearly shows two separate classes of HMXBs.
- The relative number of systems moving through each pathway is strongly metallicity dependent.



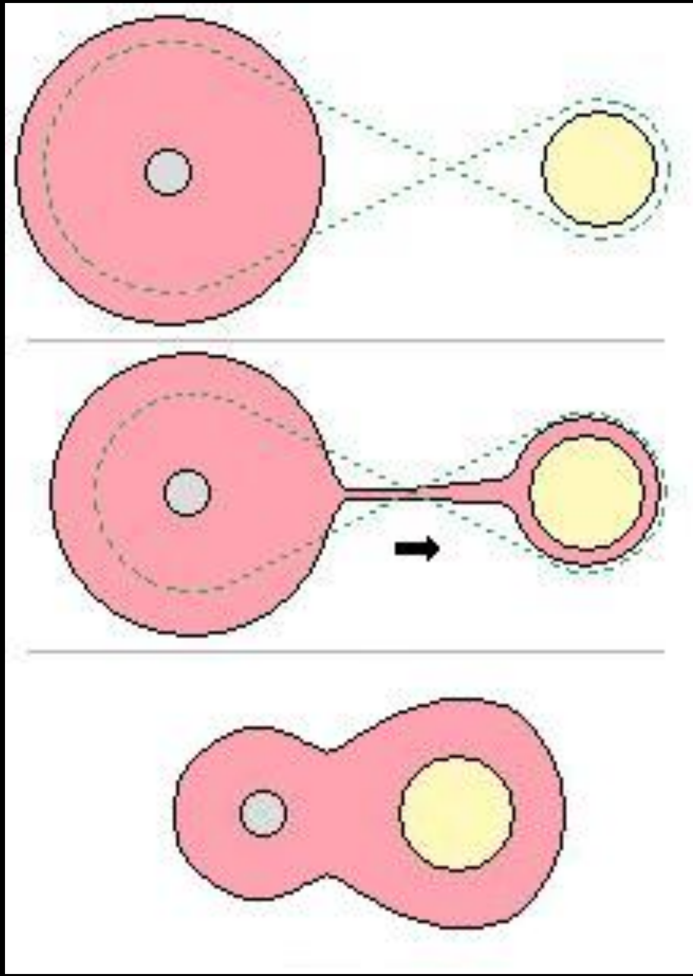
HMXB Pathways



Within each evolution pathway, the metallicity dependence is minimal. However, metallicity greatly affects the number of systems moving through each pathway.

The Roche Lobe Overflow Pathway

- Roche Lobe overflow HMXBs require common envelope phases to achieve tight binary orbits.



http://en.wikipedia.org/wiki/File:Common_envelope_diagram.jpg

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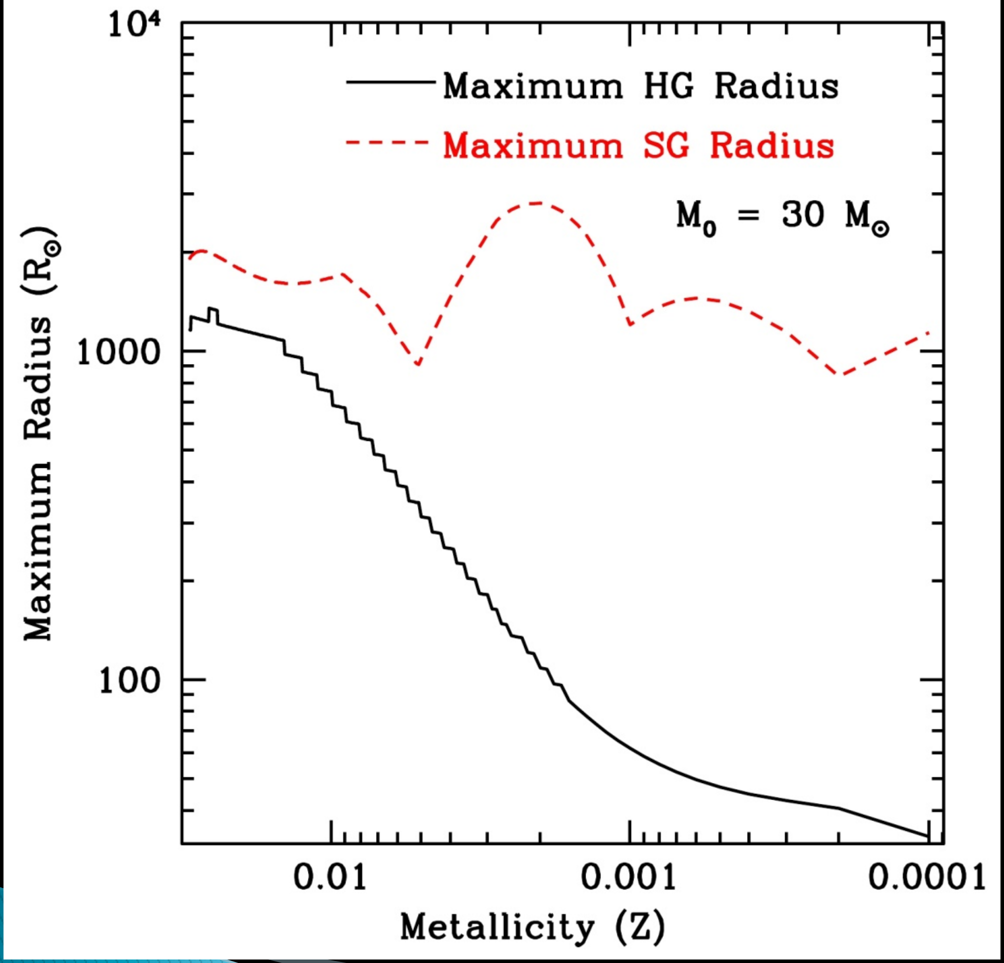
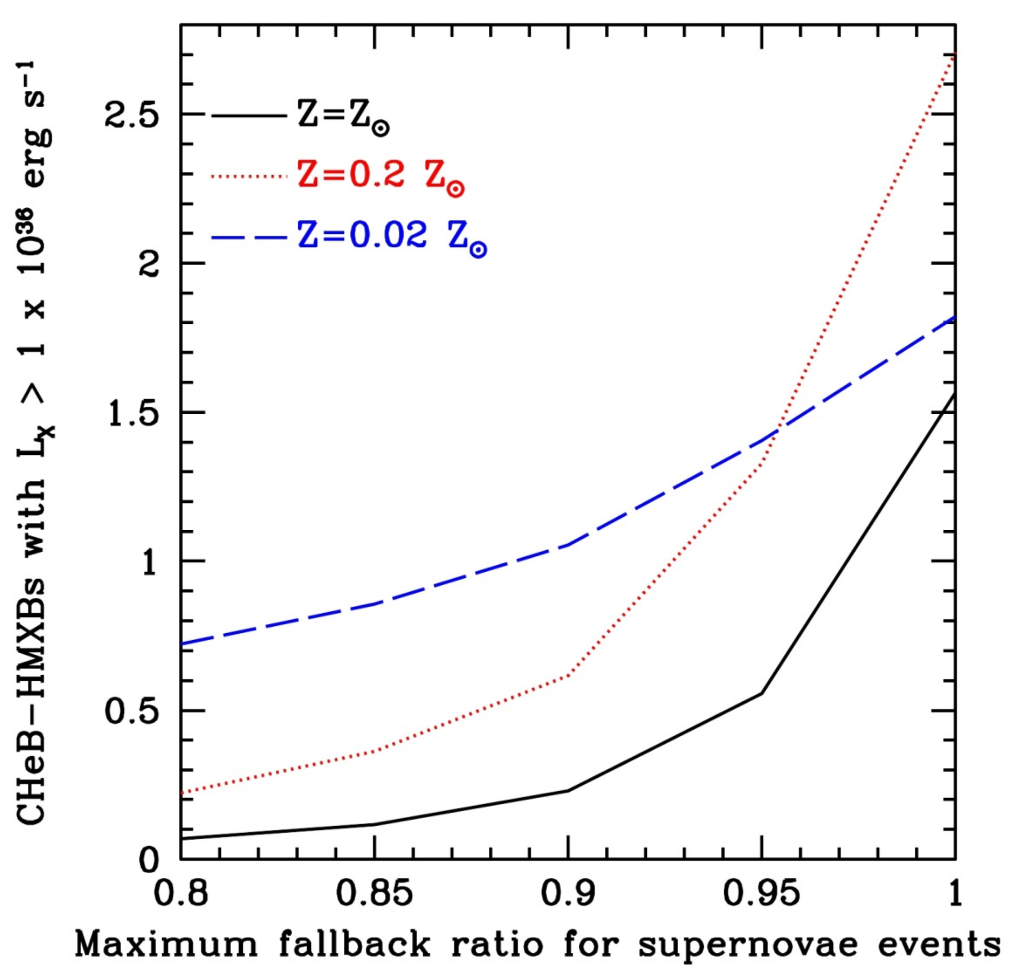


Roche Lobe overflow HMXBs require common envelope phases, which are preferentially formed at low metallicity.

The (super)Giant Pathway



The progenitors of supergiant HMXBs require large orbital separations to allow the donor to evolve.

This makes the systems highly highly susceptible to natal kicks.

HMXB: Conclusions

1.) We can produce a robust population of bright and Ultra-Luminous HMXBs at all metallicities.

2.) HMXB formation is preferred at low metallicities, matching observations.

3.) The overabundance of low metallicity HMXBs is due to the details of their formation pathways, not the final BH mass.

Linden, Kalogera, Sepinsky, Prestwich, Zezas, Gallagher, 2010 (Submitted to ApJ, arXiv: 1005.1639)

HMXB: Future Work

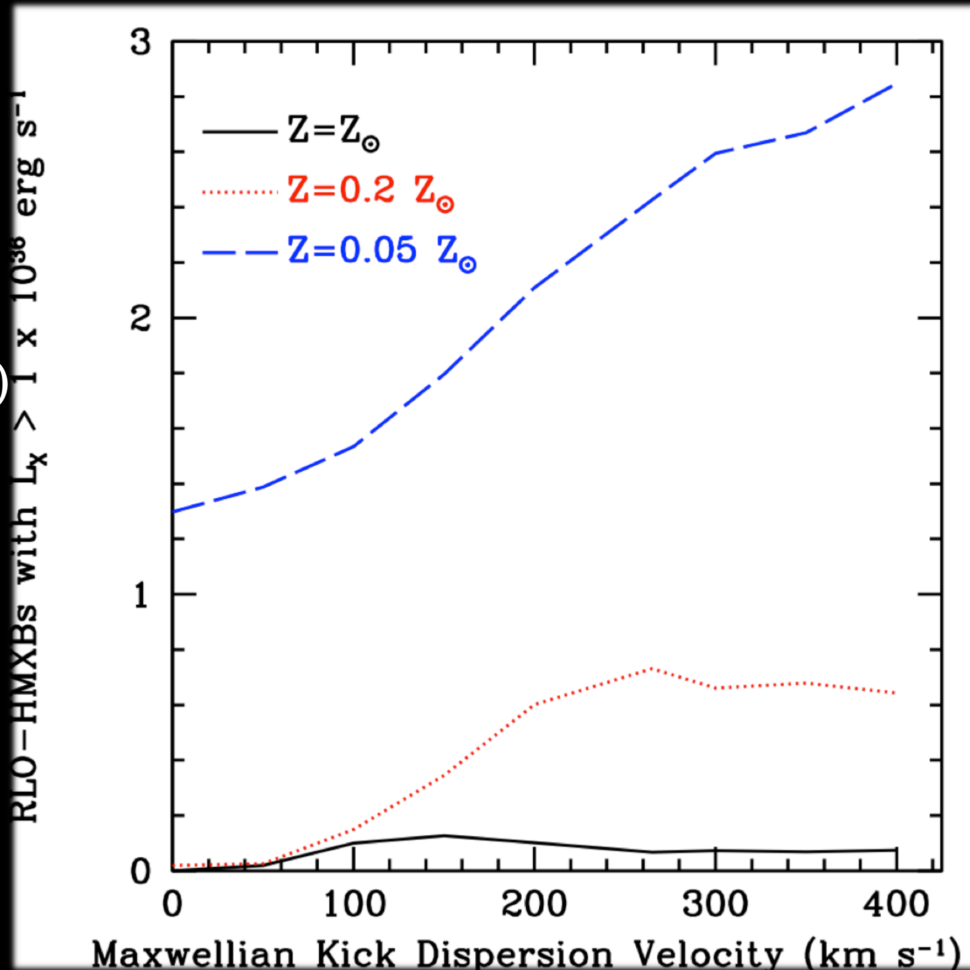
1.) Compare our theoretical models to observations of young extremely metal poor starbursts (Chandra Grant GO-12018, PI - Prestwich).

2.) Create detailed models which take into account effects such as non-spherical stellar winds and eccentric mass transfer.

The Ingredients

Creating an HMXB through Common Envelopes

- The surviving HMXB has:
  - A mass ratio near unity
  - A short orbital period (<10d)
  - Main sequence donor
    - Donor was much lighter
    - Donor's supergiant stage will cause CE and lead to merger



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