THE EFFECT OF METALLICITY ON THE HIGH MASS X-RAY BINARY POPULATION

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Overview

- 1.) The *StarTrack* Modeling code
- 2.) Classification of the HMXB population
- 3.) The metallicity dependence of HMXB
- 4.) Conclusions

The StarTrack Code

- Population synthesis code developed by Chris Belczynski to simulate the population of X-Ray binaries, binary NSs etc.

- We simulate a delta function starburst of 10^6 solar masses and follow its evolution for 20 Myr.

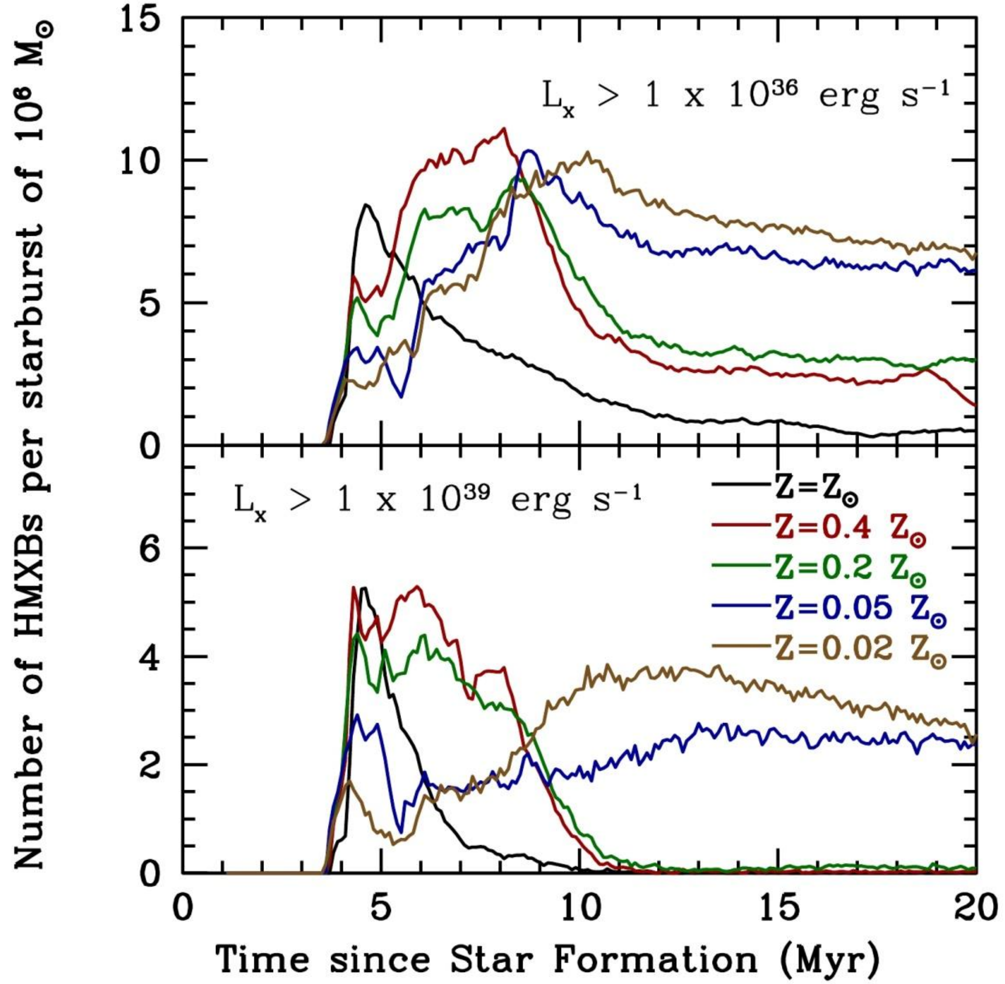
- Specific Parameters:
  - Spherical winds only
  - Luminosity cutoff of 1×10^{36} erg s^{-1} (extragalactic studies)
  - Moderate super-Eddington accretion (10x Edd. for BH, 2x for NS)
  - Common envelopes merge if the donor is in the Hertzsprung gap

The Young HMXB Population

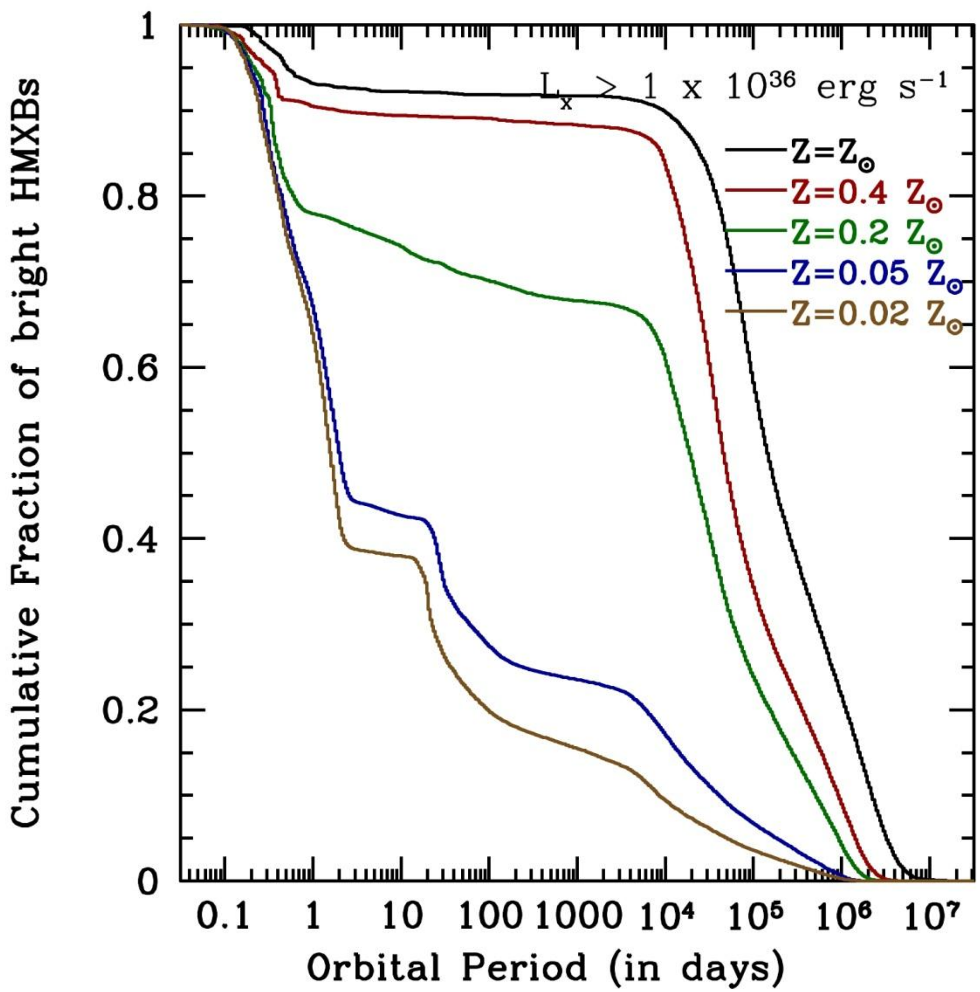
Low metallicity HMXBs prefered by a factor of 3.5 at the lower luminosity cutoff and 5.0 at the ULX cutoff

HMXB number peaks earlier at high metallicity, and decays much faster.

Both trends become more pronounced at higher luminosity cutoffs.



The Smoking Gun

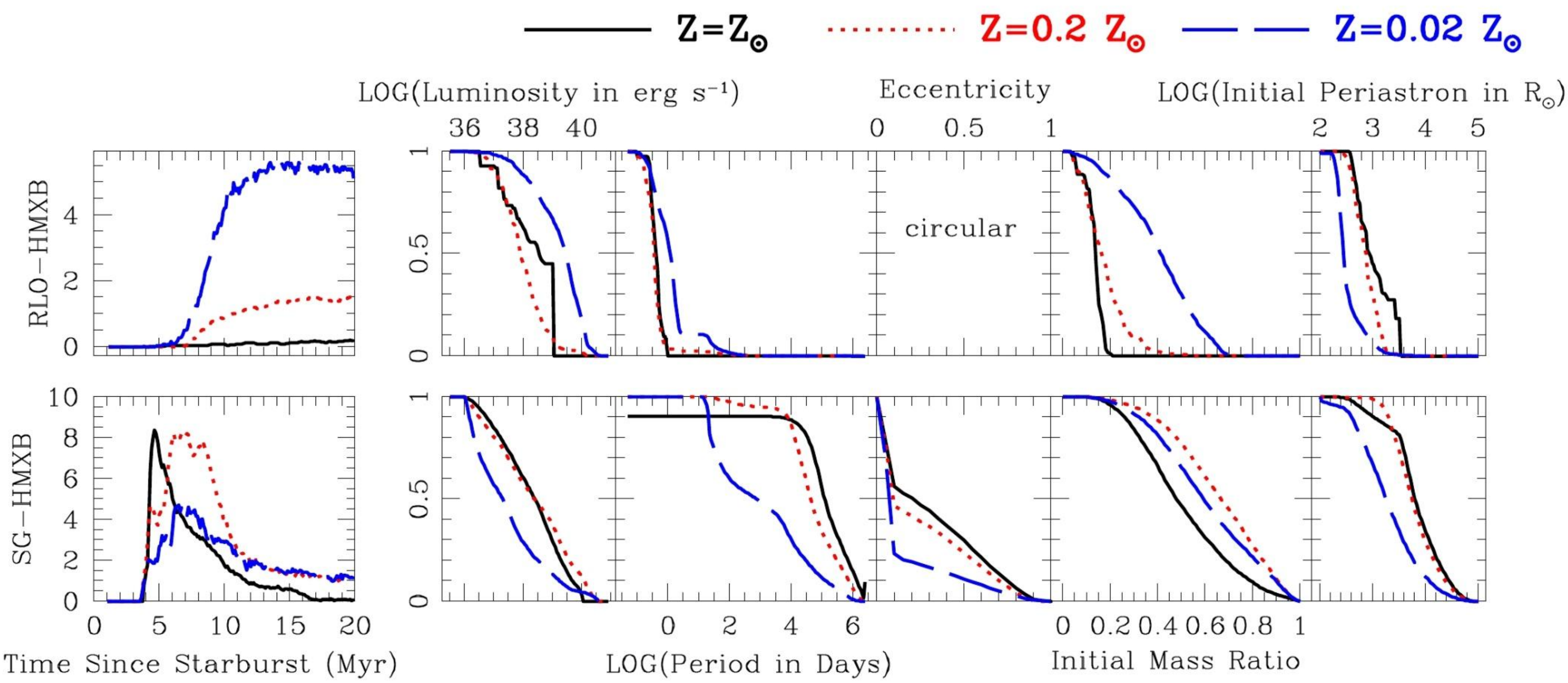


Orbital Period data clearly shows two unique classes of systems.

The number of systems moving through each pathway is strongly dependent on metallicity.

We note a peculiar gap of systems with periods between 1-10^4 days, especially at high metallicity.

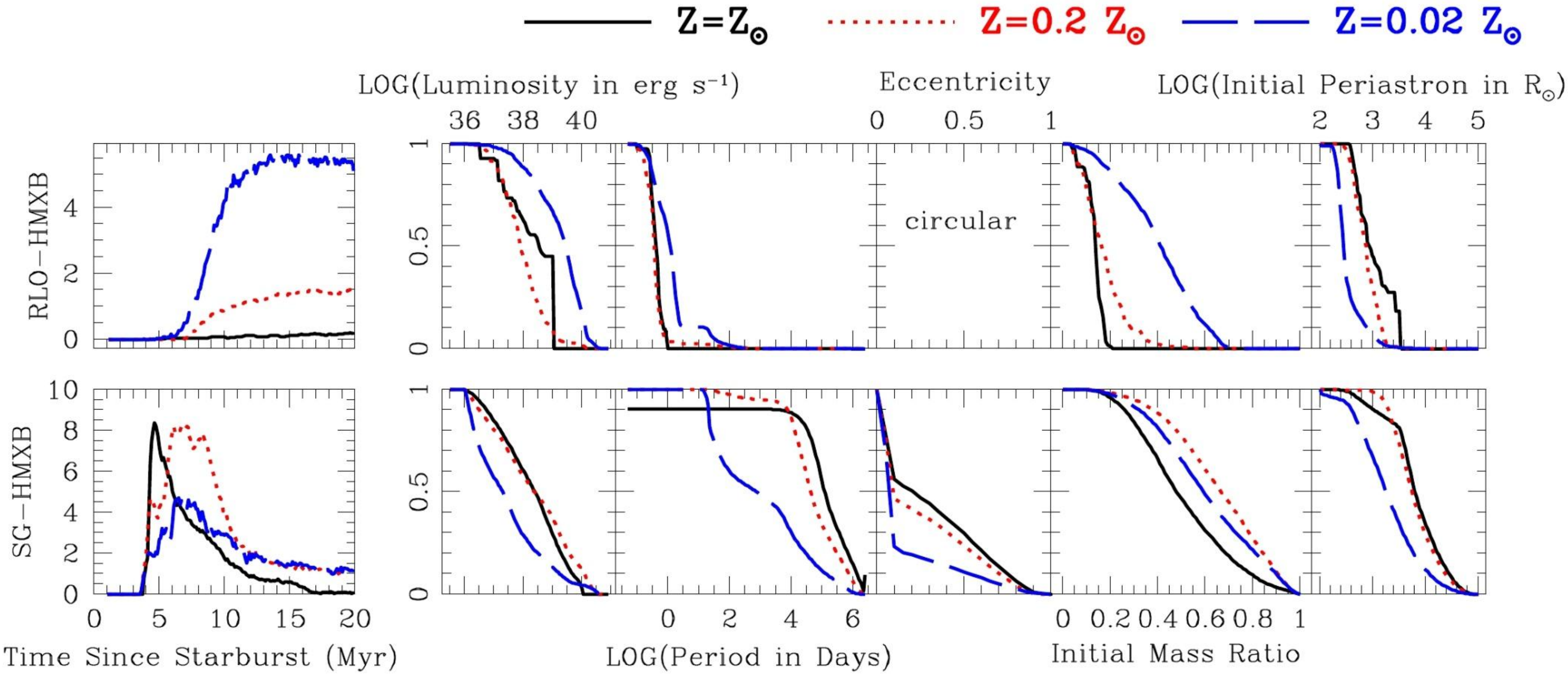
Classifying the HMXB Population



We divide the bright HMXB population into two subgroups - Systems undergoing active Roche-Lobe Overflow (top), and systems with a (super)giant donor

1.) Van Bever & Vanbeveren, 2000, 258, 462 (2000)

Classifying the HMXB Population



We note that *within* each pathway, the metallicity dependence of the HMXB population is small

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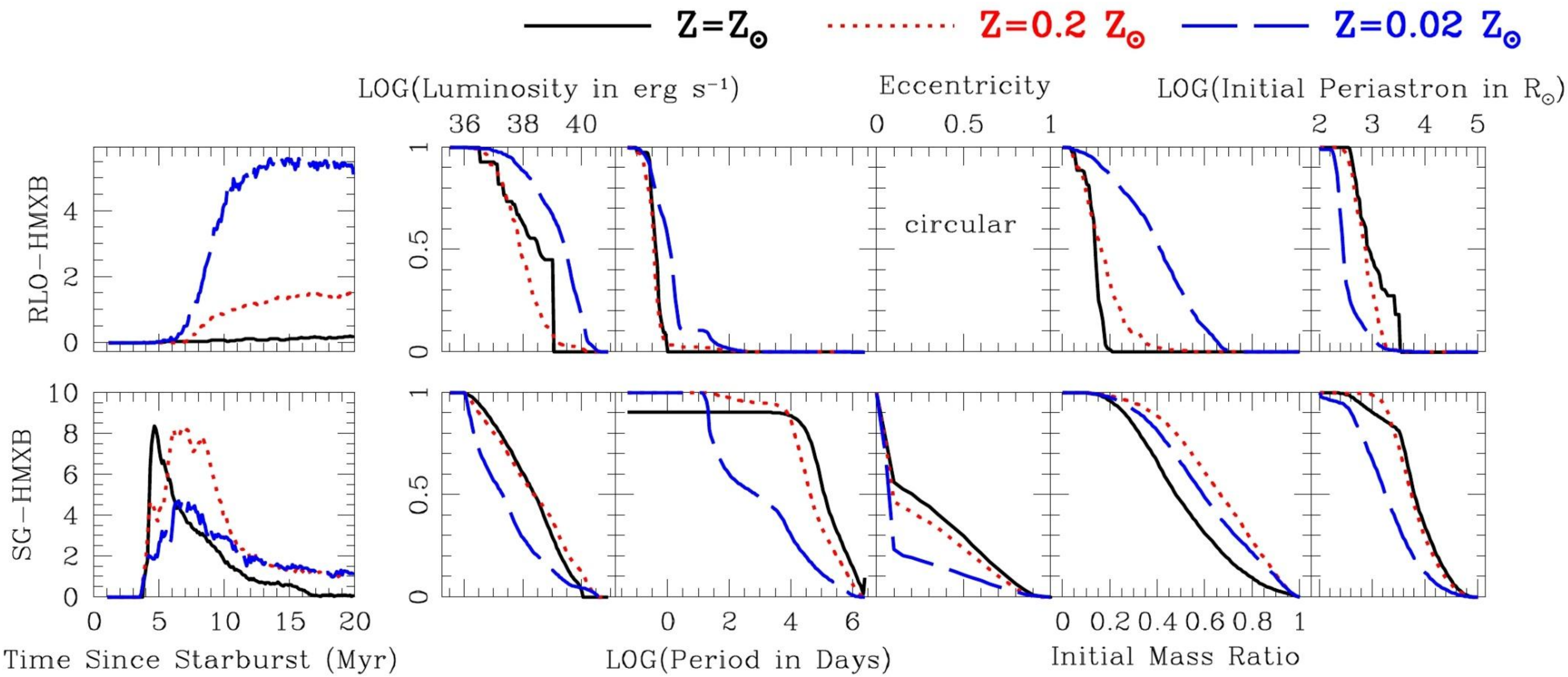


However, the number of systems moving through each pathway depends greatly on metallicity

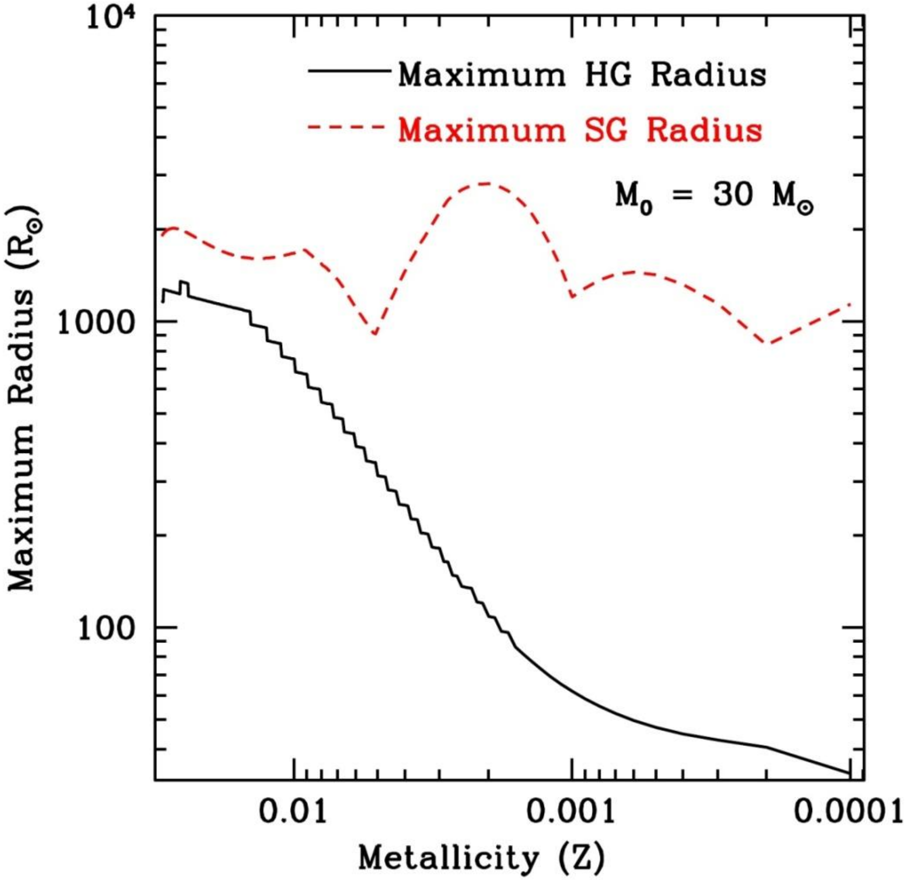
The Roche-Lobe Overflow Pathway

Roche Lobe Overflow pathway:

1.) Systems start with the periastron Roche Lobe between the maximum HG and (super)giant radius of the primary star.

2.) Systems undergo Common envelope evolution according to the energy formalism[1]– moving into tight binary orbits.

3.) The natal kick from the primary SN introduces an eccentricity which causes a second RLO and the creation of a stable HMXB.



Primary reason for metallicity dependence

1.) Webbink, R. F. 1984, ApJ, 277, 355

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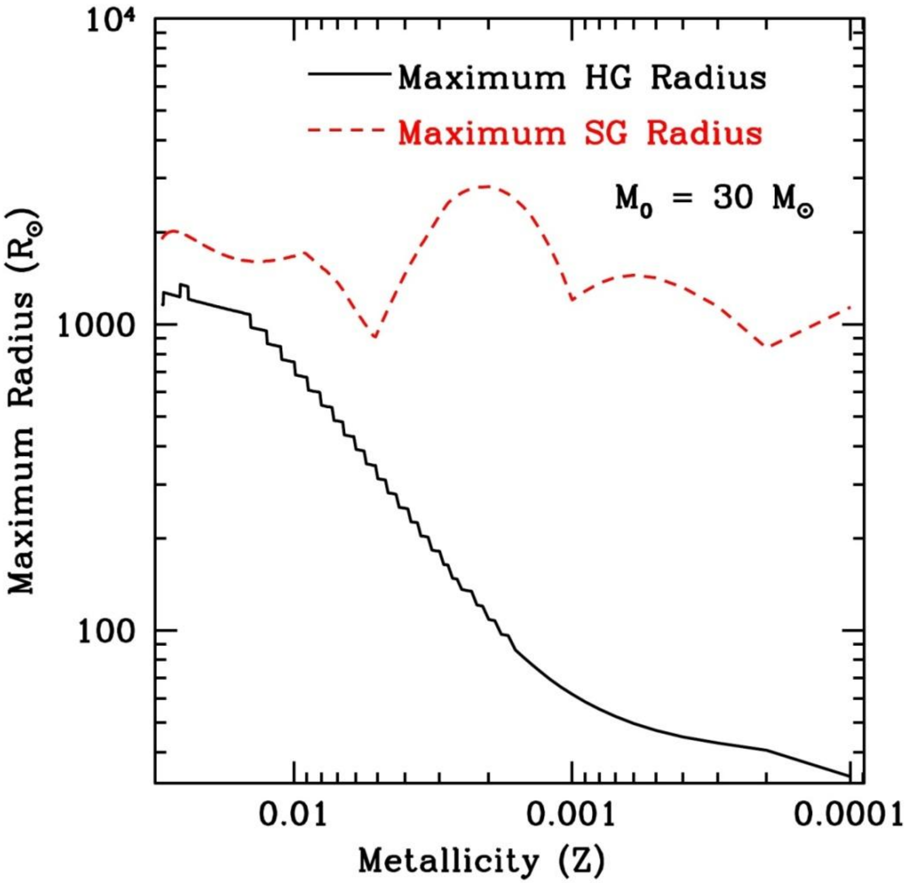

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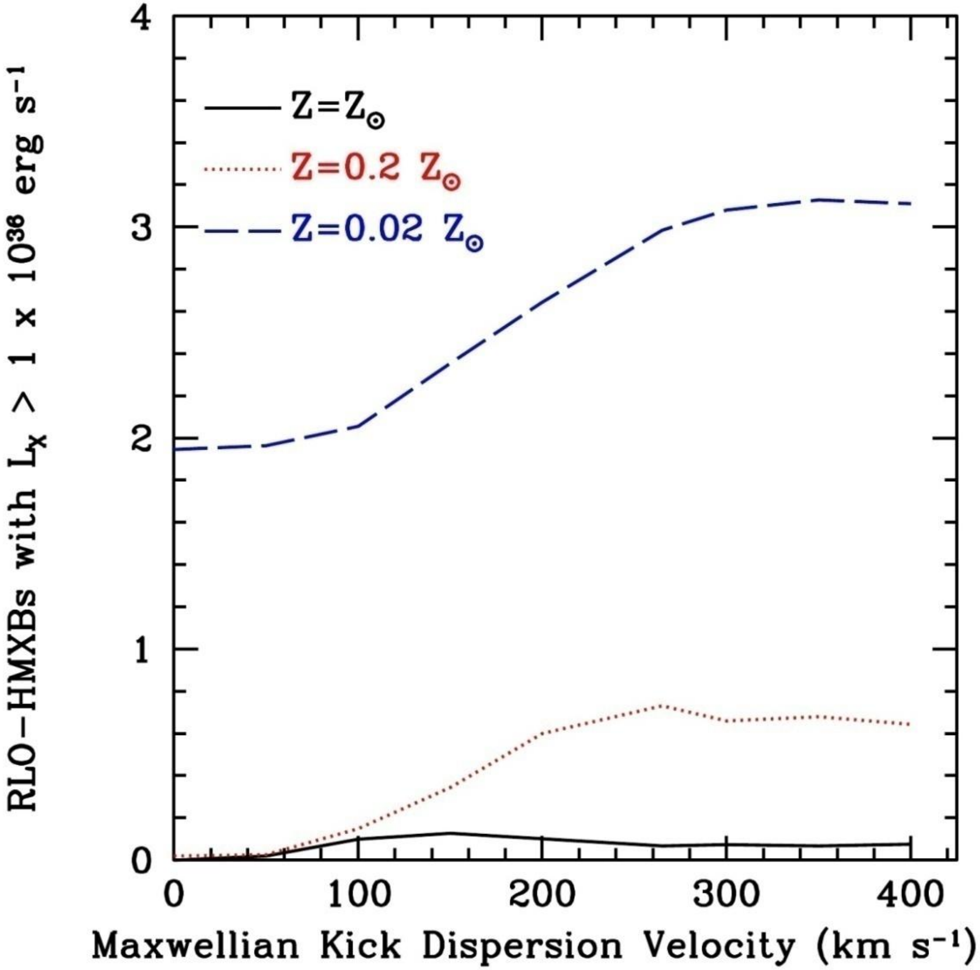

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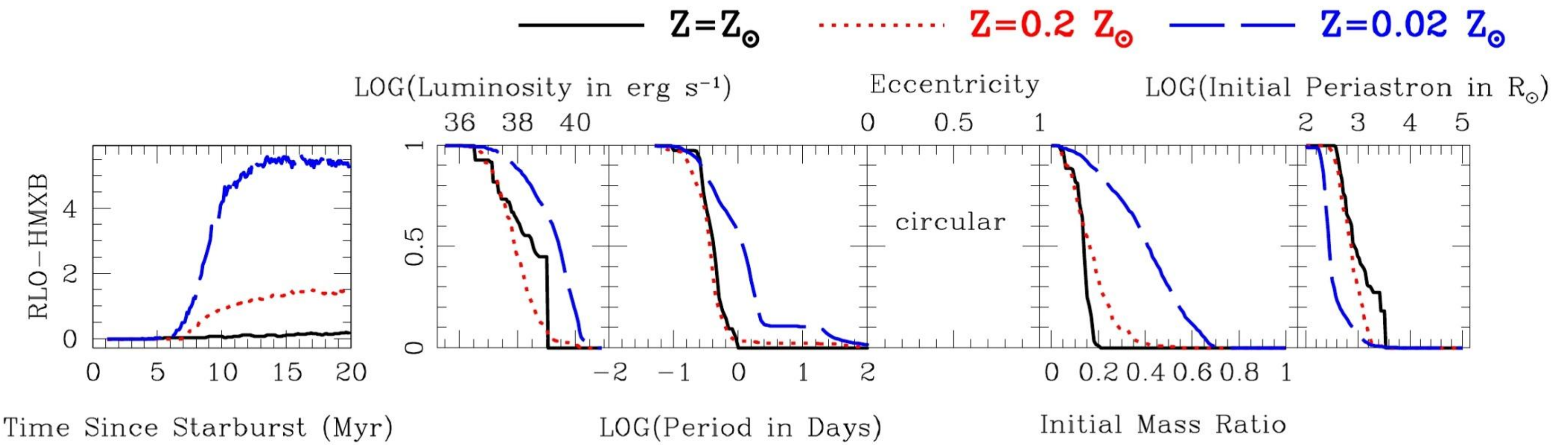
RLO-HMXB Pathway Properties

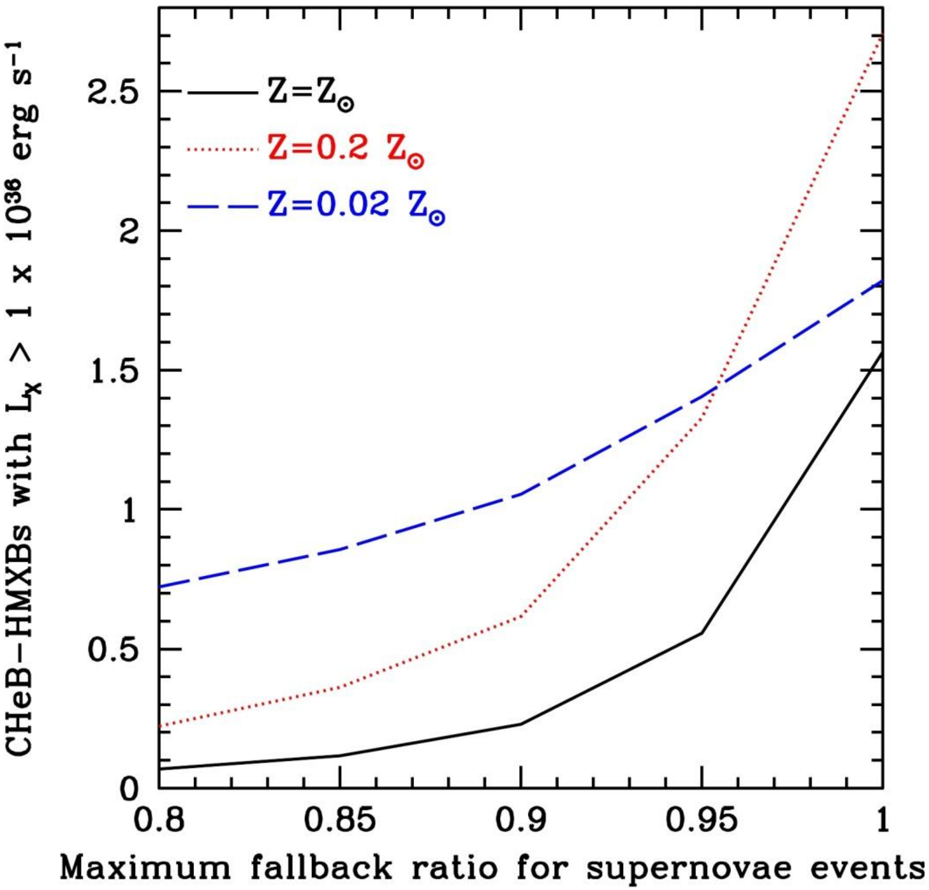


1.) Neither primary nor secondary star is particularly massive

2.) System number decays slowly after the end of the 20 Myr timeframe

3.) Systems cannot be created until after 6 Myr – the lifespan of the first non-LBV systems

The (super)Giant Pathway



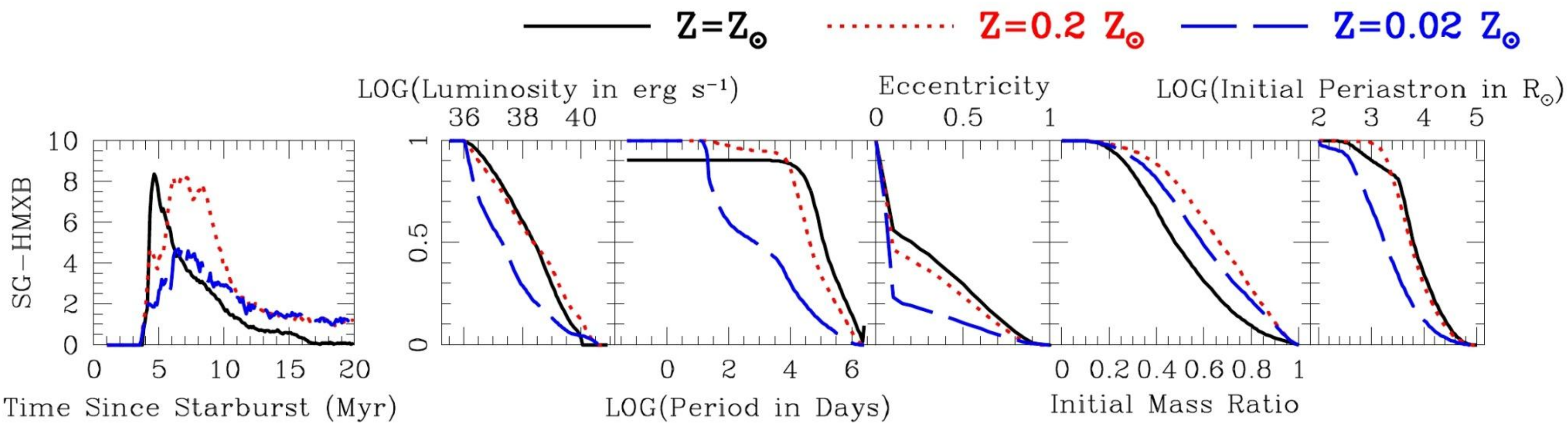
(super)Giant pathway

1.) Systems must start with large periastron separation and usually do not interact before the primary SN

2.) Nearly all systems undergo direct collapse SN with no natal kicks.

3.) System is X-ray dim until donor evolves onto the (super)Giant branch

SG-HMXB Pathway Properties



1.) Primary SN must occur very early to allow direct collapse BH

2.) Due to flat secondary/primary mass ratio distribution, secondary evolves early as well

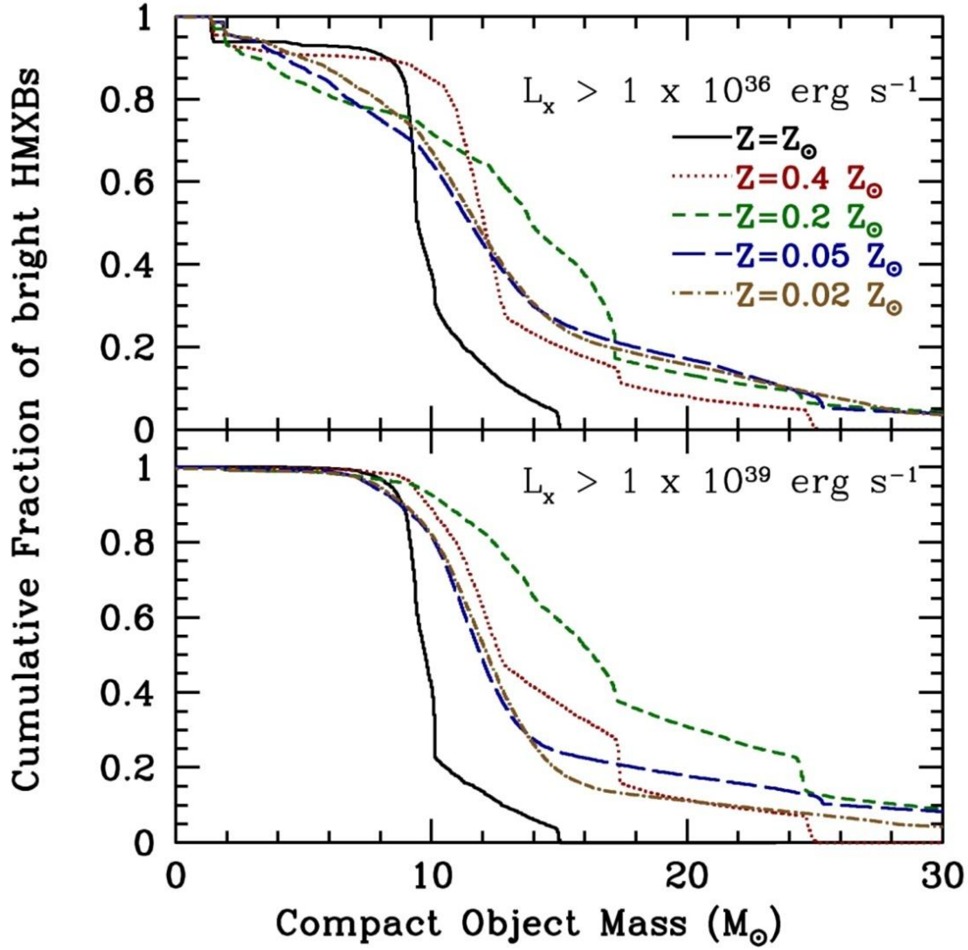
3.) Each individual system is very short lived (< 1 Myr)

4.) Metallicity dependence due to effect on wind strengths

Theoretical Results

Our models can reproduce a reasonable population of HMXBs with luminosities above the Eddington limit.

Our ULX-HMXB population does not contain particularly massive donors, but is instead created by systems moving through particular evolutionary pathways



Observational Tests

- Our Results could be observationally tested in several ways:
  - 1.) Is the ULX population of high metallicity clusters younger than in low metallicity clusters?
  - 2.) Are the orbital periods of high metallicity ULX significantly longer than in low metallicity ULX?

Conclusions and Future Prospects

- The dynamics of common envelope and mass transfer phases are critical for the understanding of ULX formation:

  - We can produce a robust population of ULX from young starbursts, when we allow mild violations of the Eddington limit

  - The abundance of low-metallicity ULX is likely due to the dynamics of RLO-HMXB creation, rather than the size of the eventual BH

Extra Slides

- **Extra Slides**

The XLF

We **allow accretion in excess of the Eddington limit:**

- up to 10x Eddington for BH
- up to 2x Eddington for NS

The super-Eddington formalism acts to:

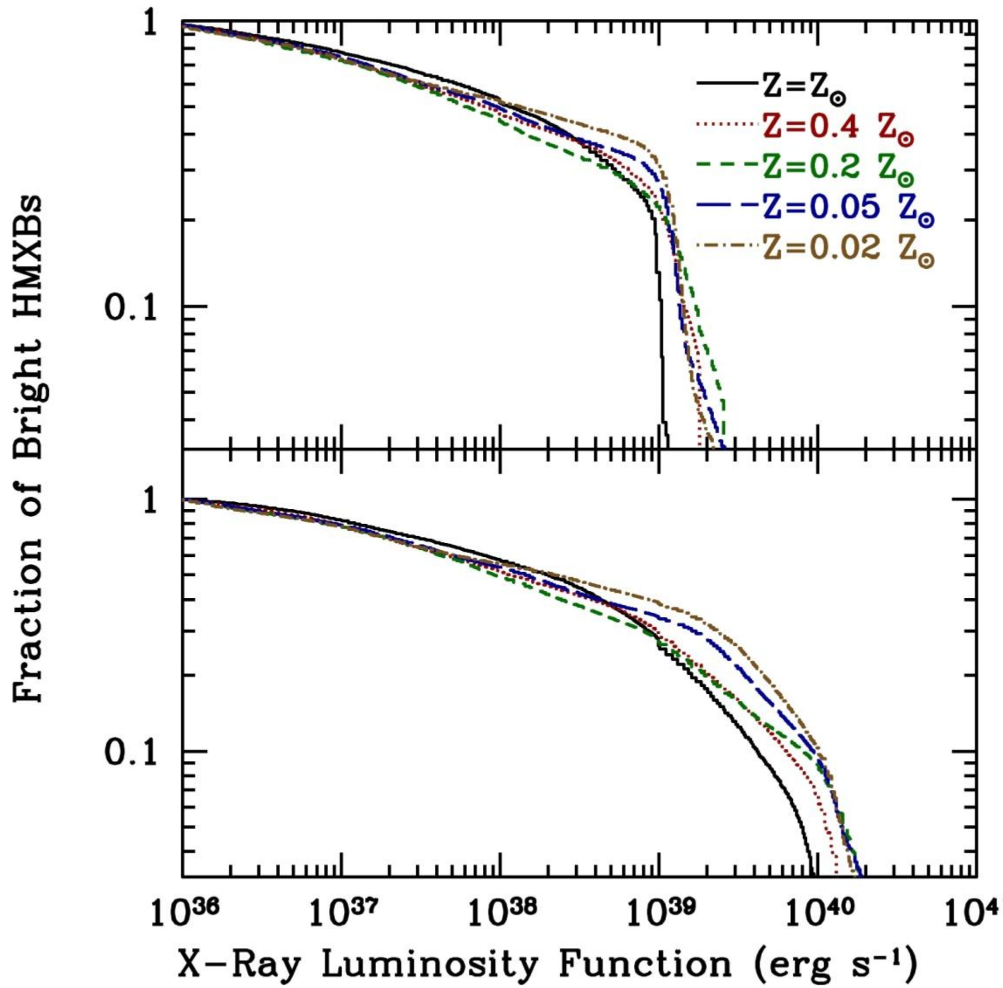
*Greatly increase HMXB above 2×10^{39} erg s^{-1}

*create no changes above 1×10^{36}erg s^{-1}

XLF is **<u>not</u>** metallicity dependent.

XLF is harder than most observations ($L^{-0.2}$ vs. $L^{-0.6}$)[1].

Likely due to loss of transient HMXBs at the low luminosity end



1.) Gilfanov, Grimm, Sunyaev, NuPhS, 194, 369 (2004)

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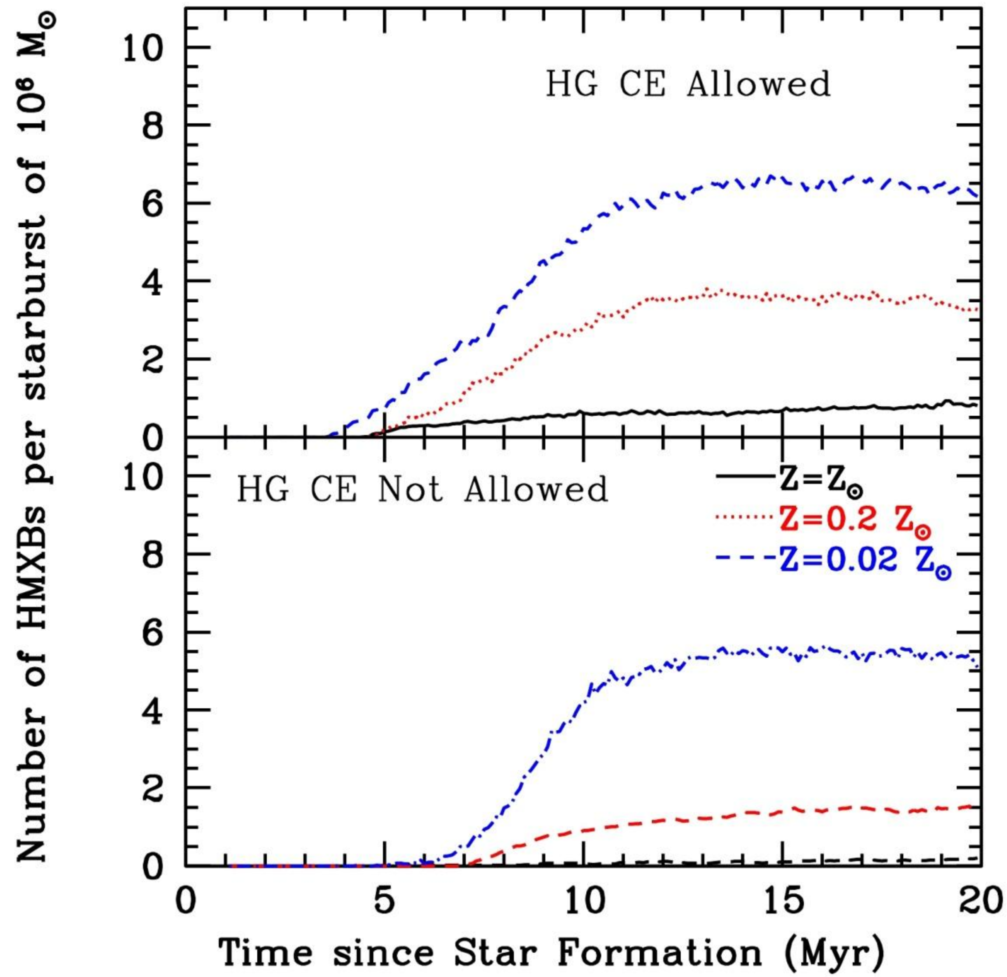

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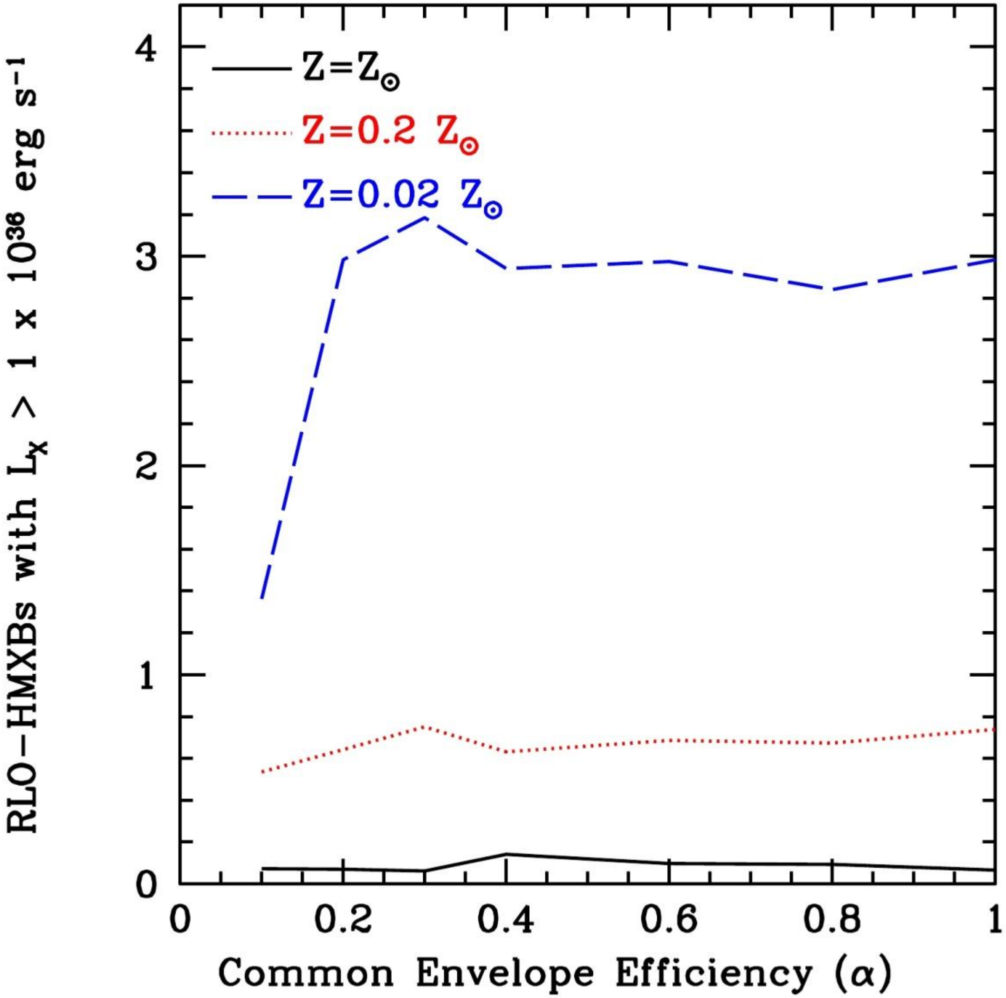

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