Mind the gap: What can we learn about stellar astrophysics from gravitational wave detections of binary black holes?

Rob Farmer

r.j.farmer@uva.nl

Collaborators:

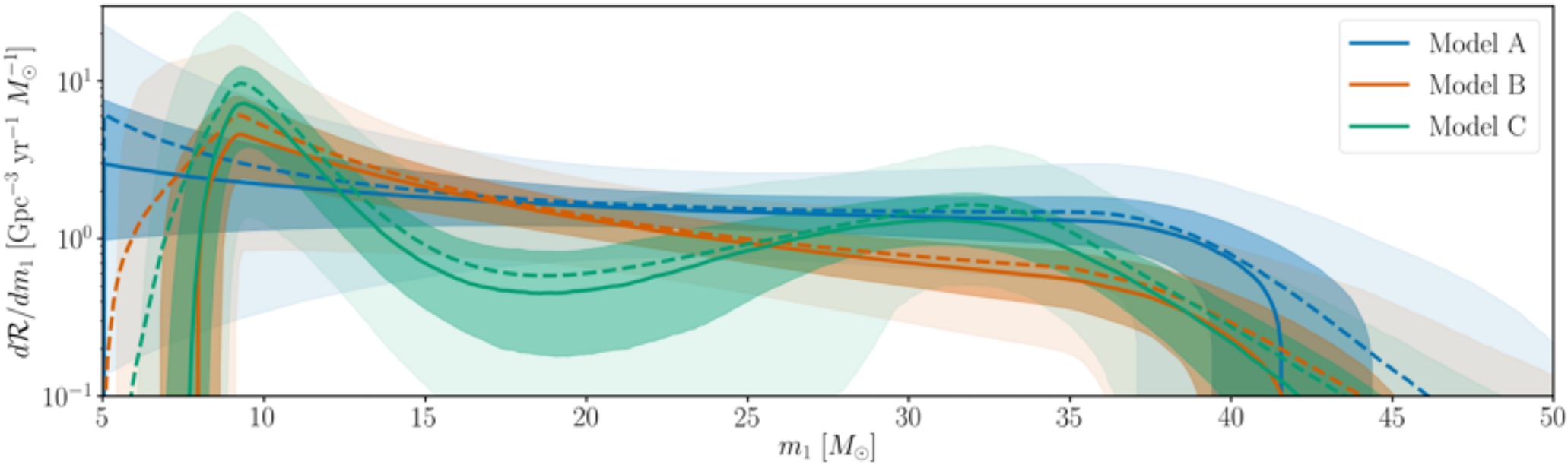
Mathieu Renzo, Selma de Mink, Stephen Justham,
Pablo Marchant, Maya Fishbach, **Eva Laplace**, Lieke van Son
Javier Fraile, Mirron van der Kolk, Sarah Kok

Gravitational waves from
merging binary black holes can constrain
nuclear reaction rates

If

we understand their stellar progenitors

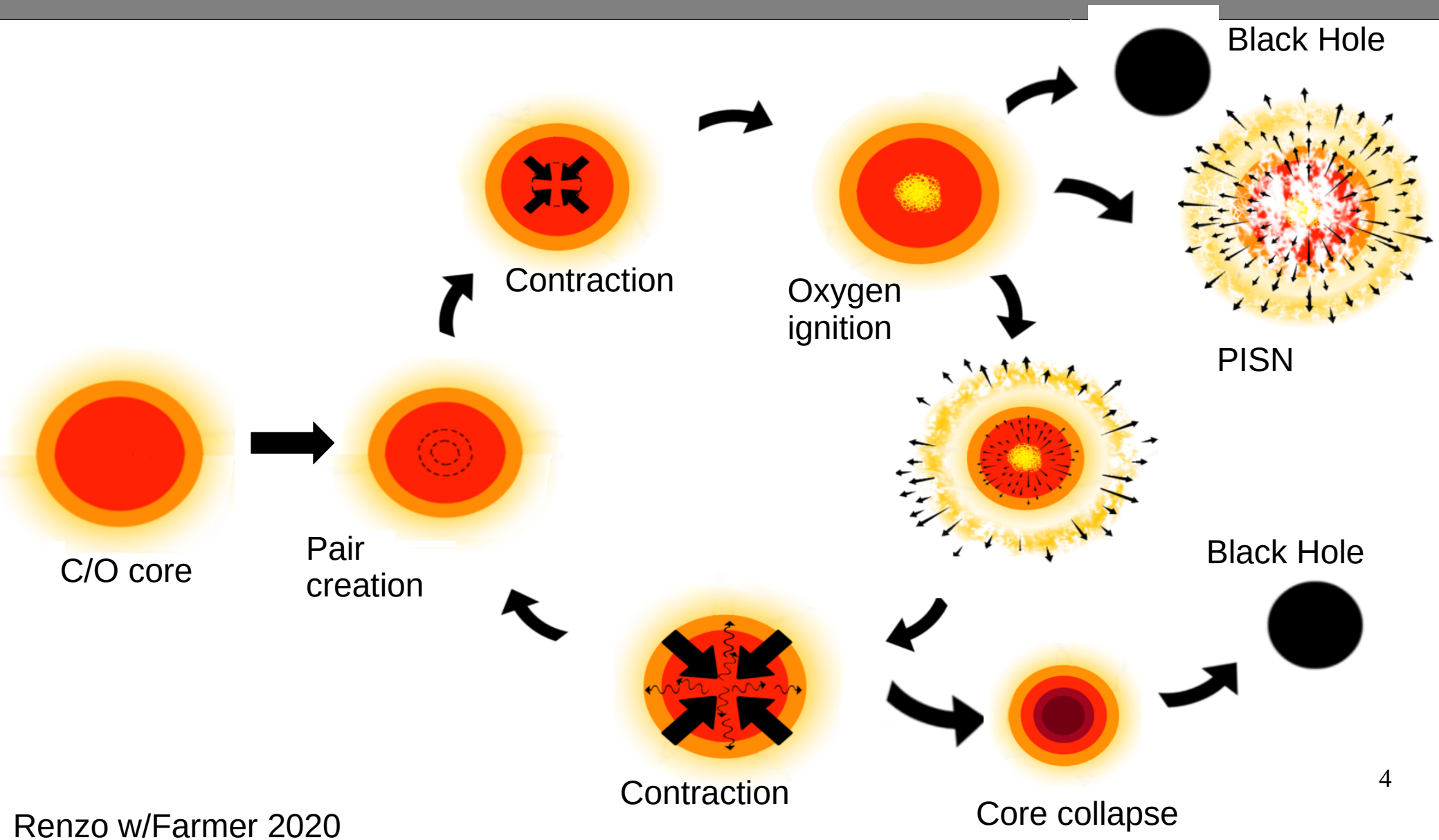
How do black holes fit into this?



O1/O2 ~43 +-10Msun

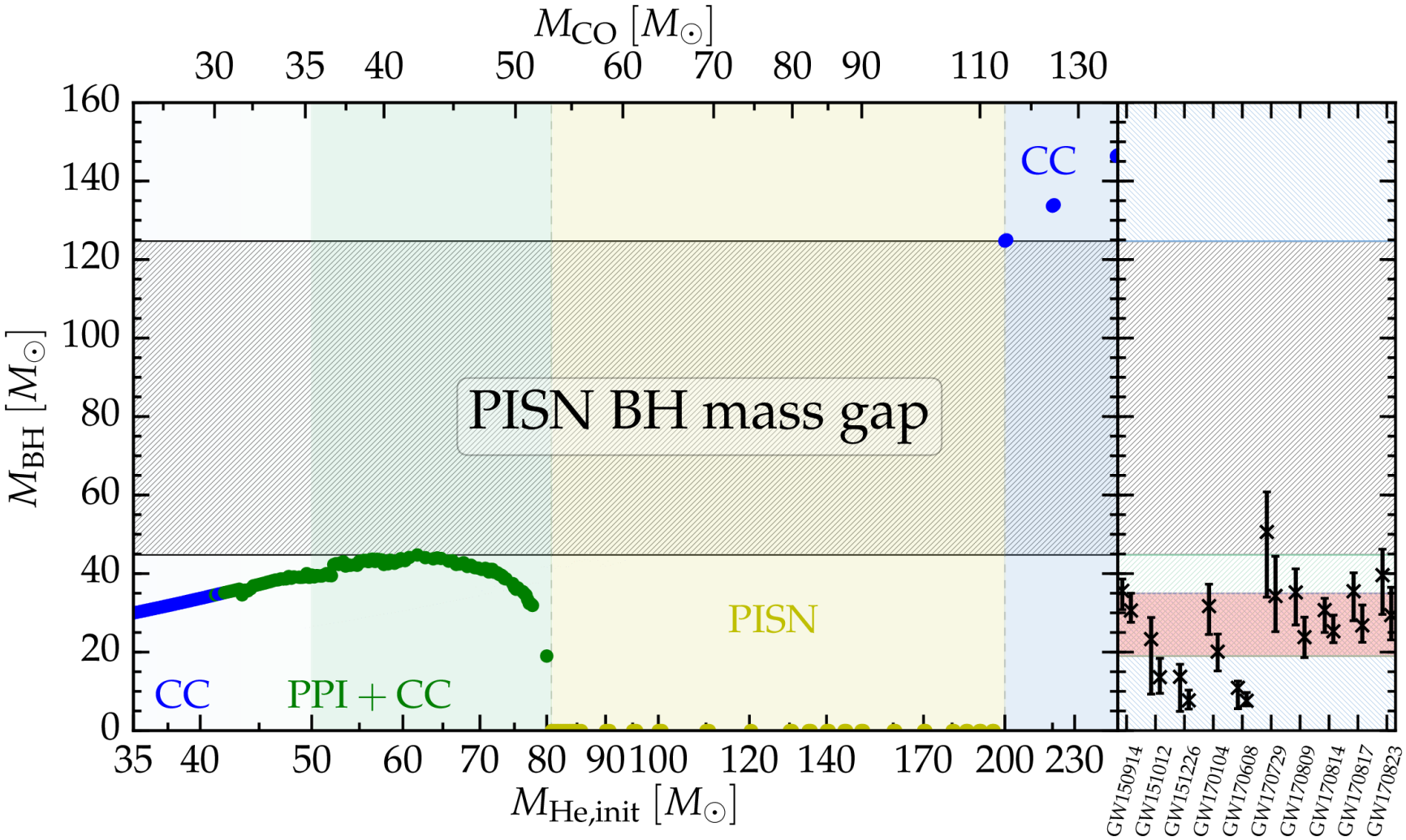
LIGO+ 2019

Pair instabilities



Renzo w/Farmer 2020

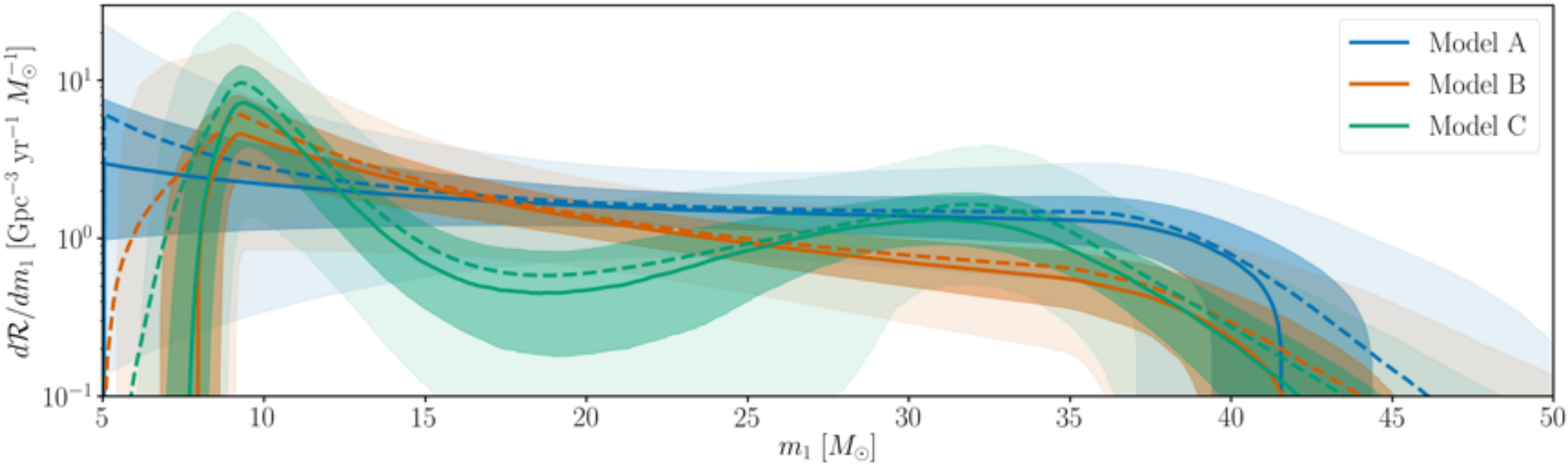
Where's the gap?



MESA

Renzo w/Farmer 2020

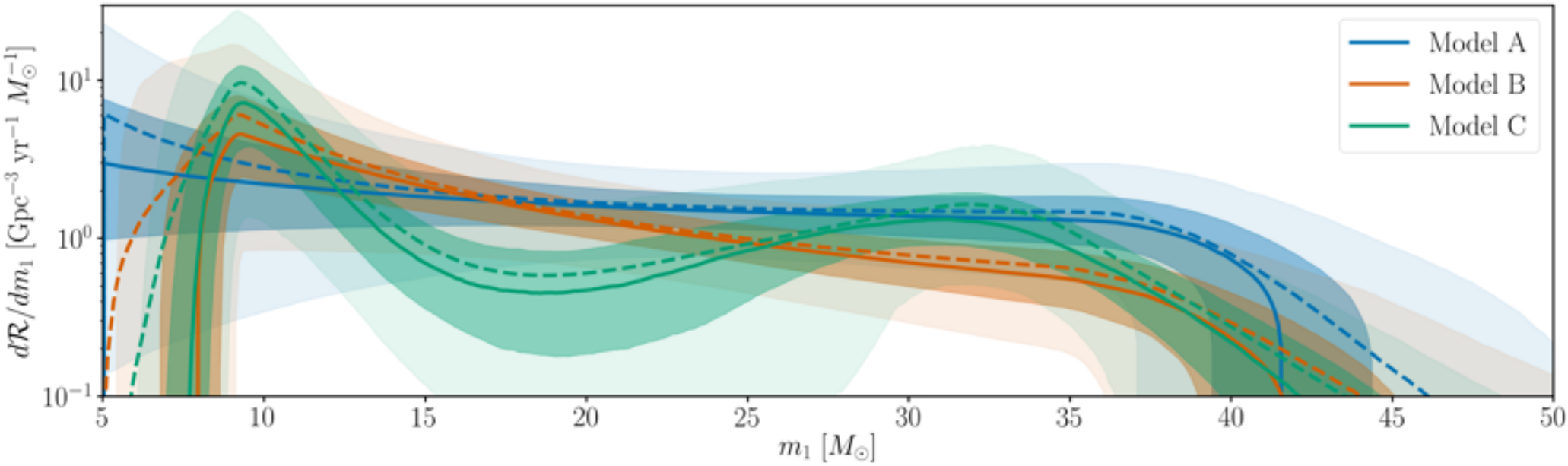
O1/O2 data



O1/O2 ~43 +-10Msun
Theory ~45Msun

LIGO+ 2018

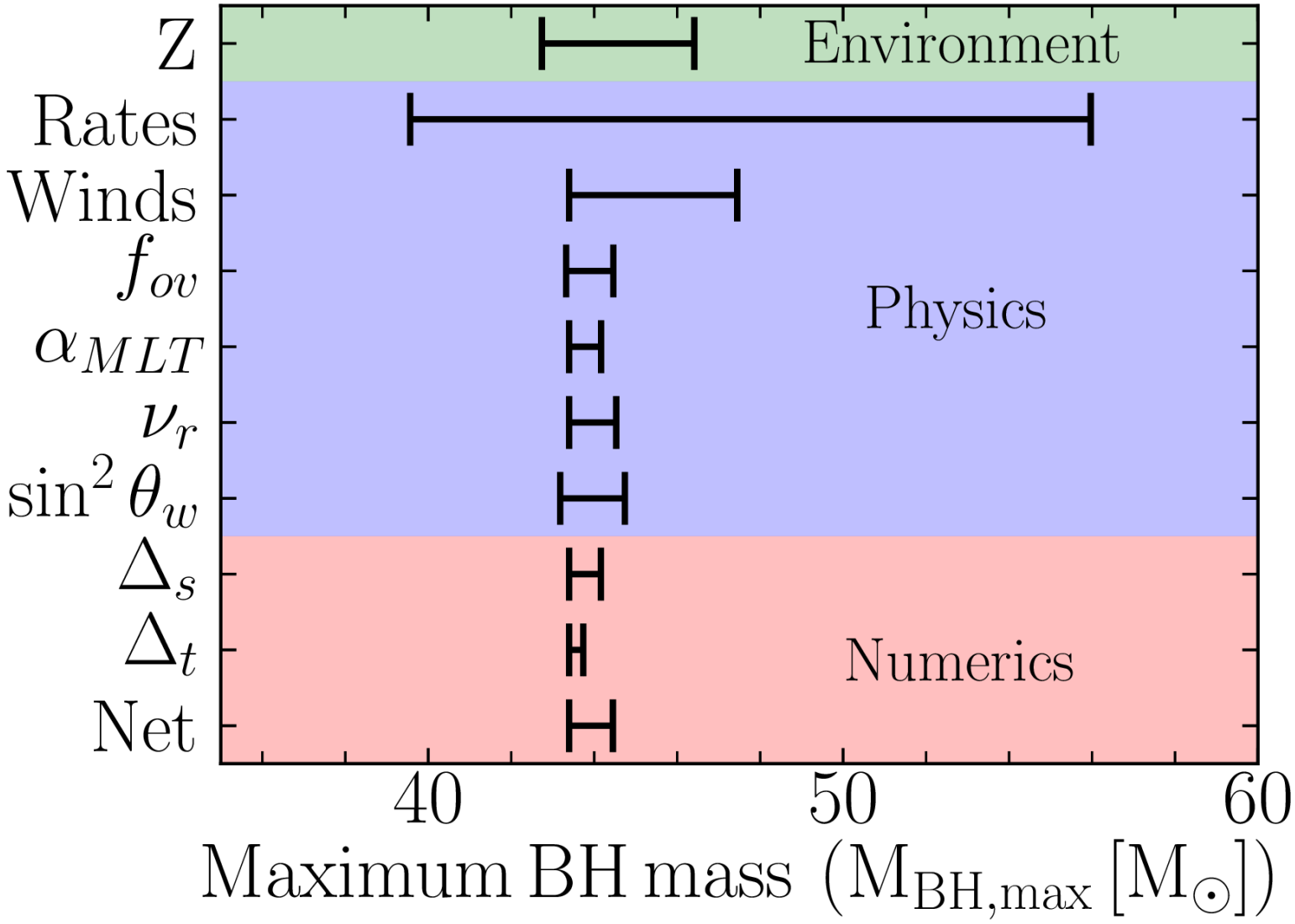
What about GW190521?



~85Msun+65MSun

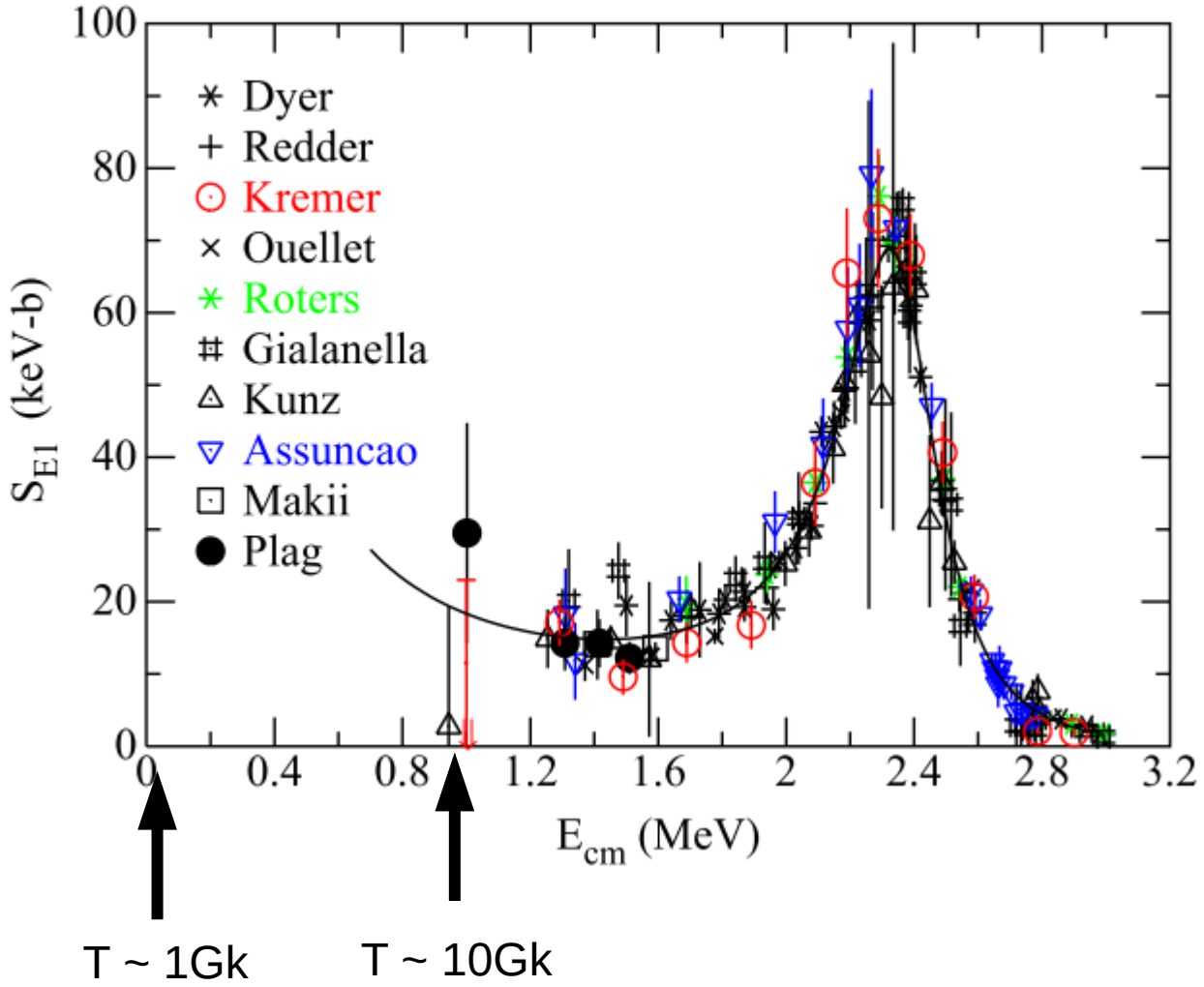
LIGO+ 2018

What sets the location of the gap?



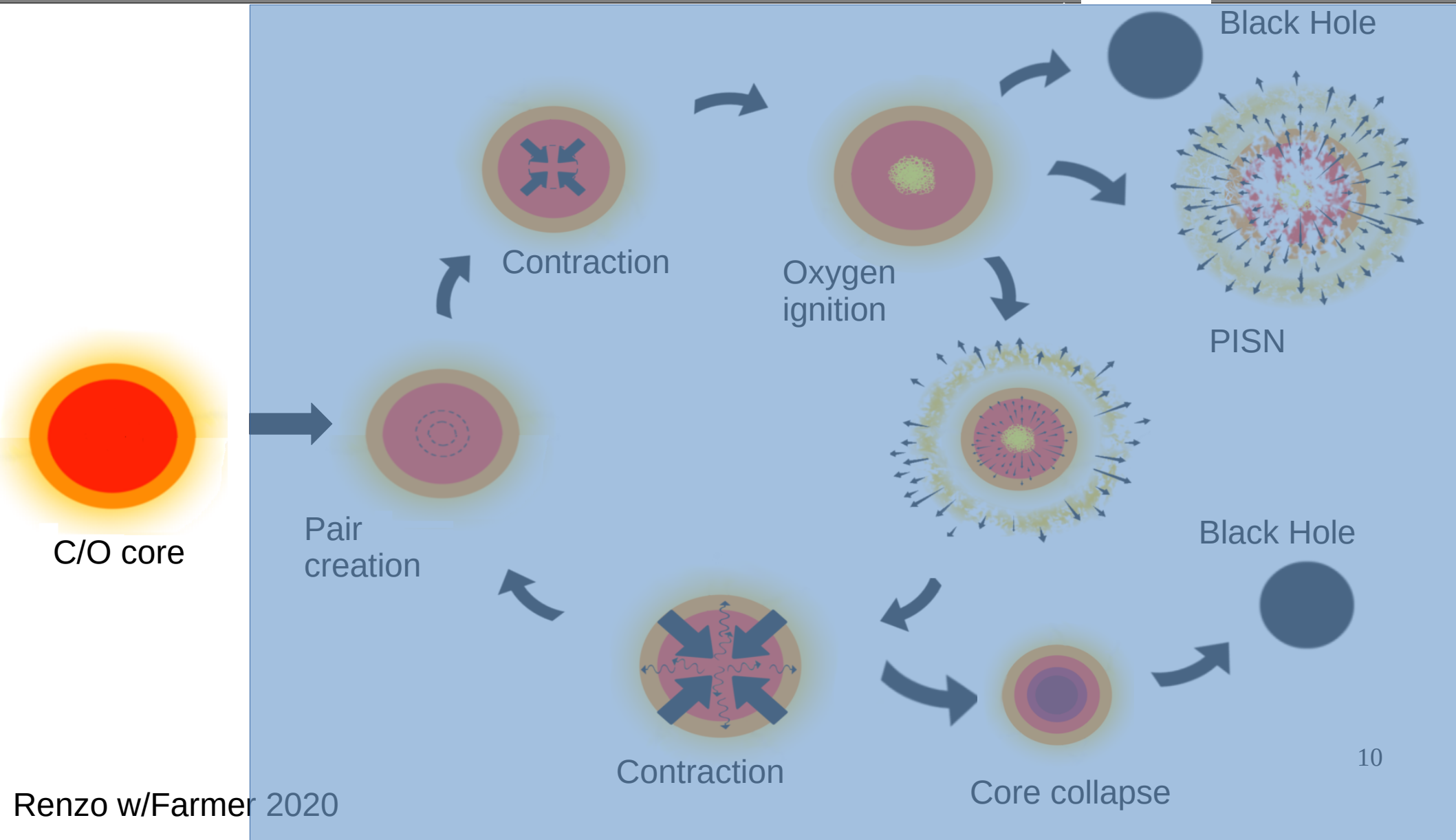
Farmer+ 2019

Why is C12(a,g)O16 so uncertain?



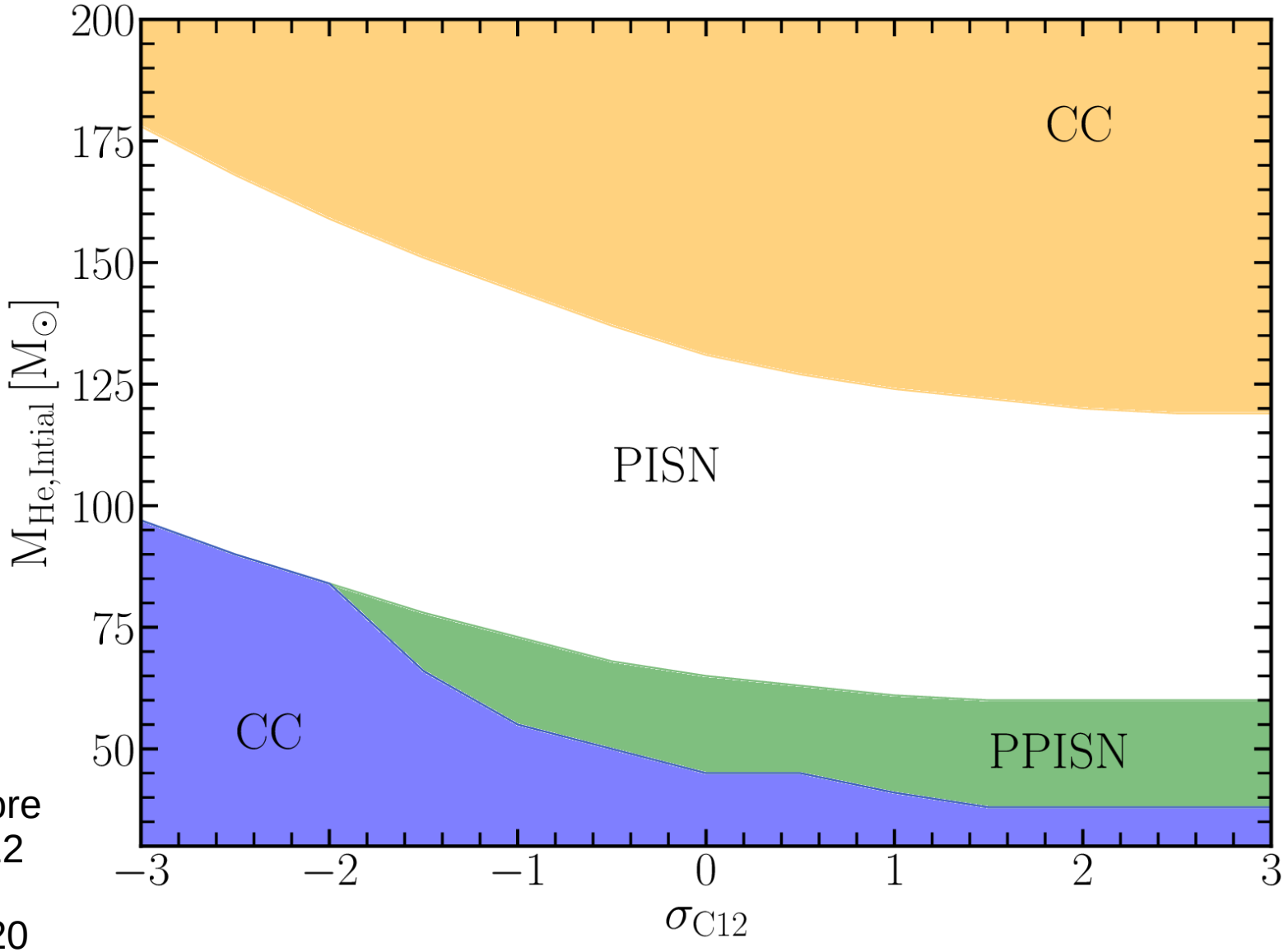
Holt et al 2019

Pair instabilities



Renzo w/Farmer 2020

What does C12(a,g)O16 do to a star?

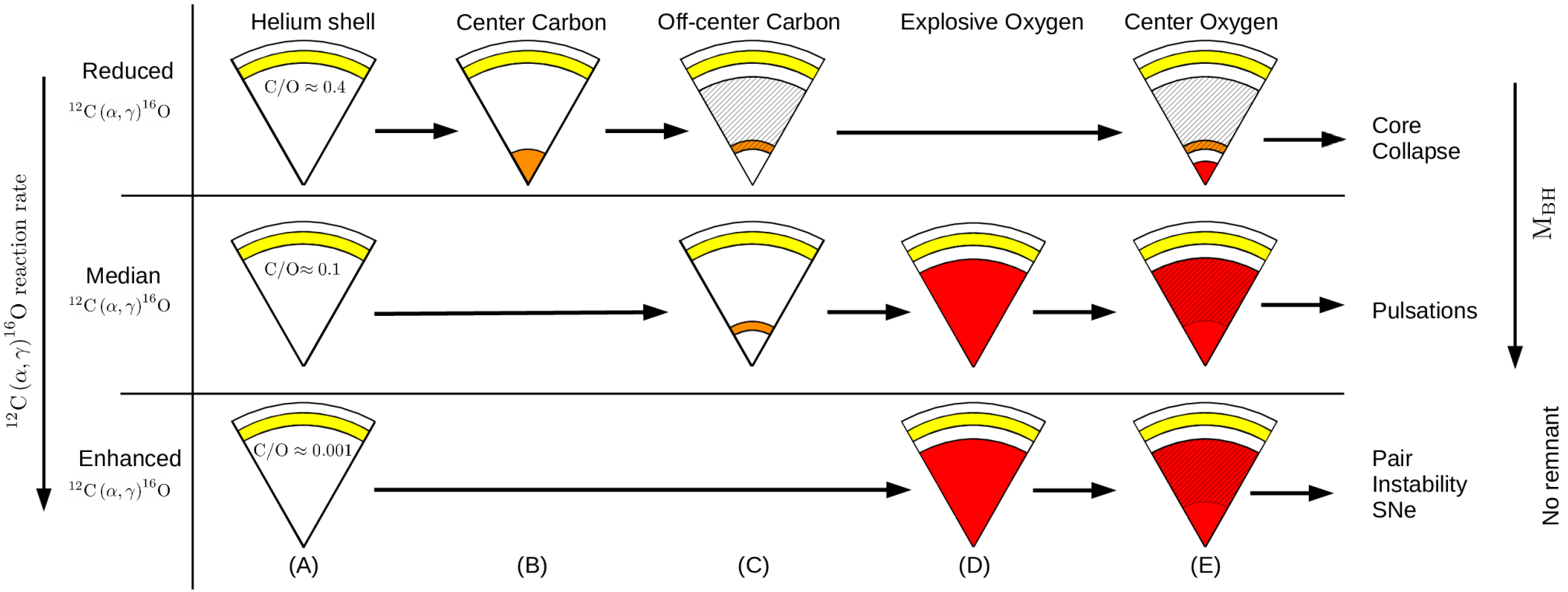


More C12

More O16

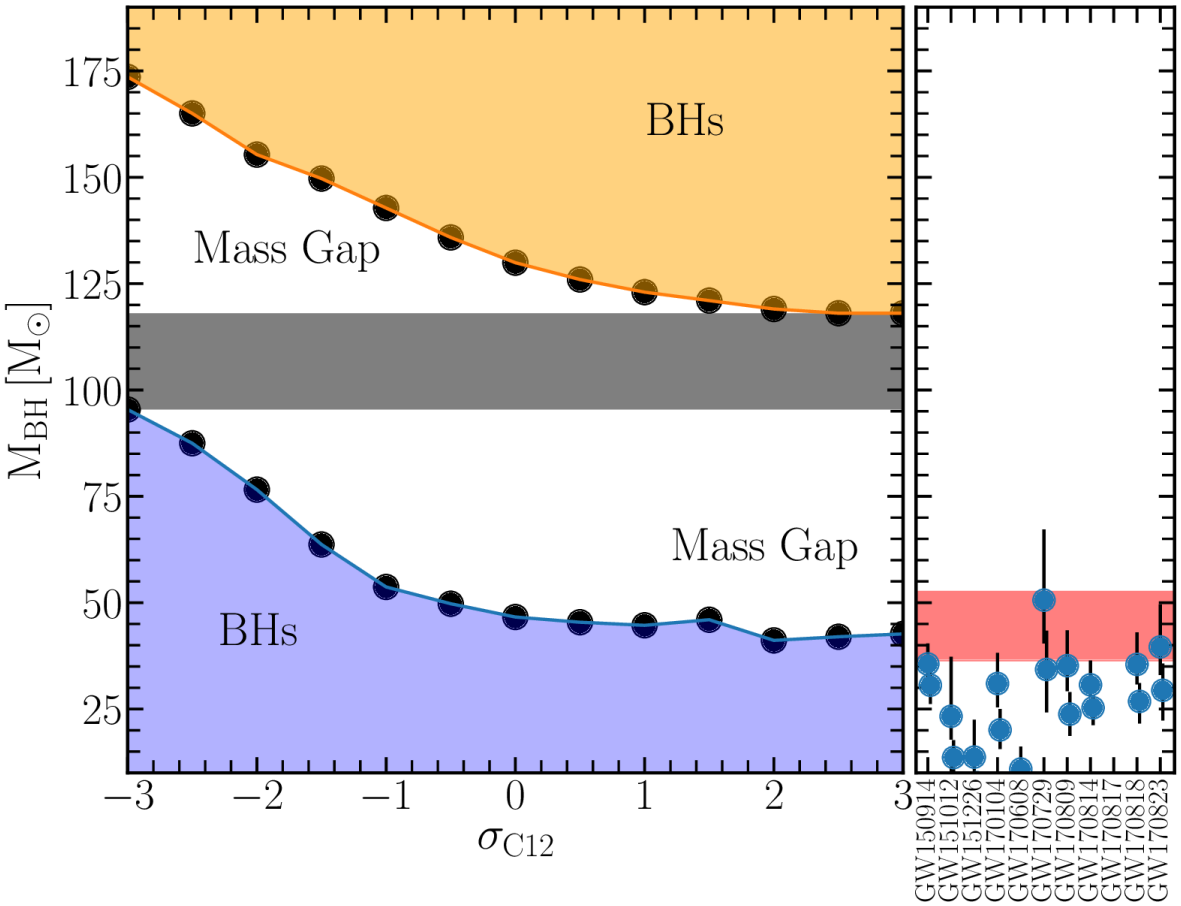
Farmer+2020

What's going on?



Farmer+2020

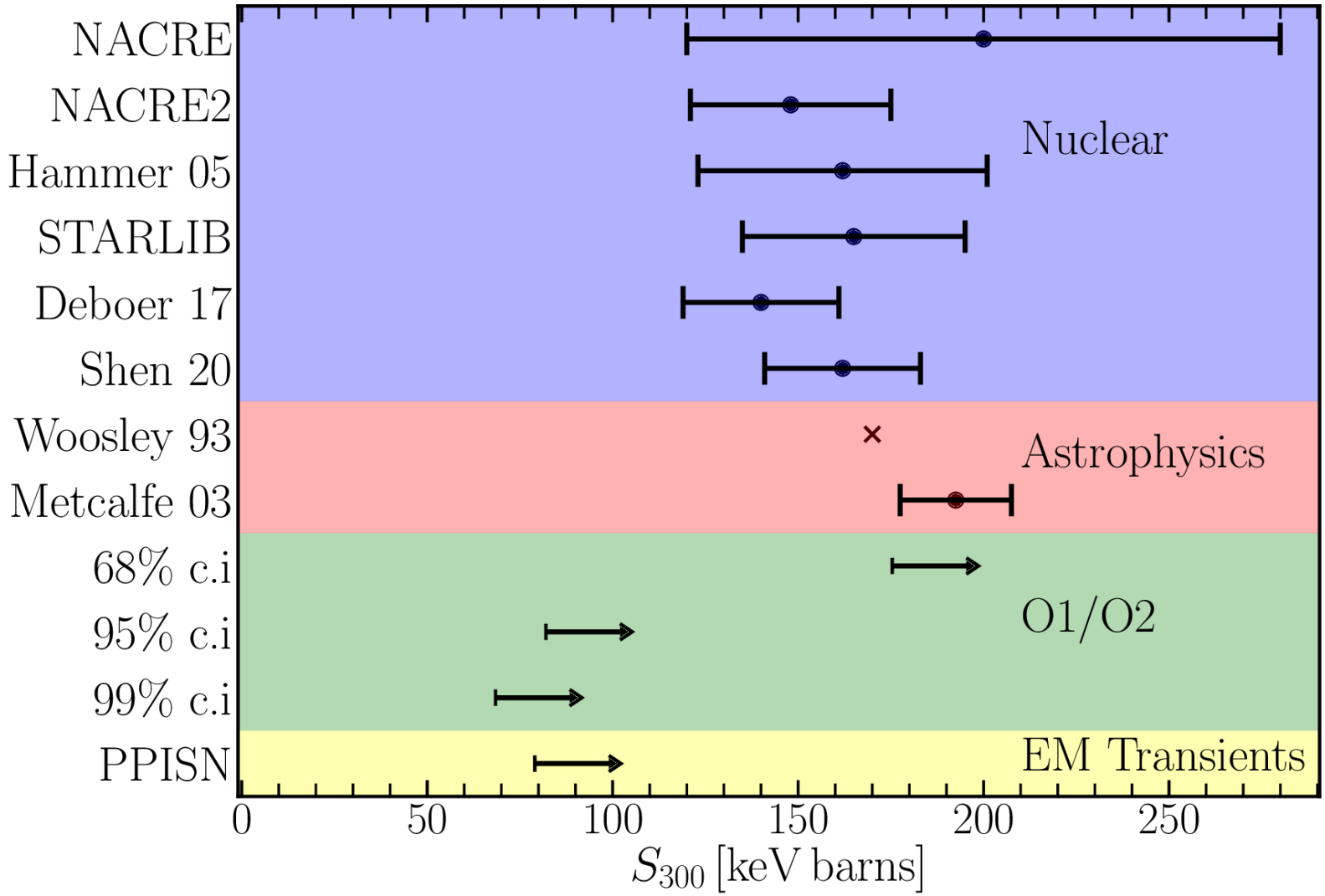
What does this do to the max BH mass?



- Changing c12(a,g)o16 rate changes C/O ratio
- Changes how C and O burn
  - Lower rates stabilises the core during C burning

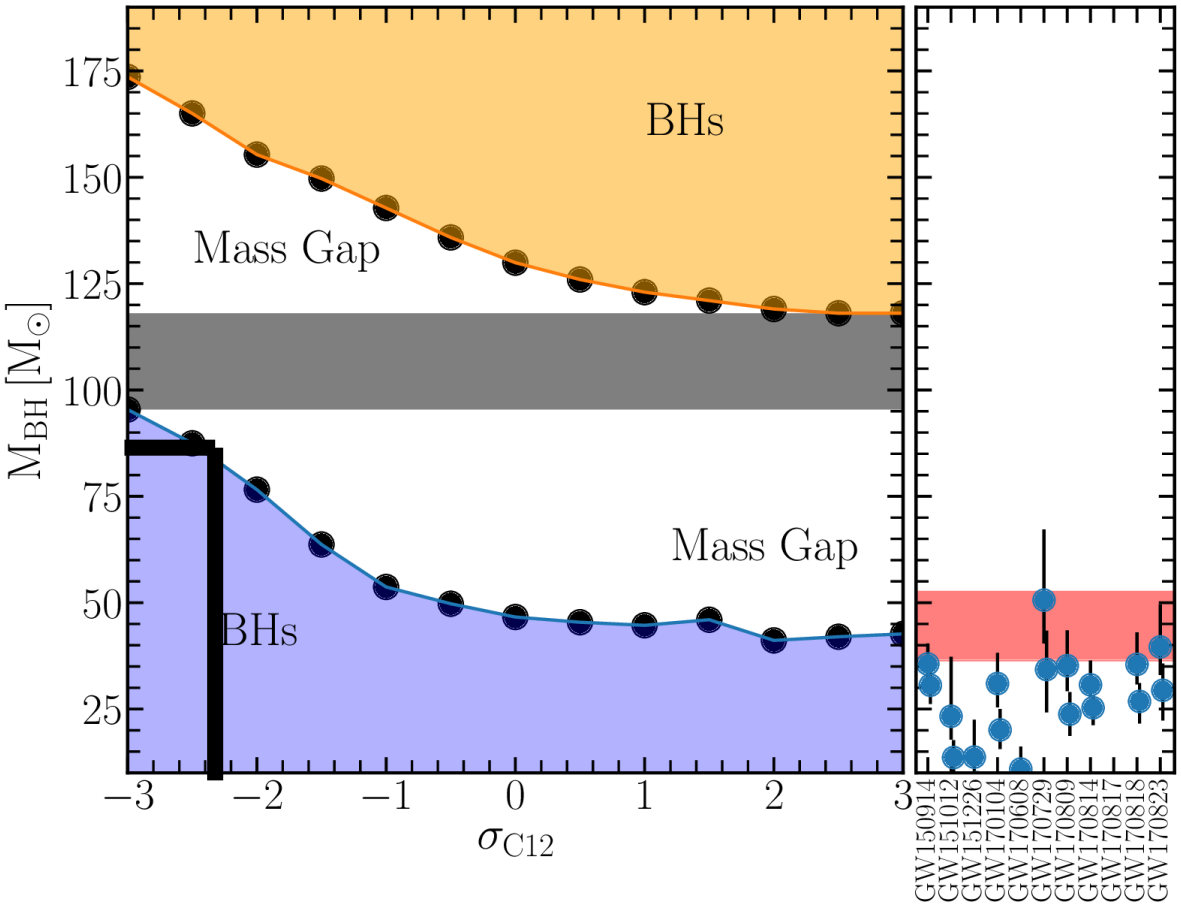
Farmer+2020

Constraints on C12(a,g)O16



Farmer+2020

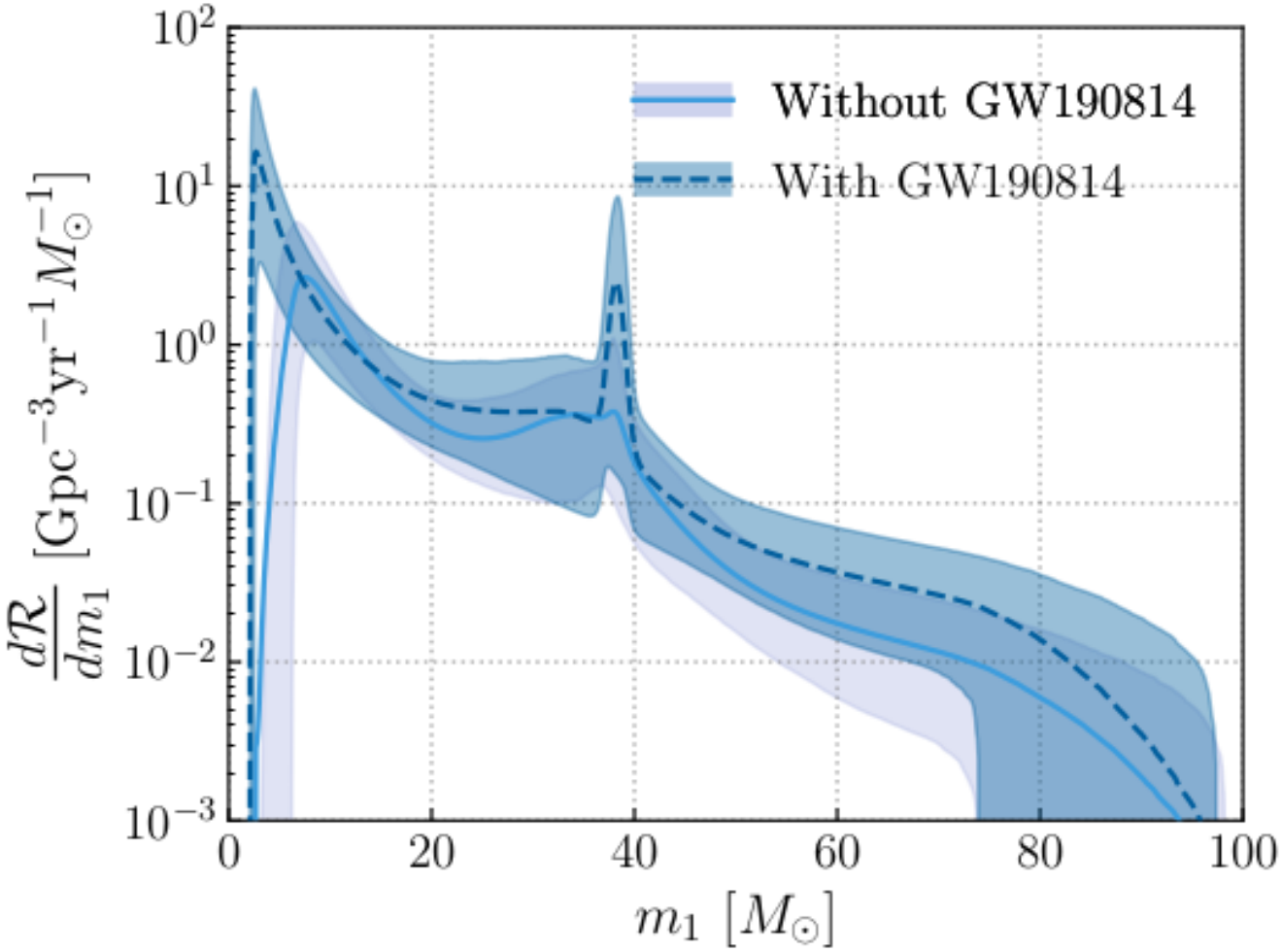
GW190521?



- Changing c12(a,g)o16 rate changes C/O ratio
- Changes how C and O burn
  - Lower rates stabilises the core during C burning
- Can go to 85Msun
  - But its 2.5 sigma change
- Correlations with other rates?
  - 3alpha, C12C12, O16O16, others
- See also Takahashi 2018, Belczynski 2020

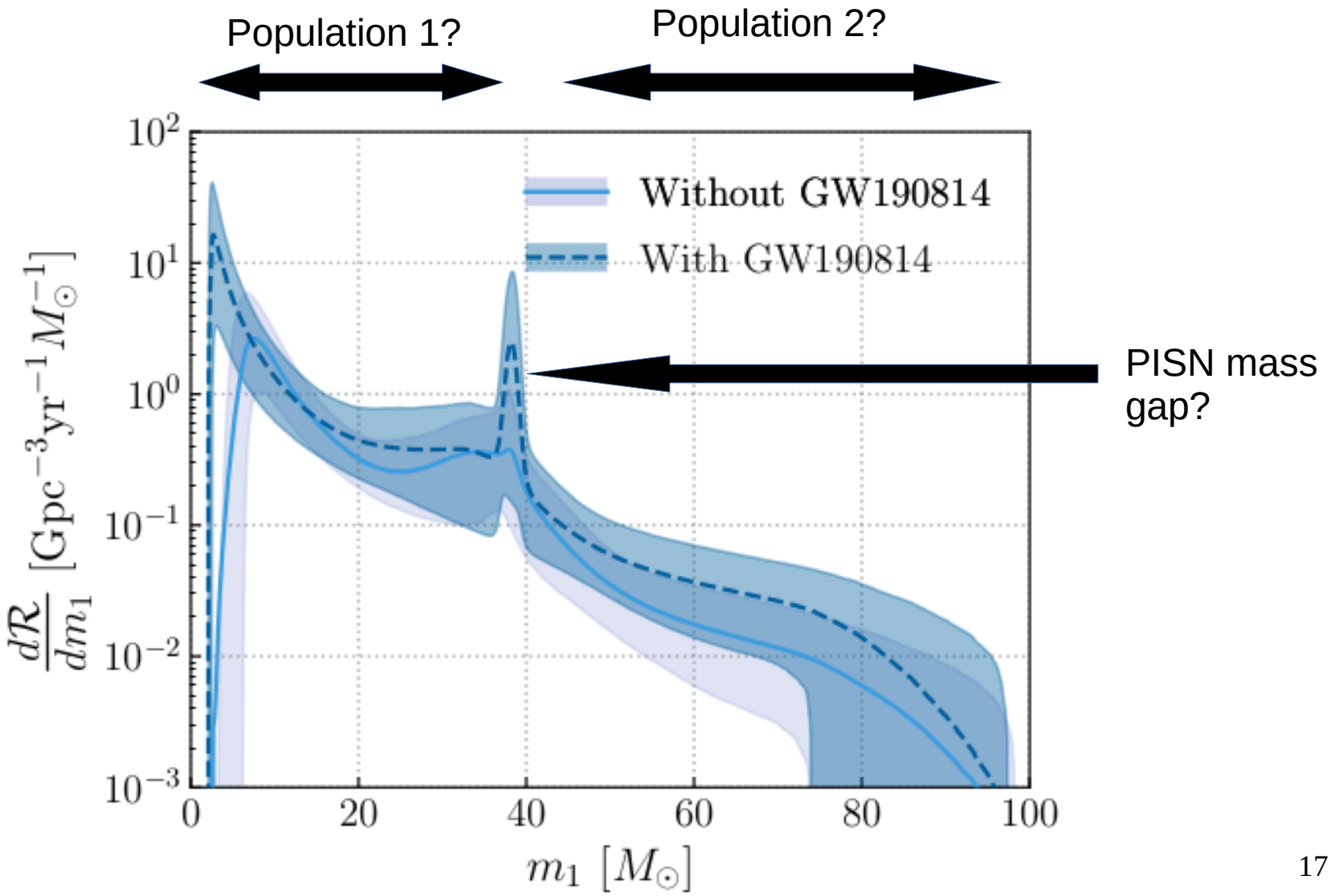
Farmer+2020

Where are we now?



LVC+ 2020

Where are we now?



LVC+ 2020

Summary

Merging binary black holes can be used to constrain stellar astrophysics through their stellar progenitors

The edge of the PISN mass gap can be used to calibrate nuclear reaction rates

O1/O2 data provides lower limits on the C12(a,g)O16 rate

Correlations with other uncertainties still need to be taken into account

There are many proposed theories for making GW190521 like systems