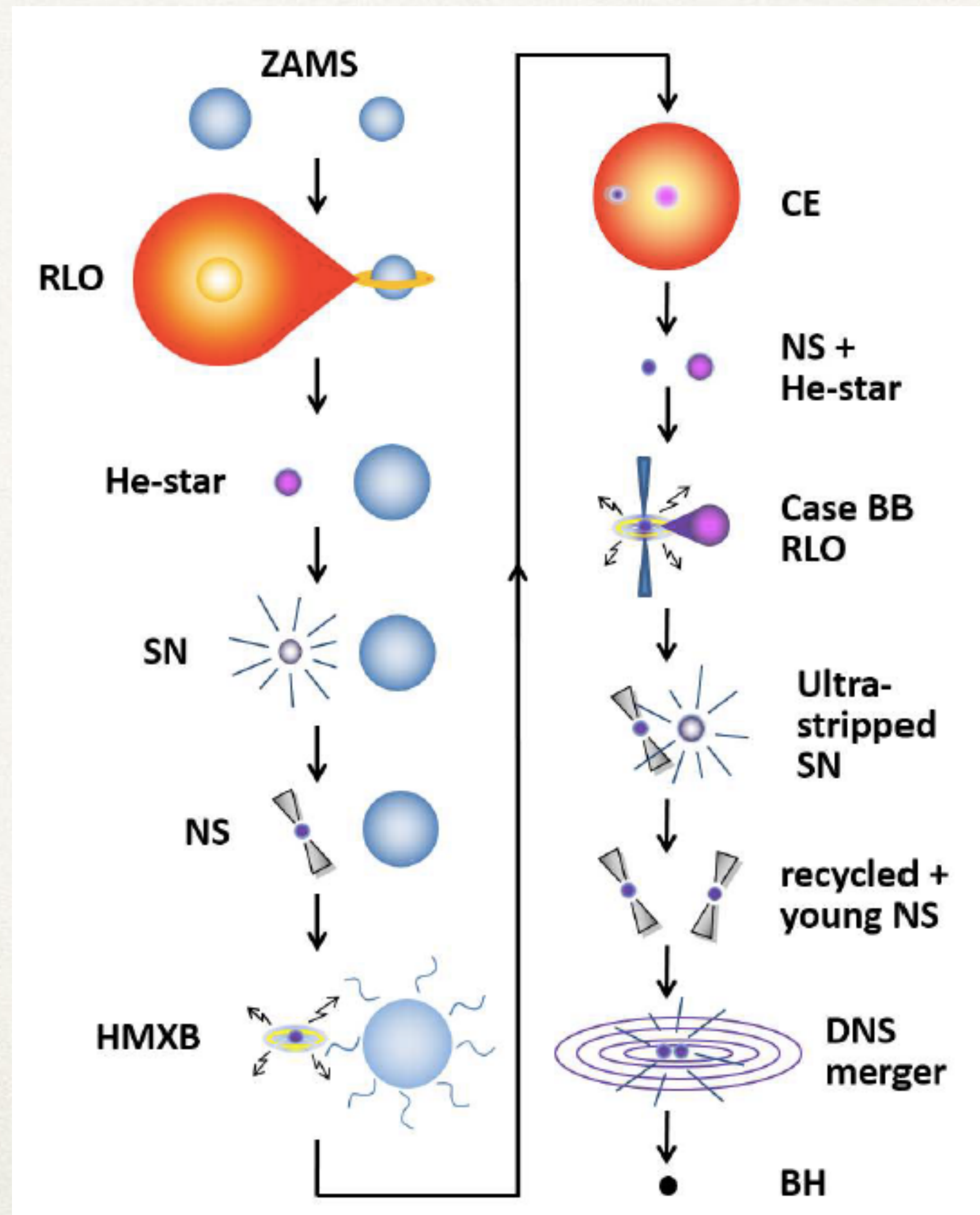


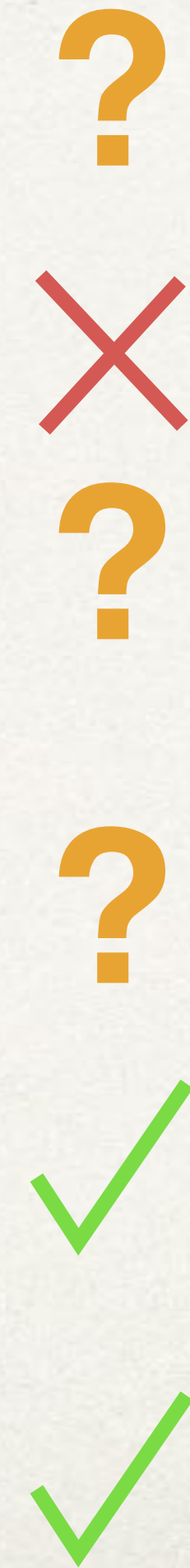
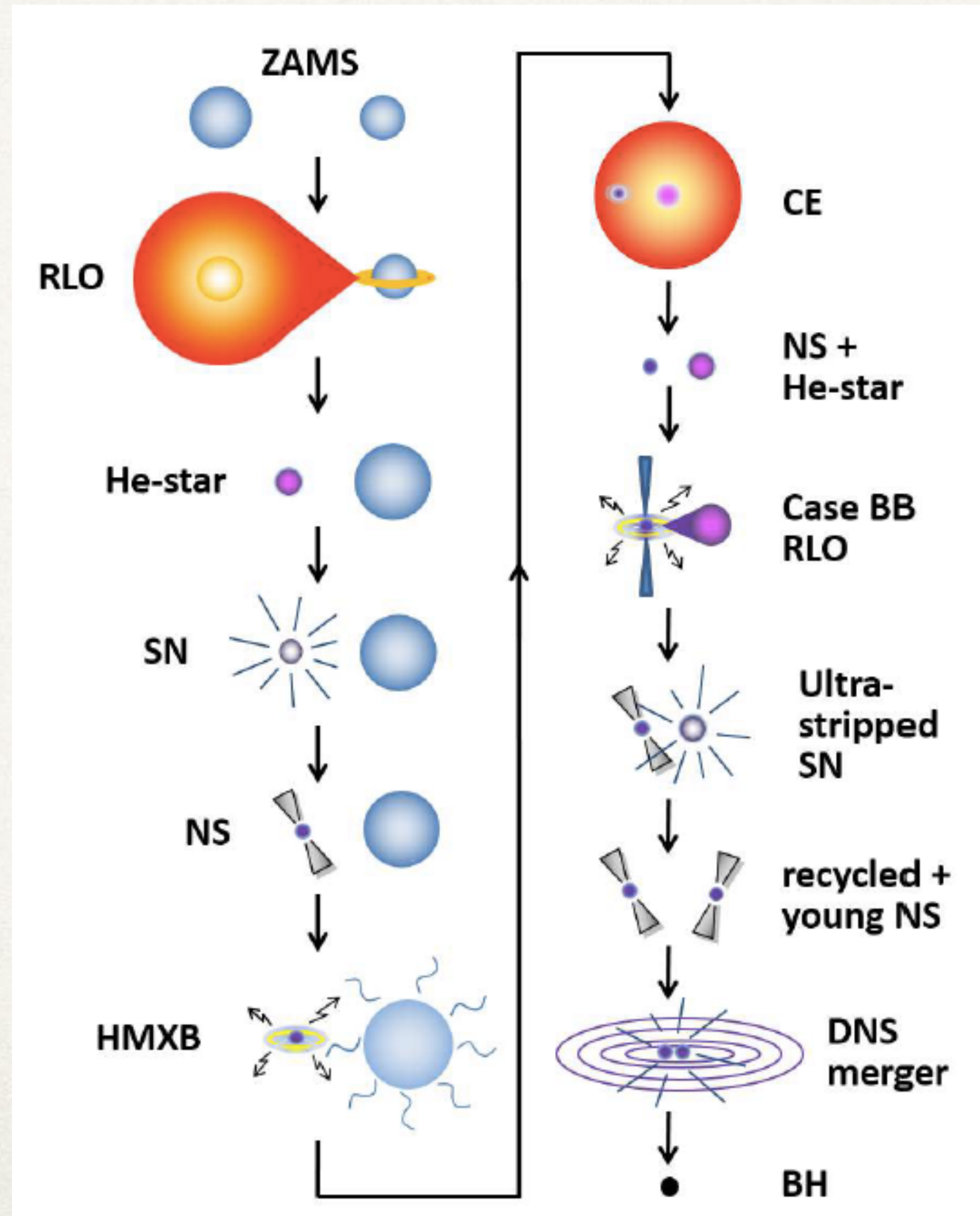
Evolution of Binary Stars into Gravitational Wave Sources

Jeff J Andrews
CIERA Fellow
Northwestern University

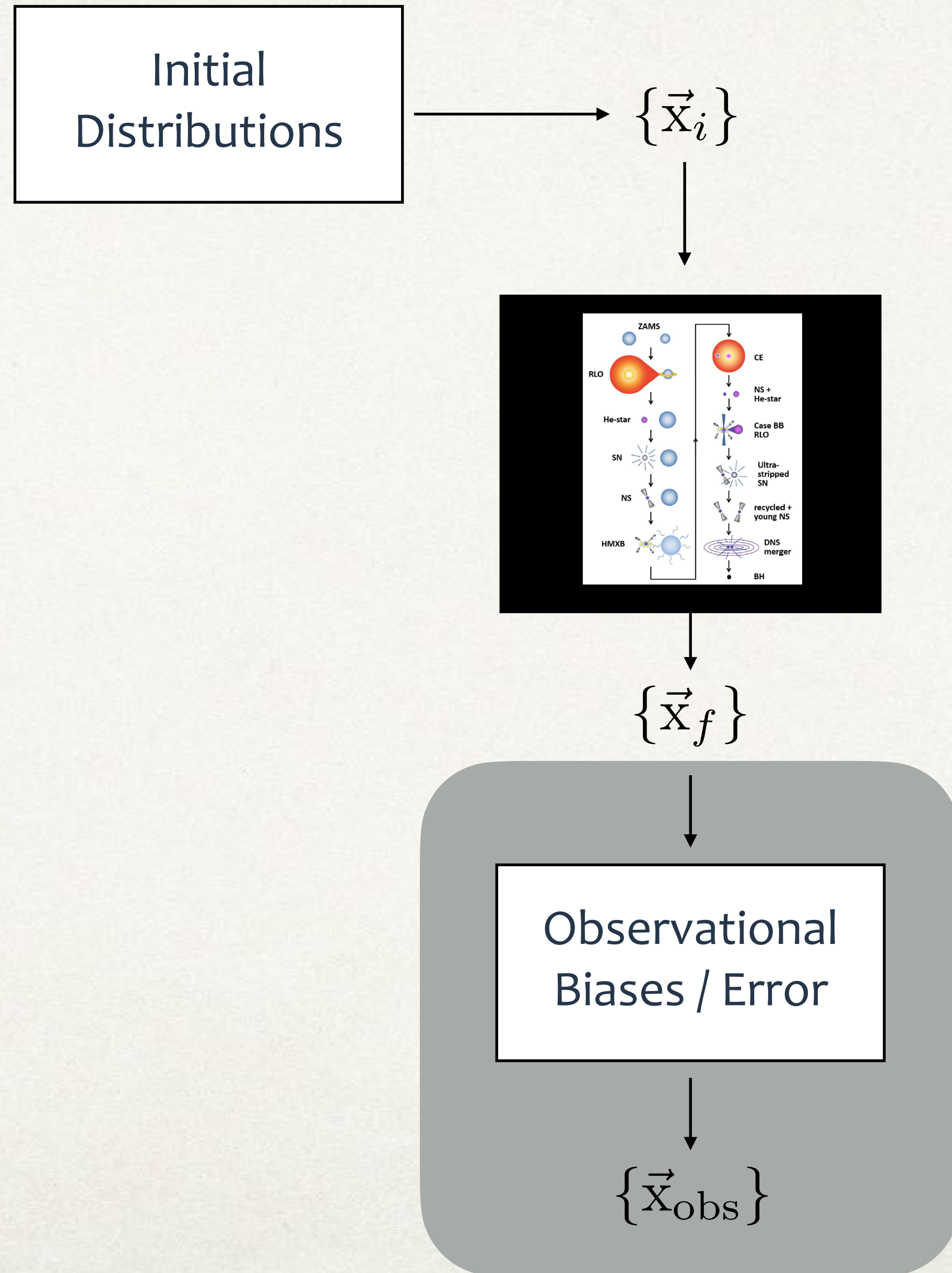
End-to-End High Mass Binary Evolution: Classical Scenario



End-to-End High Mass Binary Evolution: Classical Scenario

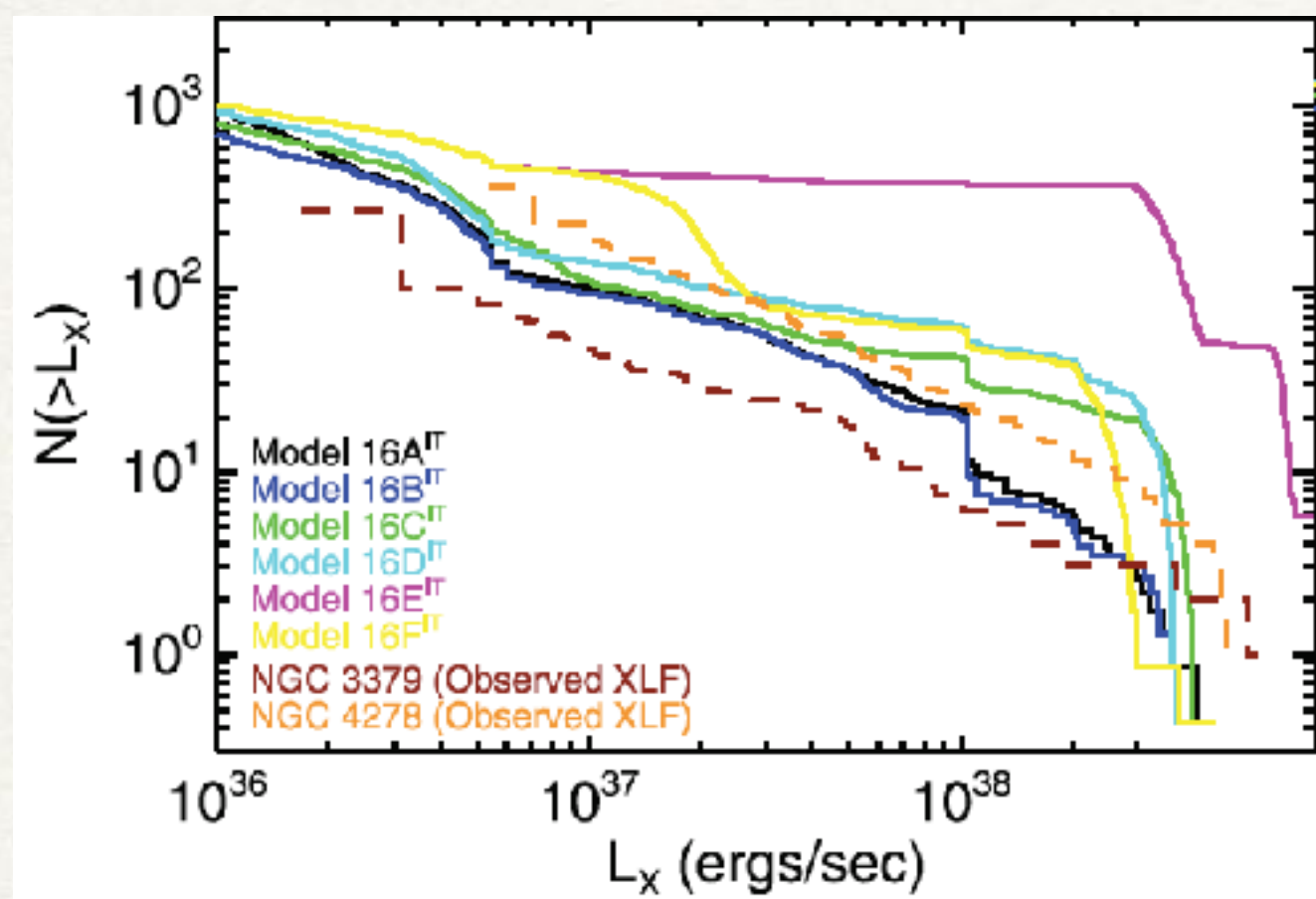


Population synthesis basics

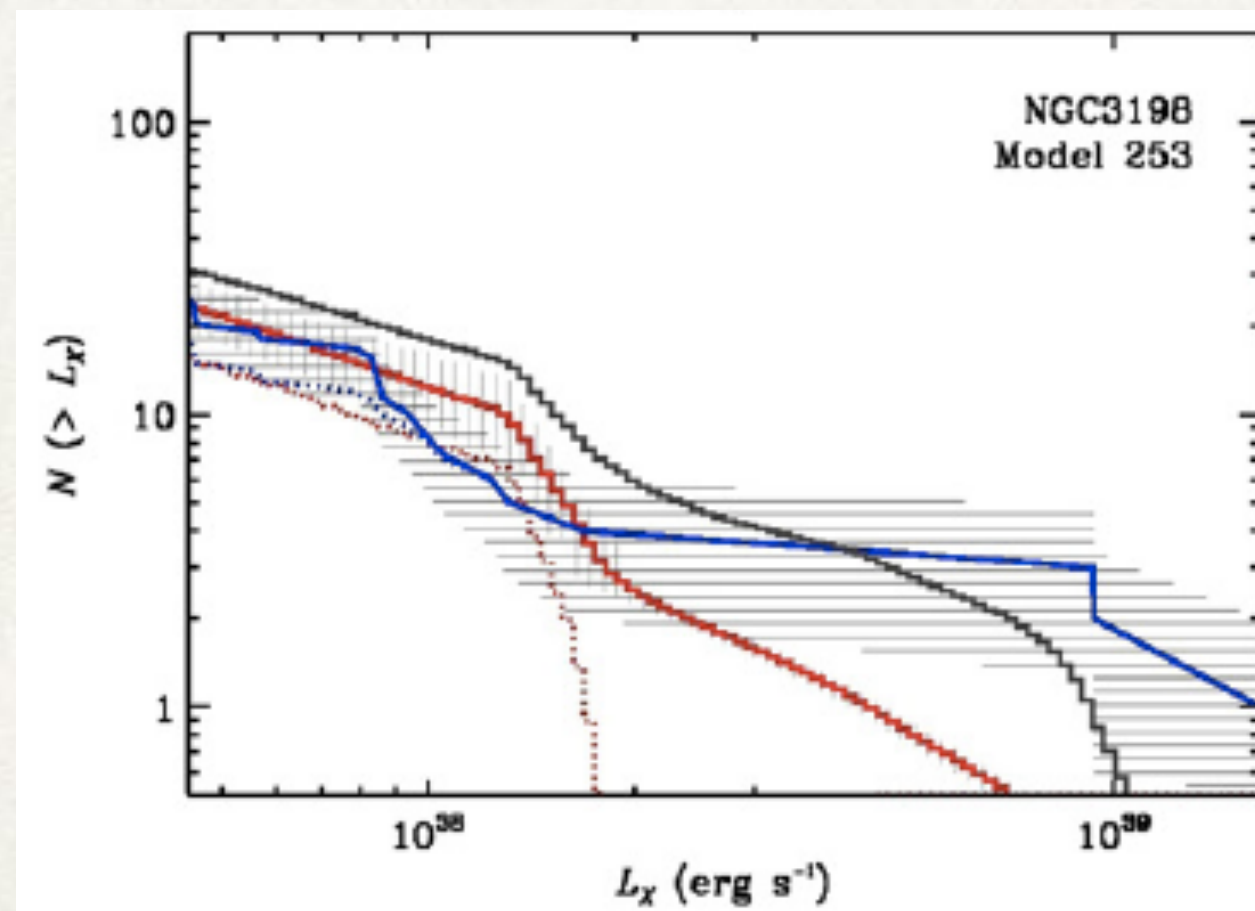


Population synthesis goals

Model selection

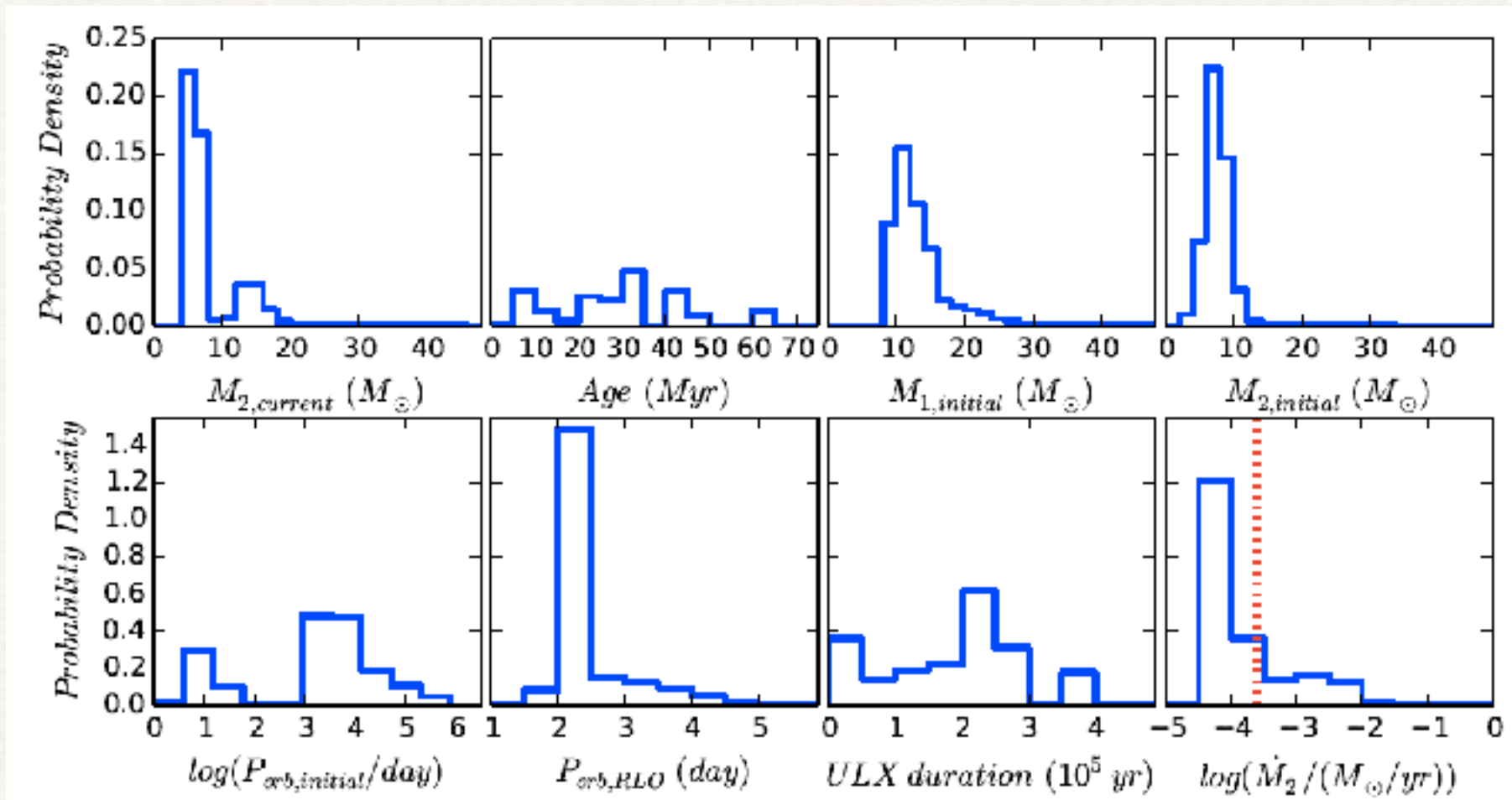


Fragos et al. (2008)



Tzanavaris et al. (2013)

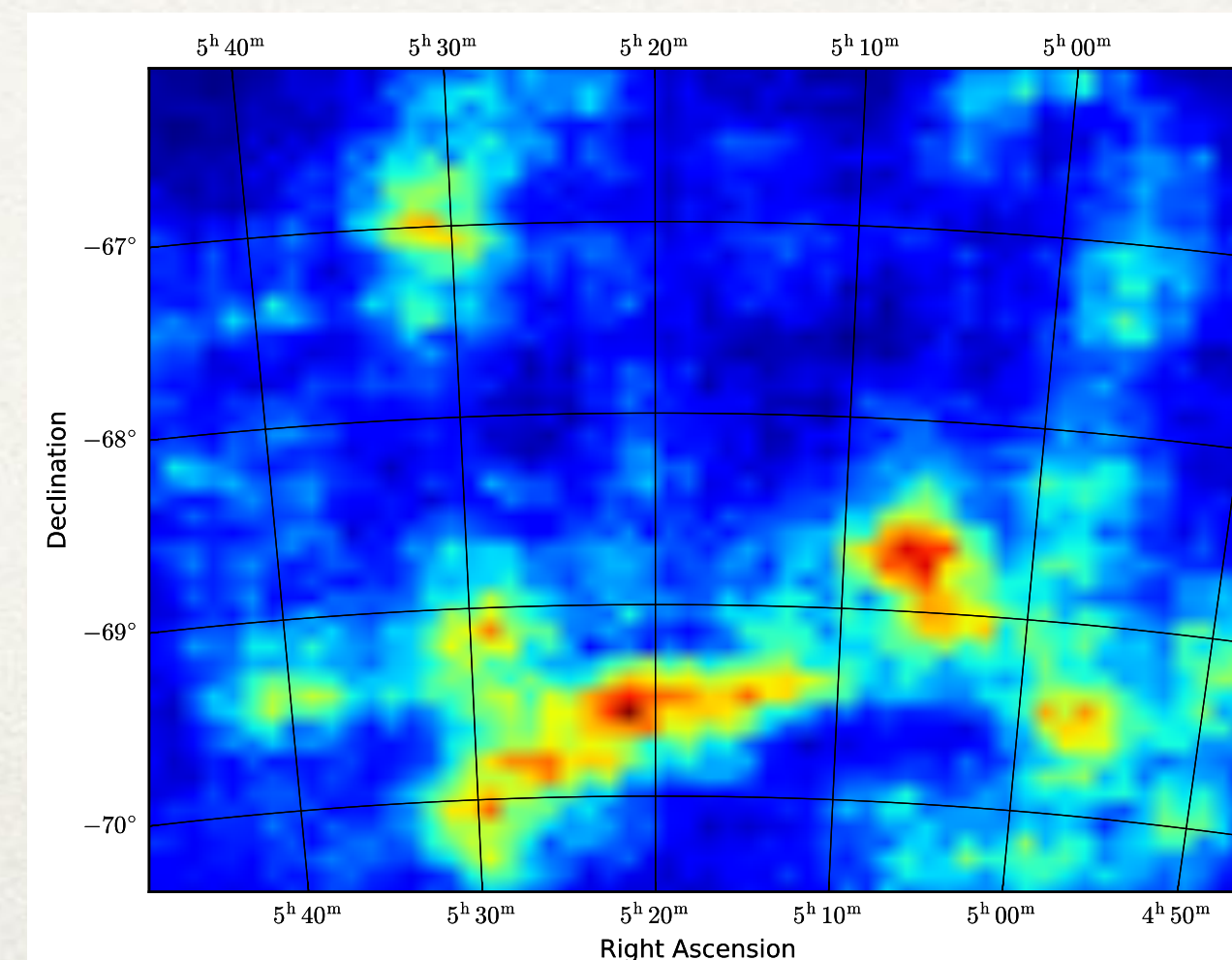
Individual system analysis



M82 X-2

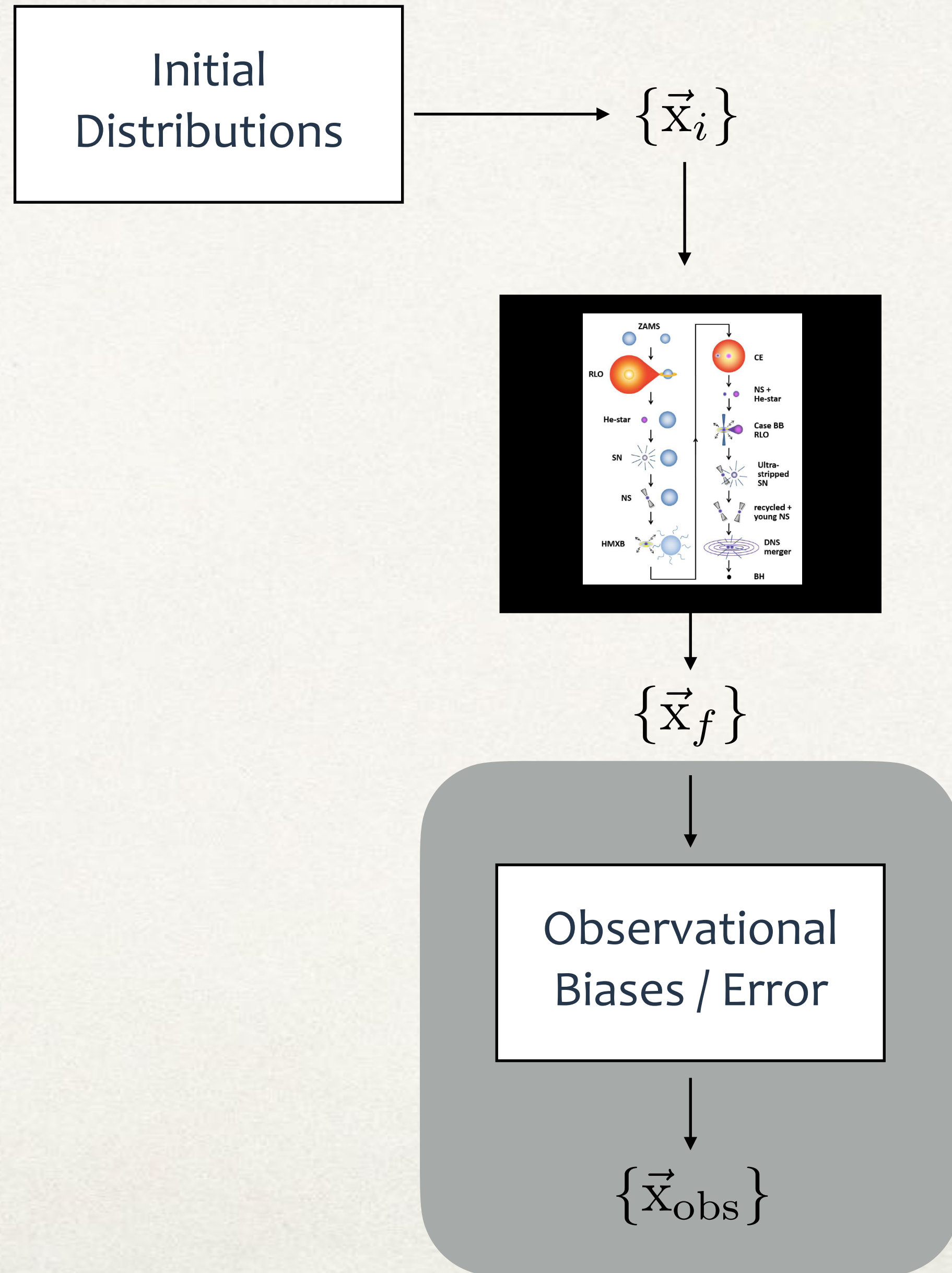
Fragos et al. (2015)

Observational prediction

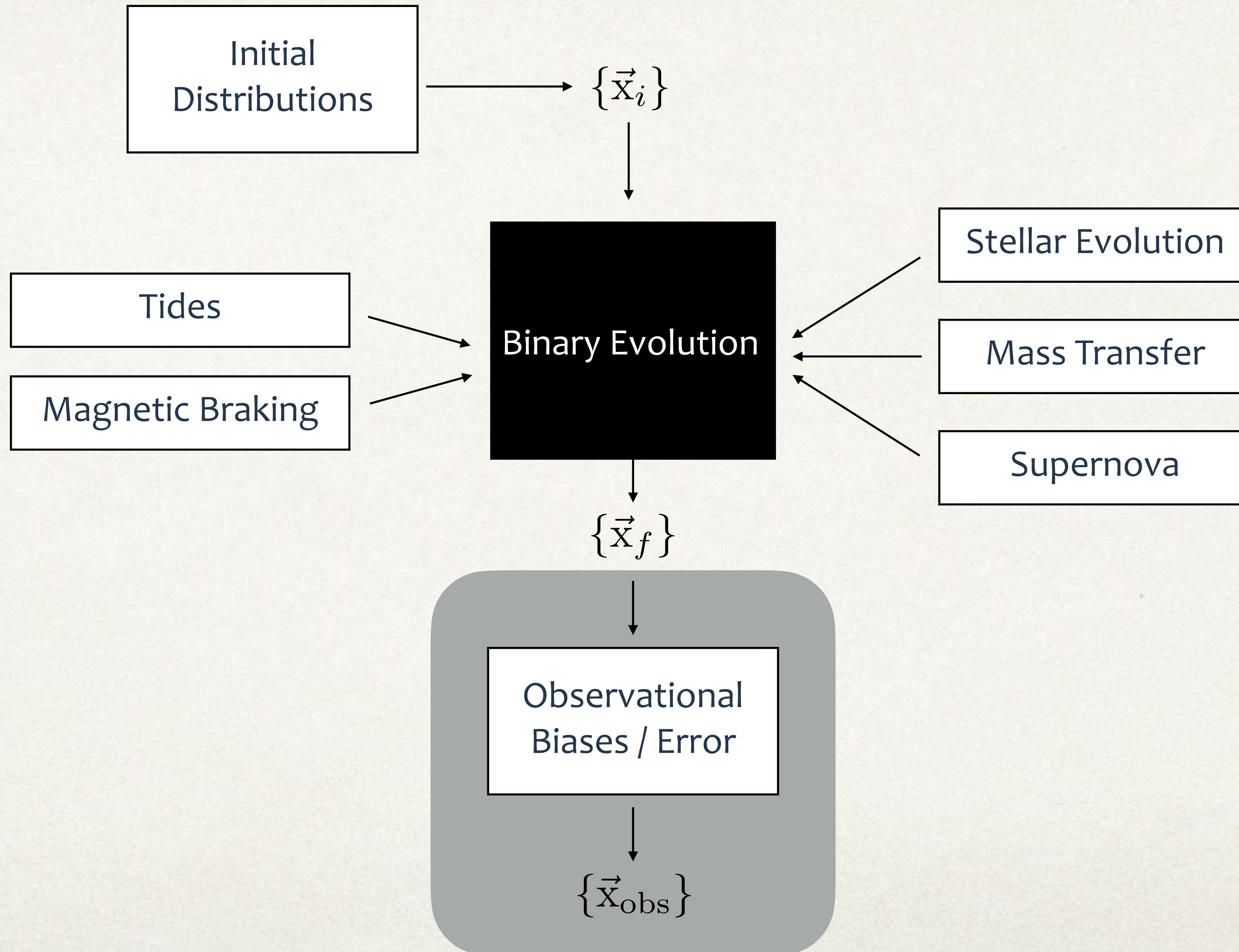


Expected
 HMXB population
 in the Large
 Magellanic Cloud

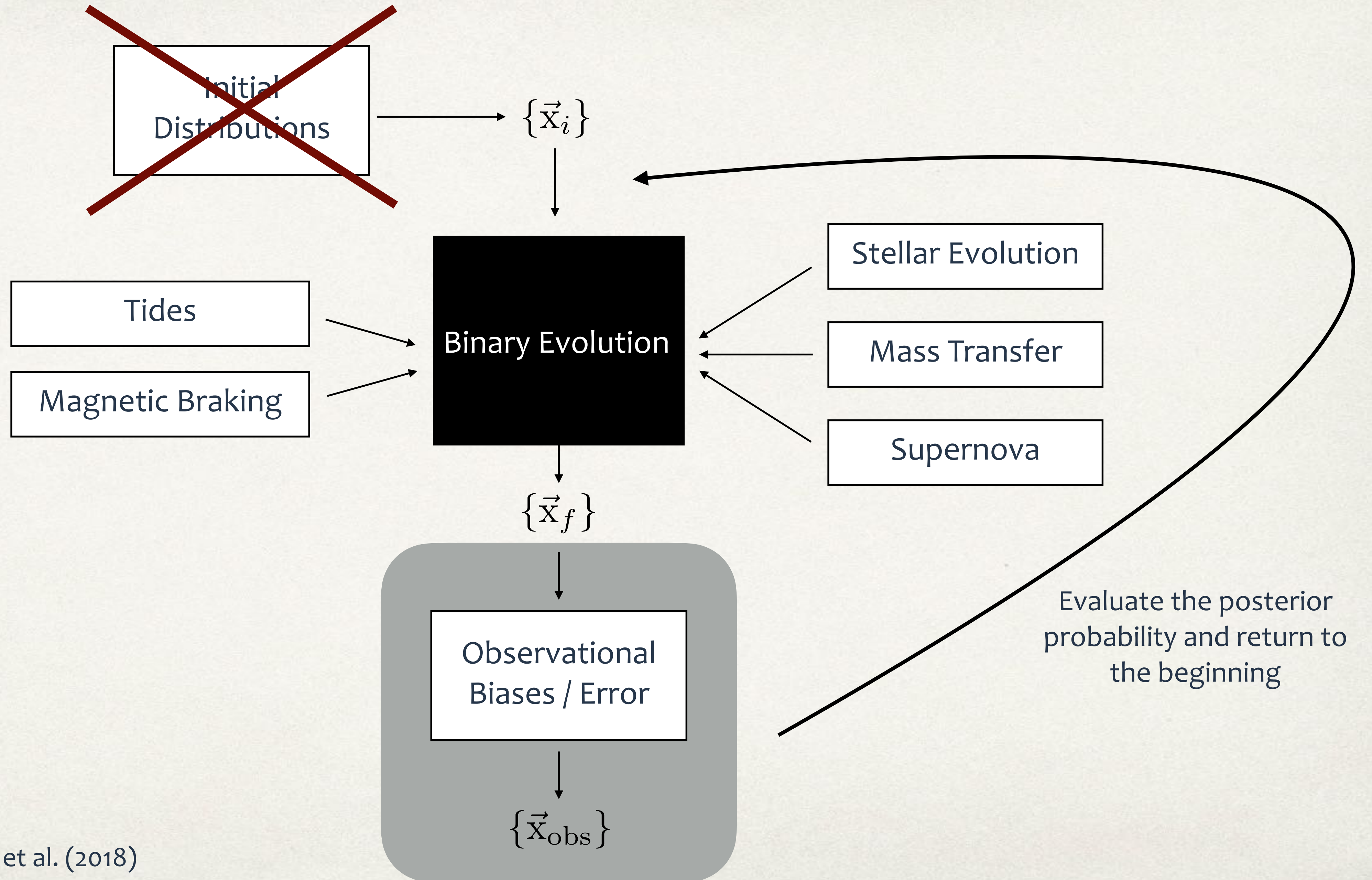
Population synthesis basics



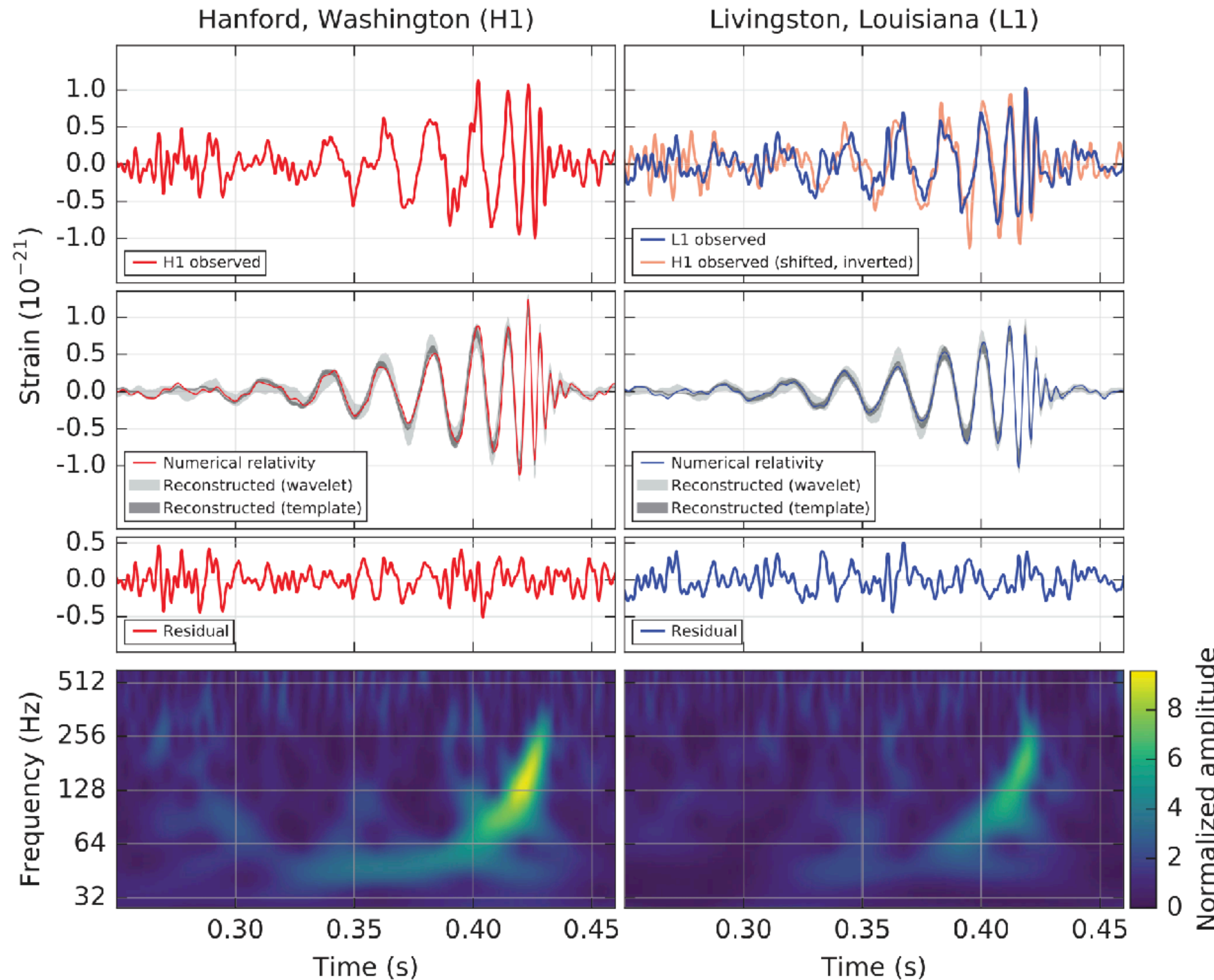
Population synthesis basics



dart_board Paradigm



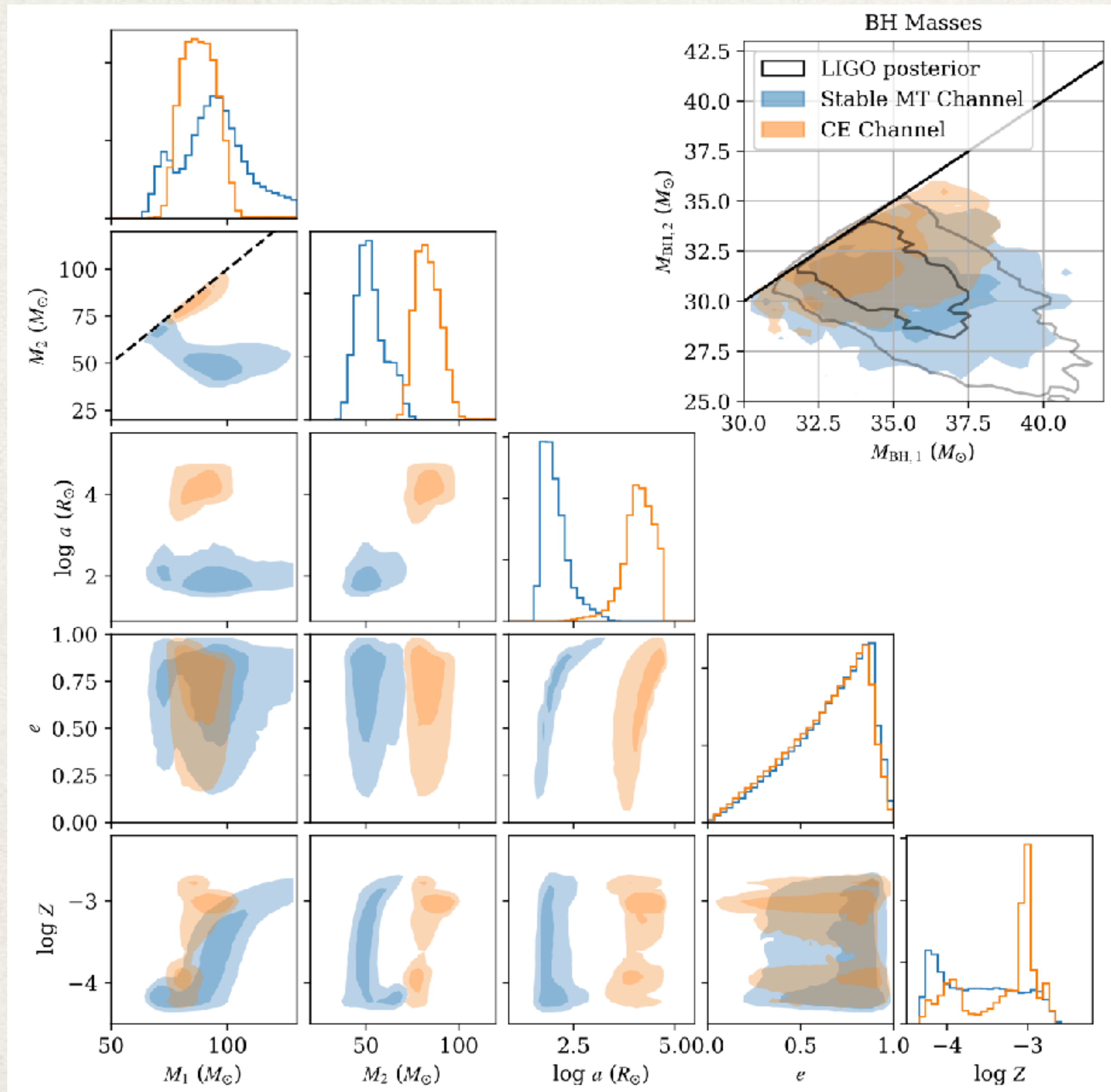
LIGO Detection Of GW150914



Numerical Relativity Fits

M_1	$36^{+5}_{-4} M_{\odot}$
M_2	$29^{+4}_{-4} M_{\odot}$
M_{final}	$62^{+4}_{-4} M_{\odot}$
Spin	$0.67^{+0.05}_{-0.07}$
Distance	$410^{+160}_{-180} \text{ Mpc}$
Redshift	$0.09^{+0.03}_{-0.04}$

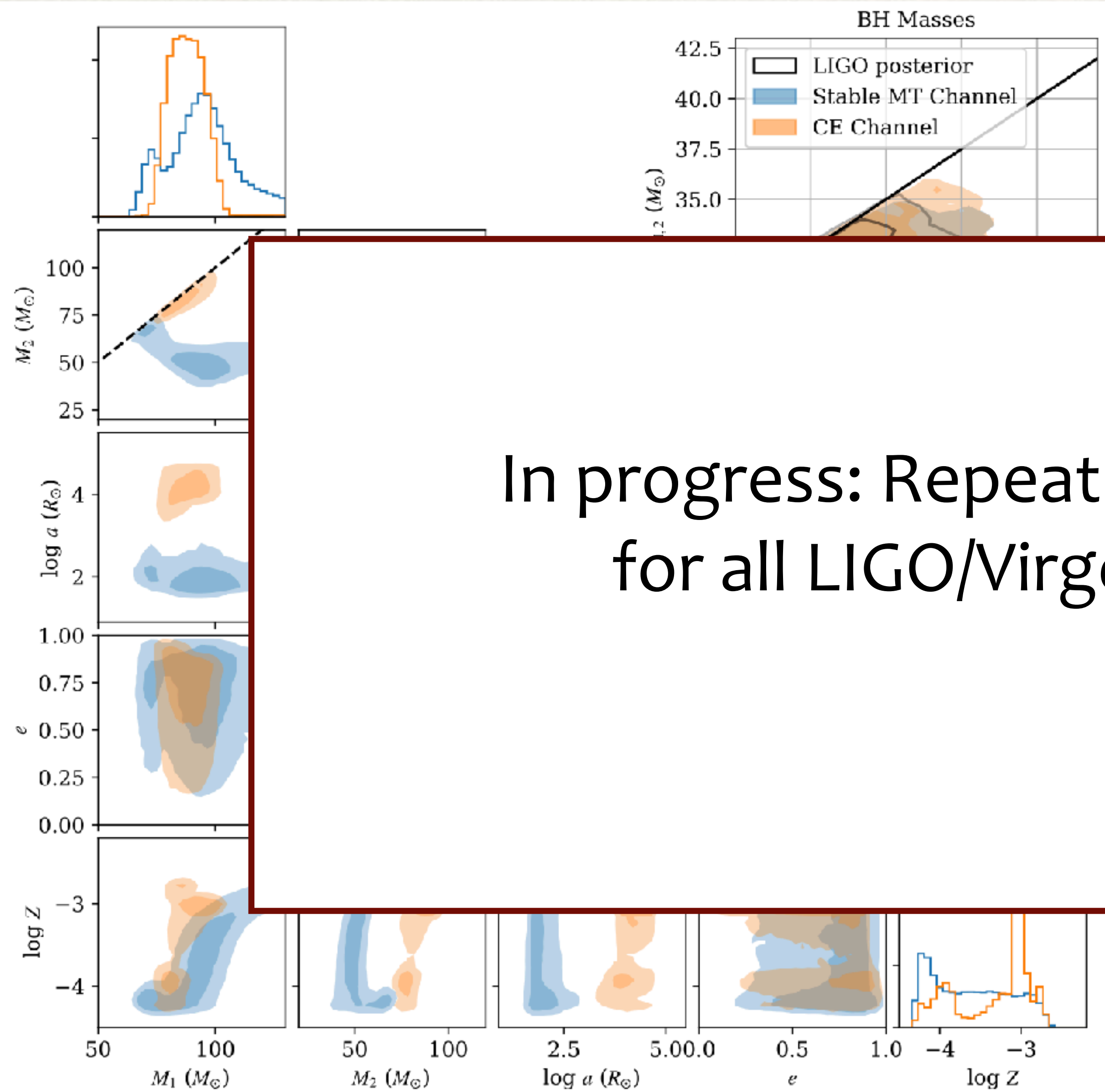
Bayesian analysis of GW150914 formation



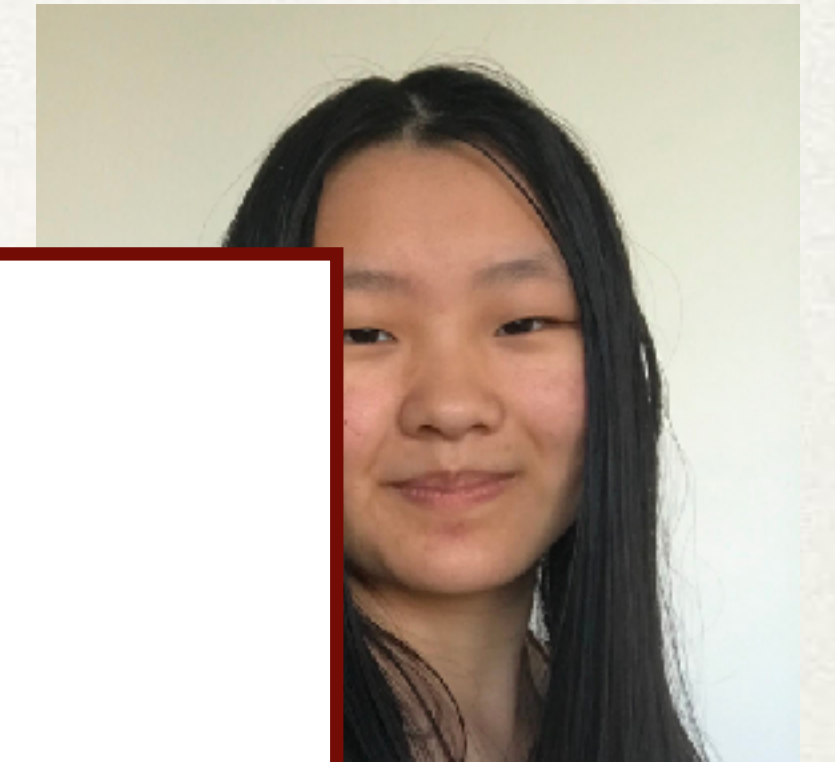
Work by
Julianne Cronin



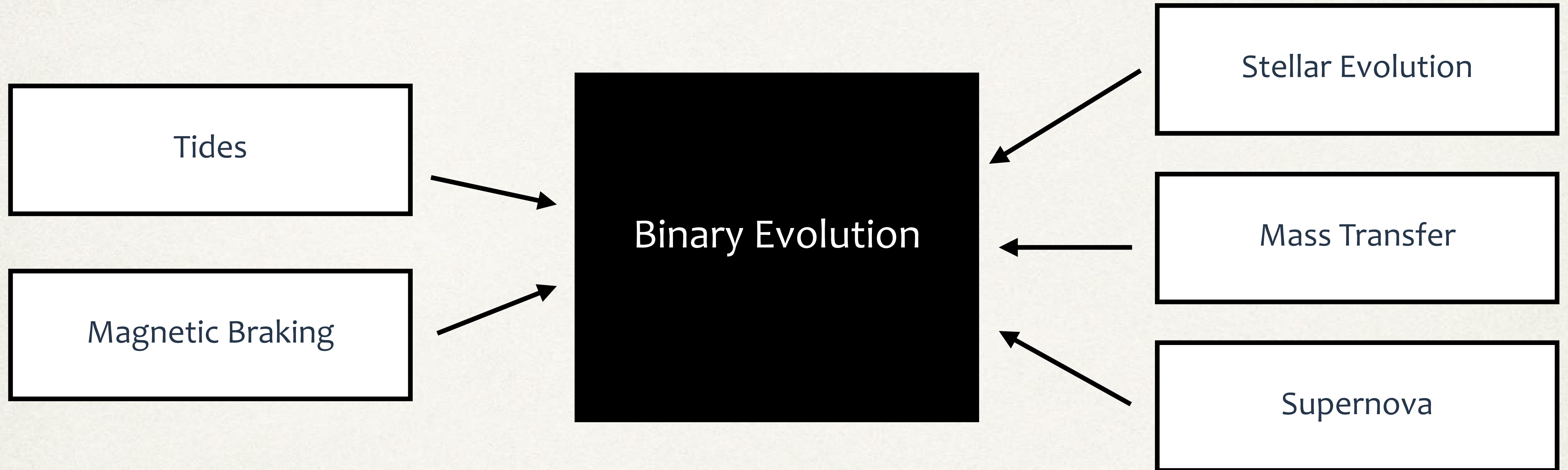
Bayesian analysis of GW150914 formation



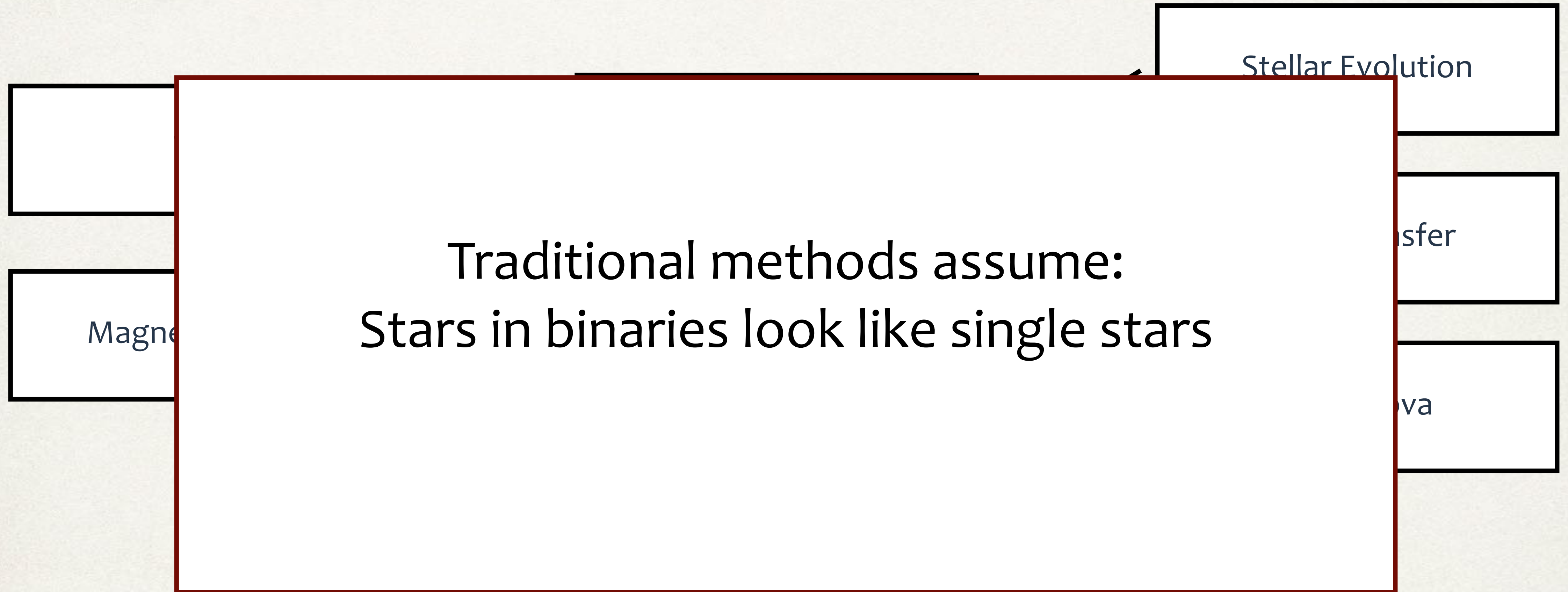
In progress: Repeating this exercise for all LIGO/Virgo detections

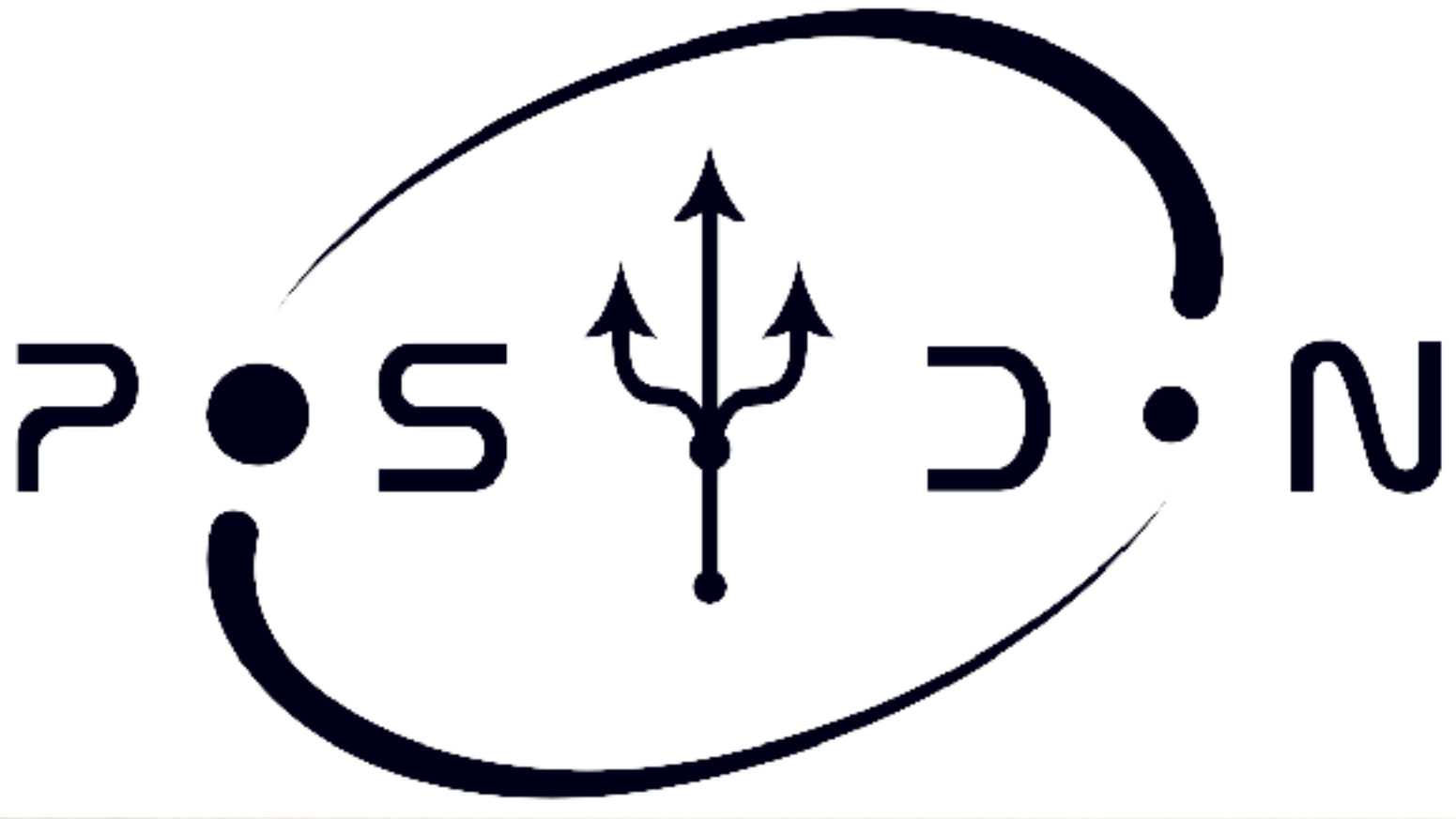


Improving the Black Box



Improving the Black Box



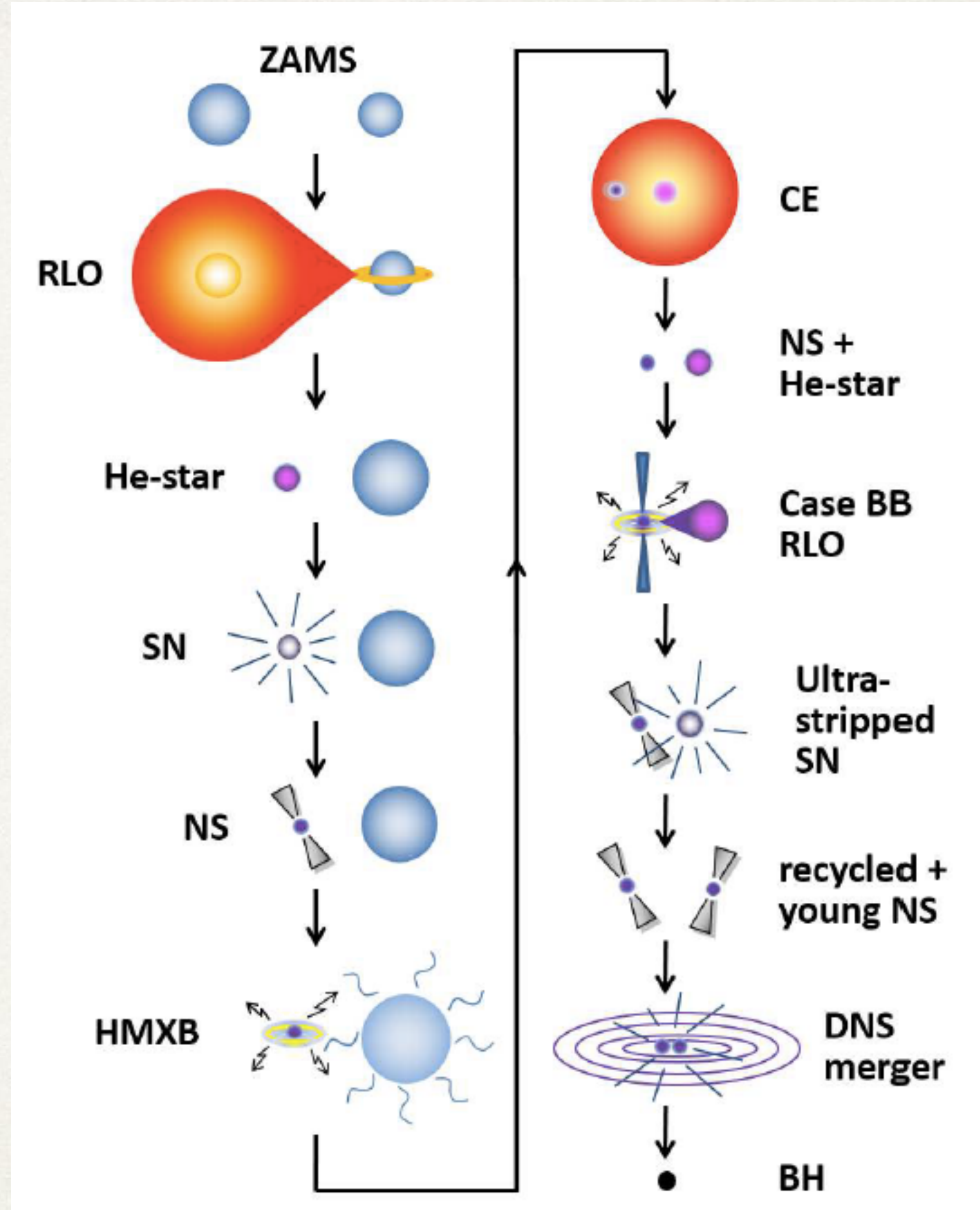
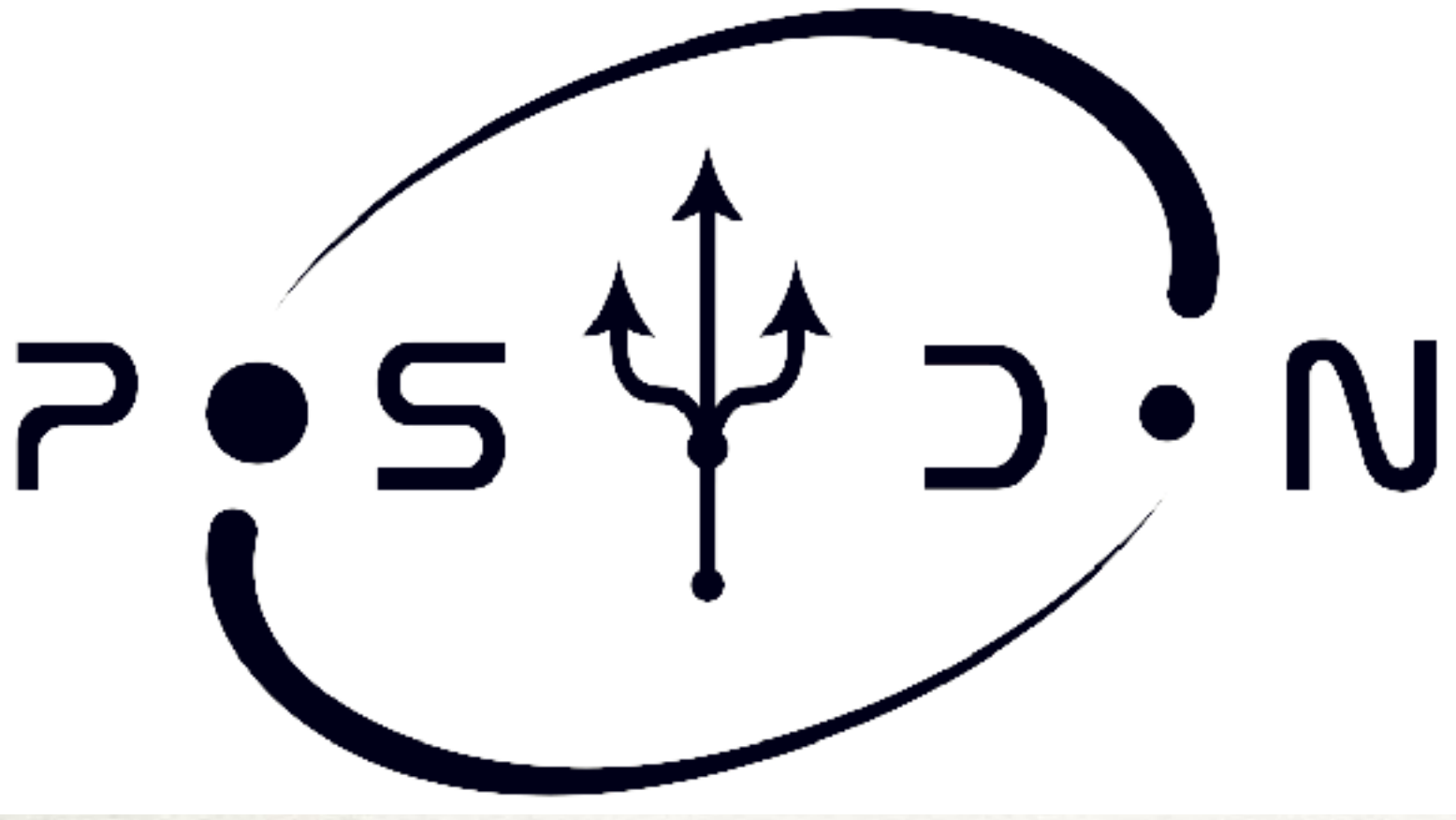


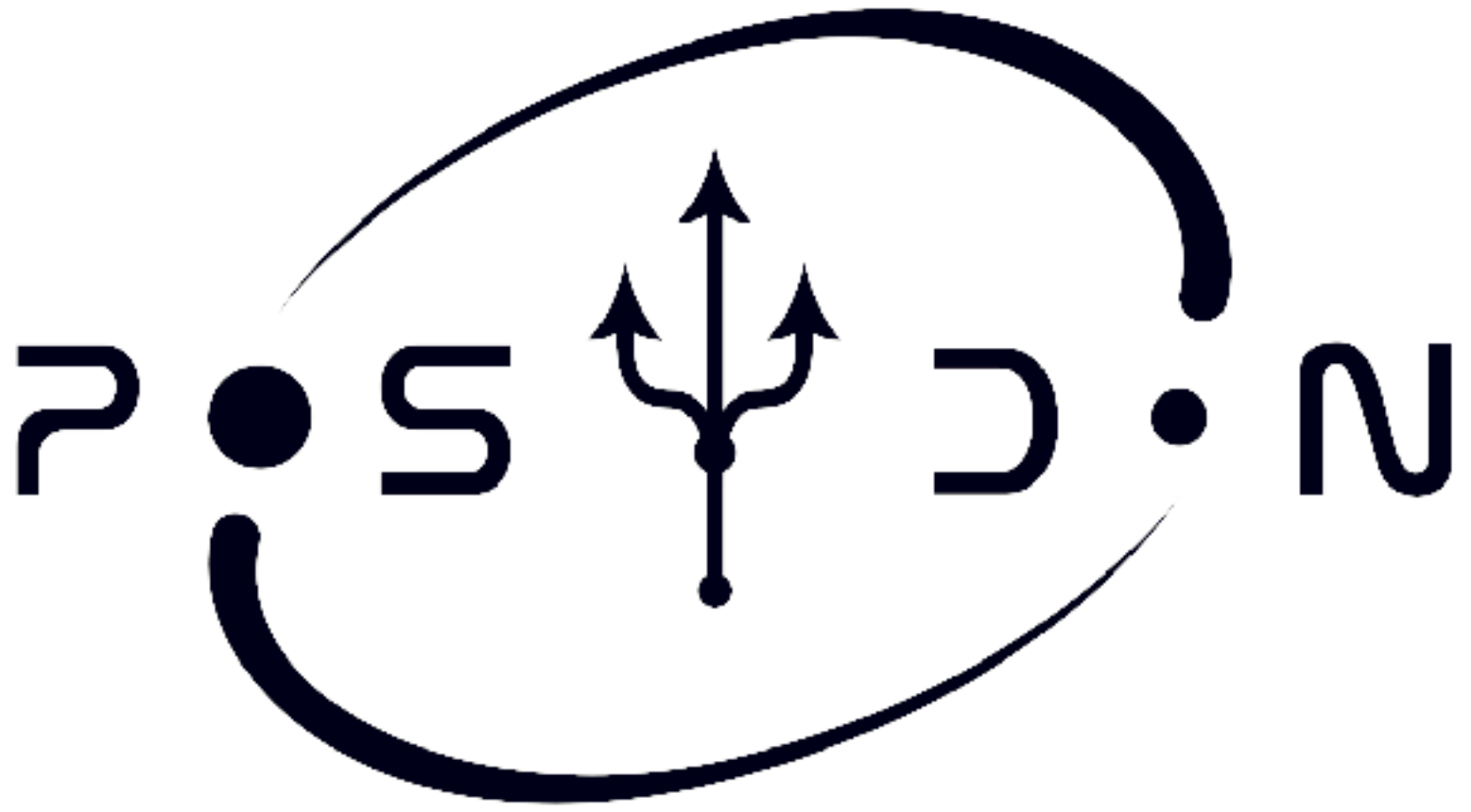
POSYDON is a new framework for binary population synthesis studies that uses detailed stellar structure and binary evolution simulations (Fragos et al. 2022; under review).



The POSYDON collaboration: Jeff Andrews, Simone Bavera, Christopher Berry, Scotty Coughlin, Aaron Dotter, Tassos Fragos, Monica Gallegos, Jaime Roman Garza, Prabin Giri, Vicky Kalogera, Aggelos Katsaggelos, Konstantinos Kovelakas, Devina Misra, Juanga Perez, Ying Qin, Kyle Rocha, Petter Stahle, Xu Teng, Pablo Ruiz, Nam Hai Tran, Goce Trajcevski, Manos Zapartas

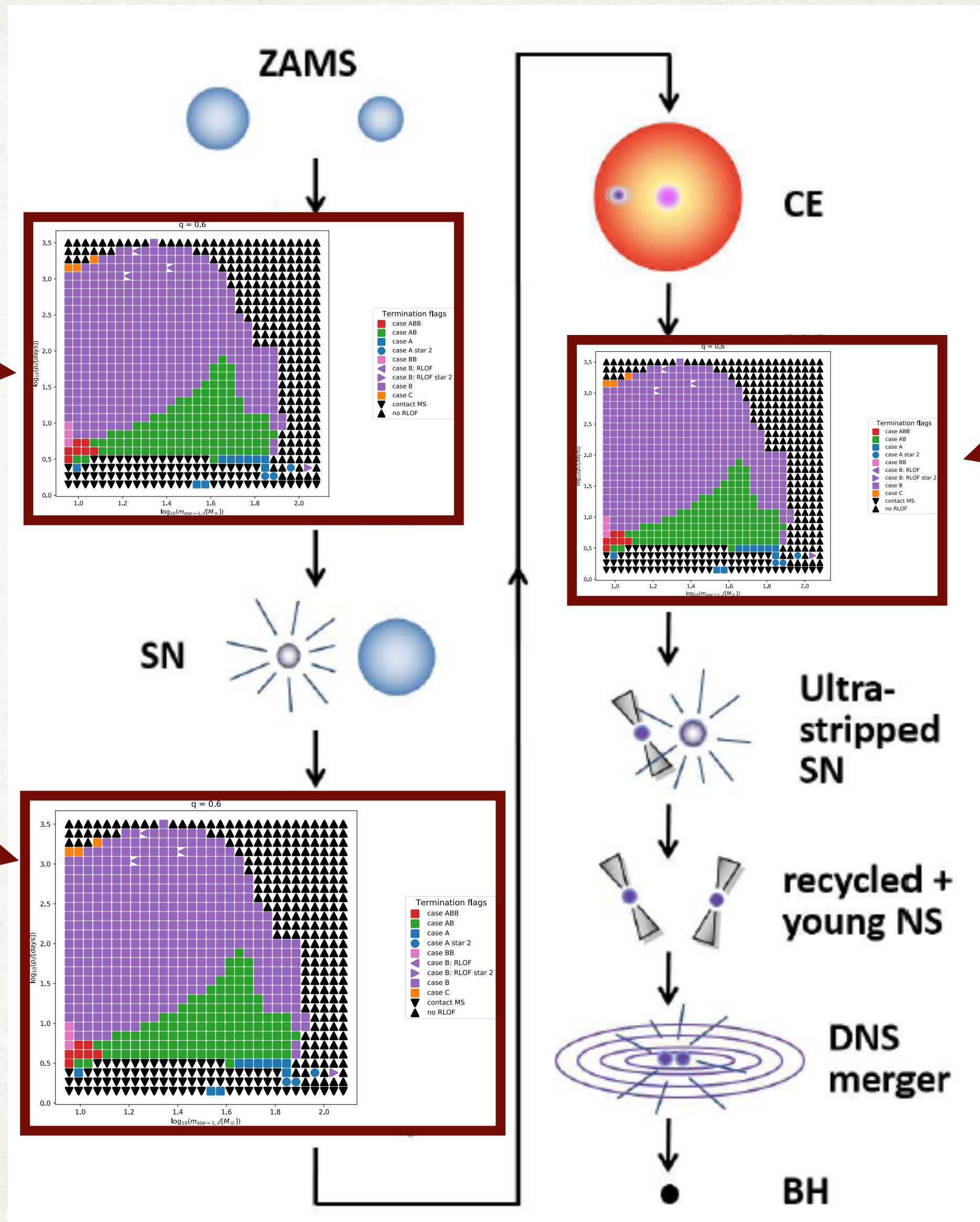






MS - MS
Grid

BH/NS - MS
Grid

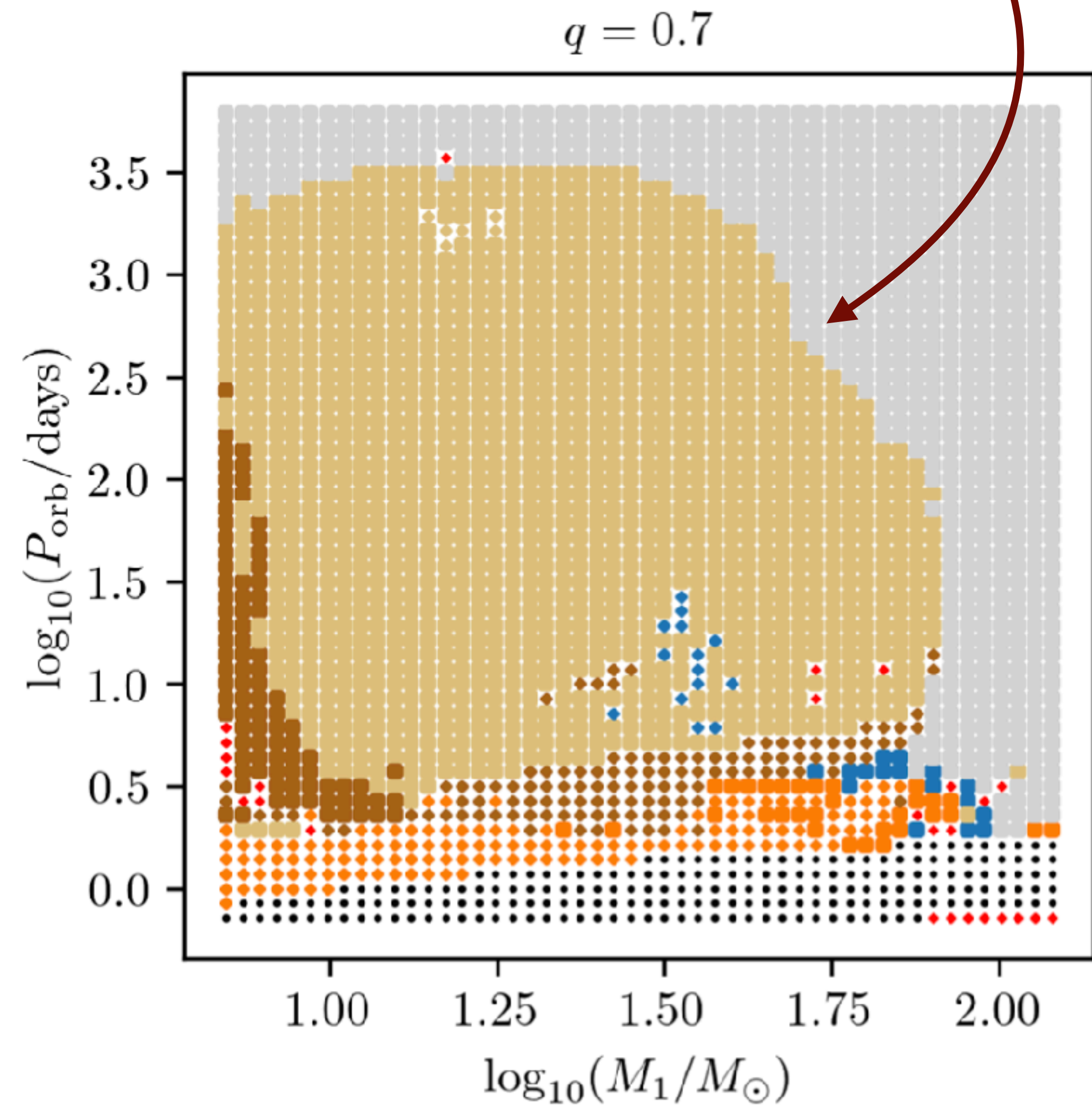
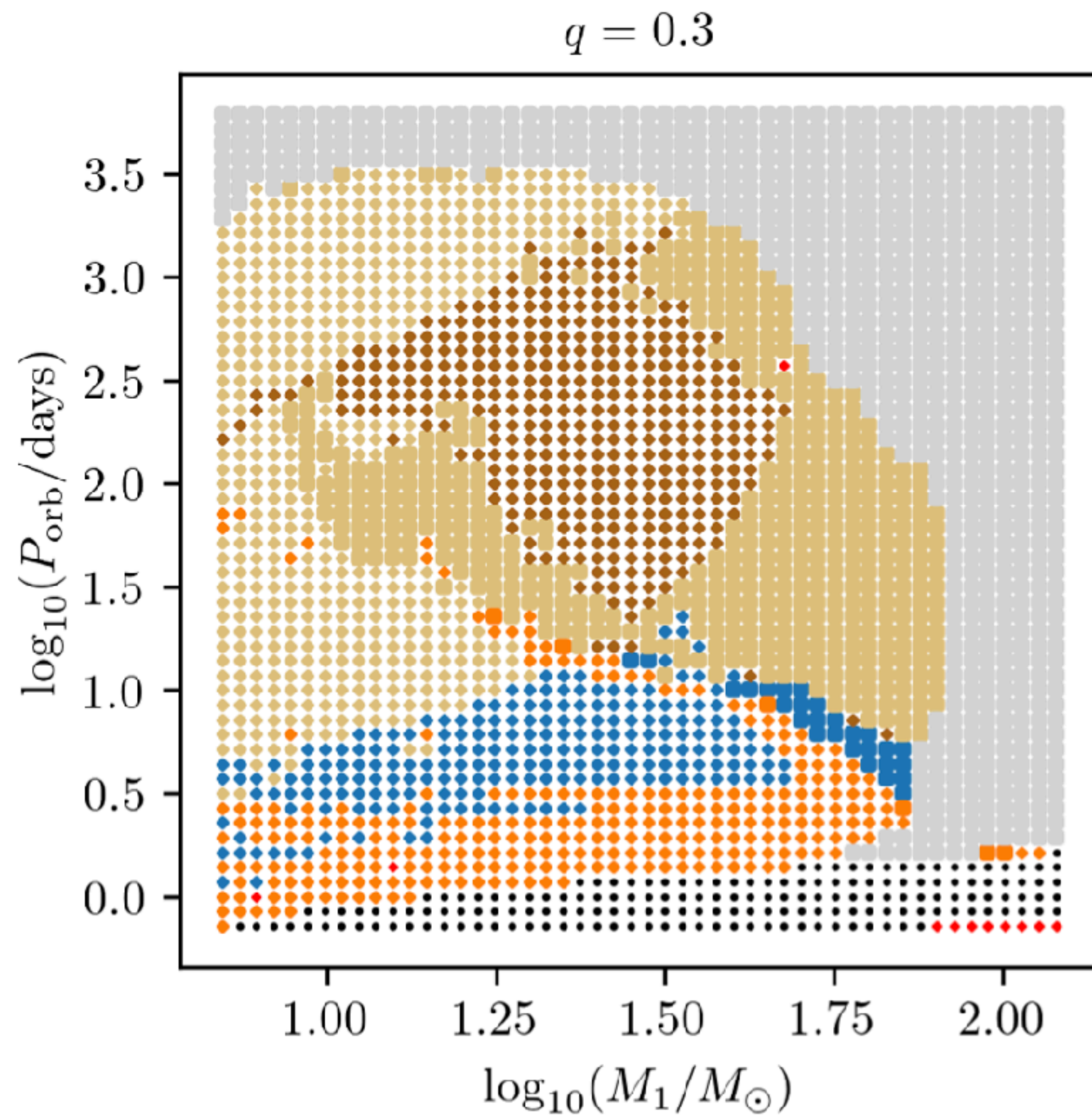


Replace key steps
in binary evolution
with MESA grids

BH/NS - He-star
Grid

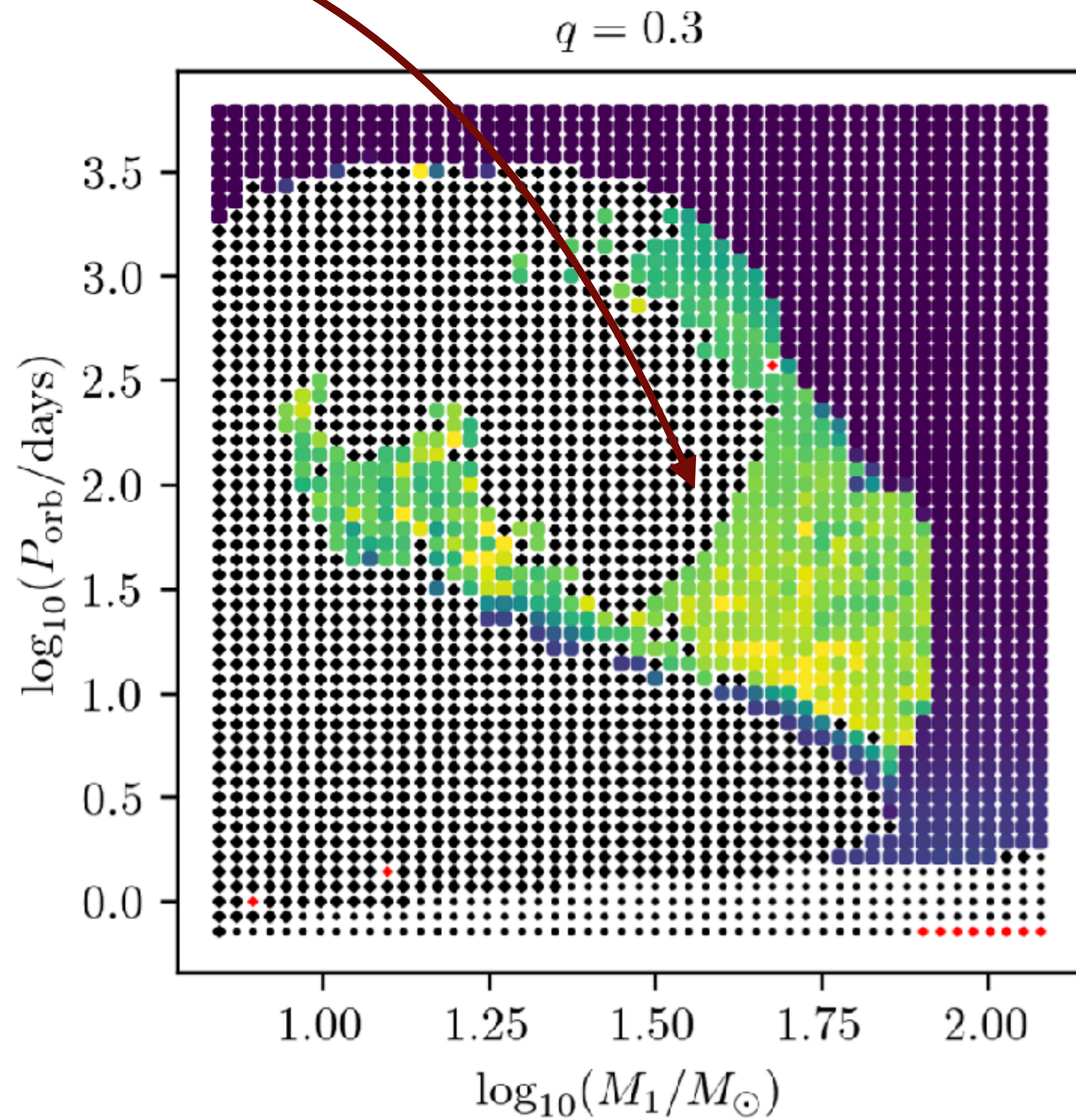
POSYDON Grids

Classification



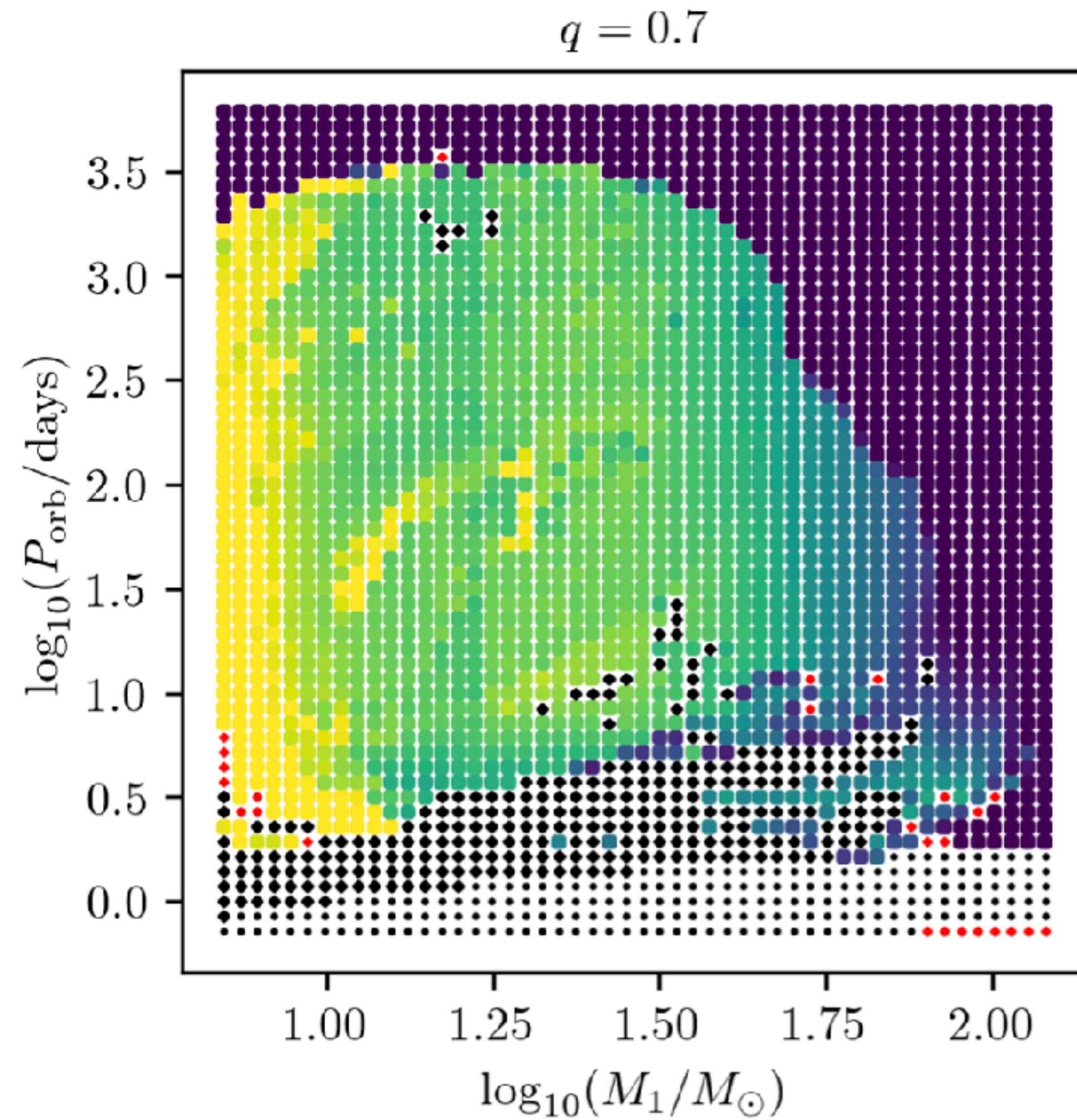
Interpolation

POSYDON Grids



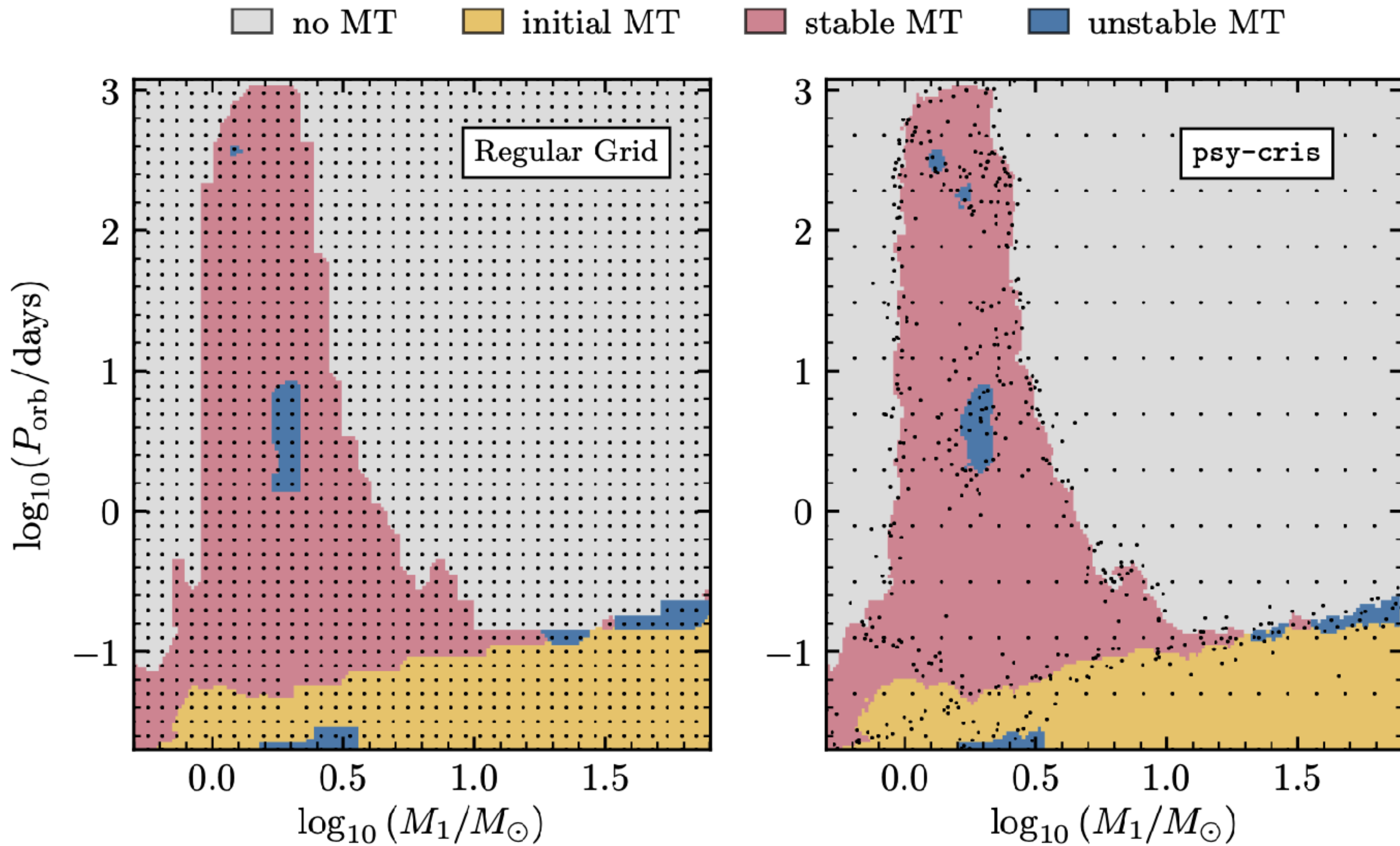
Fragos et al. (2022)

$(\omega_s/\omega_{s,\text{crit}})^2$



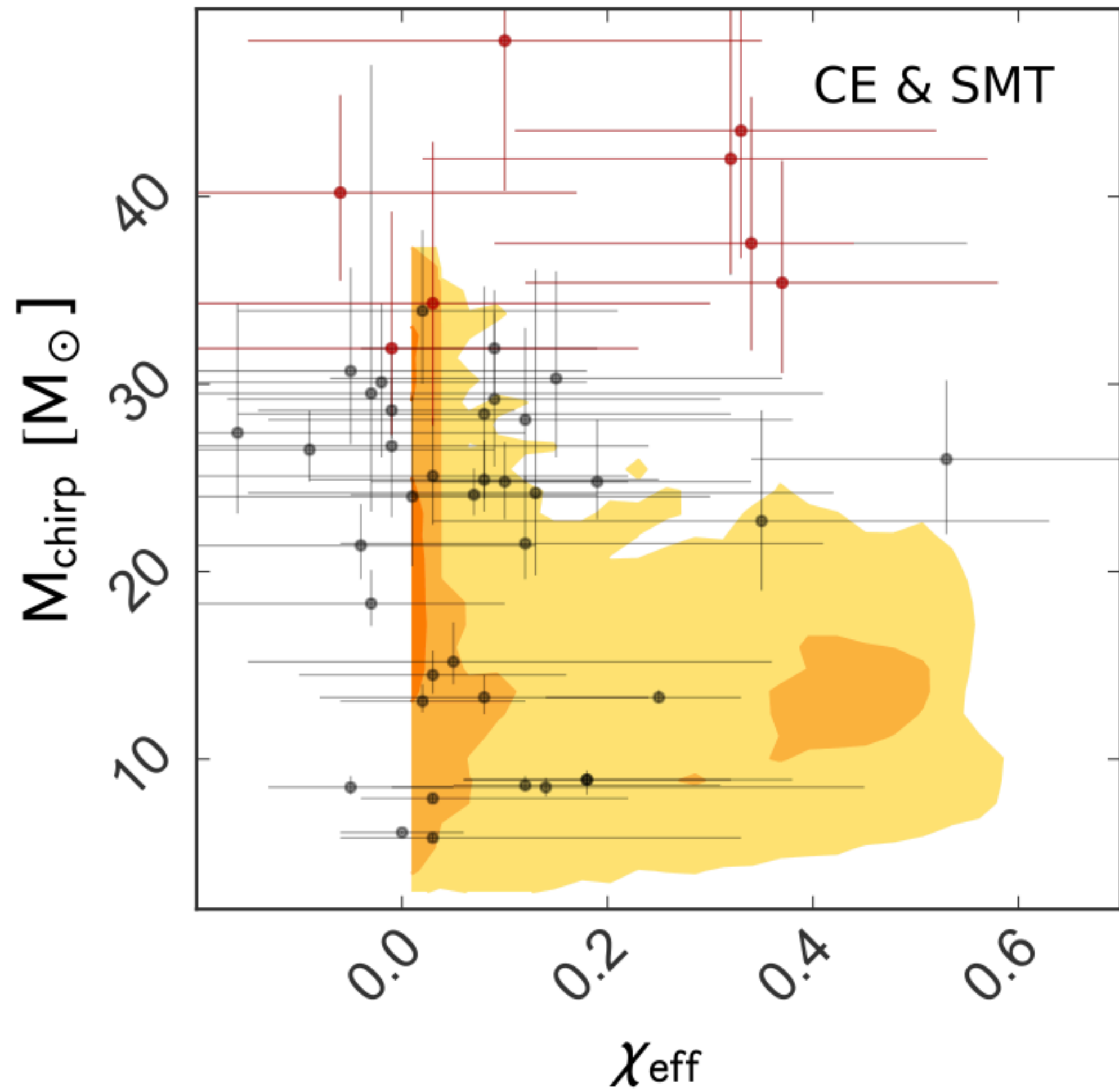
$(\omega_s/\omega_{s,\text{crit}})^2$

psy-cris: Active Learning for Grid Sampling



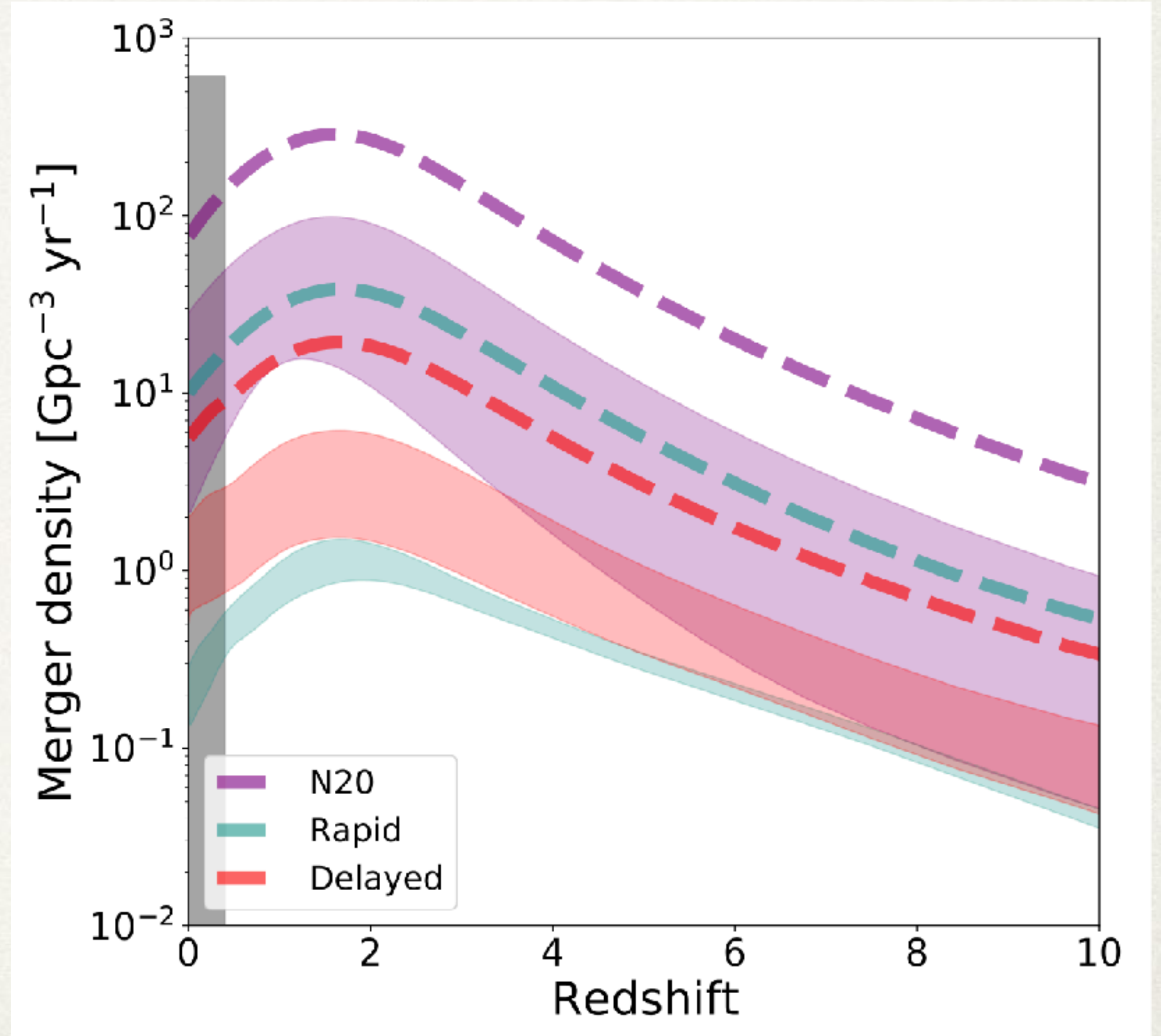
First POSYDON Results

BH-BH Mergers

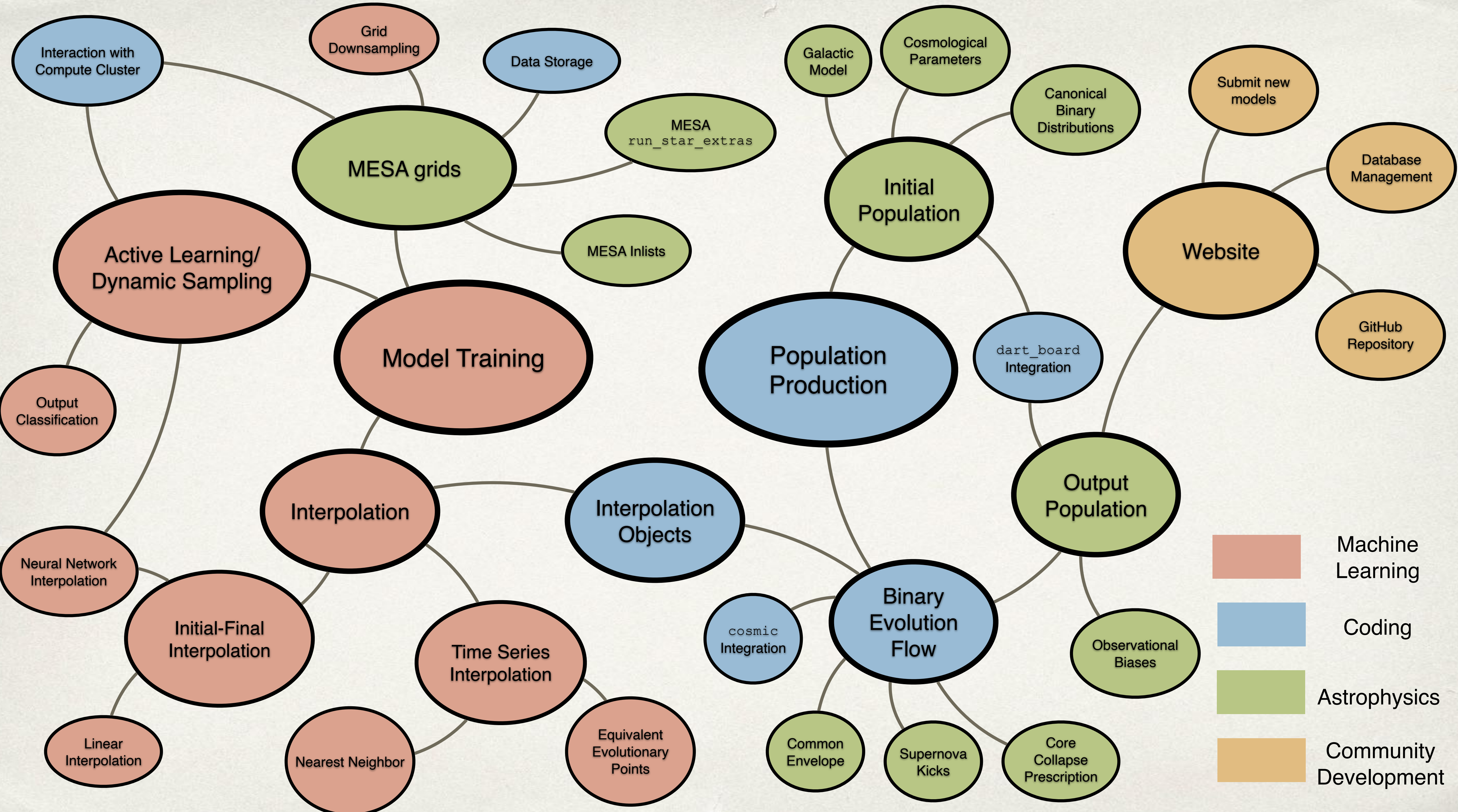


Bavera et al. (2020)

BH-NS Mergers



Roman-Garza et al. (2021)



- Machine Learning
- Coding
- Astrophysics
- Community Development

Example System Evolution

