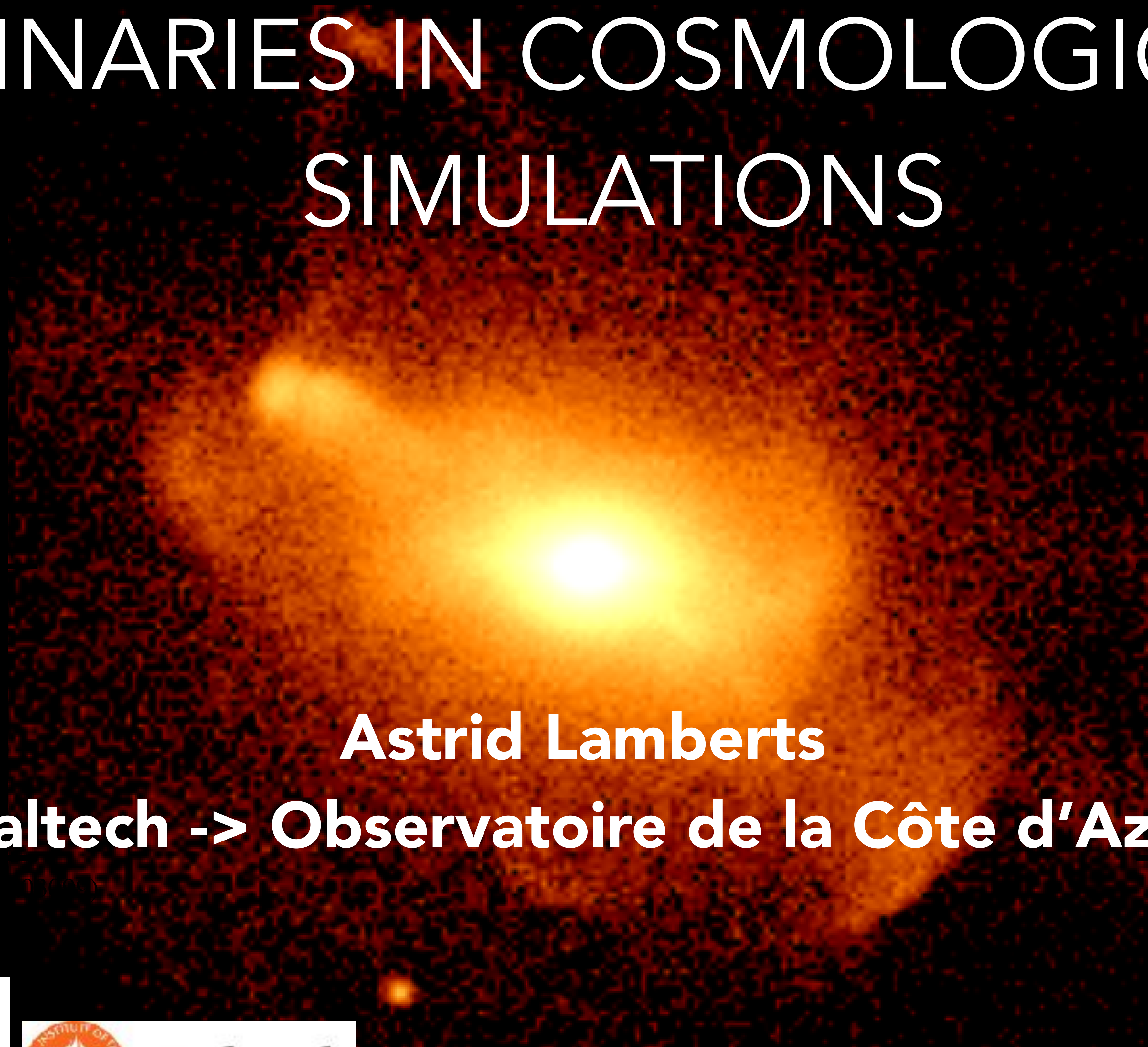
PLANTING COMPACT BINARIES IN COSMOLOGICAL SIMULATIONS



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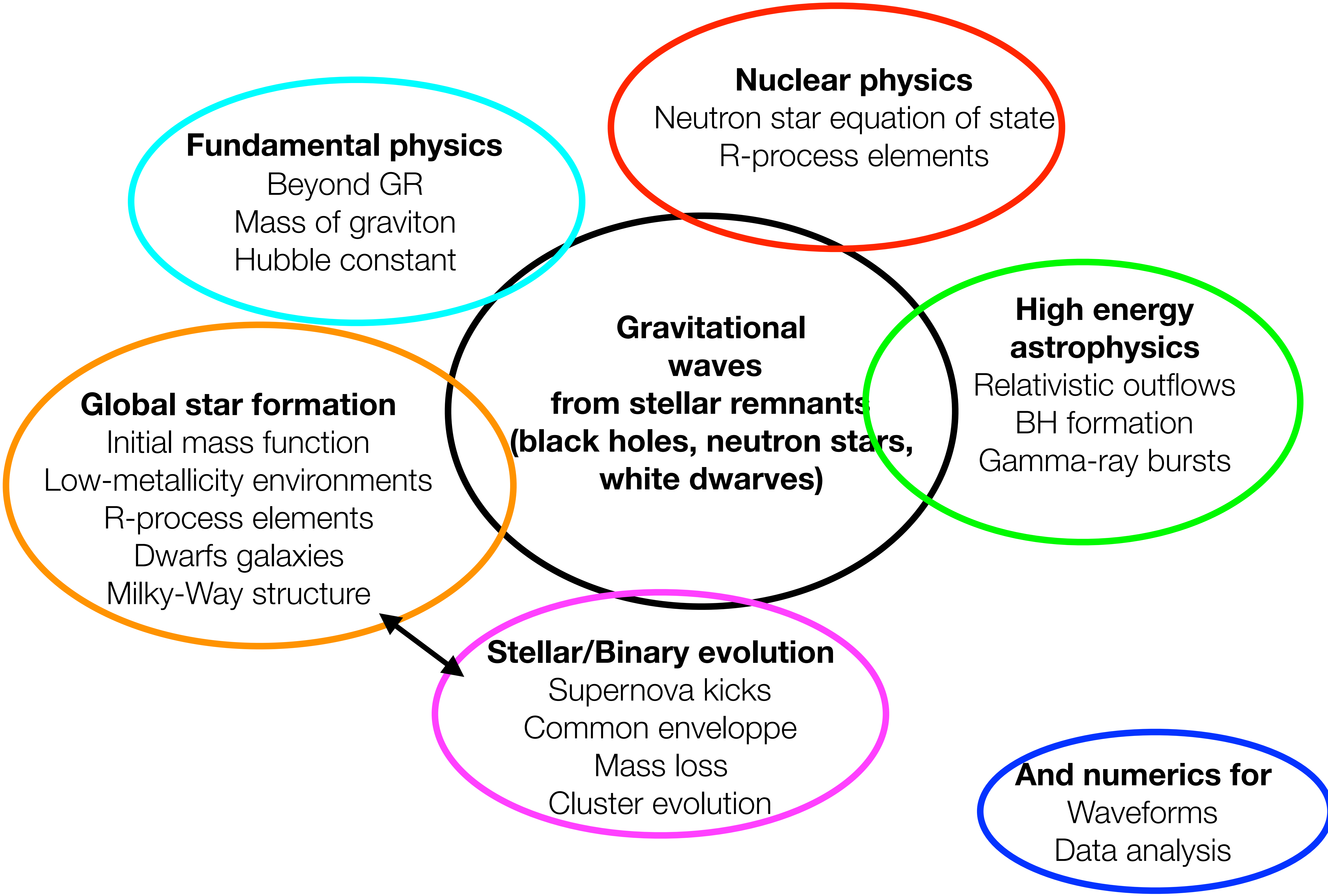
Membre de UNIVERSITÉ CÔTE D'AZUR

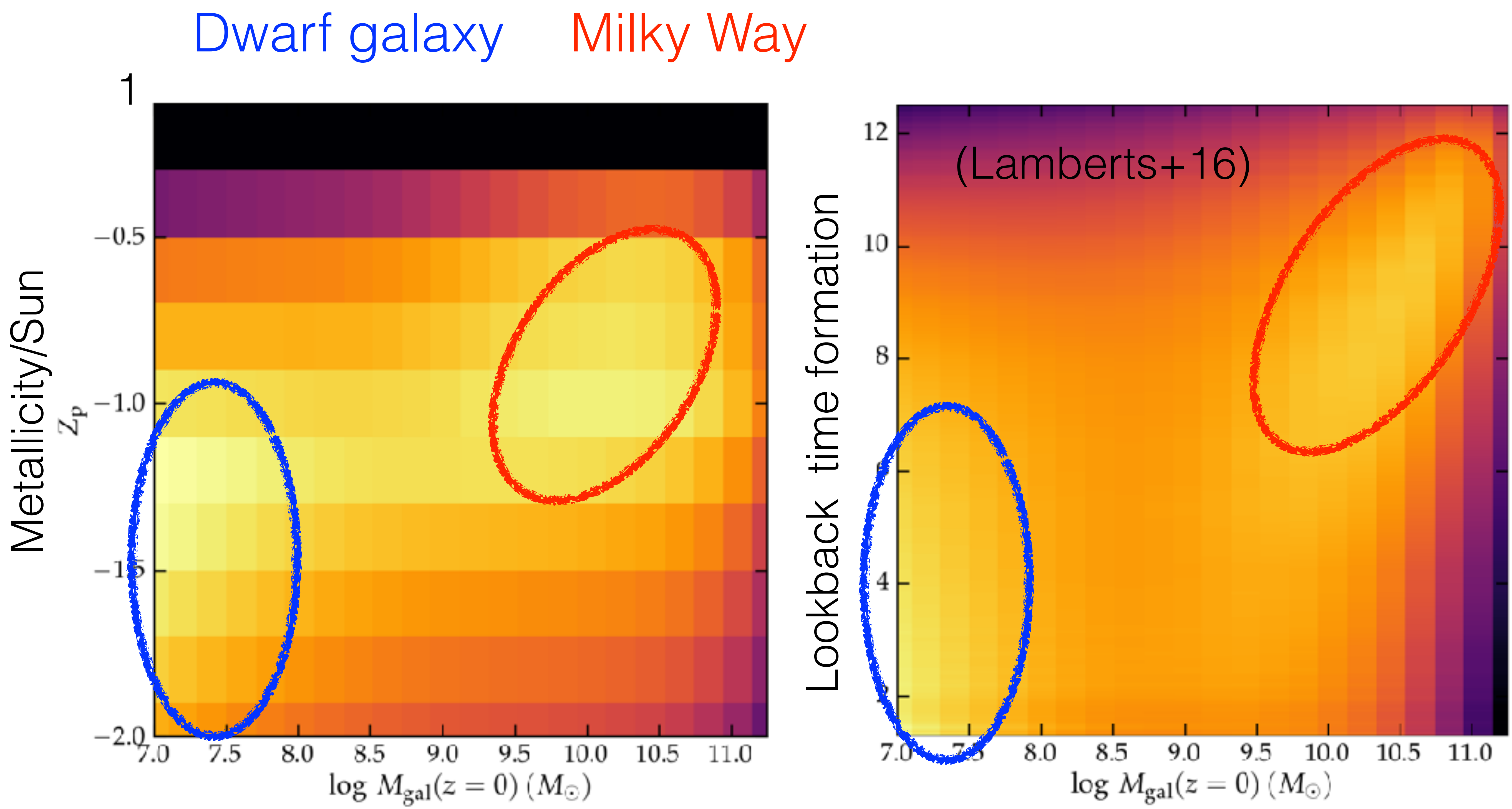
Caltech

Astrosim 2018

NEW FIELD IN ASTRONOMY



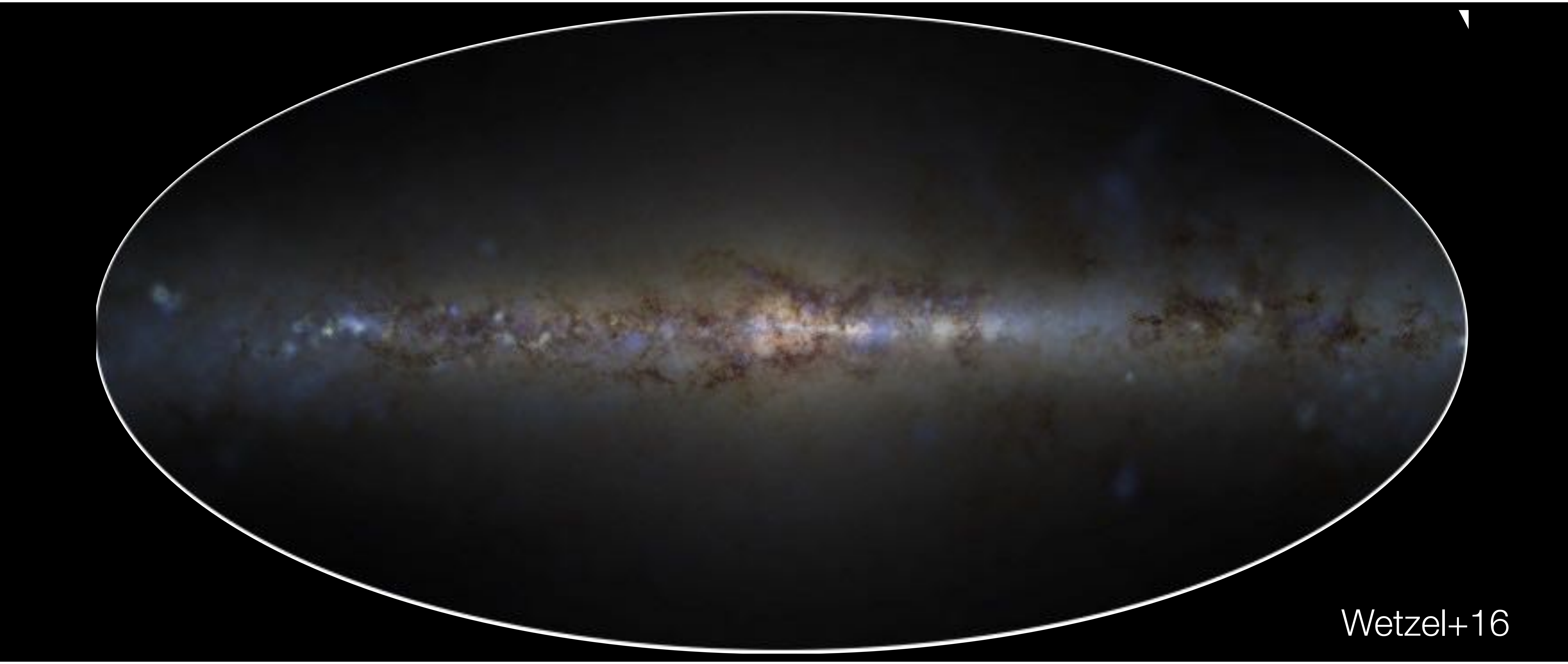
FORMATION OF GW PROGENITORS



COMBINE MERGER MODELS WITH COSMOLOGICAL SIMULATIONS

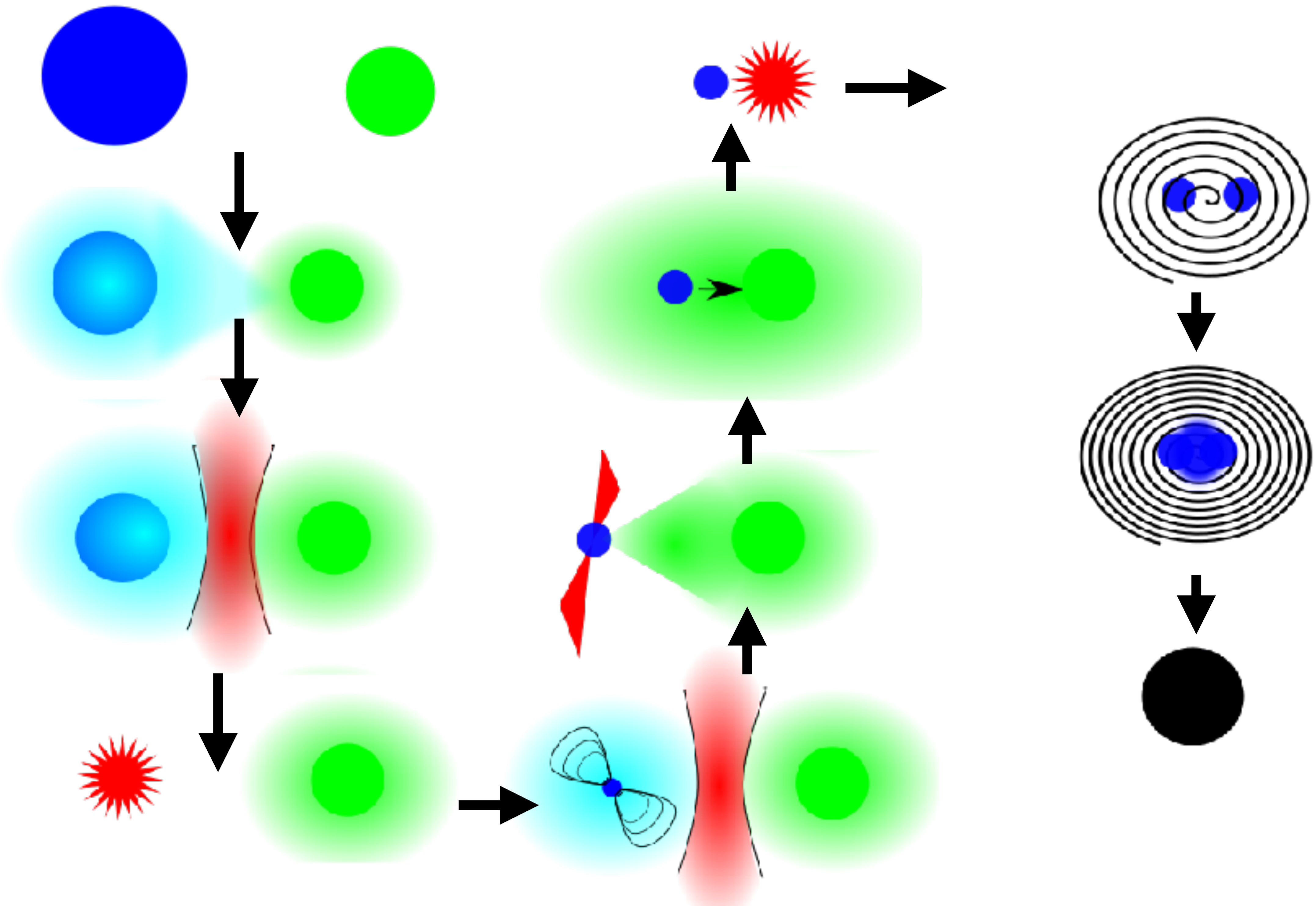
FIRE SIMULATIONS

Feedback In Realistic Environments project (FIRE, Hopkins+14,17)



Ex: LATTE simulation Mass resolution : 7000 Msun

MAKING BINARY COMPACT OBJECTS



MAKING BINARY COMPACT OBJECTS

- Binary population synthesis code (BSE, Hurley+2002): simplified stellar and binary model.

- Many free parameters: how to explore N-dimensional space?

- Input: Initial masses, periods, eccentricities: ~ million systems.

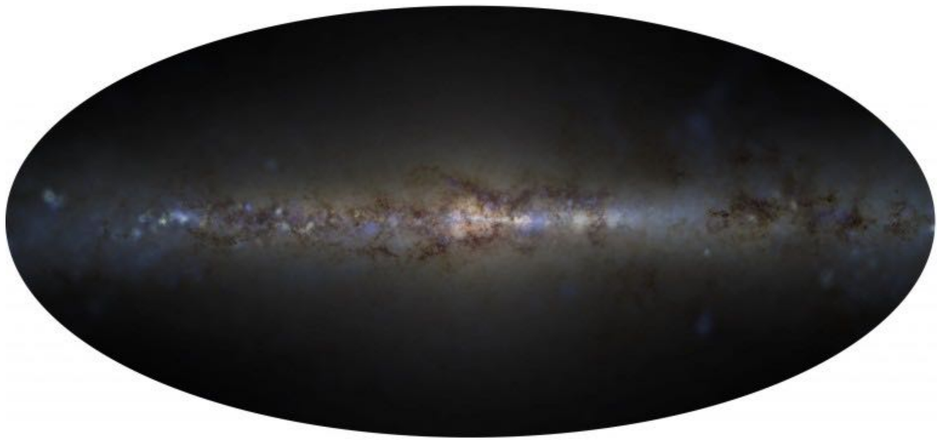
- Explore metallicity from 1% of Solar to Solar.

  => Create a dataset of compact object formation/merger properties.

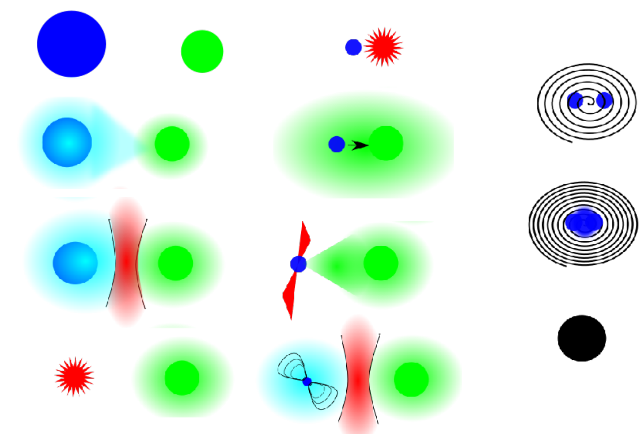
- For black holes: mergers in clusters (CMC code, with Carl Rodriguez): N body code + stellar/binary interactions.

  => Create dataset of mergers from clusters, different masses, mass profiles, metallicities, stellar evolution

GROWING COMPACT BINARIES IN GALAXIES



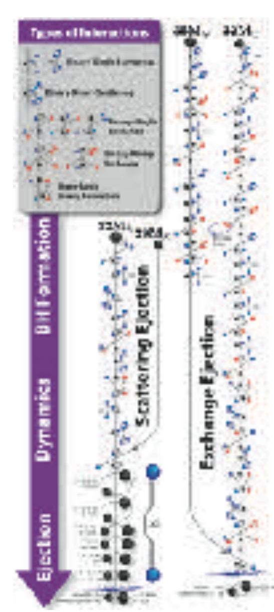
Star formation history
Metallicity
Positions/Trajectory
Gas properties



Binary population model
Metallicity dependent

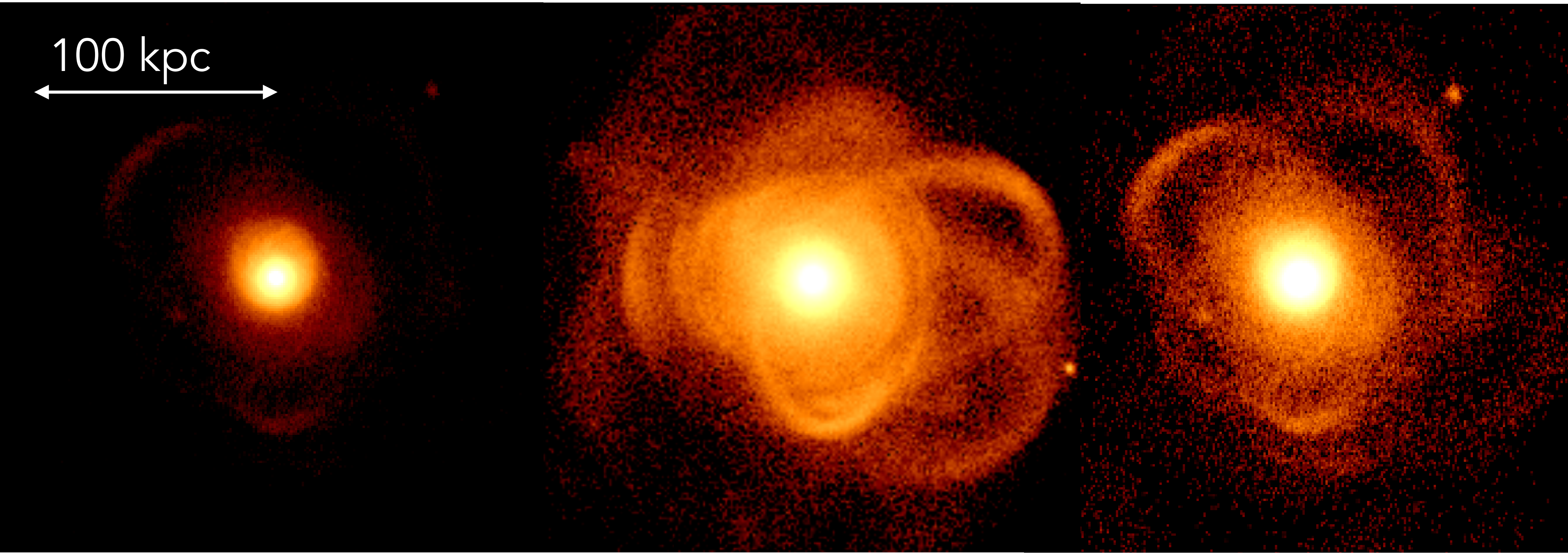
Gravitational wave emission

Star cluster properties
(M. Grudic)



cluster mergers
(C. Rodriguez)

IMPACT OF COMPLEX STAR FORMATION



$>10^{10}$ stars

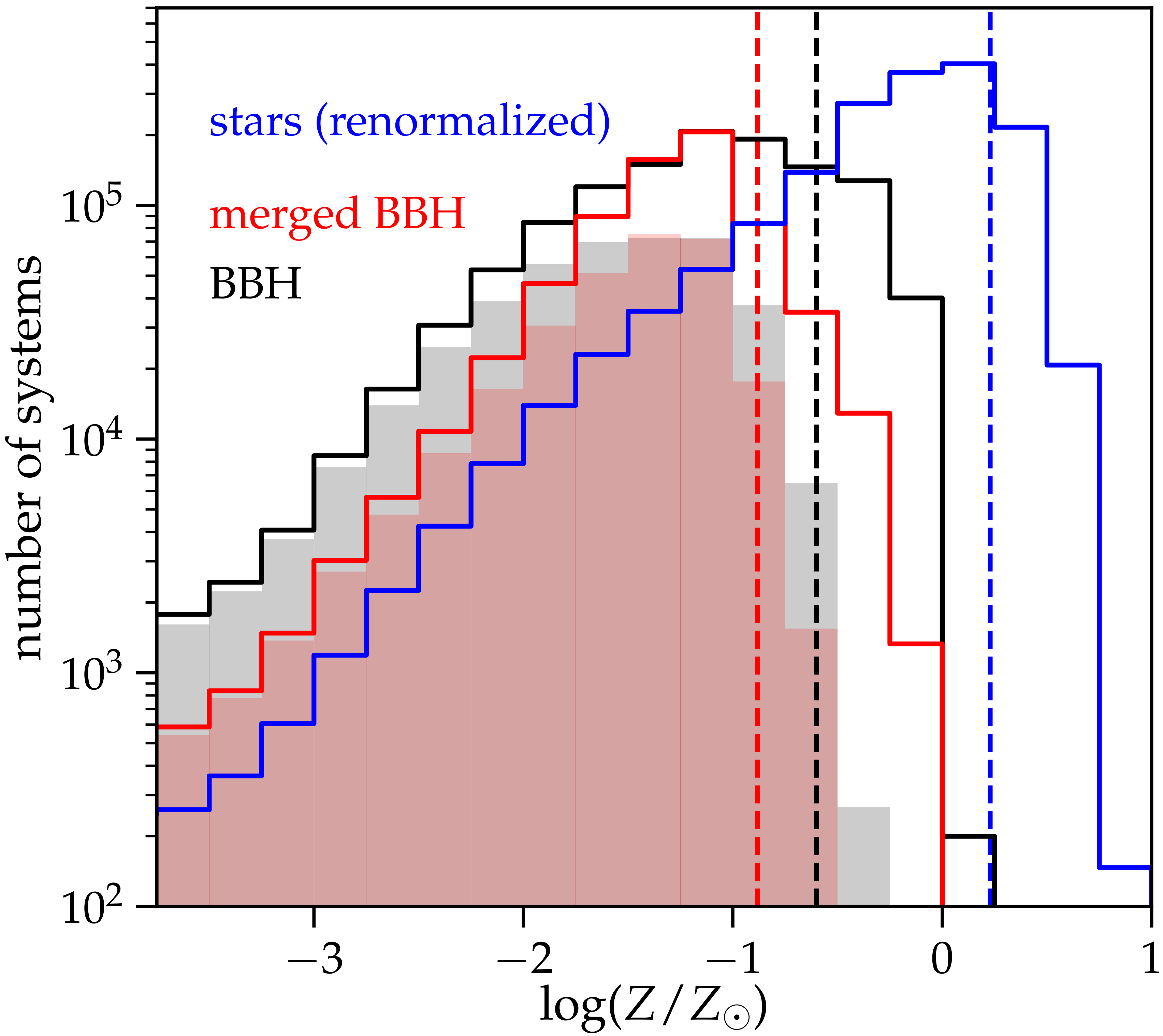
1 million binary black holes

100 million binary white dwarfs

Different populations found in different structures

Lamberts+18; Blunt, Lamberts+ in prep.

Impact of dwarf galaxies



Mean metallicity
~ 20% of Sun

1/3 of black holes were
Formed outside Milky Way
-> dwarf galaxies matter
-> needs high resolution

Lamberts+18

"Individual" Numerical Requirements

FIRE simulations : MW-like galaxies:

10 runs with 1-5 million CPU (M~7000 Msun)

1 run with 25 million CPU in progress (M~900 Msun)

Outputs : 7-20 GB/snapshot x 600 : 5-10 TB/run

National/European-scale supercomputers

Cluster evolution : 100 000 CPU hours, need ~20 models

scaling difficult beyond ~100 CPU, specific supercomputers

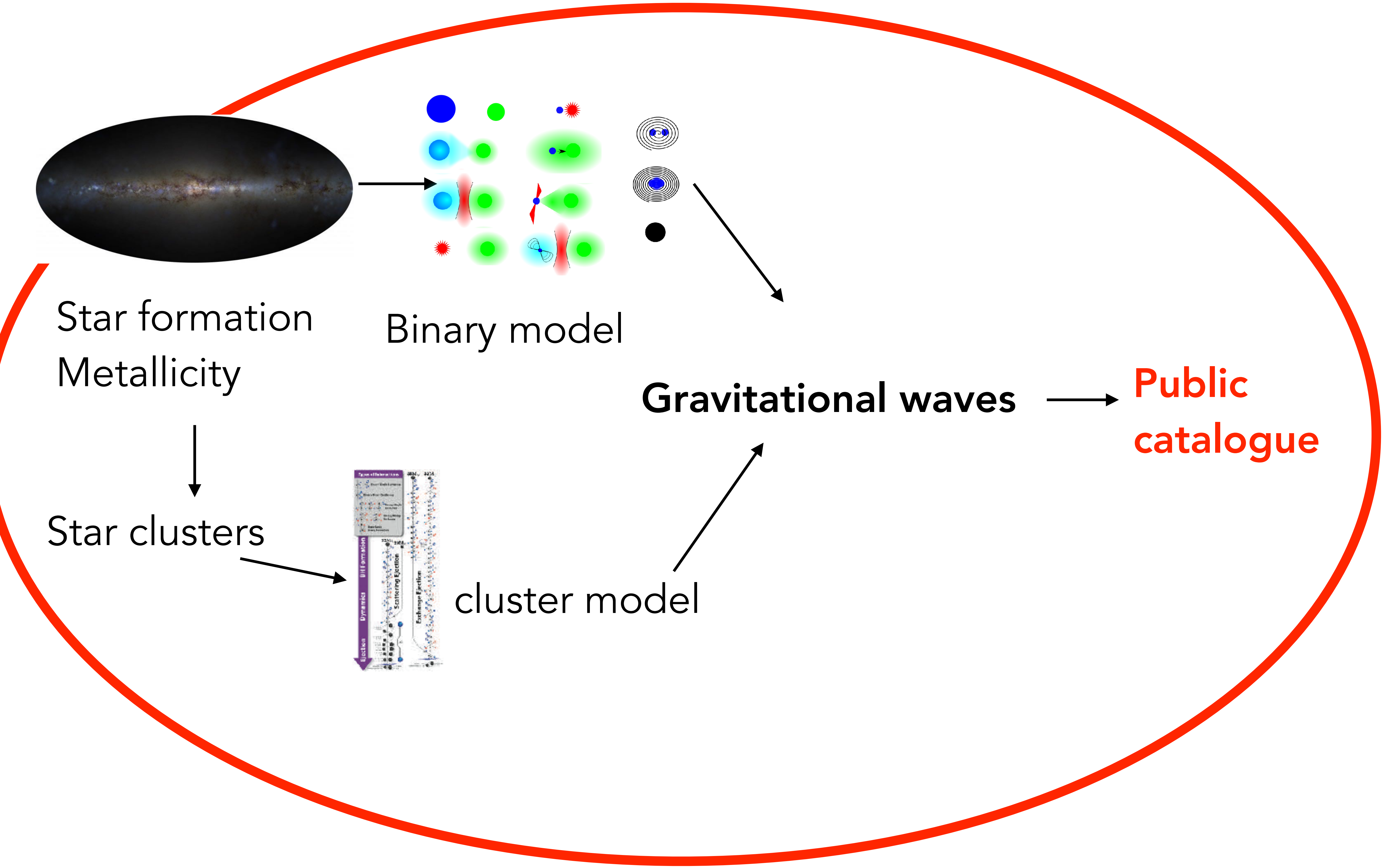
10 million binaries: ~24 CPU hours

Need ~100 models for white dwarfs

~700 models for black holes

Embarrassingly parallel, ok on local clusters, needs "bookkeeping"

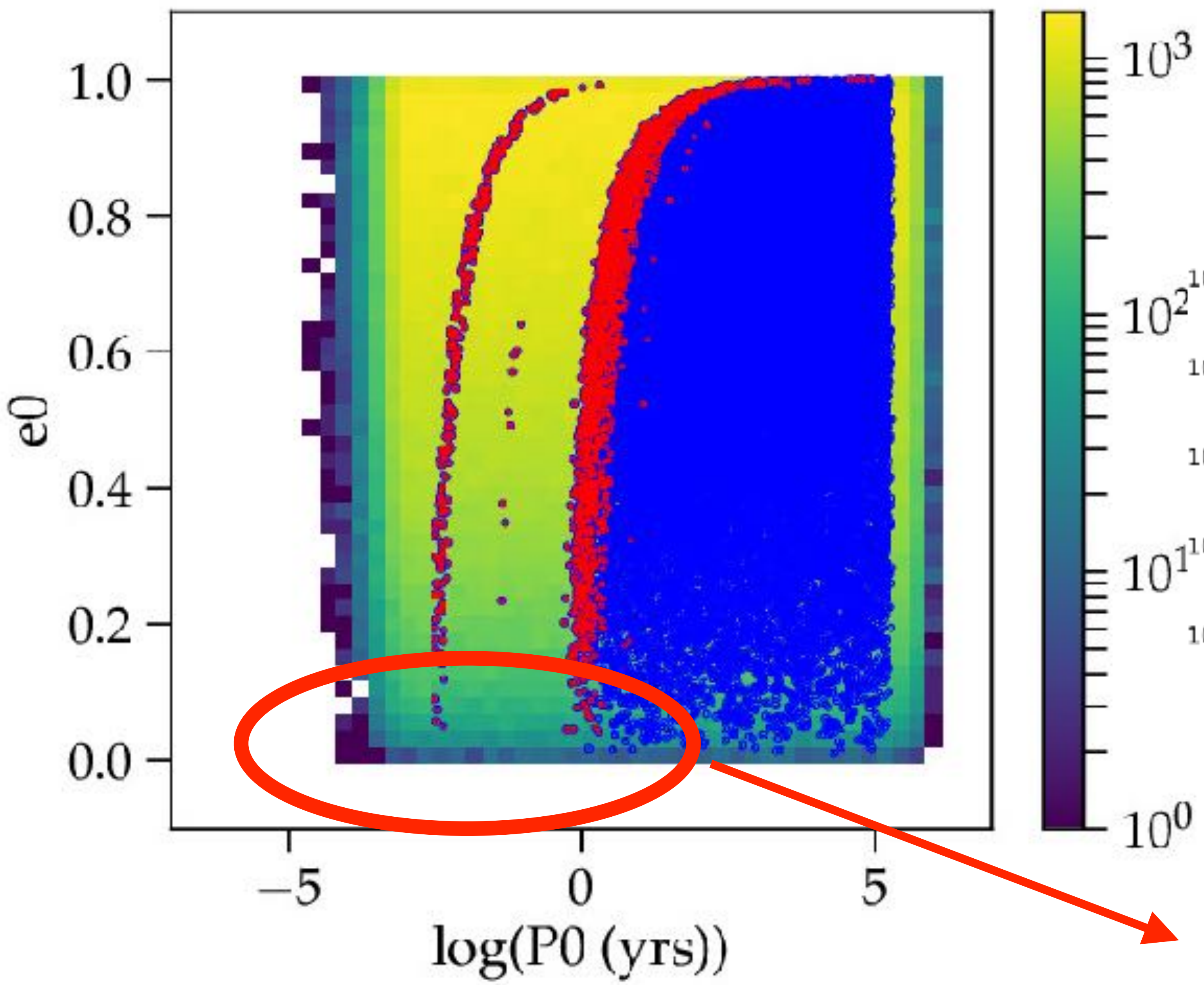
BRINGING IT ALL TOGETHER



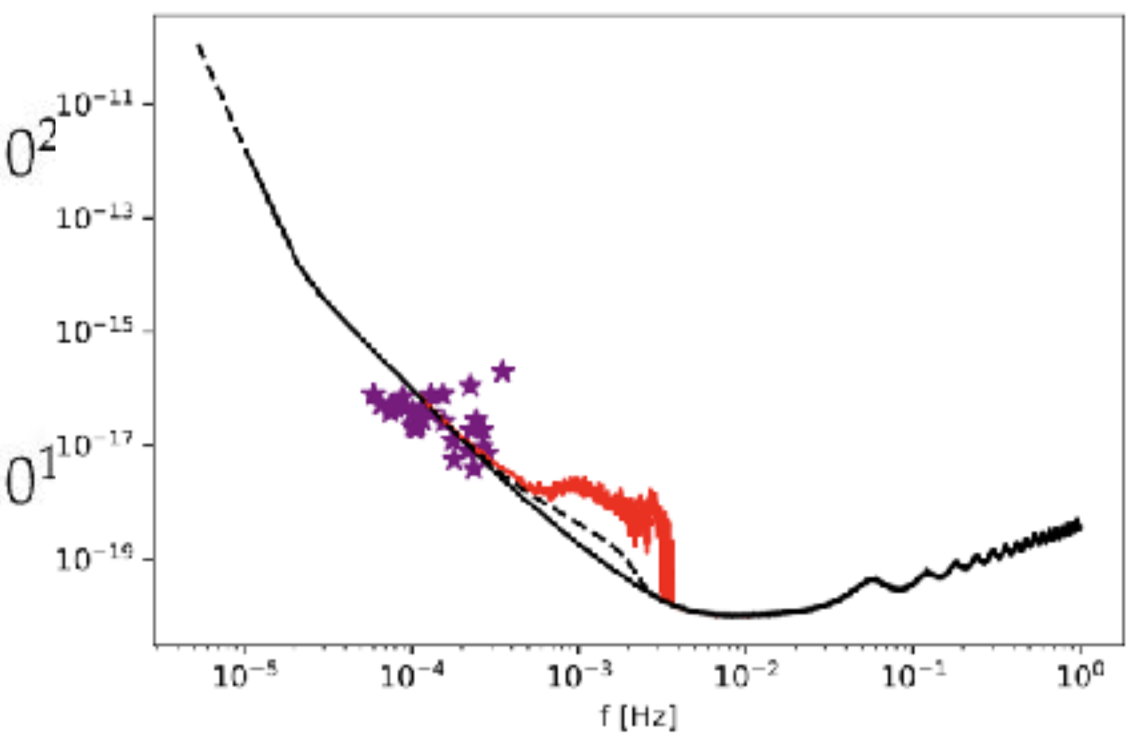
BRINGING IT ALL TOGETHER

1) MW simulations for LISA predictions

Sampling issues : initial conditions need to be sampled properly (x10)



Galactic background in LISA



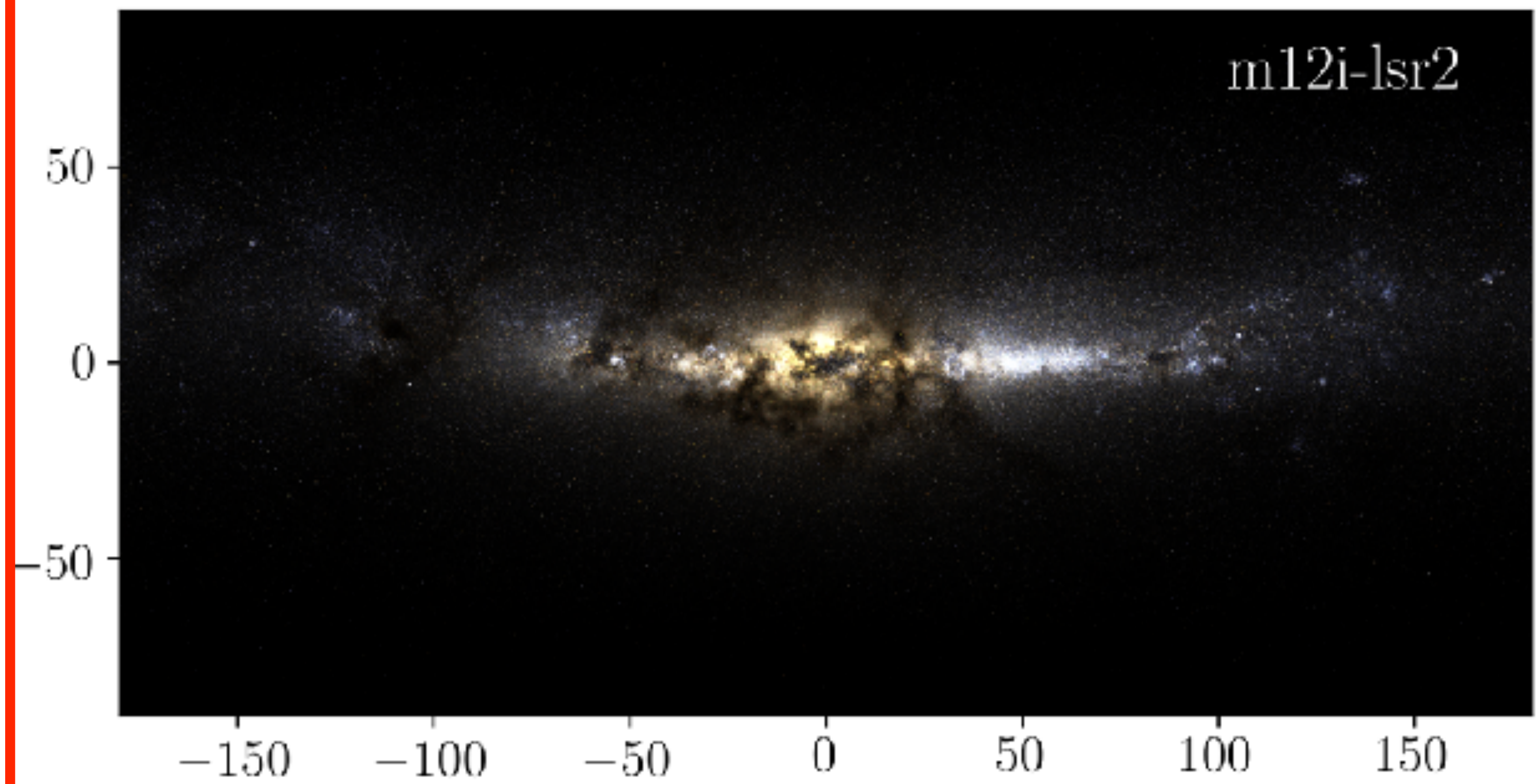
Missing binaries = underestimated background

Bringing it all together

2) Communicating results and accessibility

Making a catalogue: accessible, durable, easy to use, advertised : how?

2D/3D visualisation



Mock GAIA catalogues
(Sanderson + 2018)
5 billion stars

Week on local cluster:
Bottleneck: writing to disk

2TB / catalogue

In prep: double white dwarf catalogues (~100 million objects)

BRINGING IT ALL TOGETHER

3) LIGO/Virgo mergers from binaries and clusters

FIREBOX simulation. 15 Mpc/h, M~60 000 Msun
~50 MW galaxies, 1000 dwarf galaxies
5 million CPU (PRACE, R. Feldmann), 50 TBs, 200 GB/output

Needs for analysis:

Storage and high-memory computing (finding cloud properties, Determine galactic tides, start particle history)

Flexible outputs, good time sampling (for gas evolution)

Intermediate data products: which formats?

Visualisation: tools?

Statistical tools to analyze different models