The illusion of **field** vs **cluster** origin

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18/11/2020 NBIA LIGO Workshop

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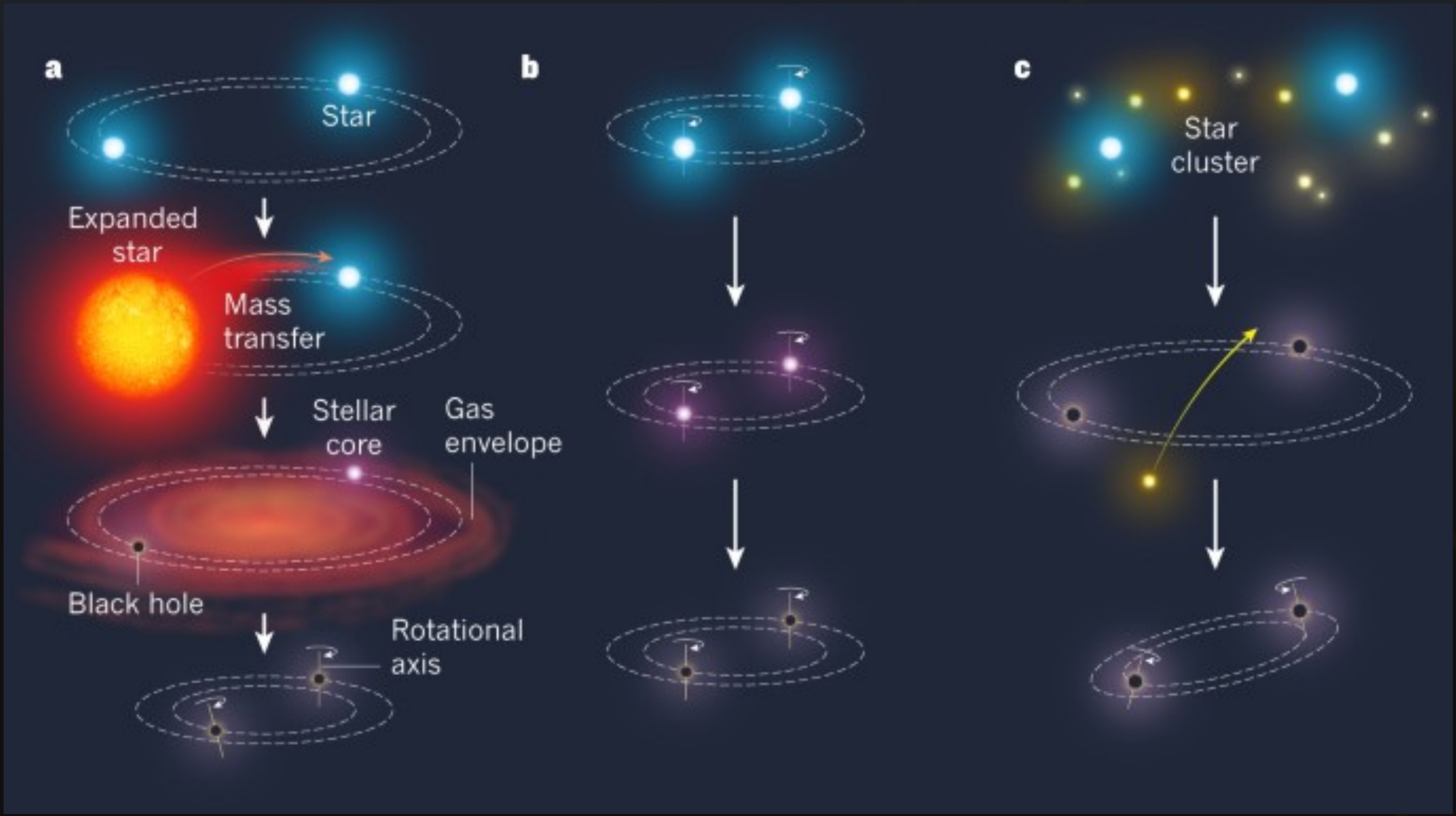
Field vs Cluster



Mandel & Famer 2017

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The Emergence of Structure in the Binary Black Hole Mass Distribution

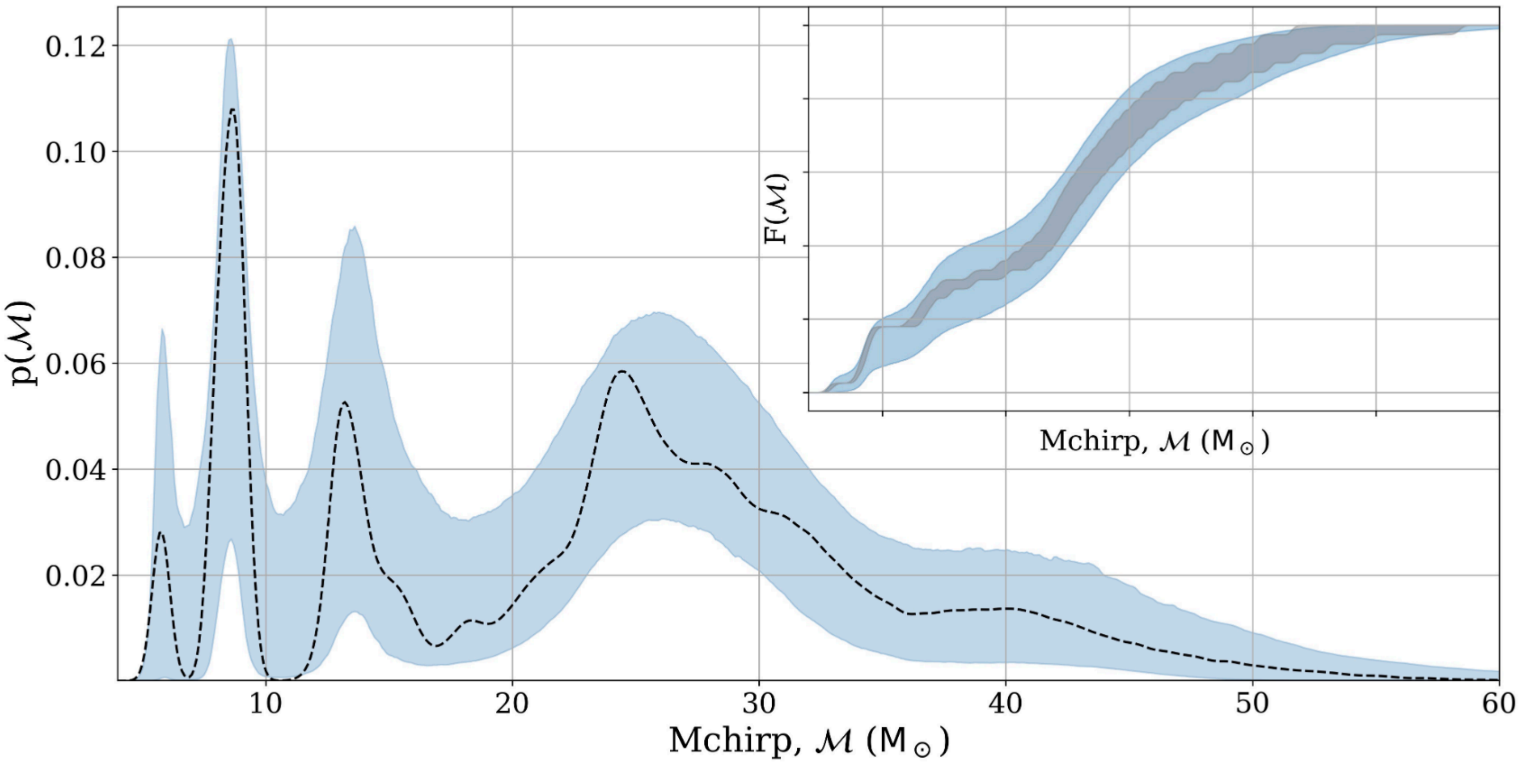

Figure 3. The blue band is the 90% confidence of the density of the posterior predictive obtained after applying selection effects to the reconstructed chirp mass distribution. The dashed curve is the mean observed chirp mass distribution. Inset:The blue band is the 90% confidence of the cumulative probability of the posterior predictive obtained after applying selection effects to the reconstructed chirp mass distribution. The grey band is the 90% confidence obtained by bootstrapping various realisations of the observed data. The observed data is enclosed within the 90% confidence of the posterior's prediction.

Tiwari & Fairhurst 2020 (2011.04502)

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Spin Measurements

$$\chi_{\rm eff} = \frac{c}{GM}\left(\frac{\vec{S}_1}{m_1} + \frac{\vec{S}_2}{m_2}\right)\cdot\frac{\vec{L}}{\left|\vec{L}\right|} \equiv \frac{1}{M}\left(m_1\chi_1 + m_2\chi_2\right),$$

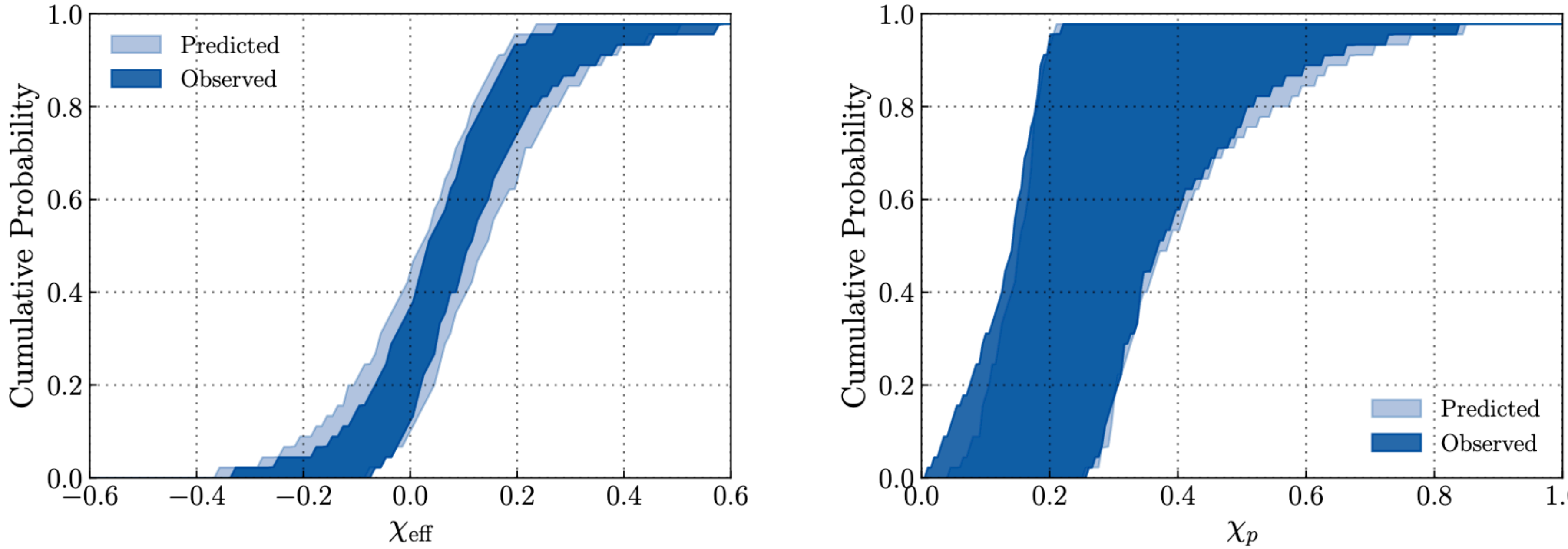
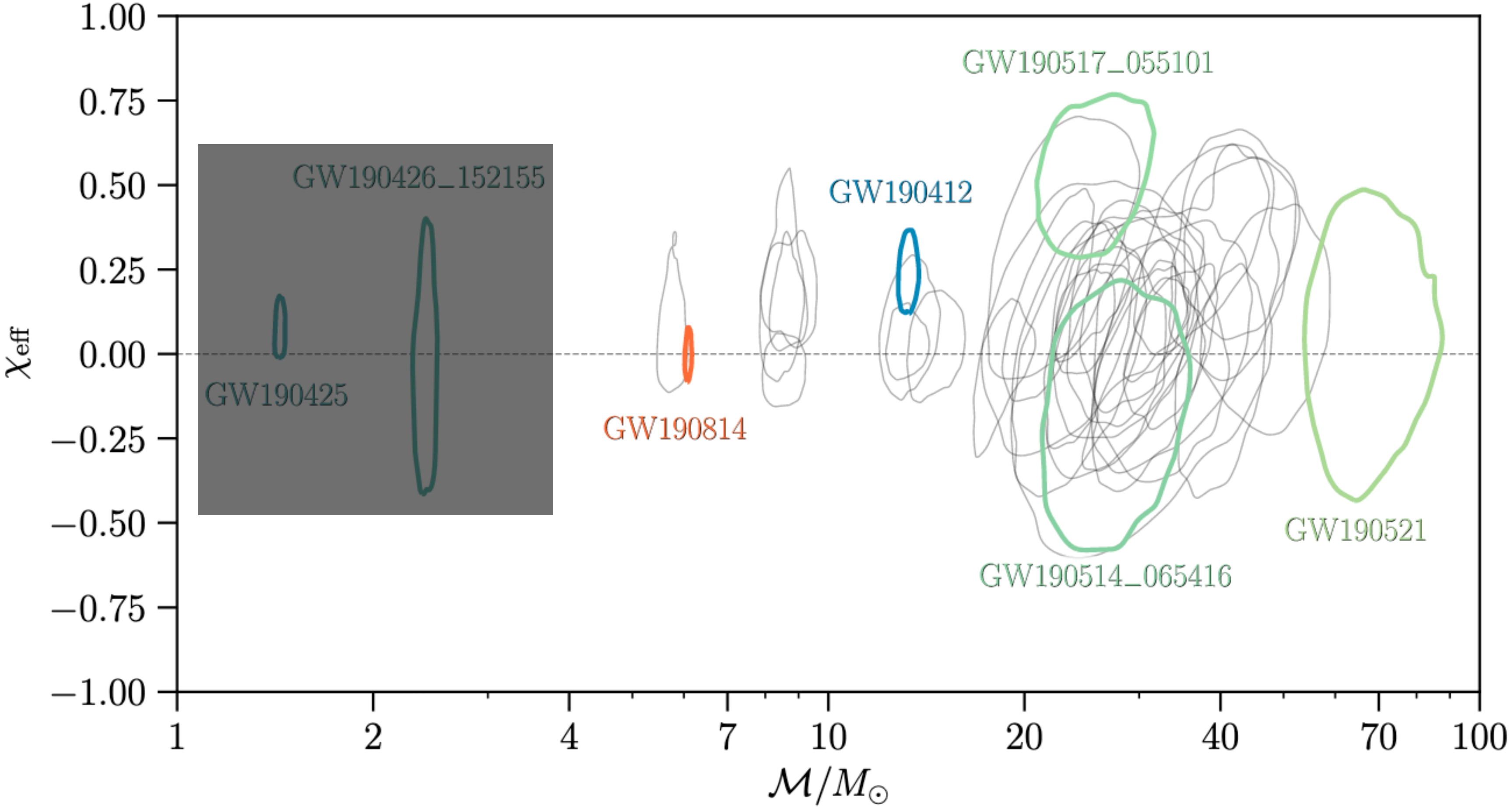


Figure 24. Population predictive checks for the effective aligned spin $\chi_{\rm eff}$ (*left*) and effective precessing spin $\chi_{\rm p}$ (*right*) of BBH mergers using the Gaussian spin model. The light shaded regions show the central 90% credible bounds on the posterior predictive distributions. According to the model, we expect the observed distributions on $\chi_{\rm eff}$ and $\chi_{\rm p}$ to lie within the light shaded region 90% of the time. The dark shaded regions show the 90% credible bounds on the observed distributions in GWTC-2, found using the population-informed posteriors of the confident BBH events in GWTC-2. The overlap between the dark and light regions shows that the model passes the posterior predictive check. The results for the Default model are similar, indicating that both models are a good fit to the data.

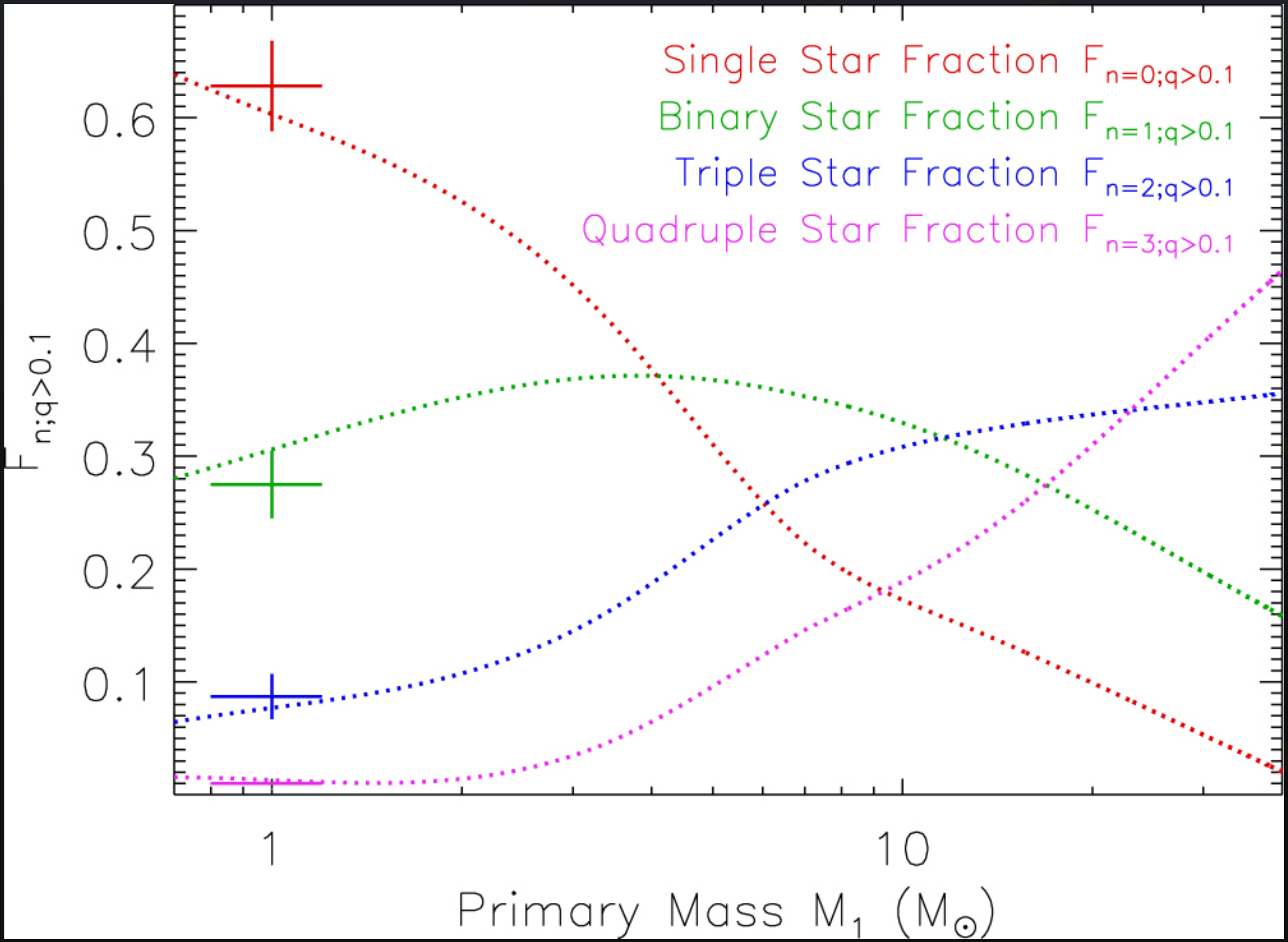
https://dcc.ligo.org/LIGO-P2000077/public

Mass-Spin Measurements



GWTC-2 (2010.14527)

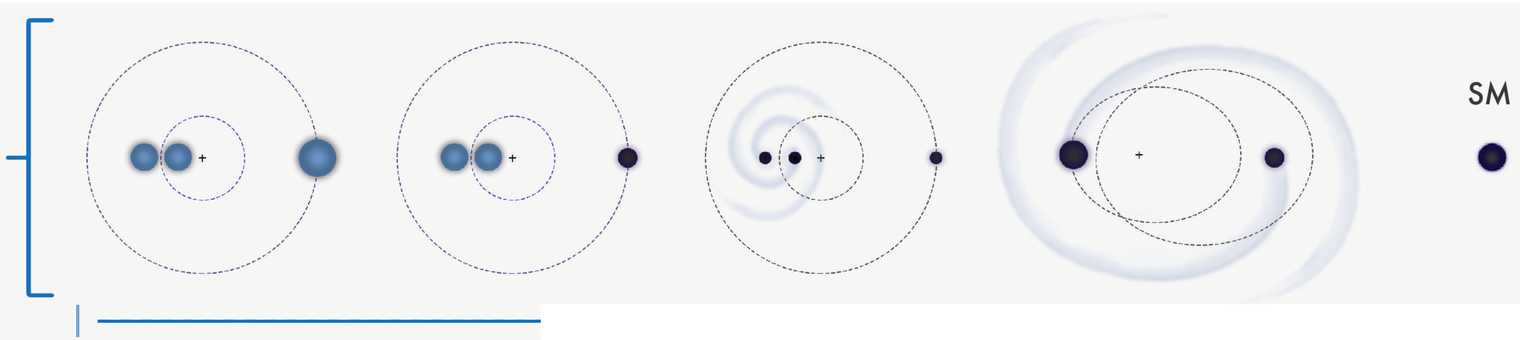
Massive Stellar Multiplicity



Moe & Di Stefano 2017 (1606.05347)

Isolated Triples Leading to BBHs

GW170729



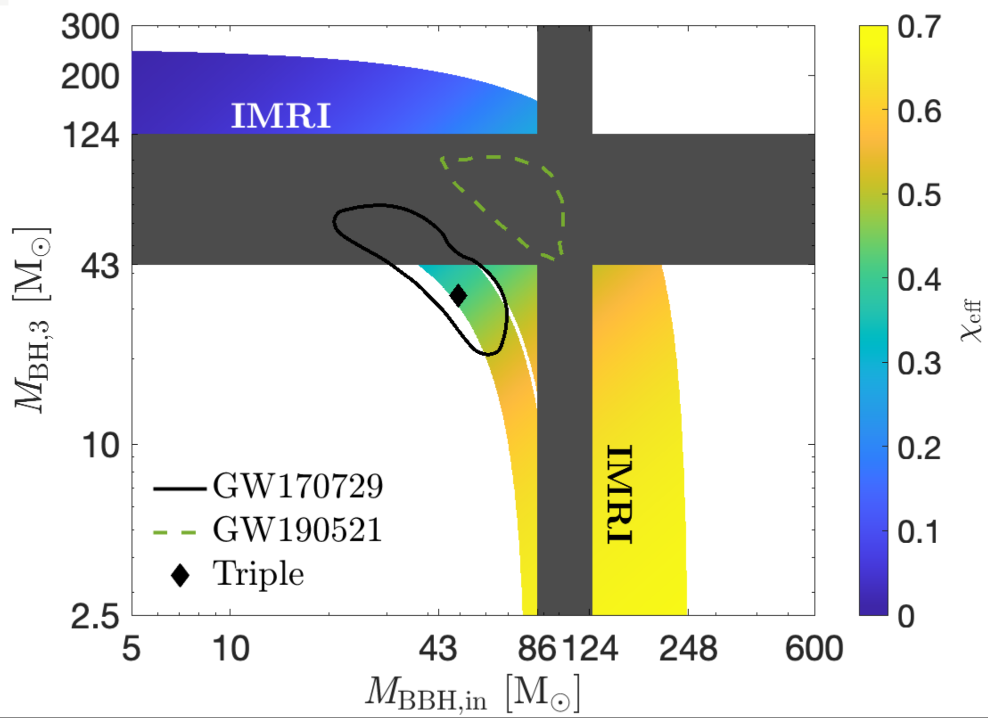
Initial conditions:

M_1=M_2=26 Msol, a_{in}≈12 Rsol, M_3≈33 Msol, a_{out}≈45 Rsol, e_{in}=e_{out}=0

GW170729*:

M_{chirp}≈35 Msol, χ_{eff}≈0.4, z≈0.5.

$$\chi_{\rm eff} = \frac{c}{GM}\left(\frac{\vec{S}_1}{m_1} + \frac{\vec{S}_2}{m_2}\right) \cdot \frac{\vec{L}}{\left|\vec{L}\right|} \equiv \frac{1}{M}\left(m_1\chi_1 + m_2\chi_2\right),$$



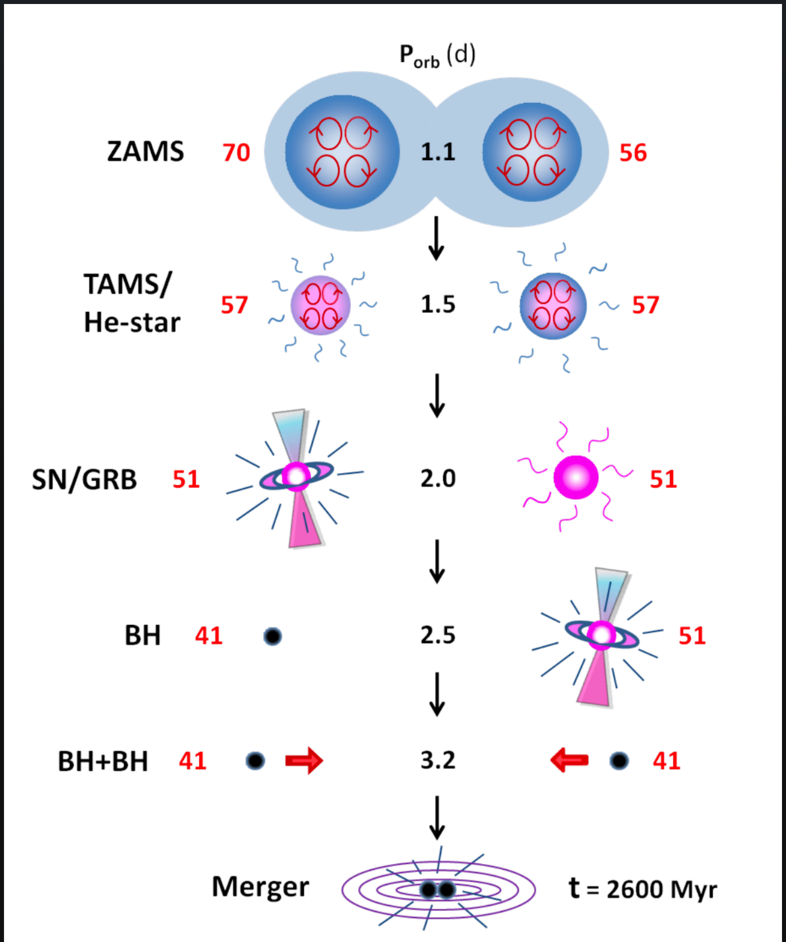
Vigna-Gomez+2020b (2010.13669)

*GWTC-1 (1811.12907)

Field/Cluster/Dynamic Degeneracy

Author	Topic	Physics/Method
Farr+2017, Rodriguez+2016, etc.	Spin distributions	Data analysis
Spera+2019, Di Carlo+2019,2020a,b, Renzo+2020, etc.	PISN mass-gap	Stellar mergers
Farrell+2020, Kinugawa+2020, Tanikawa+2020, etc.	PISN mass-gap	Zero metallicity (Pop III)
Fishbach & Holz 2020	PISN mass-gap	Data analysis
Schrøder+2018, Batta & Ramirez-Ruiz 2019, etc.	Natal BH spins	3D hydrodynamics
Steinle & Kesden 2020	Spin-misalignment in field binaries, Black hole kicks	Population synthesis
Fragione+2020, Vigna-Gomez+2020, Samsing & Hotokezaka 2020, etc.	Triples: PISN mass-gap, spins, second generation mergers	3-body dynamics, single-binary dynamics, population synthesis
Safarzadeh+2020, Hoang+2020, etc.	Quadruples: mass-gap and spins	4-body dynamics
Romero-Shaw+2020, Samsing+2020, etc.	Eccentricity	Data analysis, single-binary dynamics

My Suggestion: **CHE** Binaries as a Probe for Natal BH Spin/Kick



- Ideal (maybe **WR 20a** q≈0.9903):
  - Mass ratio q>0.98
  - Chi_p ≈ 0
  - 0.4 > a (??)
  - e = 0
- LVC:
  - Mass ratio q≳0.95
  - Likely aligned spins (kick)
  - Maximal spin a~a_{max} (birth)
  - e ≈ 0

Marchant+2016, de Mink & Mandel 2016, etc.
(??) Batta & Ramirez-Ruiz+2019

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BBHs from CHE Binaries: Rates

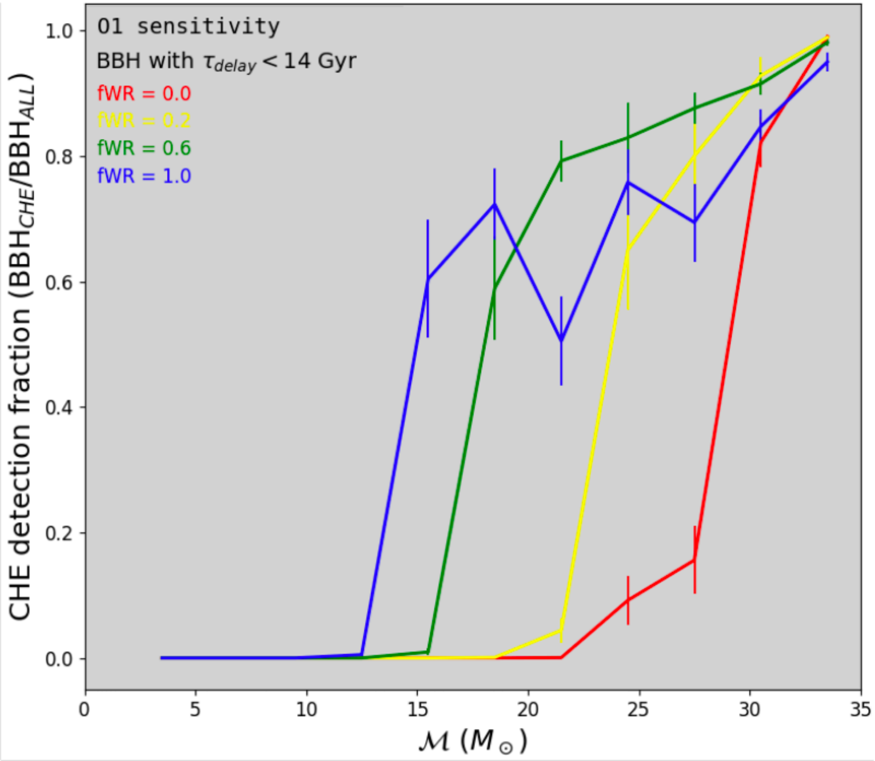

Figure 15. The fraction of BBHs formed through the CHE channel among all BBHs detectable at aLIGO O1 sensitivity, plotted as a function of chirp mass.

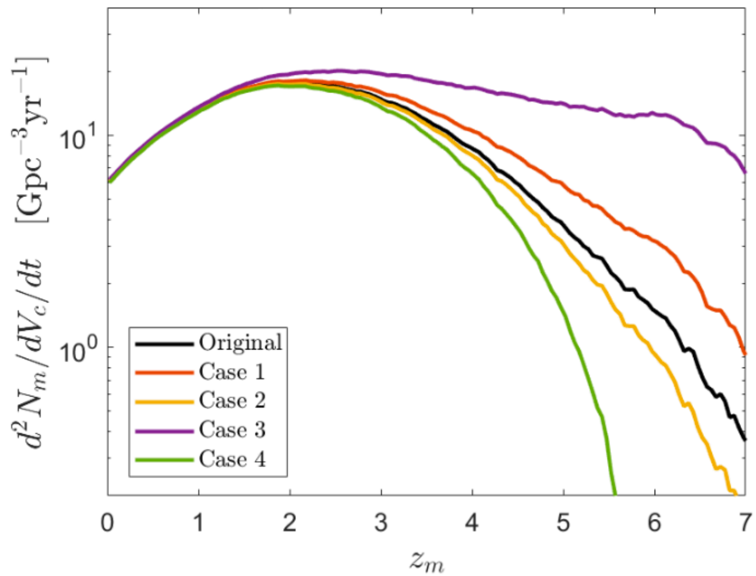

Figure 15. The co-moving cosmological BHBH merger rate for the default SFR case (labeled "Original" in the figure) as well as for each of the four cases of high-redshift deviations in SFR, as a function of merger redshift z_m. To see the four cases, see Figure 14.

Riley+2020 (left), du Buisson+2020 (right)

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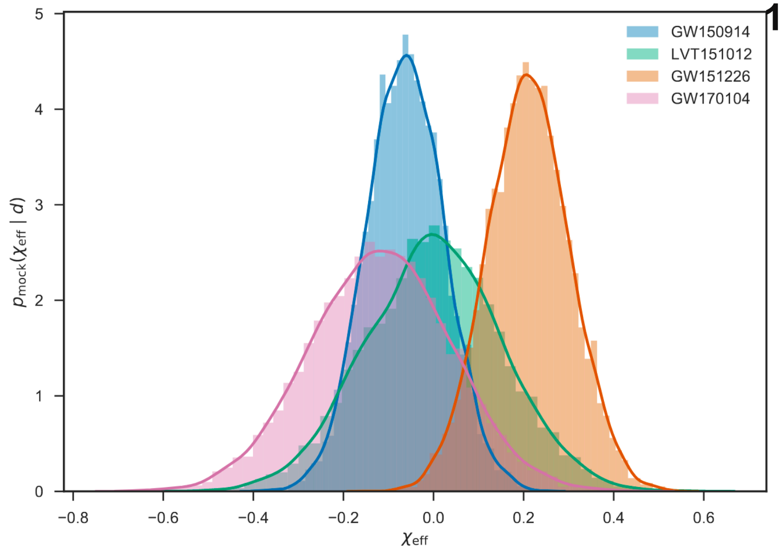
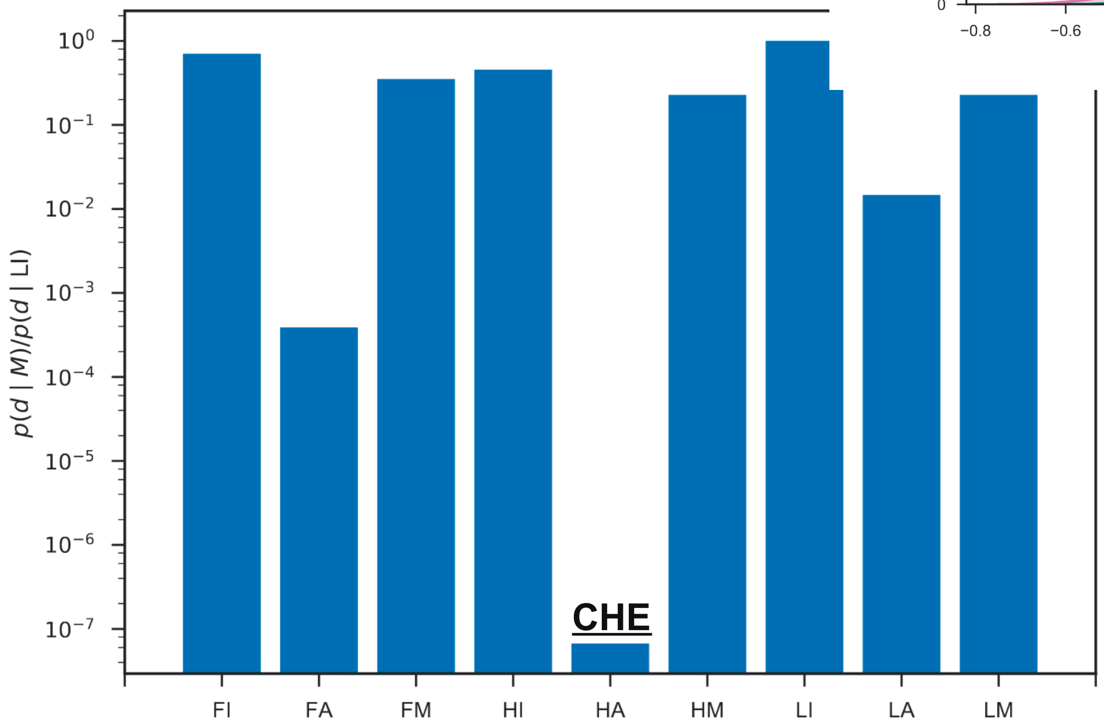
Early(ish) efforts





F: flat

H: high

L: low

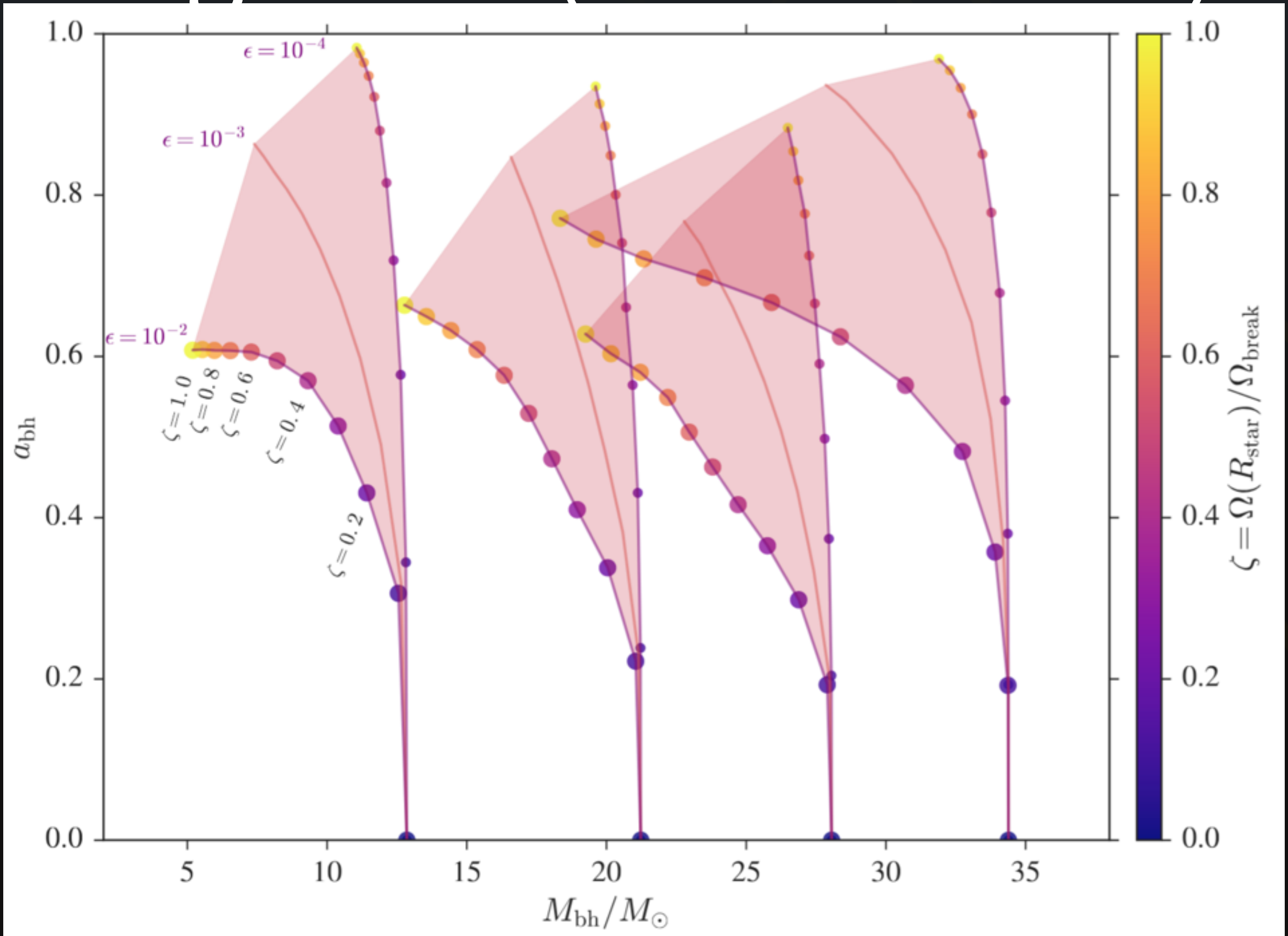
I: isotropic

A: aligned

M: mixed

Farr+2017

Birth Spins from Rapidly Rotating Stars (such as CHE)



Batta & Ramirez-Ruiz 2019 (1904.04835)

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My Open(?) Questions

1) Do we trust the highly spinning highly precessing **waveforms** for accurate inference of spin parameters?
2) Are natal **kicks and** natal **spins correlated**?
3) What is the effect of low/high **natal spin**?
4) How can we truly **disentangle field vs cluster origin**?
   - How bad do we need to disentangle it?
5) What are the pros, cons and caveats of the **CHE channel**?

Can we really make such definitive statements out of it?

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