MG14 ROME 12-18 JULY 2015

BINARY SYSTEMS ASSOCIATED WITH SHORT AND LONG GRBS AND THEIR DETECTABILITY

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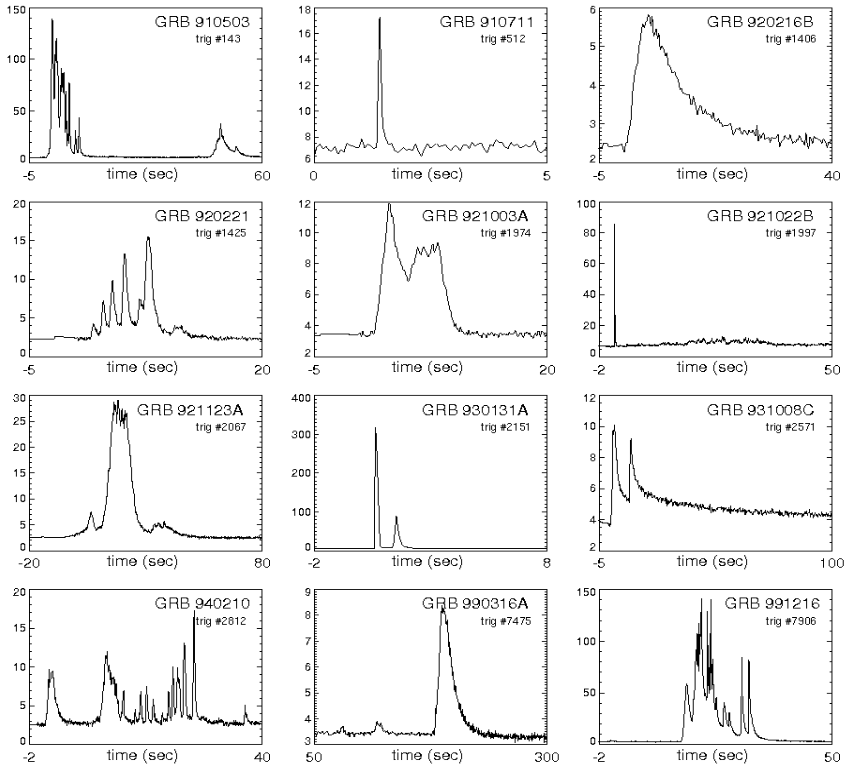
Gamma-Ray Bursts

(see Thursday morning plenary talks: Piran, Gehrels, Ruffini, Fryer)

- **GRBs are cosmological systems (observed up to z=9.4 GRB 090429B; also z=8, GRB 090423)**
- **Most energetic objects (up to a few *10^{54} erg* of *isotropic energy)***
- **Complex light-curves but in general characterized by a prompt and an extended afterglow emission**
- **Duration: "Short" GRBs <2 seconds and "Long" GRBs >2 seconds**
- **Probe the Physics of *Gravitational Collapse and Black Hole formation***

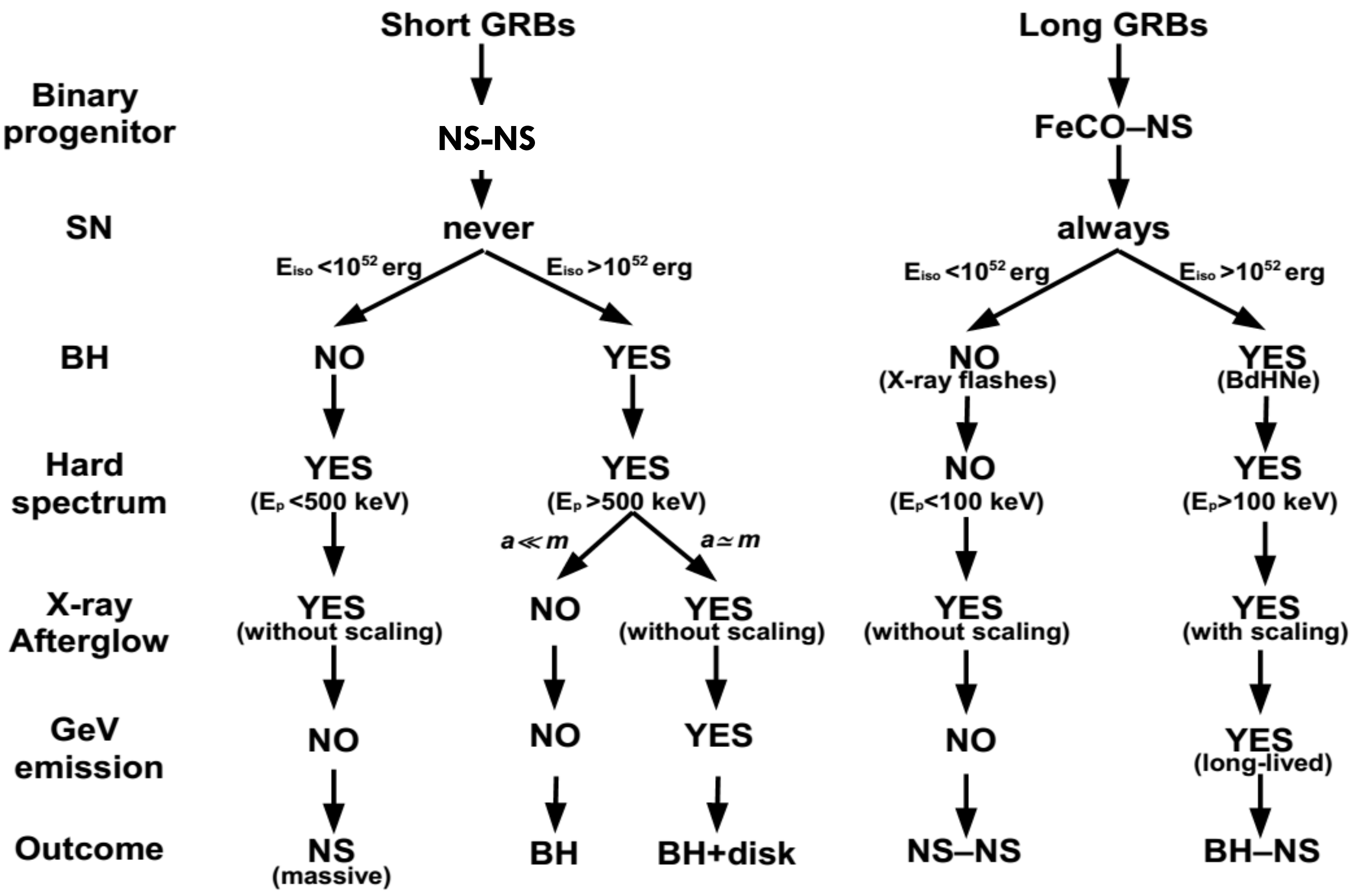


Short and Long GRB Families

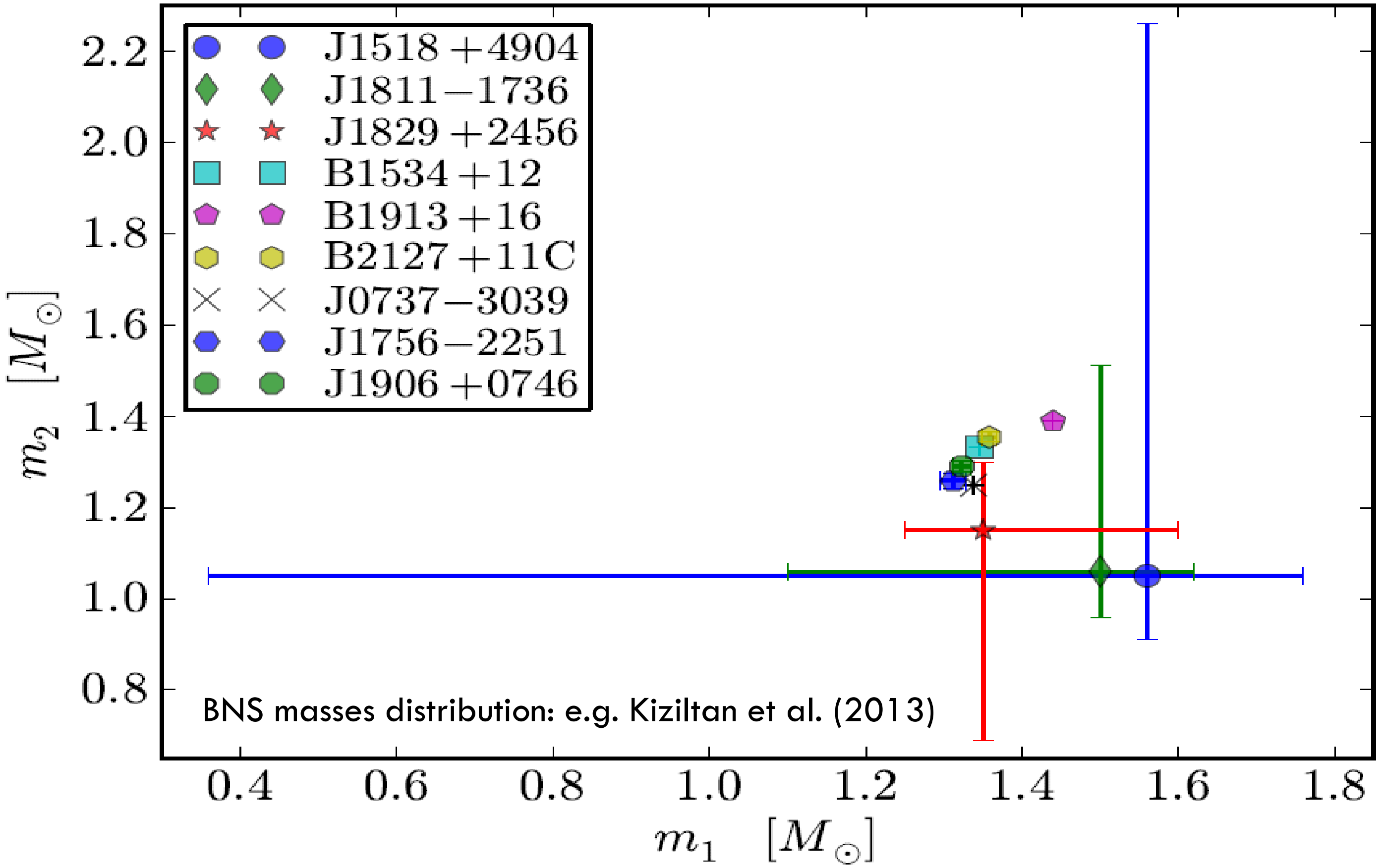
Ruffini et al., ApJ (2015); arXiv: 1412.1018v4
Ruffini et al. ApJ (2015); arXiv:1405.5723

All GRBs are composite and originate from binary systems

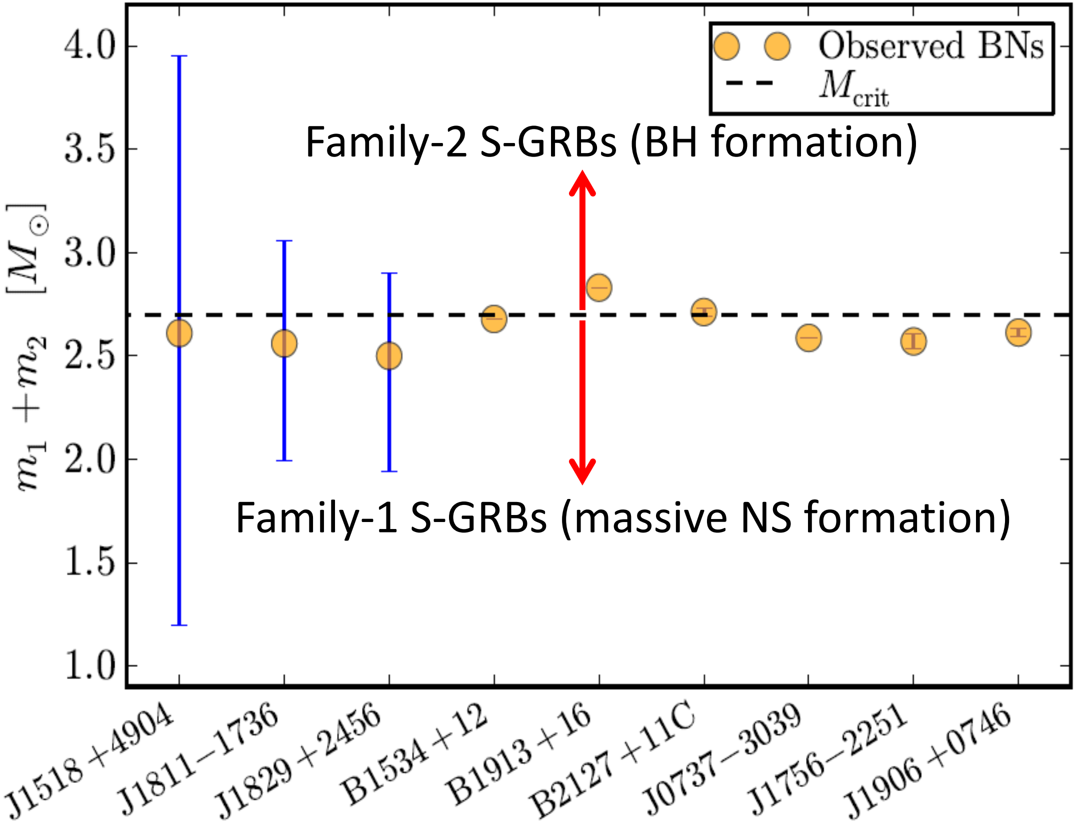
See Ruffini's plenary talk Thursday morning for details



Galactic Binary NSs: will they form BHs?



Families of Short GRBs



NS mass distribution in BNS peaks at 1.32 M_{sun}

(Kiziltan et al. 2013)

So:

$M_{BNS} \sim 2.64\ M_{sun}$

(neglecting NS binding energy and angular momentum)

Ruffini et al., ApJ (2015); arXiv: 1412.1018v4

Which are the mass and angular momentum of the merged core?

Depends on:

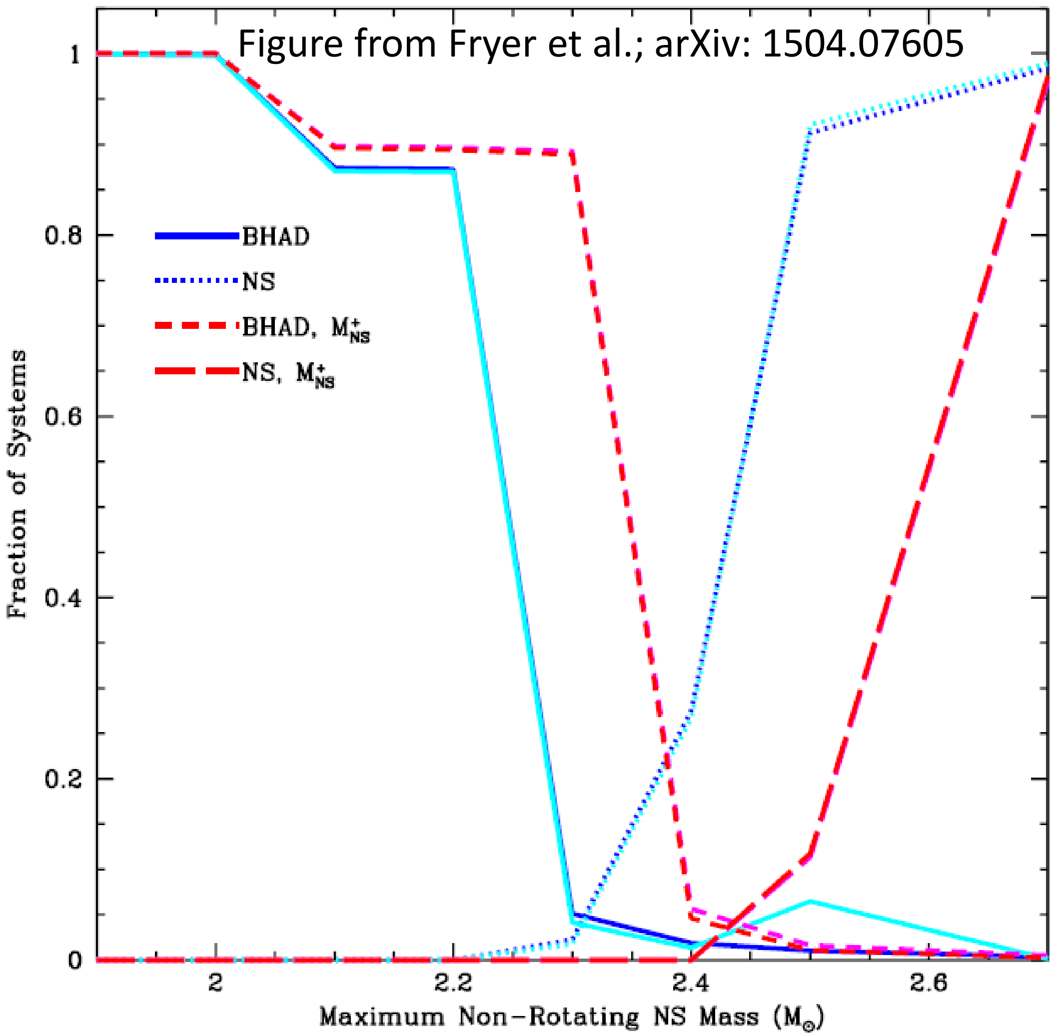
1) Mass-ratio of the binary (M1/M2 ~1 for the galactc BNS)

2) Degree at which baryon and angular momentum are conserved (mass and angular momentum loss, mass and angular momentum of a surrounding disk):

$(M_1,M_2) \rightarrow (M_{b1},M_{b2}) \rightarrow M_{bf} = \alpha\,(M_{b1}+M_{b2})$; where $\alpha <= 1$

$J_{mc} = \beta\, J_i \sim \beta\, J_{bin}$ (contact); where $\beta <= 1$

Fate of the Merged Core?



F-1S-GRB Rate: (1-10) Gpc^-3 y^-1

see, e.g., E. Berger, ARAA 52, 43 (2014)

F-2 S-GRB Rate: (0.2-6.2)x10^{-4} Gpc^-3 y^-1

Ruffini et al., ApJ (2015); arXiv: 1412.1018v4

Galactic BNS rate: (10-10000) Gpc^-3 y^-1

Abadie et al.; arXiv: 1003.2480

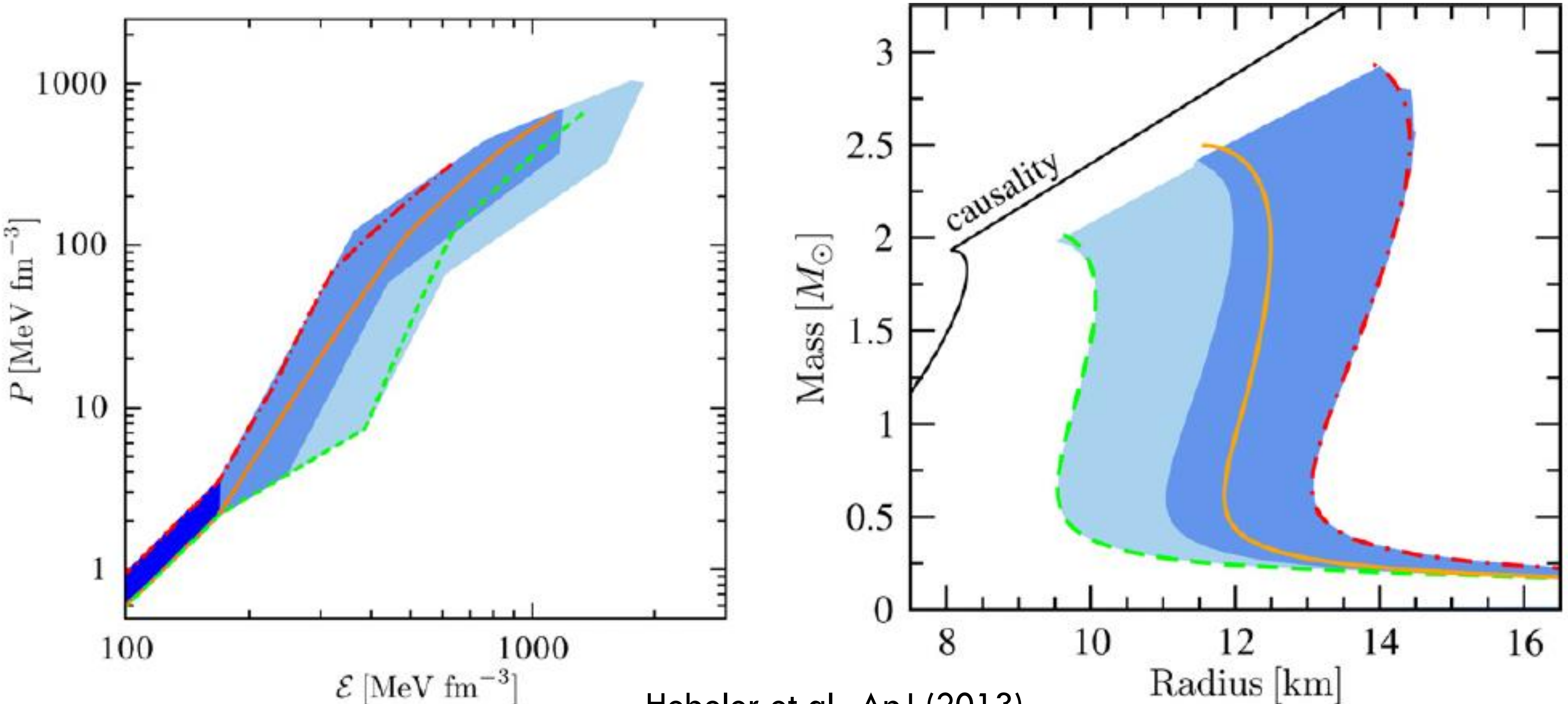
The relative rates:

F1SGRB/GBNS = 10^{-4} - 1

F2SGRB/GBNS = 2x10^{-9} – 6.2x10^{-5}

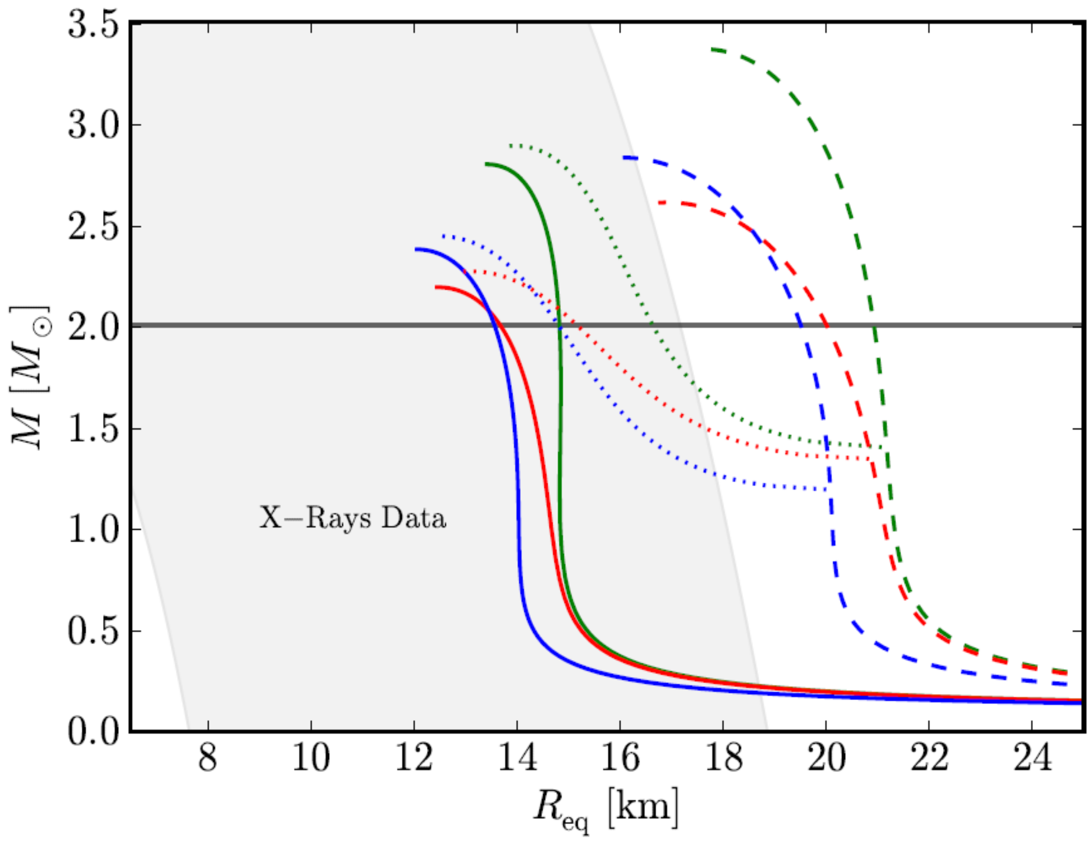
suggests quite large critical NS mass!

Constraining the nuclear EOS and Mass-Radius Relation



Hebeler et al., ApJ (2013)

NS Mass-Radius Relation: Observational Constraints



- Maximum NS mass observed: 2 Msun

  (Antoniadis et al., Science (2013)

- Fastest NS observed: f=716 Hz

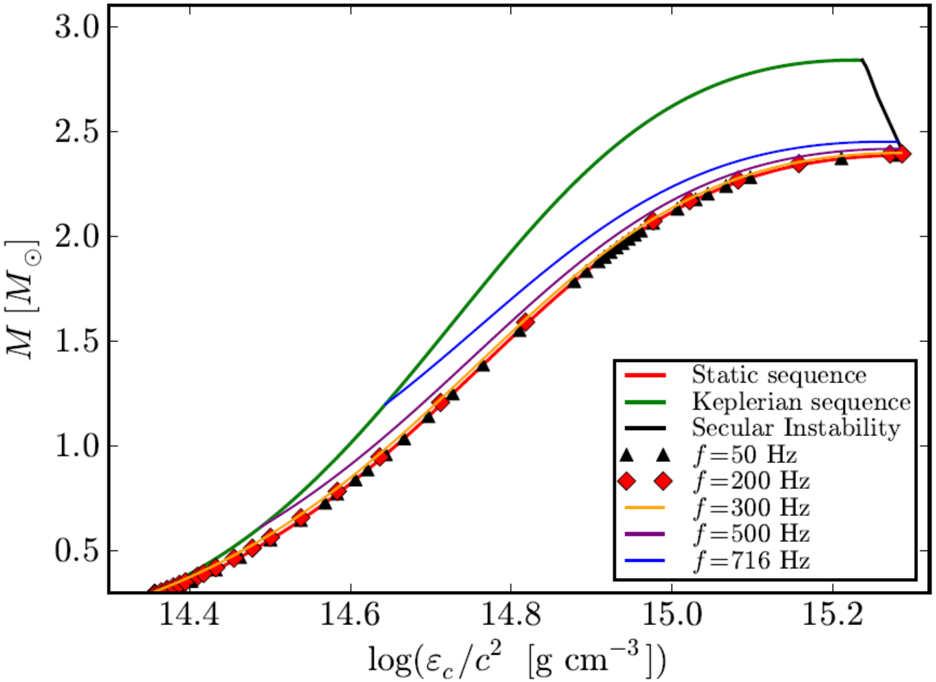
  (Demorest et al., Science (2006)

- Radii from X-ray emisison: mainly from low-mass X-ray binaries (LMXBs), and X-ray isolated NSs (XINSs): shaded area

  (Lattimer & Steiner, EPJ (2014)

Figure from Cipolletta, et al. PRD 92, 023007 (2015); arXiv: 1506.05926

Rotating NS configurations: secular instability line

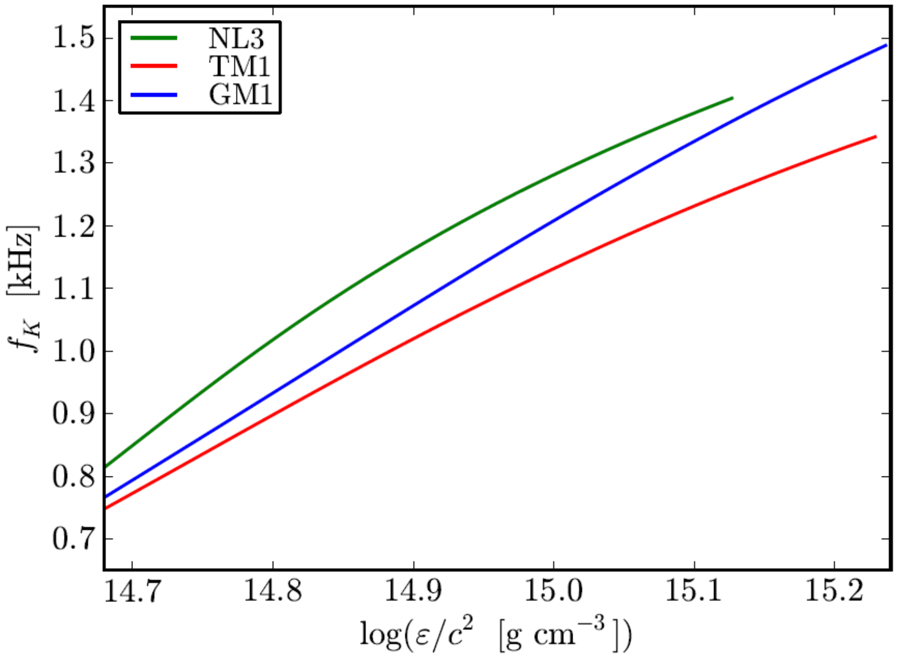


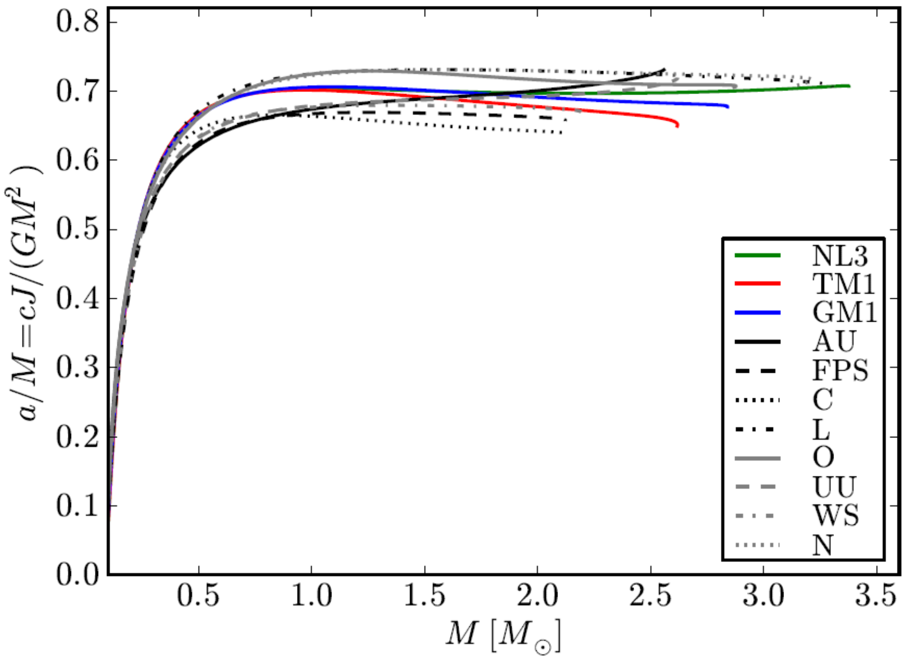
$$M_{NS}^{crit} = M_{NS}^{J=0}(1 + k j_{NS}^{p})$$

	$M_{crit}^{J=0}$ $M_\odot$	$R_{crit}^{J=0}$ km	$M_{max}^{J\neq0}$ $M_\odot$	$R_{max}^{J\neq0}$ km	f_K kHz	p	k
NL3	2.81	13.49	3.38	17.35	1.34	1.68	0.006
GM1	2.39	12.56	2.84	16.12	1.49	1.69	0.011
TM1	2.20	12.07	2.62	15.98	1.40	1.61	0.017

Taken from Cipolletta, et al. PRD 92, 023007 (2015)
arXiv: 1506.05926

Rotating NS configurations: full rotation in GR





Figures from Cipolletta, et al. PRD 92, 023007 (2015); arXiv: 1506.05926

Neutron Star Binding Energy

(Cipolletta, Cherubini, Filippi, Rueda, Ruffini, PRD 92, 023007 (2015); arXiv: 1506.05926

Static Configurations

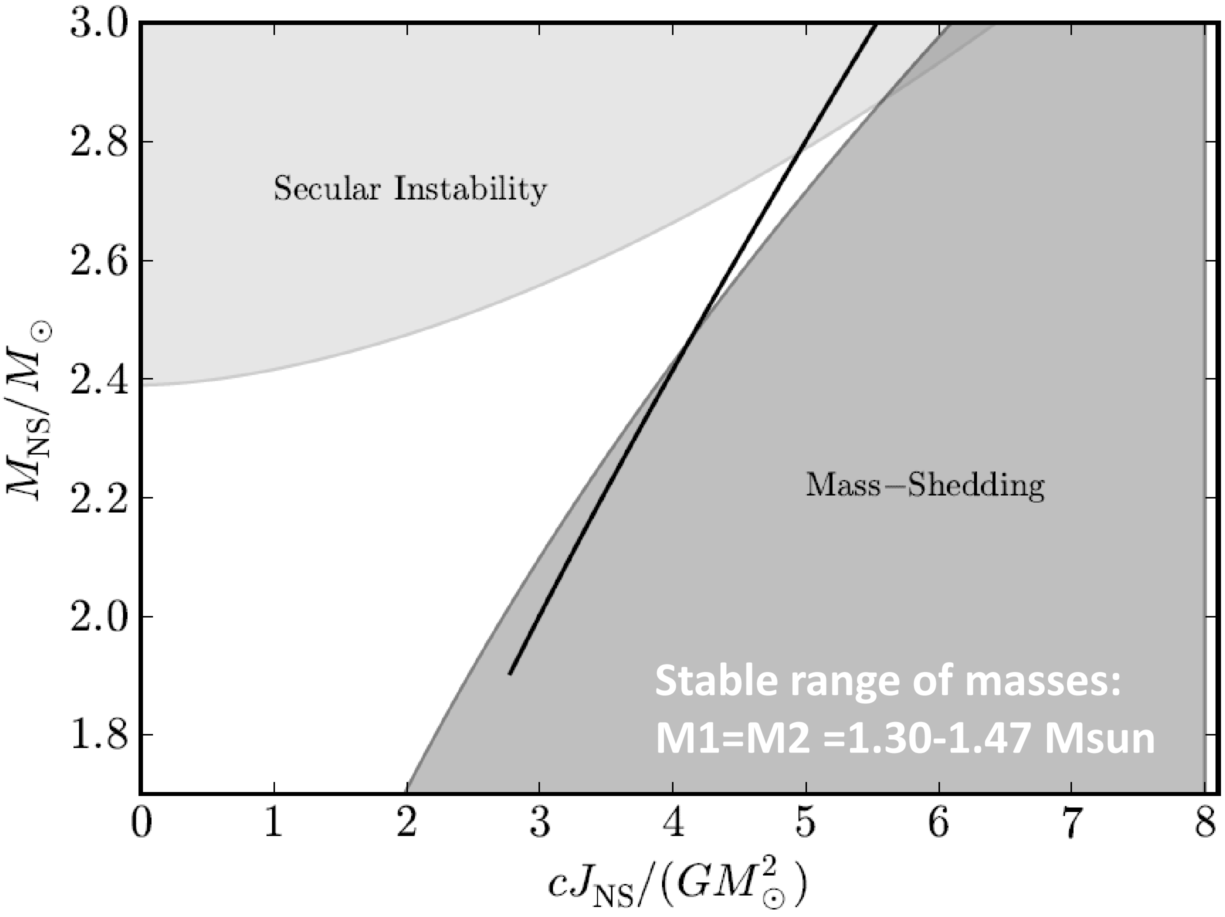
$$\frac{M_b}{M_\odot} \approx \frac{M}{M_\odot} + \frac{13}{200}\left(\frac{M}{M_\odot}\right)^2$$

Rotating Configurations

c J/(G M^2_{sun})

$$\frac{M_b}{M_\odot} = \frac{M}{M_\odot} + \frac{13}{200}\left(\frac{M}{M_\odot}\right)^2\left(1 - \frac{1}{130} j^{1.7}\right)$$

Fate of the merged core?



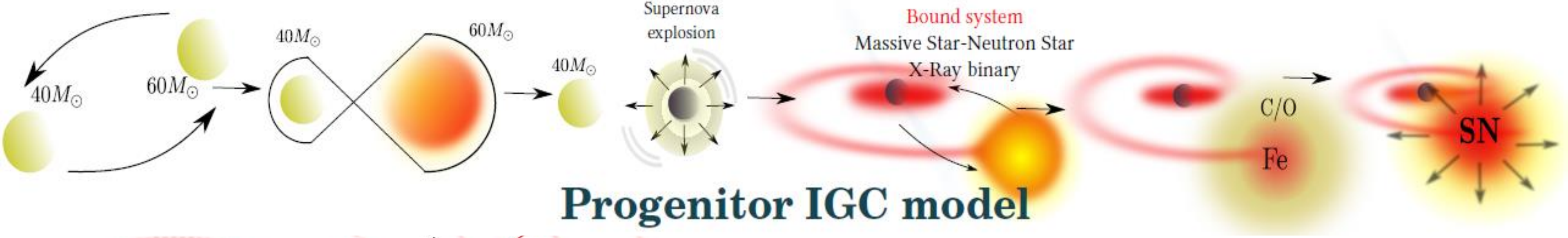
In this example:

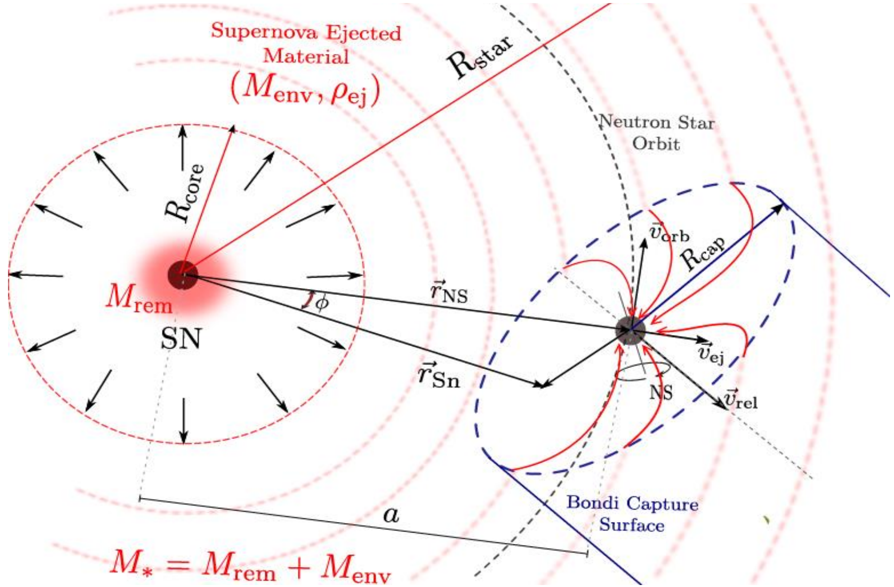
- EOS: GM1

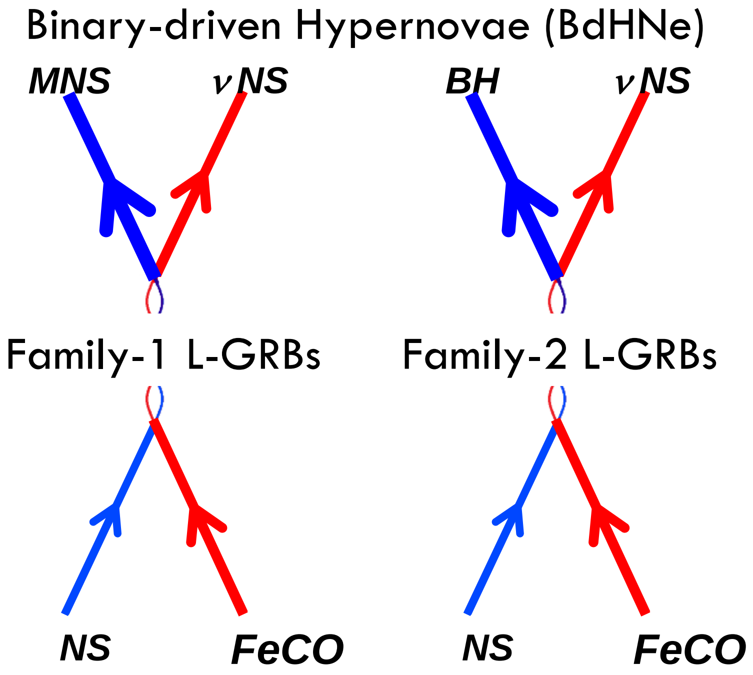
- 90% of the angular momentum at the merger assumed to be kept by the new compact core

- 1.0 Msun < M1=M2 < 2.0 Msun

Now let’s turn to long GRBs



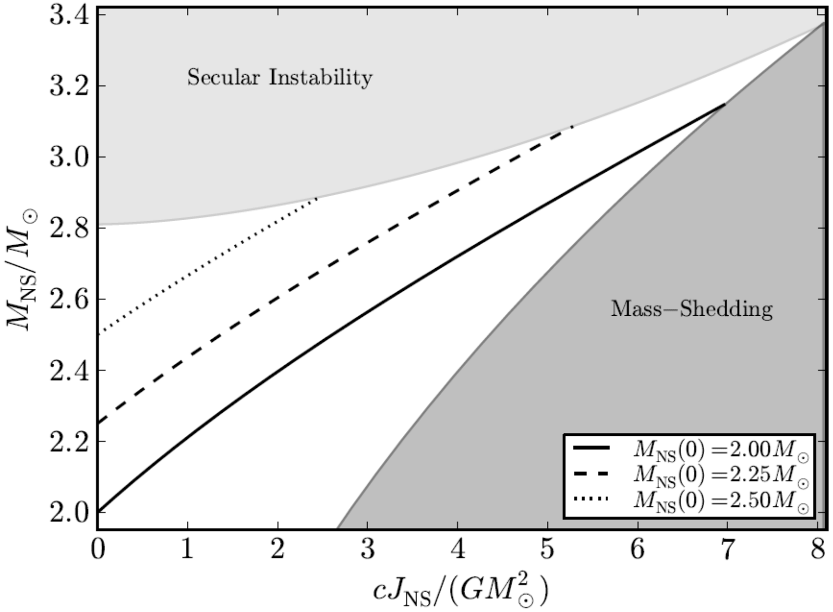


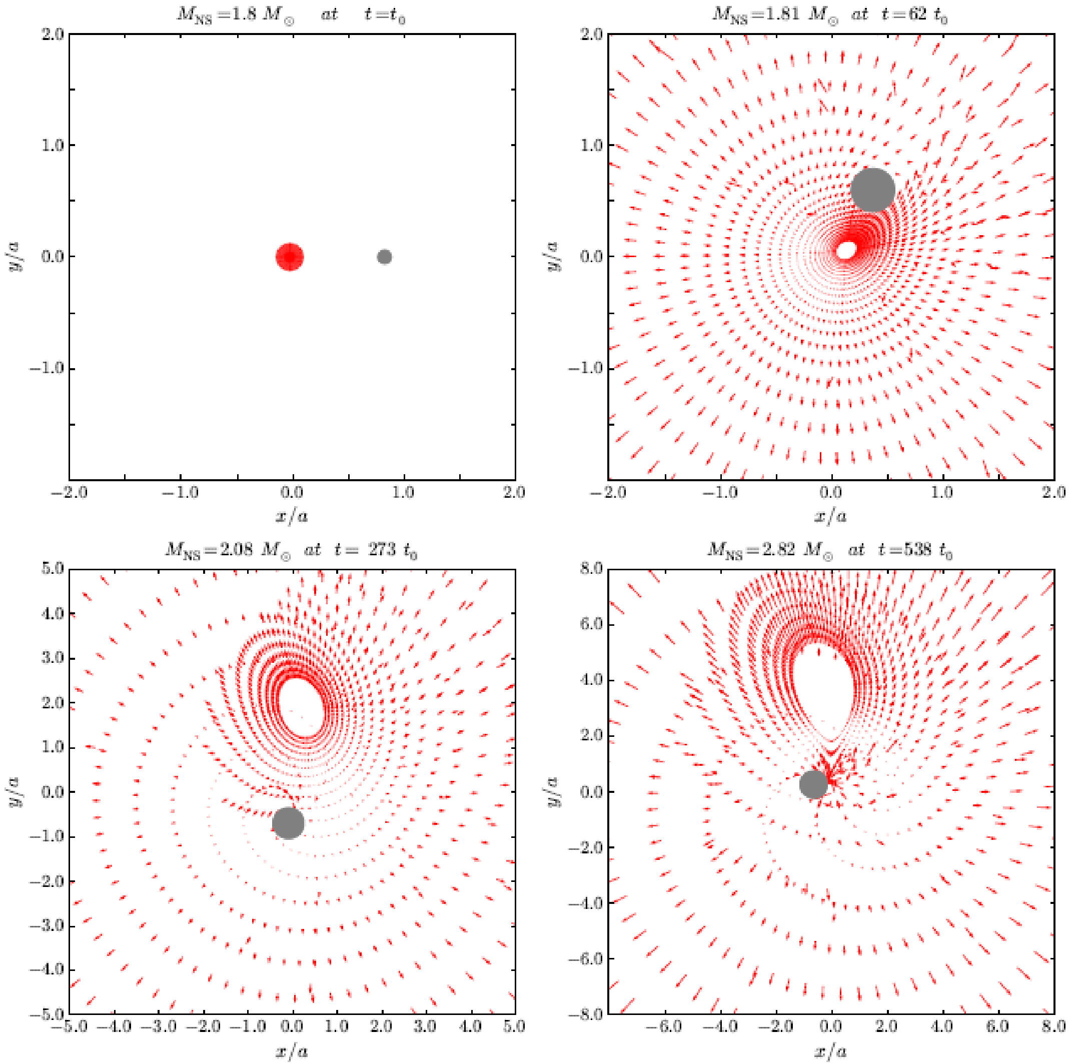


Ruffini et al. ApJ (2015); arXiv:1405.5723

Rueda & Ruffini, ApJL (2012)
Izzo, Rueda, Ruffini, A&AL (2012)
Fryer, Rueda, Ruffini, ApJL (2014); arXiv:1409.1473
Becerra et al. (2015); arXiv:1505.07580
Fryer et al. (2015); arXiv: 1505.02809

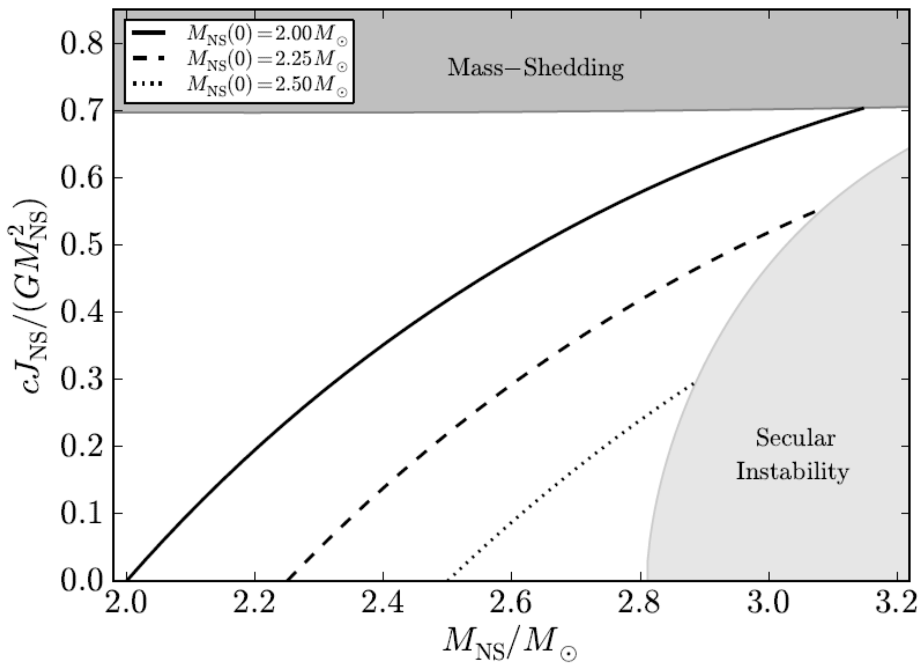
NS evolution during hypercritical accretion in BdHNe

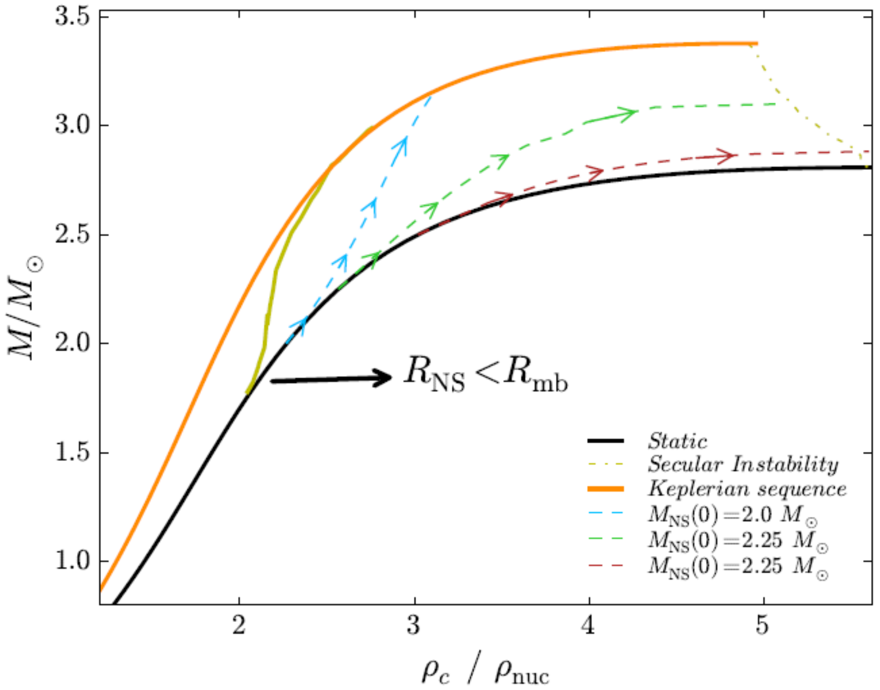




Becerra et al., arXiv: 1505.07580

NS evolution up to the instability point





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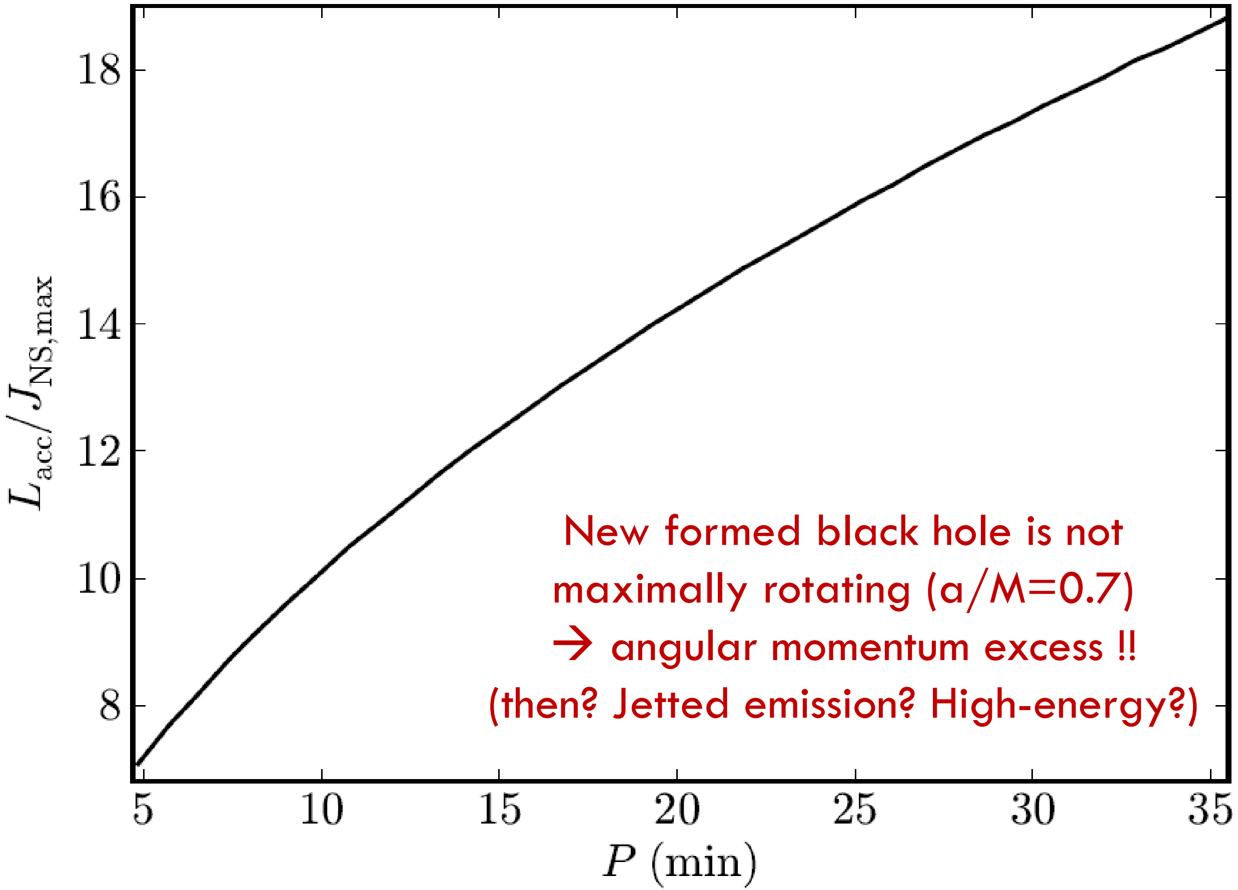
On the role of angular momentum in BdHNe



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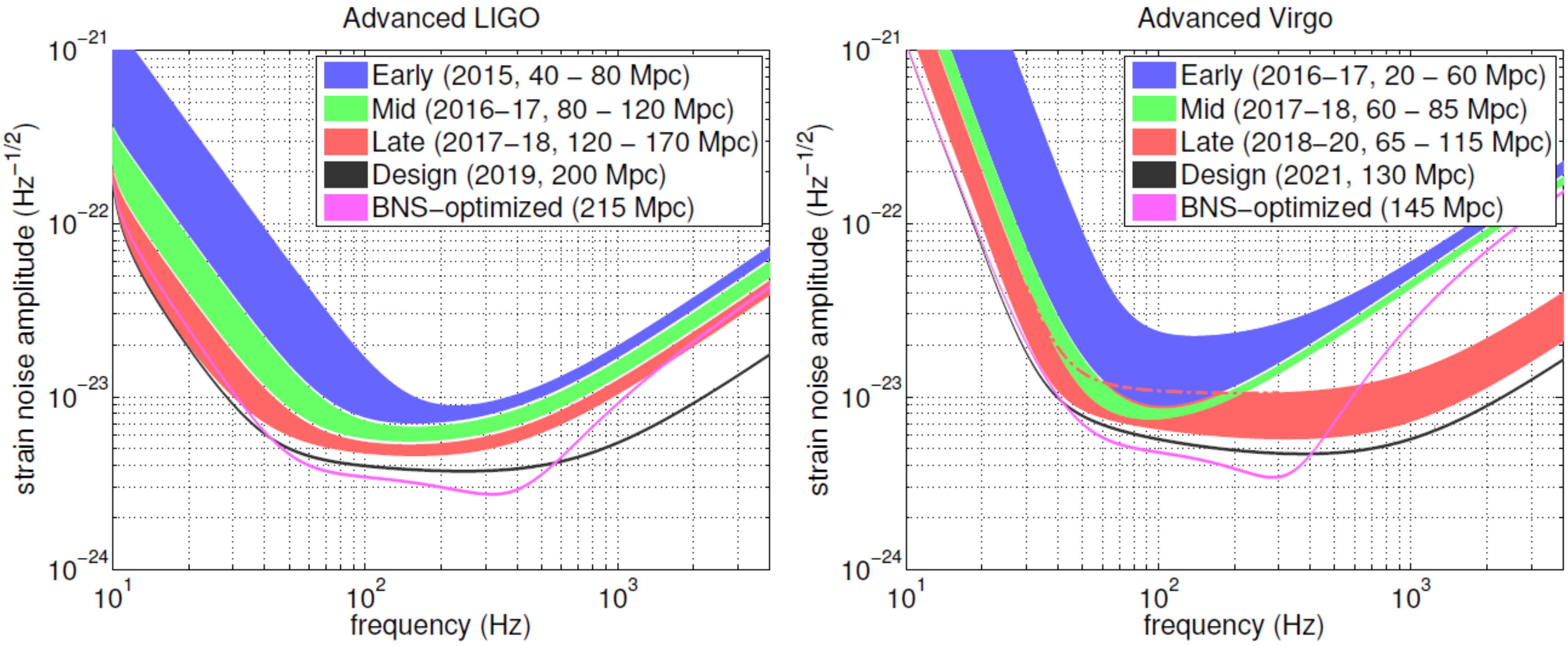
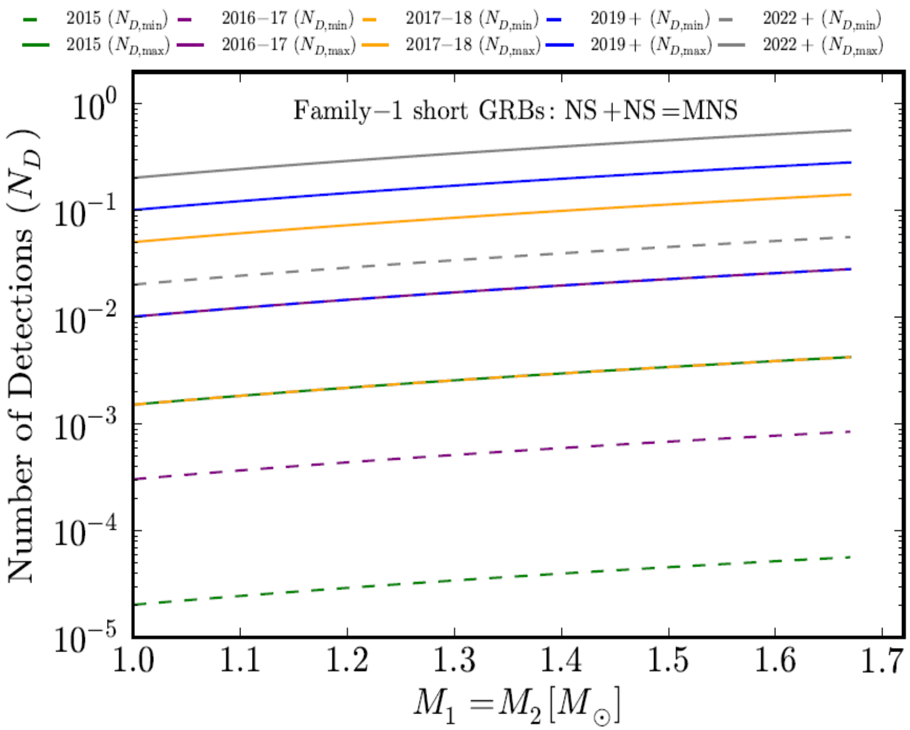
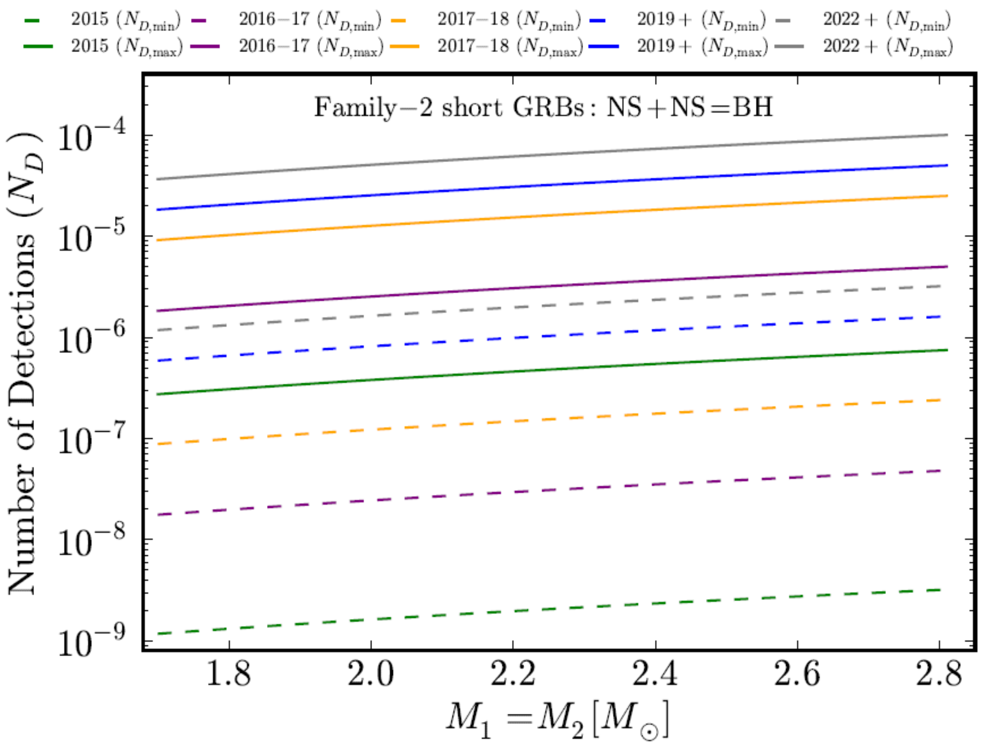
Gravitational Waves Emission and Detectability



Taken from Reports LIGO-P1200087, VIR-0288A-12 , J. Aasi et al. arXiv: 1304.0670

GWs Detectability from Short GRBs





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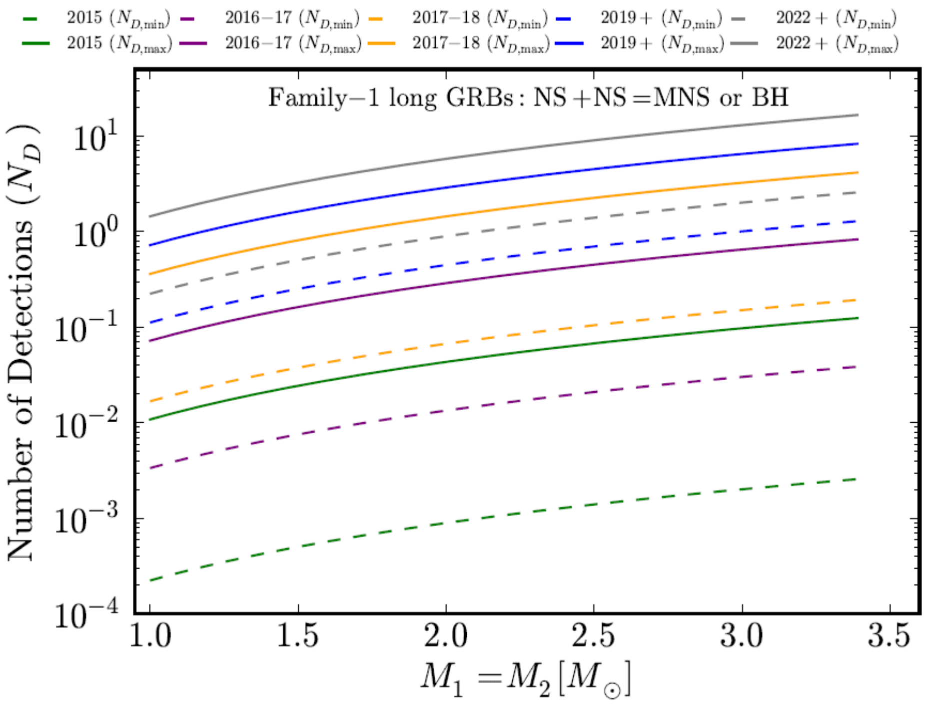

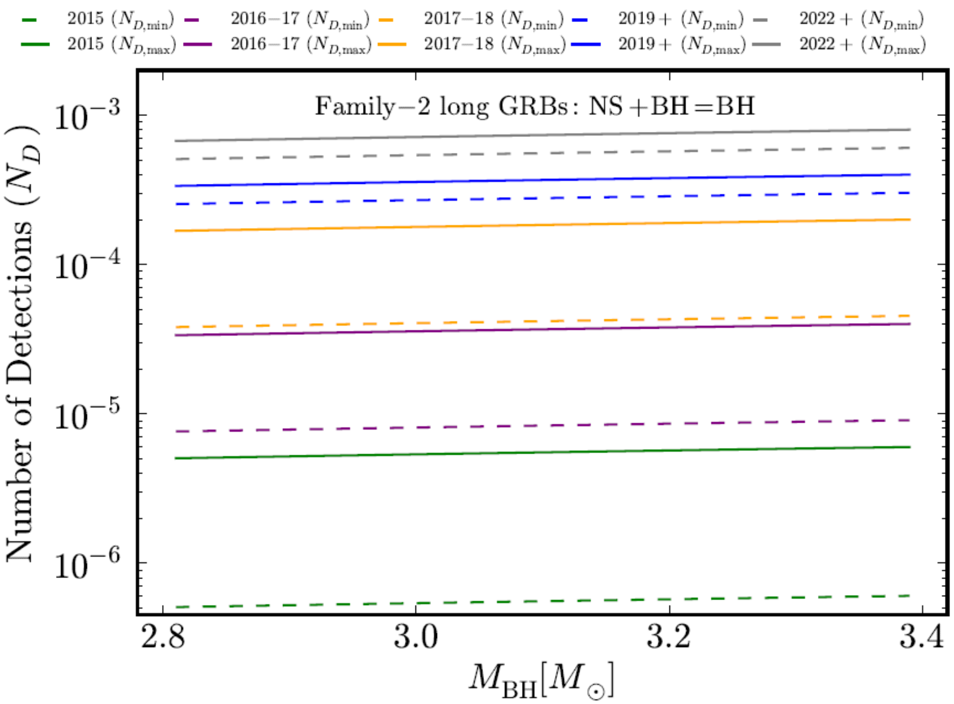

F-1L-GRB Rate: (11-71) Gpc^-3 y^-1

Kovacevic et al., A&A 569, A108 (2014)

F-2 L-GRB Rate: (6.5-8.6)x10^{-3} Gpc^-3 y^-1

Muccino et al., to be submitted.

Concluding Remarks…

Concerning Short GRBs:

- *Two families of short GRBs produced by NS binary mergers exist depending upon the fate of the merged core: F-1: BH not formed; F-2: BH formed*
- *Probably most of galactic-like BNSs do not produce BHs after the merger*
- *The relative rates of Family 1 and Family 2 short GRBs encodes information on the critical mass of NSs*
- *F-1 S-GRBs could be promising sources for aLIGO (if current event rate is underestimated)*

Concerning Long GRBs:

- Two families of long GRBs produced by the IGC paradigm exist depending upon the fate of the accretion of the SN ejecta onto the NS companion: F-1: BH not formed; F-2: BH formed
- The relative rates of Family 1 and Family 2 short GRBs encodes information on the critical mass of NSs
- F-1 L-GRBs produce BNS which in due time will merge and will be a most promising source for aLIGO, being in principle detectable from 2017 on