Binary-driven hypernovae and the understanding of long gamma-ray bursts

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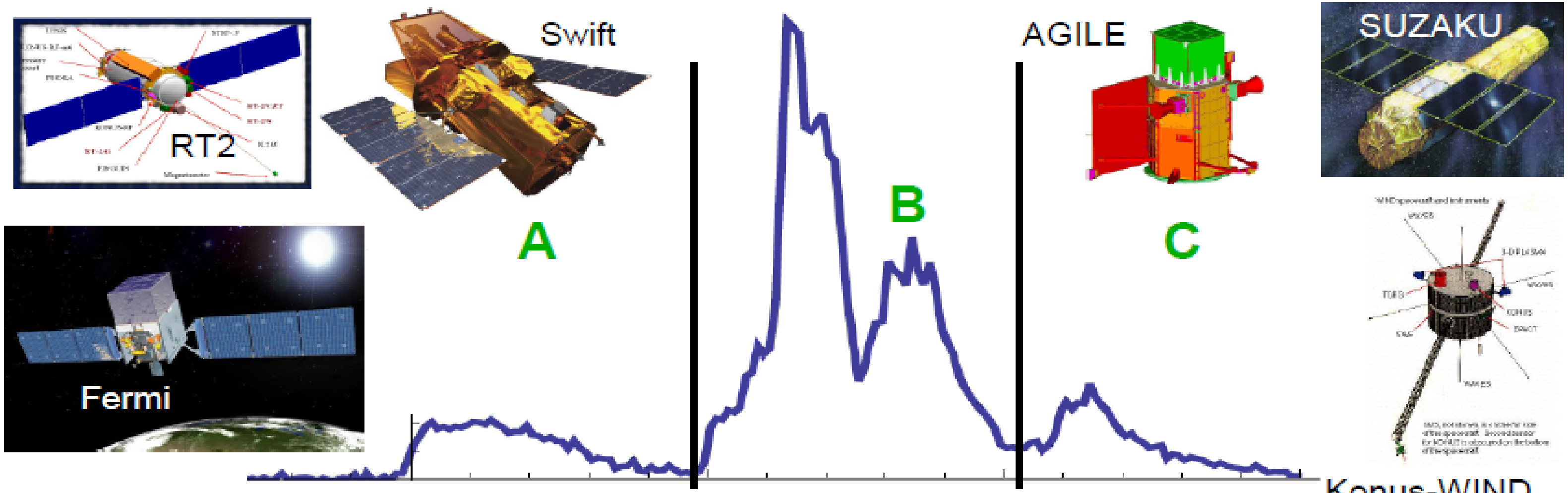
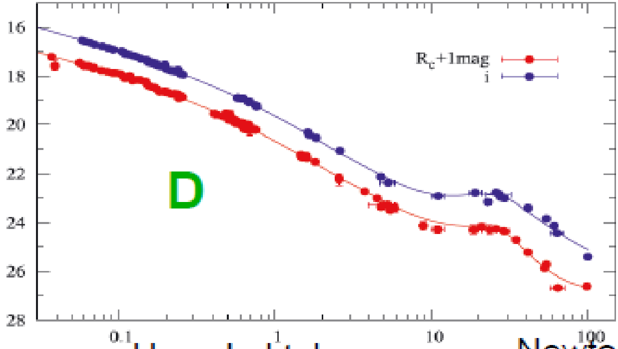


GRB 090618

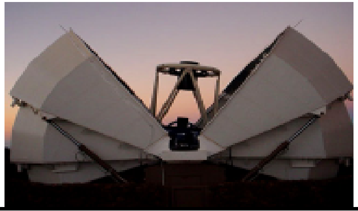
Eiso=2.8x10^{53} erg

Z=0.54

Ruffini et al. *PoS(Texas2010)*, 101 (2011)
Izzo et al., *A&A*, 543, A10 (2012)



Faulkes North



Gemini North

Herschel telescope

Newton telescope

Short and long GRB sub-classes

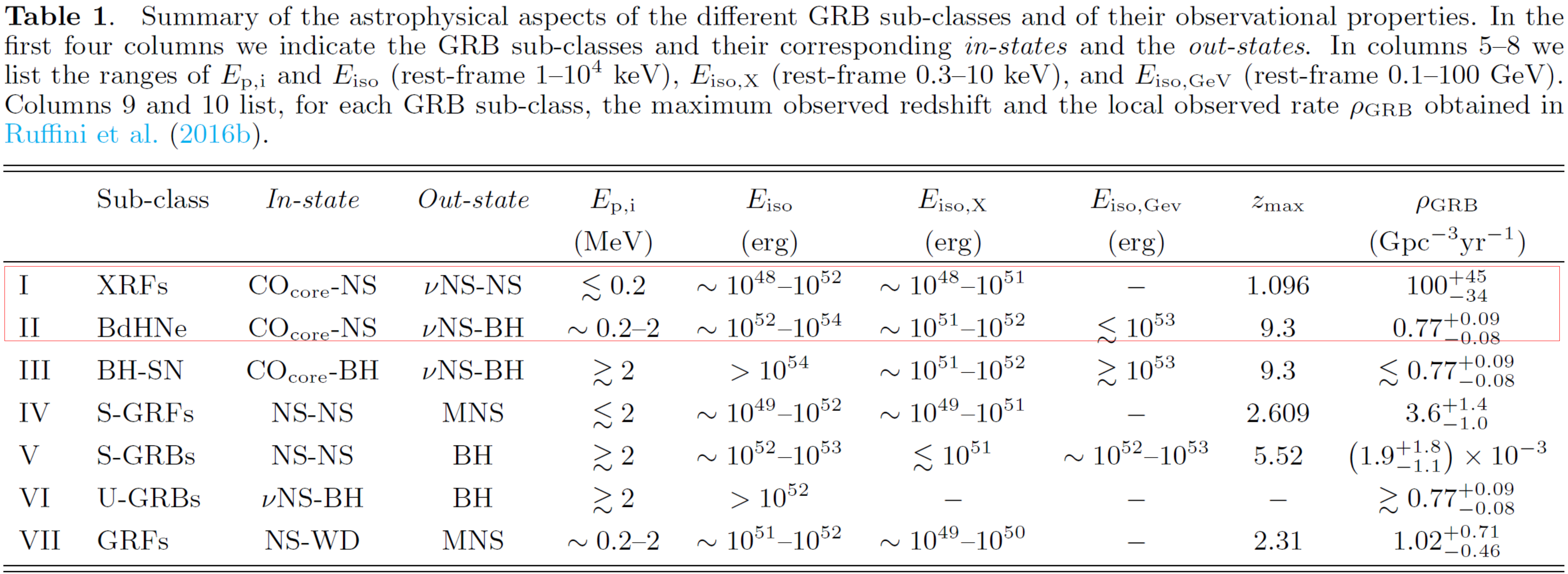
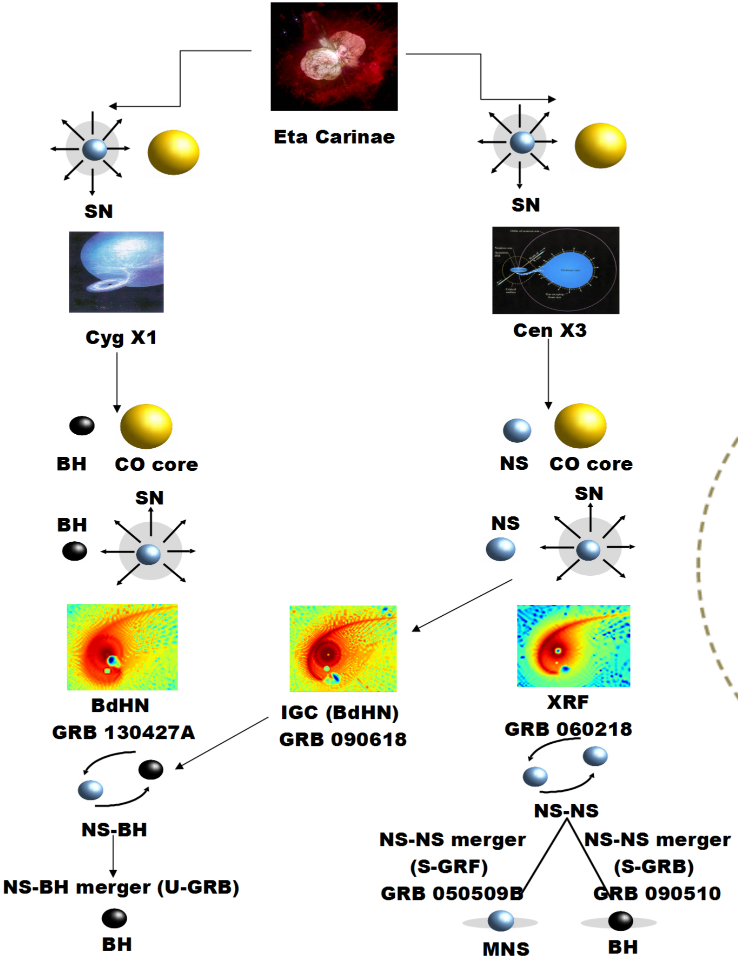


Table 1. Summary of the astrophysical aspects of the different GRB sub-classes and of their observational properties. In the first four columns we indicate the GRB sub-classes and their corresponding *in-states* and the *out-states*. In columns 5–8 we list the ranges of $E_{\rm p,i}$ and $E_{\rm iso}$ (rest-frame 1–10^4 keV), $E_{\rm iso,X}$ (rest-frame 0.3–10 keV), and $E_{\rm iso,GeV}$ (rest-frame 0.1–100 GeV). Columns 9 and 10 list, for each GRB sub-class, the maximum observed redshift and the local observed rate $\rho_{\rm GRB}$ obtained in Ruffini et al. (2016b).

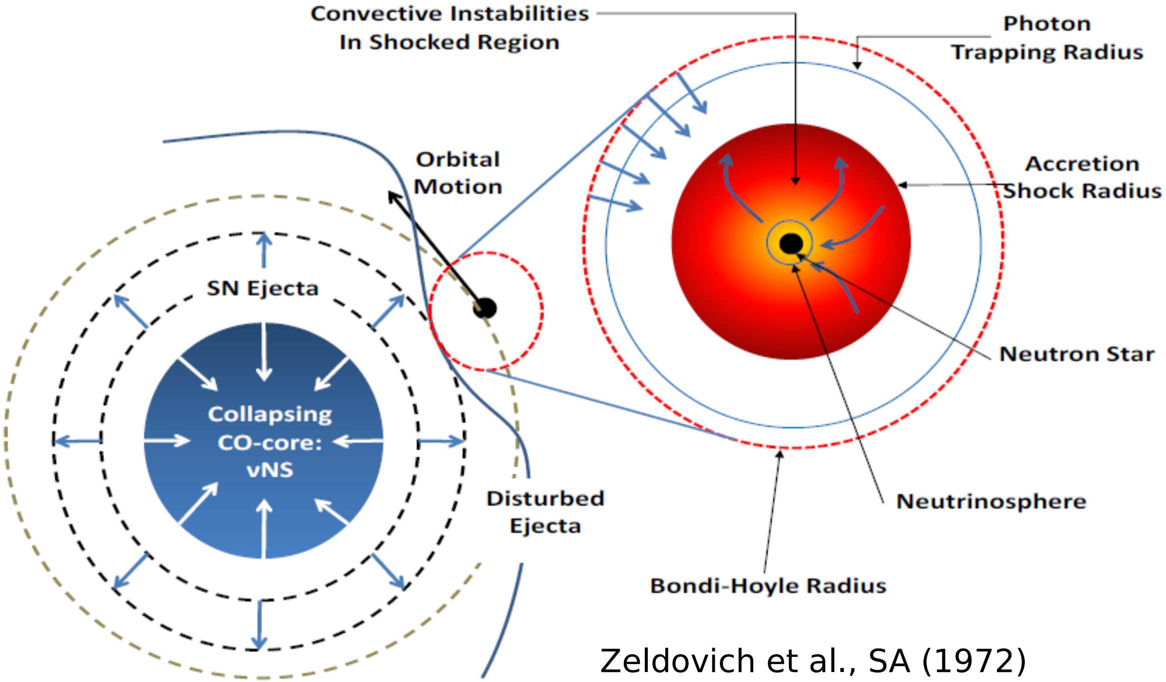
	Sub-class	*In-state*	*Out-state*	$E_{\rm p,i}$ (MeV)	$E_{\rm iso}$ (erg)	$E_{\rm iso,X}$ (erg)	$E_{\rm iso,Gev}$ (erg)	$z_{\rm max}$	$\rho_{\rm GRB}$ ($\rm Gpc^{-3}yr^{-1}$)
I	XRFs	$\rm CO_{core}$-NS	νNS-NS	$\lesssim 0.2$	$\sim 10^{48}$–10^{52}	$\sim 10^{48}$–10^{51}	–	1.096	100^{+45}_{-34}
II	BdHNe	$\rm CO_{core}$-NS	νNS-BH	~ 0.2–2	$\sim 10^{52}$–10^{54}	$\sim 10^{51}$–10^{52}	$\lesssim 10^{53}$	9.3	$0.77^{+0.09}_{-0.08}$
III	BH-SN	$\rm CO_{core}$-BH	νNS-BH	$\gtrsim 2$	$> 10^{54}$	$\sim 10^{51}$–10^{52}	$\gtrsim 10^{53}$	9.3	$\lesssim 0.77^{+0.09}_{-0.08}$
IV	S-GRFs	NS-NS	MNS	$\lesssim 2$	$\sim 10^{49}$–10^{52}	$\sim 10^{49}$–10^{51}	–	2.609	$3.6^{+1.4}_{-1.0}$
V	S-GRBs	NS-NS	BH	$\gtrsim 2$	$\sim 10^{52}$–10^{53}	$\lesssim 10^{51}$	$\sim 10^{52}$–10^{53}	5.52	$(1.9^{+1.8}_{-1.1}) \times 10^{-3}$
VI	U-GRBs	νNS-BH	BH	$\gtrsim 2$	$> 10^{52}$	–	–	–	$\gtrsim 0.77^{+0.09}_{-0.08}$
VII	GRFs	NS-WD	MNS	~ 0.2–2	$\sim 10^{51}$–10^{52}	$\sim 10^{49}$–10^{50}	–	2.31	$1.02^{+0.71}_{-0.46}$

Ruffini et al., ApJ (2015,2016); arXiv: 1602.02732

A common evolutionary scenario for short and long GRBs



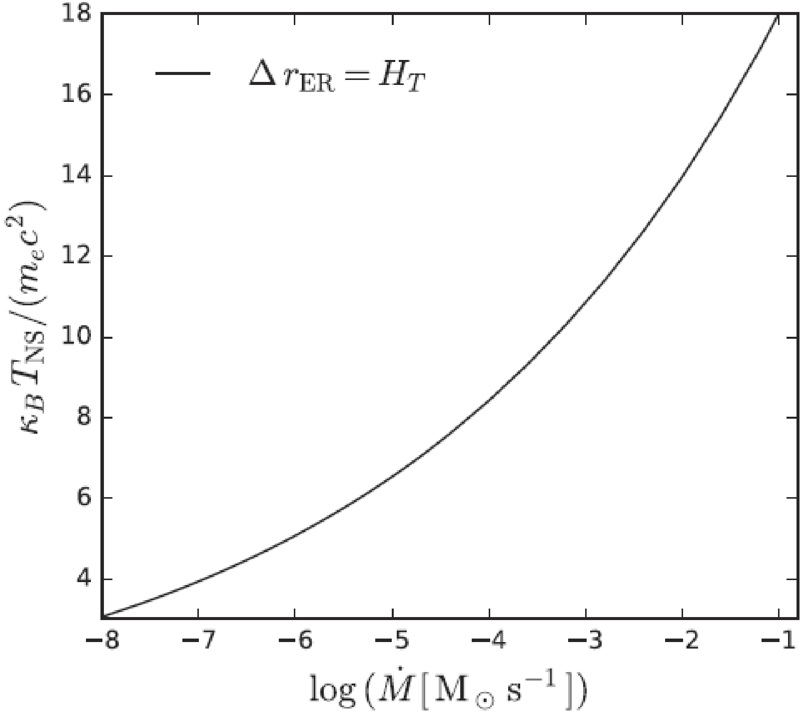
Binary-driven hypernovae (BdHNe)

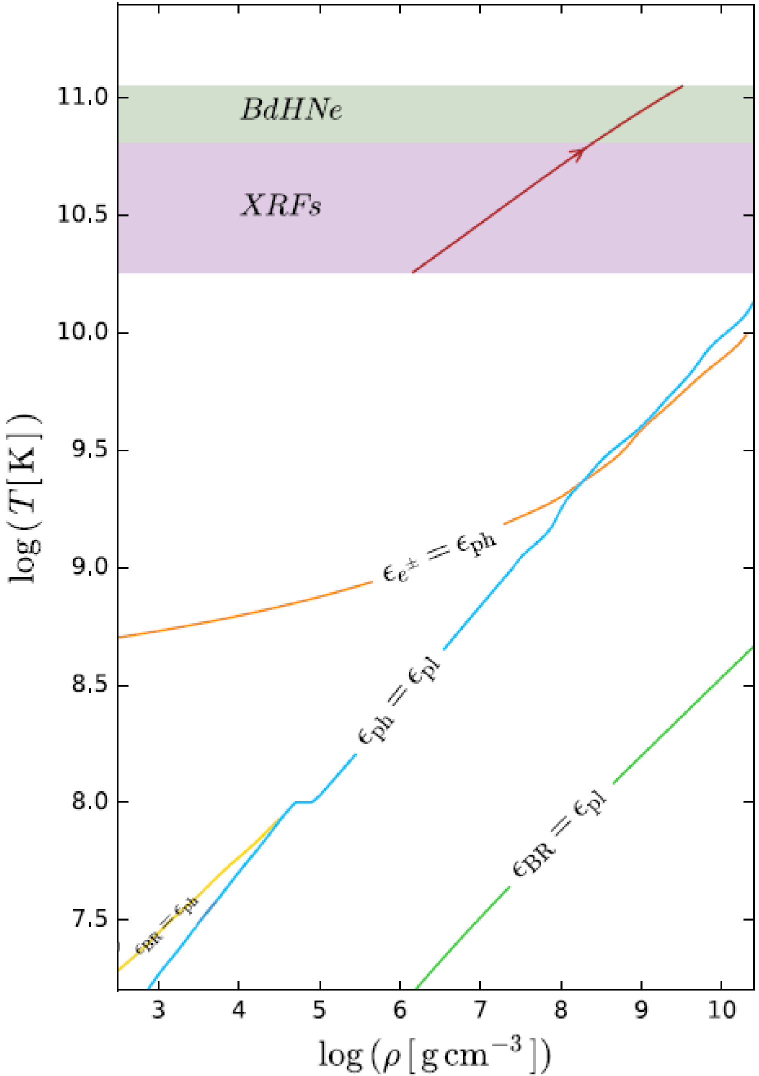


Zeldovich et al., SA (1972)
Ruffini & Wilson, PRL (1973)
Rueda & Ruffini, ApJL (2012)
Fryer, Rueda, Ruffini, ApJL (2014)

T-rho near the NS surface and neutrino production

Becerra, Bianco, Fryer, Rueda, Ruffini, ApJ 2016;
arXiv:1606.02523





Some numbers related to the neutrino emission

Becerra, Guzzo, Rueda, Ruffini, Uribe, Torres, ApJ 2018; arXiv:1712.07210

$\dot{M}$ ($M_\odot$ s^{-1})	ρ (g cm^{-3})	k_BT (MeV)	$\eta_{e^\mp}$	$n_{e^-}-n_{e^+}$ (cm^{-3})	$k_BT_{\nu\bar{\nu}}$ (MeV)	$\langle E_\nu\rangle$ (MeV)	$F^C_{\nu_e,\bar{\nu}_e}$ (cm^{-2}s^{-1})	$F^C_{\nu_x,\bar{\nu}_x}$ (cm^{-2}s^{-1})	$n^C_{\nu_e\bar{\nu}_e}$ (cm^{-3})	$n^C_{\nu_x\bar{\nu}_x}$ (cm^{-3})	$\sum_i n^C_{\nu_i\bar{\nu}_i}$ (cm^{-3})
10^{-8}	1.46×10^{6}	1.56	∓0.325	4.41×10^{29}	1.78	6.39	4.17×10^{36}	1.79×10^{36}	2.78×10^{26}	1.19×10^{26}	3.97×10^{26}
10^{-7}	3.90×10^{6}	2.01	∓0.251	1.25×10^{30}	2.28	8.24	3.16×10^{37}	1.36×10^{37}	2.11×10^{27}	9.00×10^{26}	3.01×10^{27}
10^{-6}	1.12×10^{7}	2.59	∓0.193	3.38×10^{30}	2.93	10.61	2.40×10^{38}	1.03×10^{38}	1.60×10^{28}	6.90×10^{27}	2.29×10^{28}
10^{-5}	3.10×10^{7}	3.34	∓0.147	9.56×10^{30}	3.78	13.69	1.84×10^{39}	7.87×10^{38}	1.23×10^{29}	5.20×10^{28}	1.75×10^{29}
10^{-4}	8.66×10^{7}	4.30	∓0.111	2.61×10^{31}	4.87	17.62	1.39×10^{40}	5.94×10^{39}	9.24×10^{29}	3.96×10^{29}	1.32×10^{30}
10^{-3}	2.48×10^{8}	5.54	∓0.082	7.65×10^{31}	6.28	22.70	1.04×10^{41}	4.51×10^{40}	7.00×10^{30}	3.00×10^{30}	1.00×10^{31}
10^{-2}	7.54×10^{8}	7.13	∓0.057	2.27×10^{32}	8.08	29.22	7.92×10^{41}	3.39×10^{41}	5.28×10^{31}	2.26×10^{31}	7.54×10^{31}

$$T_{\rm acc} \approx \left(\frac{3P_{\rm shock}}{4\sigma/c}\right)^{1/4} = \left(\frac{7}{8}\frac{\dot{M}_{\rm acc}v_{\rm acc}c}{4\pi R_{\rm NS}^2\sigma}\right)^{1/4}$$

$$\epsilon_{e^-e^+} \approx 8.69\times10^{30}\left(\frac{k_BT}{1\,{\rm MeV}}\right)^9 \ {\rm MeV\,cm^{-3}\,s^{-1}}$$

$$\Delta r_\nu = \frac{\epsilon_{e^-e^+}}{\nabla\epsilon_{e^-e^+}} = \frac{\Delta r_{\rm ER}}{9} \approx 0.08R_{\rm NS}$$

$$L_\nu \approx 4\pi R_{\rm NS}^2\Delta r_\nu\epsilon_{e^-e^+} \approx 10^{48}\text{–}10^{57}\ {\rm MeV\ s^{-1}}$$

$$\frac{\varepsilon_e^0}{\varepsilon_x^0} = \frac{\varepsilon_e^0}{\varepsilon_\mu^0+\varepsilon_\tau^0} = \frac{C_{+,e}^2}{C_{+,\mu}^2+C_{+,\tau}^2} \approx \frac{7}{3}$$

$$n^C_{\nu_i} = n^C_{\bar{\nu}_i},\quad F^C_{\nu_i} = F^C_{\bar{\nu}_i}\quad \forall i\in\{e,\mu,\tau\}$$

$$\frac{n^C_{\nu_e}}{n^C_{\nu_x}} = \frac{n^C_{\bar{\nu}_e}}{n^C_{\bar{\nu}_x}} = \frac{F^C_{\nu_e}}{F^C_{\nu_x}} = \frac{F^C_{\bar{\nu}_e}}{F^C_{\bar{\nu}_x}} \approx \frac{7}{3}.$$

NS EOS (Relativistic Mean-Field Models)

(e.g. *Rueda, Ruffini, Xue, Nucl. Phys. A 872, 286, 2011)*

$$\mathcal{L} = \mathcal{L}_g + \mathcal{L}_f + \mathcal{L}_\sigma + \mathcal{L}_\omega + \mathcal{L}_\rho + \mathcal{L}_\gamma + \mathcal{L}_{\rm int}$$

$$\mathcal{L}_g = -\frac{R}{16\pi G},$$

$$\mathcal{L}_\gamma = -\frac{1}{16\pi} F_{\mu\nu} F^{\mu\nu},$$

$$\mathcal{L}_\sigma = \frac{1}{2}\nabla_\mu \sigma \nabla^\mu \sigma - U(\sigma), \quad U(\sigma) = U_0 + U(\sigma, 4)$$

$$\mathcal{L}_\omega = -\frac{1}{4}\Omega_{\mu\nu}\Omega^{\mu\nu} + \frac{1}{2} m_\omega^2 \omega_\mu \omega^\mu,$$

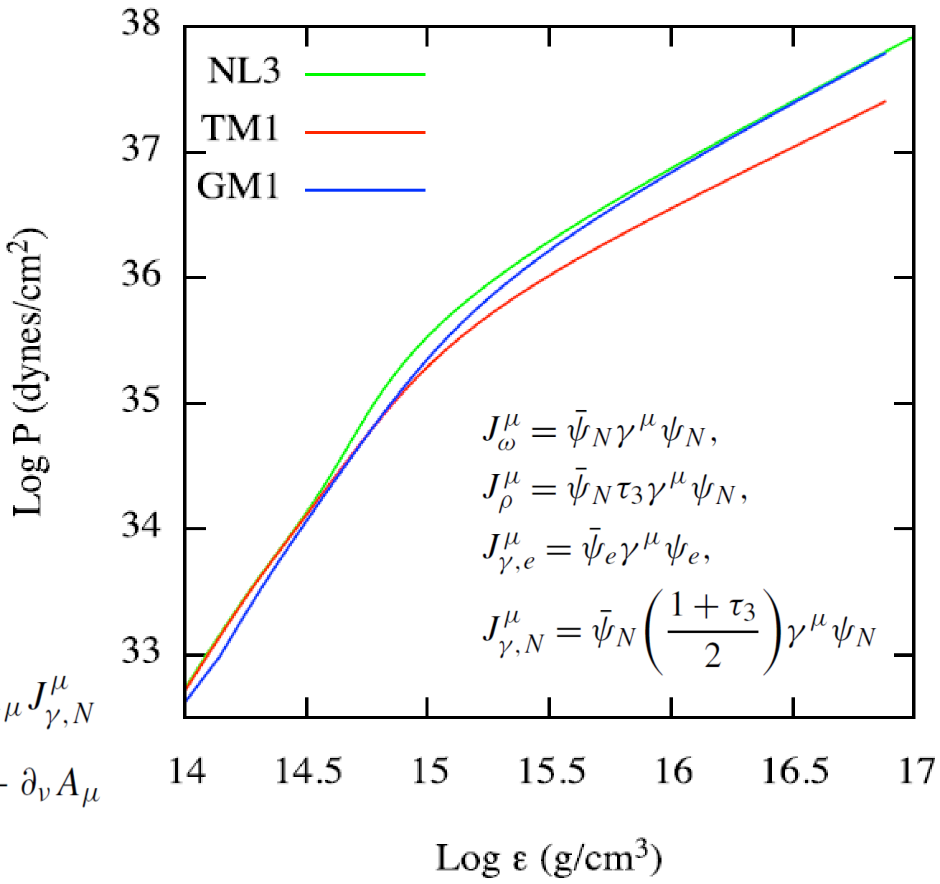
$$\mathcal{L}_\rho = -\frac{1}{4}\mathcal{R}_{\mu\nu}\mathcal{R}^{\mu\nu} + \frac{1}{2} m_\rho^2 \rho_\mu \rho^\mu,$$

$$\mathcal{L}_{\rm int} = -g_\sigma \sigma \bar{\psi}_N \psi_N - g_\omega \omega_\mu J^\mu_\omega - g_\rho \rho_\mu J^\mu_\rho + e A_\mu J^\mu_{\gamma,e} - e A_\mu J^\mu_{\gamma,N}$$

$$\Omega_{\mu\nu} \equiv \partial_\mu \omega_\nu - \partial_\nu \omega_\mu, \; \mathcal{R}_{\mu\nu} \equiv \partial_\mu \rho_\nu - \partial_\nu \rho_\mu, \; F_{\mu\nu} \equiv \partial_\mu A_\nu - \partial_\nu A_\mu$$

$$U_0 \equiv \frac{1}{2} m_\sigma^2 \sigma^2,$$

$$U(\sigma, 4) \equiv \tfrac{1}{3} g_2 \sigma^3 + \tfrac{1}{4} g_3 \sigma^4$$



$$J^\mu_\omega = \bar{\psi}_N \gamma^\mu \psi_N,$$

$$J^\mu_\rho = \bar{\psi}_N \tau_3 \gamma^\mu \psi_N,$$

$$J^\mu_{\gamma,e} = \bar{\psi}_e \gamma^\mu \psi_e,$$

$$J^\mu_{\gamma,N} = \bar{\psi}_N \left(\frac{1+\tau_3}{2}\right) \gamma^\mu \psi_N$$

Rotating NSs: full rotation in GR

(e.g. Cipolletta et al., PRD 2015; arXiv: 1506.05926)

$$ds^2 = -e^{2\nu}dt^2 + e^{2\psi}(d\phi - \omega dt)^2 + e^{2\lambda}(dr^2 + r^2 d\theta^2) \qquad T^{\alpha\beta} = (\varepsilon + P)u^\alpha u^\beta + P g^{\alpha\beta}$$

$$\nabla\cdot(B\nabla\nu) = \frac{1}{2}r^2\sin^2\theta B^3 e^{-4\nu}\nabla\omega\cdot\nabla\omega + 4\pi B e^{2\zeta-2\nu}\left[\frac{(\varepsilon+P)(1+v^2)}{1-v^2} + 2P\right]$$

$$\nabla\cdot(r^2\sin^2\theta B^3 e^{-4\nu}\nabla\omega) = -16\pi r\sin\theta B^2\ e^{2\zeta-4\nu}\frac{(\varepsilon+P)v}{1-v^2} \qquad \nabla\cdot(r\sin(\theta)\nabla B) = 16\pi r\sin\theta B e^{2\zeta-2\nu}P$$

$$\begin{aligned}
\zeta_{,\mu} = &-\left\{\left(1-\mu^2\right)\left(1+r\frac{B_{,r}}{B}\right)^2 + \left[\mu - \left(1-\mu^2\right)\frac{B_{,r}}{B}\right]^2\right\}^{-1}\Bigg[\frac{1}{2}B^{-1}\left\{r^2 B_{,rr} - \left[\left(1-\mu^2\right)B_{,\mu}\right]_{,\mu} - 2\mu B_{,\mu}\right\} \\
&\times\left\{-\mu + \left(1-\mu^2\right)\frac{B_{,\mu}}{B}\right\} + r\frac{B_{,r}}{B}\left[\frac{1}{2}\mu + \mu r\frac{B_{,r}}{B} + \frac{1}{2}\left(1-\mu^2\right)\frac{B_{,\mu}}{B}\right] + \frac{3}{2}\frac{B_{,\mu}}{B}\left[-\mu^2 + \mu\left(1-\mu^2\right)\frac{B_{,\mu}}{B}\right] \\
&-\left(1-\mu^2\right)r\frac{B_{,\mu r}}{B}\left(1+r\frac{B_{,r}}{B}\right) - \mu r^2(\nu_{,r})^2 - 2\left(1-\mu^2\right)r\nu_{,\mu}\nu_{,r} + \mu\left(1-\mu^2\right)(\nu_{,\mu})^2 - 2\left(1-\mu^2\right)r^2 B^{-1}B_{,r}\nu_{,\mu}\nu_{,r} \\
&+\left(1-\mu^2\right)B^{-1}B_{,\mu}\left[r^2(\nu_{,r})^2 - \left(1-\mu^2\right)(\nu_{,\mu})^2\right] + \left(1-\mu^2\right)B^2 e^{-4\nu}\Big\{\frac{1}{4}\mu r^4(\omega_{,r})^2 + \frac{1}{2}\left(1-\mu^2\right)r^3\omega_{,\mu}\omega_{,r} \\
&-\frac{1}{4}\mu\left(1-\mu^2\right)r^2(\omega_{,\mu})^2 + \frac{1}{2}\left(1-\mu^2\right)r^4 B^{-1}B_{,r}\omega_{,\mu}\omega_{,r} - \frac{1}{4}\left(1-\mu^2\right)r^2 B^{-1}B_{,\mu}\left[r^2(\omega_{,r})^2 - \left(\mu^2\right)(\omega_{,\mu})^2\right]\Big\}\Bigg]
\end{aligned}$$

Neutron Star Binding Energy

(Cipolletta et al., Phys. Rev. D 2015; arXiv: 1506.05926)

Static Configurations

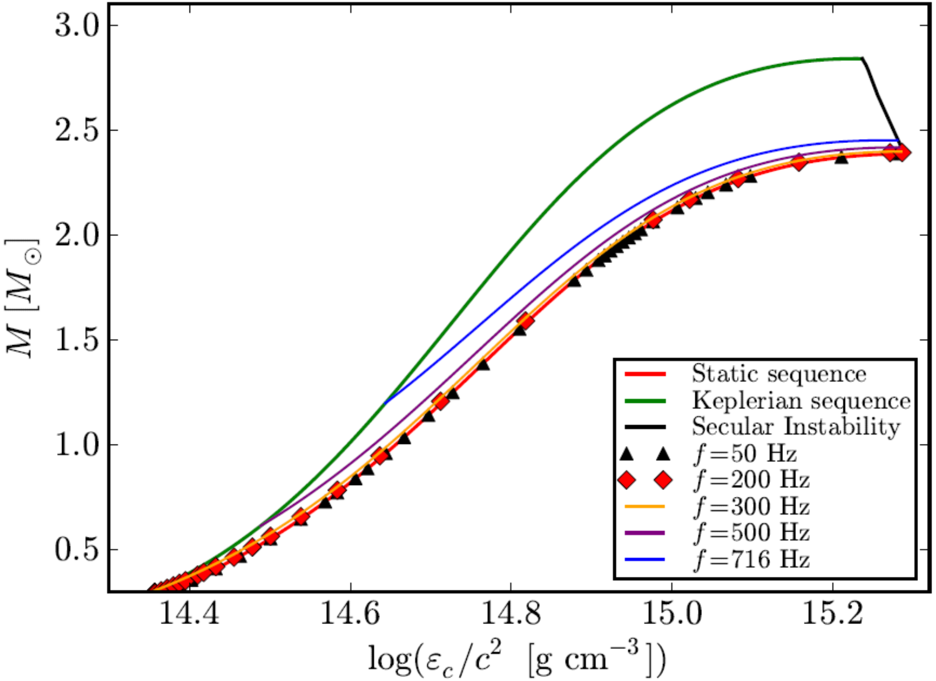
$$\frac{M_b}{M_\odot} \approx \frac{M}{M_\odot} + \frac{13}{200}\left(\frac{M}{M_\odot}\right)^2$$

Rotating Configurations

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

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

Neutron star stability region



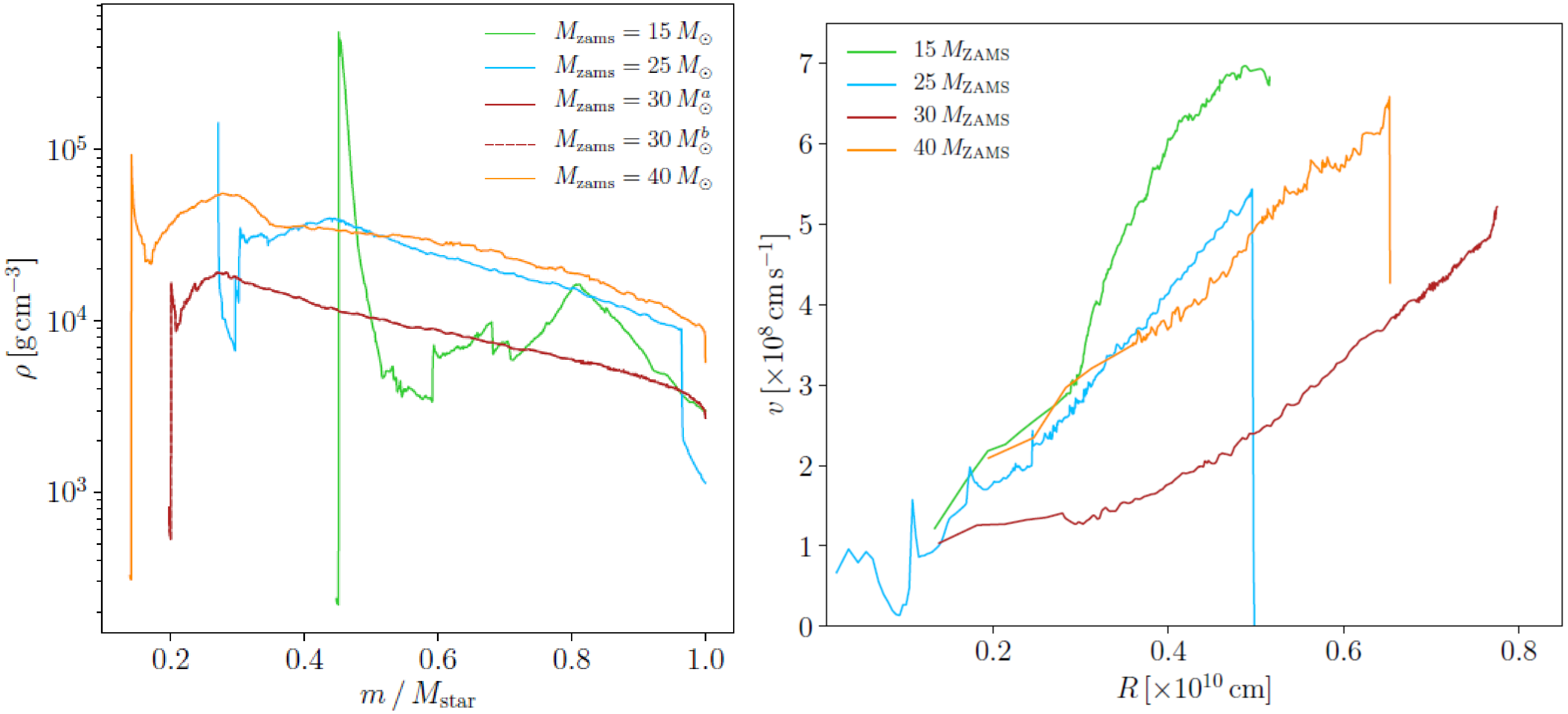
$$M_{\rm NS}^{\rm crit} = M_{\rm NS}^{J=0}(1 + k\, j_{\rm NS}^{p})$$

	$M_{\rm crit}^{J=0}$ $M_\odot$	$R_{\rm crit}^{J=0}$ km	$M_{\rm max}^{J\neq0}$ $M_\odot$	$R_{\rm max}^{J\neq0}$ 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, Cherubini, Filippi, Rueda, Ruffini, PRD (2015); arXiv:1506.05926

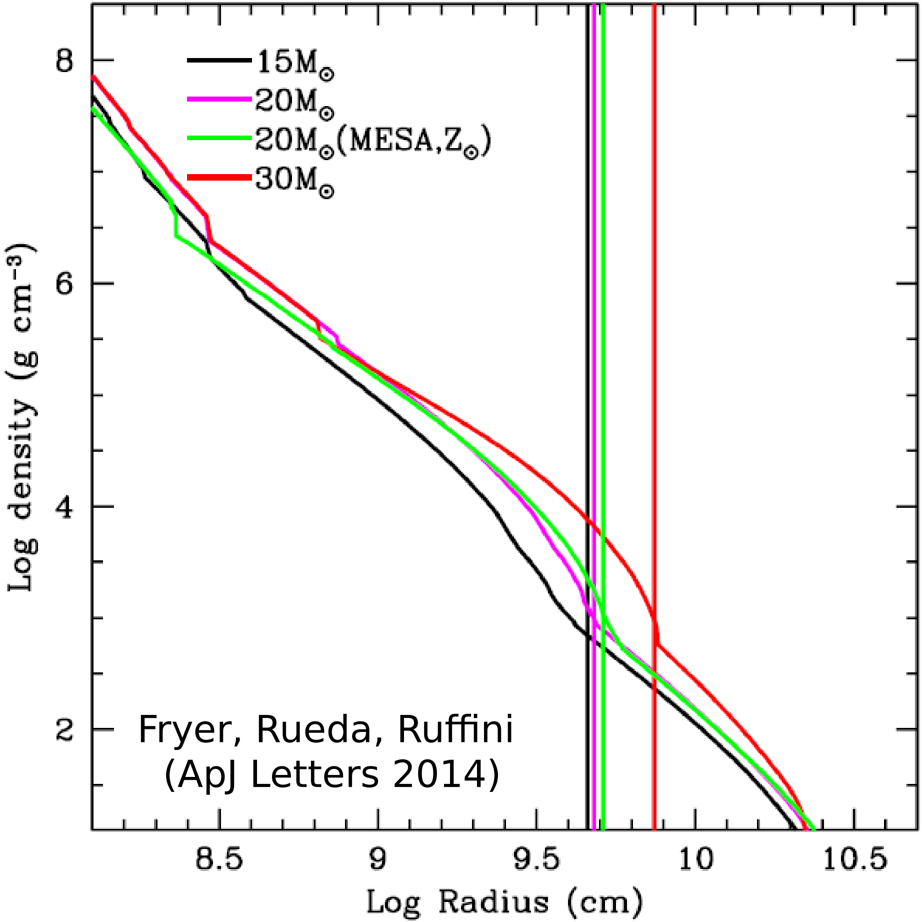
First simulations (1D):
ICRANet-LANL Collaboration

SN at t=0 (shock at CO-core surface)

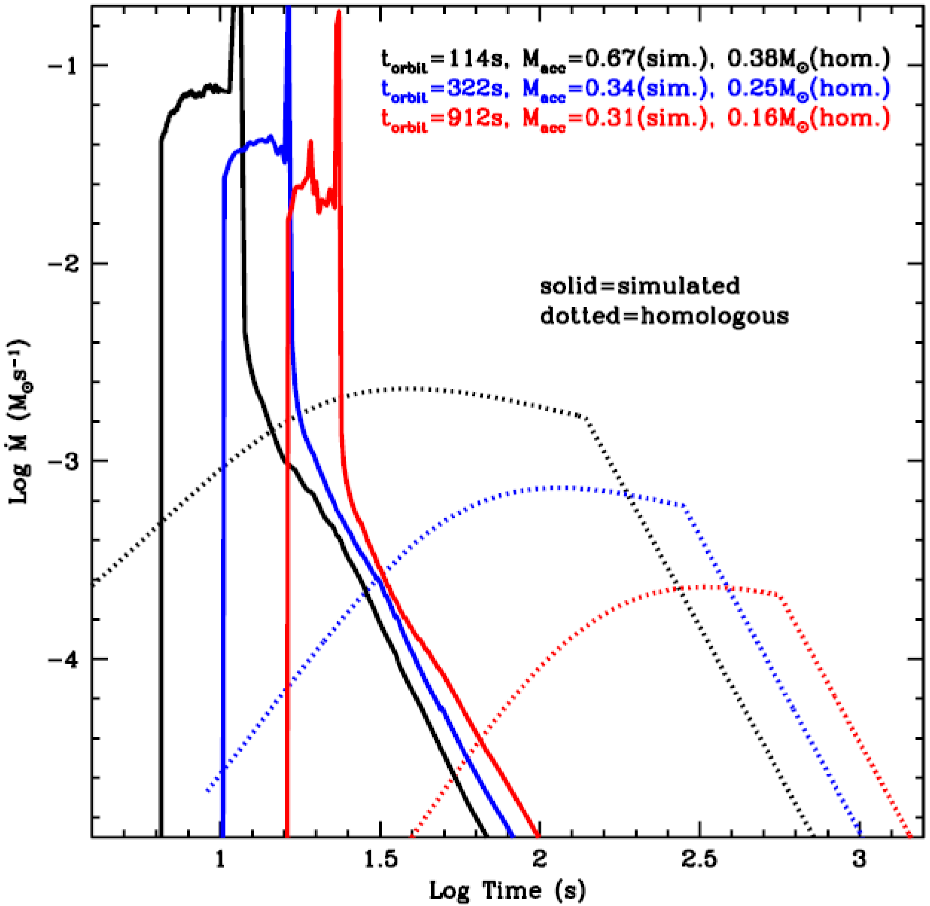


Initial conditions from Los Alamos core-collapse SN code

$$\dot{M}_{\rm BHL} = 4\pi r_{\rm BHL}^2 \rho (v^2 + c_s^2)^{1/2} \qquad r_{\rm BHL} = \frac{G M_{\rm NS}}{v^2 + c_s^2} \qquad r_{\rm trapping} = min[(\dot{M}_{\rm BHL}\kappa)/(4\pi c), r_{\rm BHL}]$$

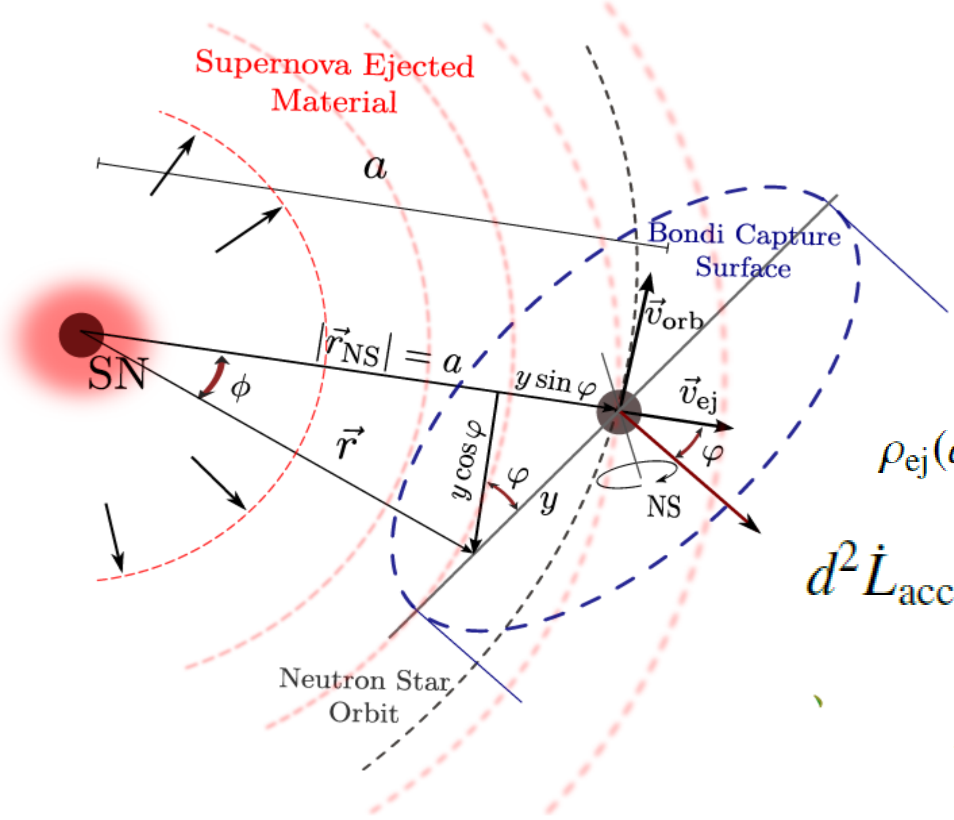


Fryer, Rueda, Ruffini (ApJ Letters 2014)



Role of angular momentum in BdHNe

(Becerra, Cipolletta, Fryer, Rueda, Ruffini, ApJ 2015; arXiv: 1505.07580)



$$\dot{M}_B(t) = \pi \rho_{\rm ej} R_{\rm cap}^2 \sqrt{v_{\rm rel}^2 + c_{\rm s,ej}^2}$$

$$R_{\rm cap}(t) = \frac{2GM_{\rm NS}(t)}{v_{\rm rel}^2 + c_{\rm s,ej}^2}$$

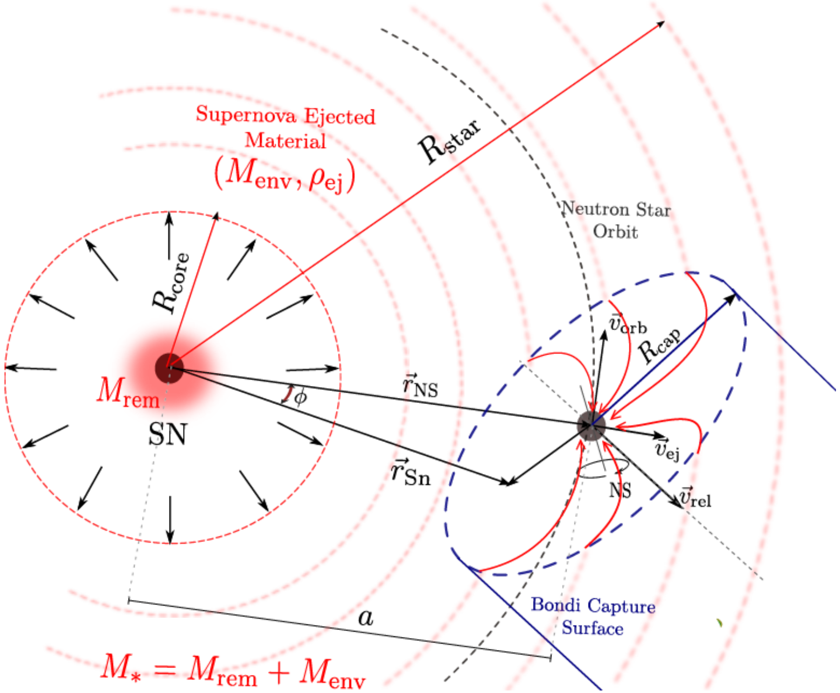
$$\rho_{\rm ej}(a) \simeq \rho_{\rm ej}(a)(1+\epsilon_\rho y) \;\; \text{and} \;\; v_{\rm rel}(a) \simeq v_{\rm rel}(a)(1+\epsilon_v y)$$

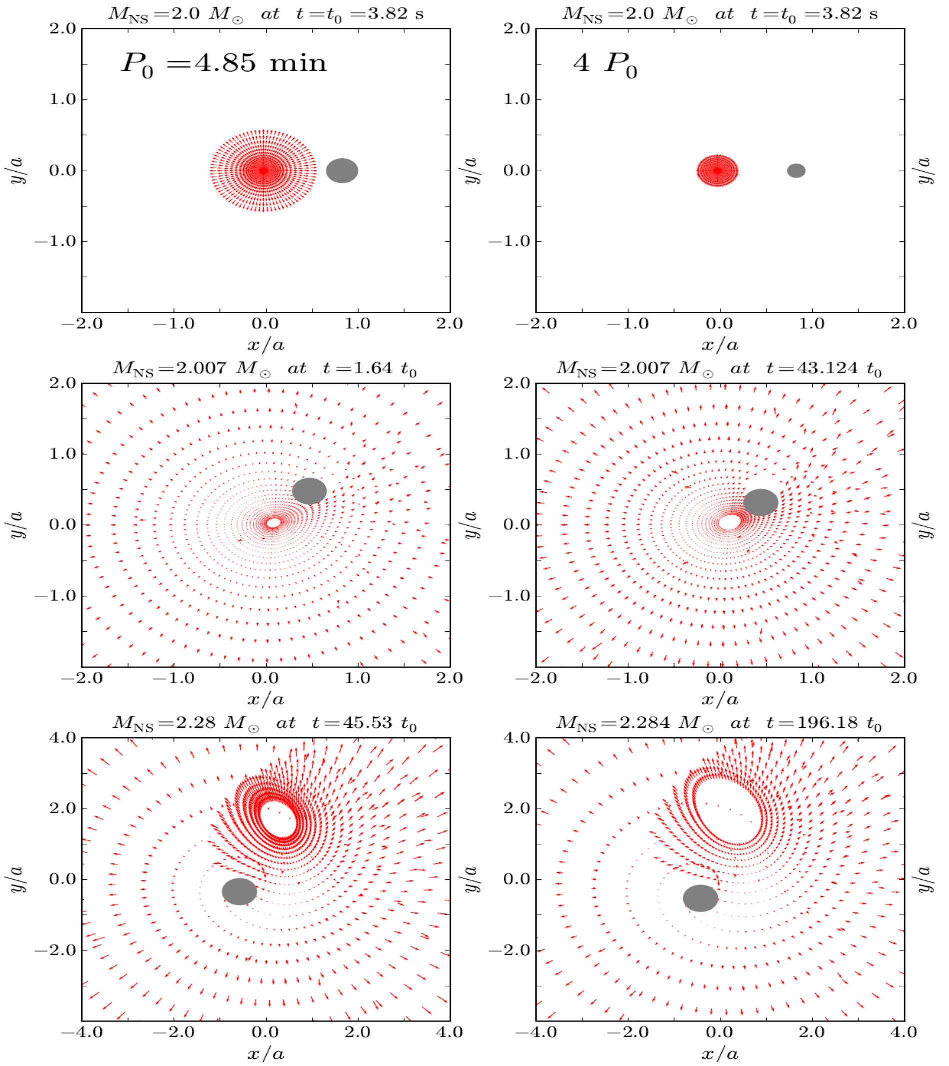
$$d^2\dot{L}_{\rm acc} = \rho_{\rm ej}(a) v_{\rm rel}^2(a) \left[y + (\epsilon_\rho + 2\epsilon_v) y^2 \right] dydz$$

$$y^2 + z^2 = R_{\rm cap}^2 = \left(\frac{2GM_{\rm NS}}{v_{\rm rel}^2(a,t)} \right)^2 (1 - 4\epsilon_v y)$$

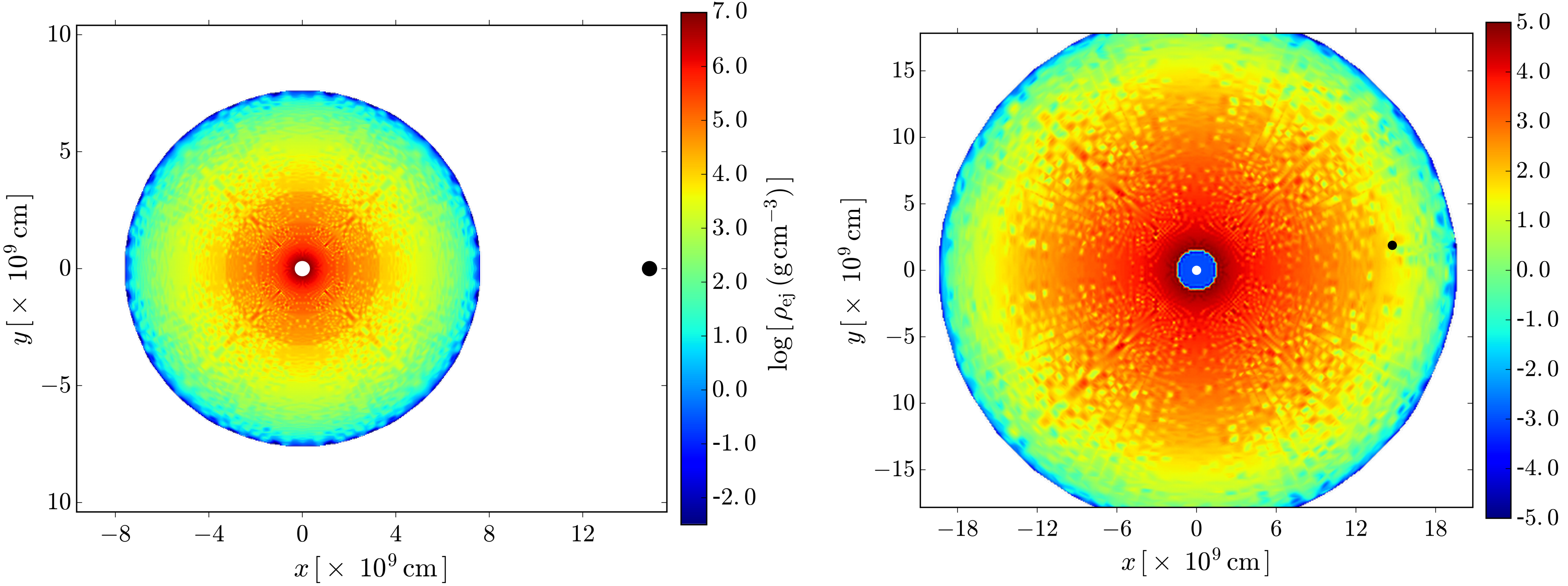
IGC simulation

Becerra, Cipolletta, Fryer, Rueda, Ruffini,
ApJ 2015: arXiv:1505.07580



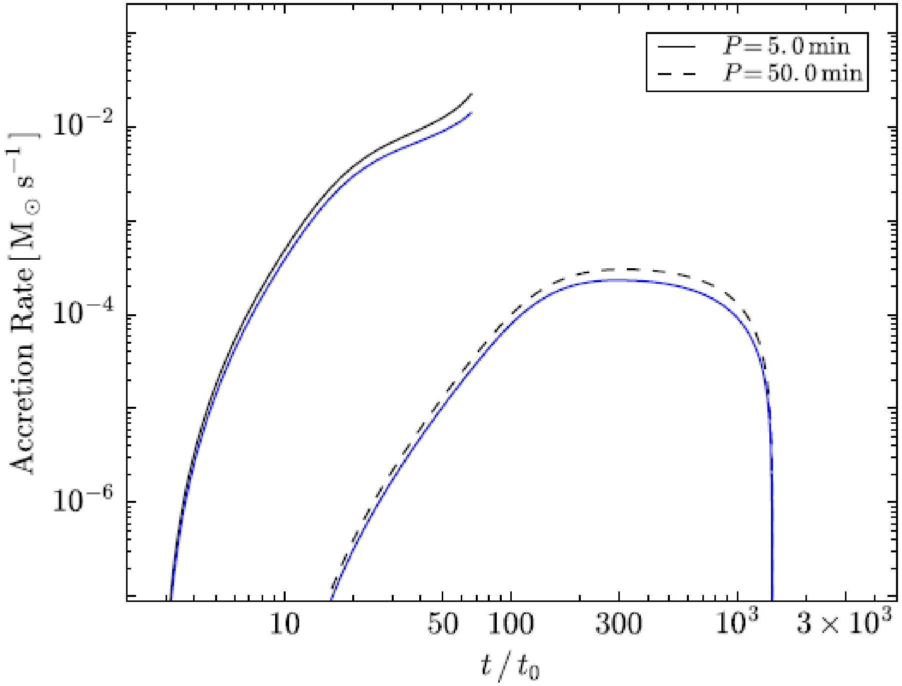


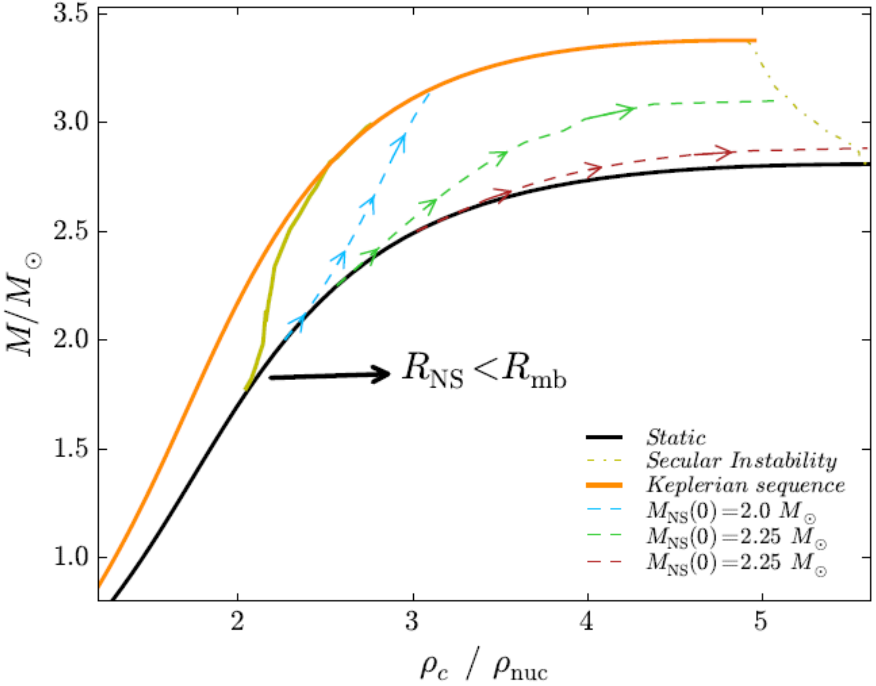
Visualizing the IGC process



Becerra, Bianco, Fryer, Rueda, Ruffini, ApJ 2016; arXiv:1606.02523

NS evolution up to the instability point

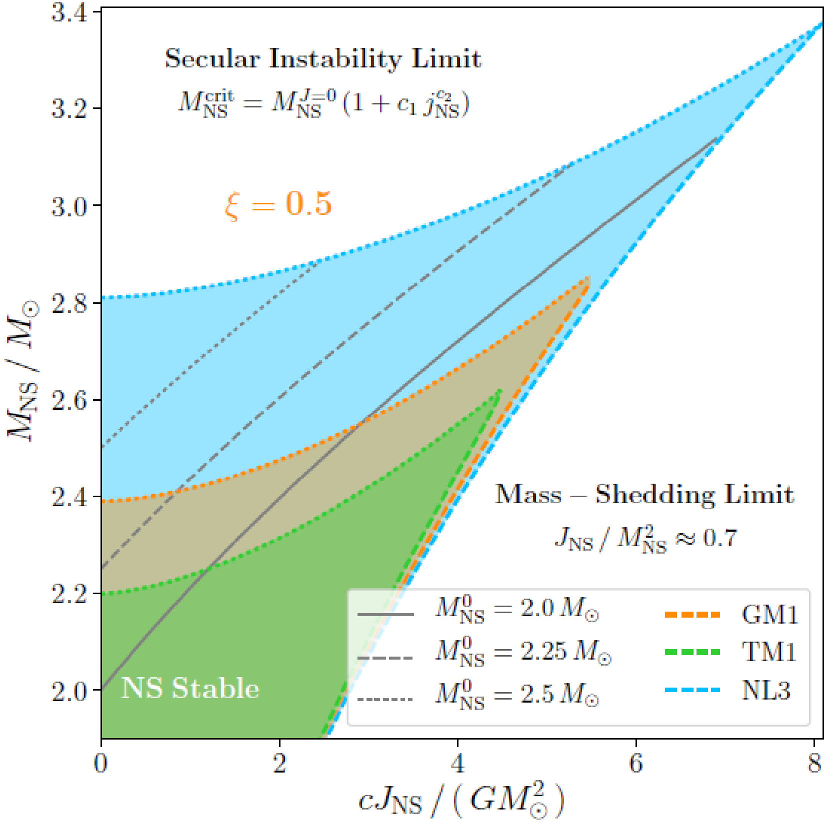


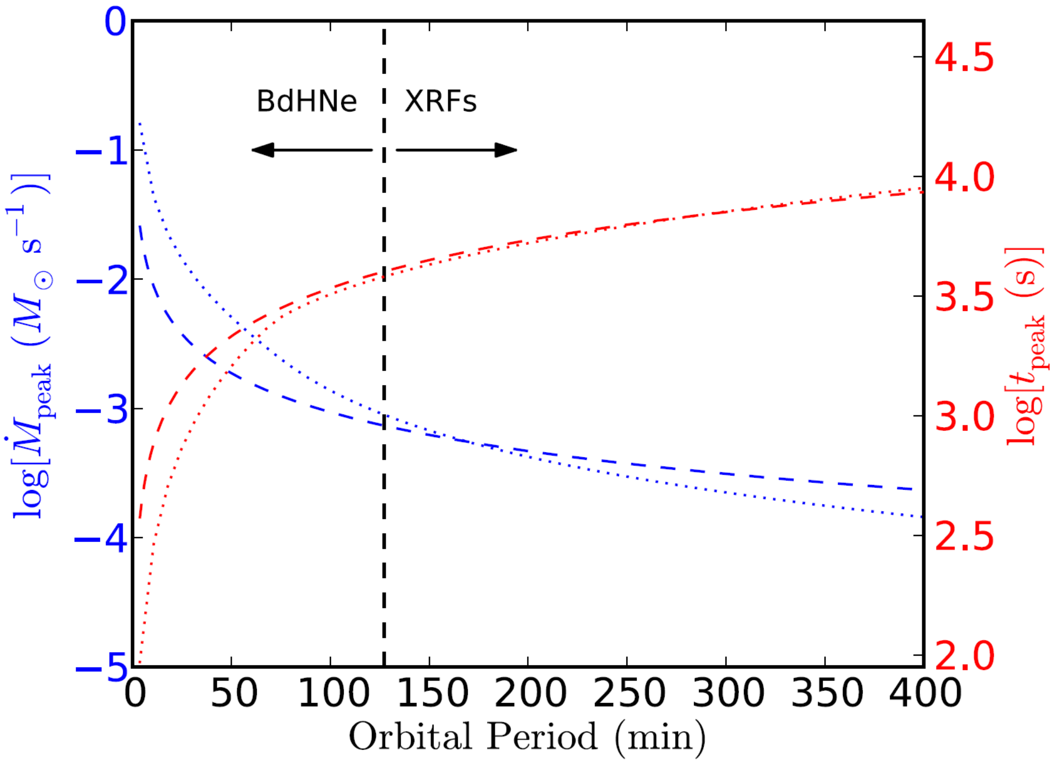


Becerra, Cipolletta, Fryer, Rueda, Ruffini, ApJ 2015; arXiv: 1505.07580
ApJ 2016; arXiv:1606.02523

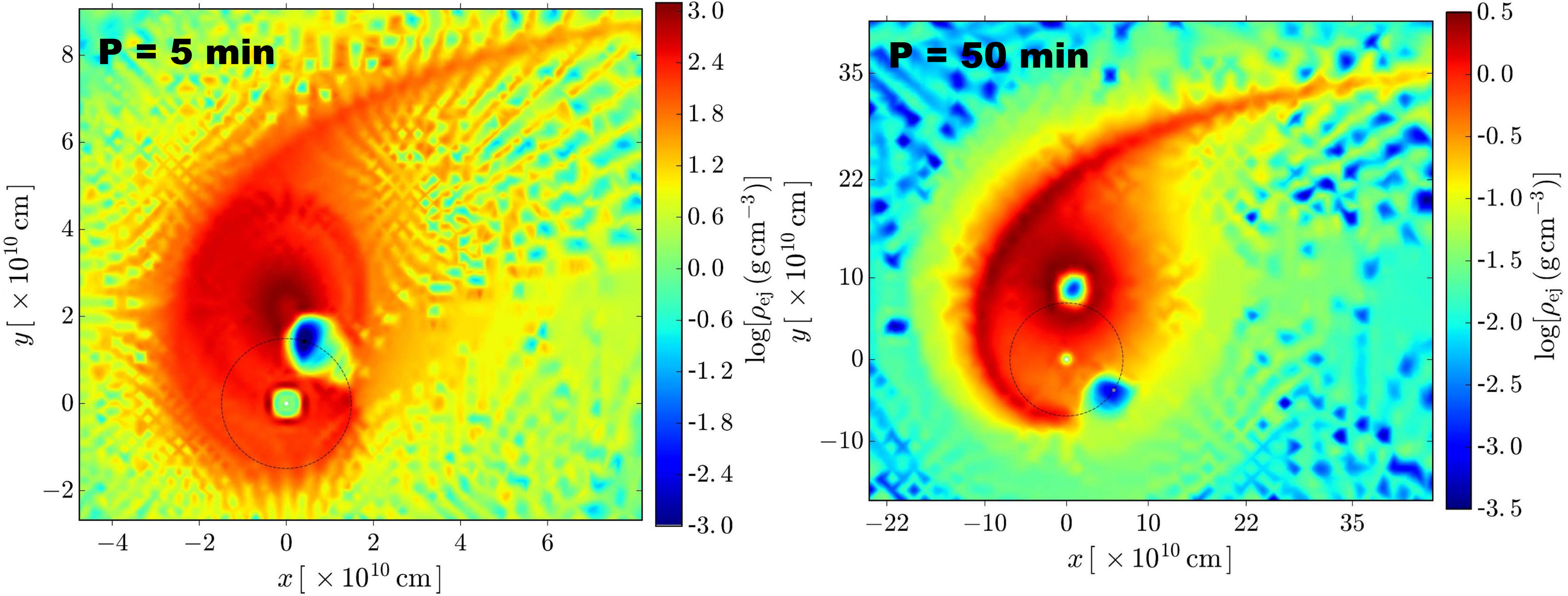
X-ray Flashes - BdHNe Separatrix

(Becerra, Bianco, Fryer, Rueda, Ruffini, ApJ 2016; arXiv:1606.02523)



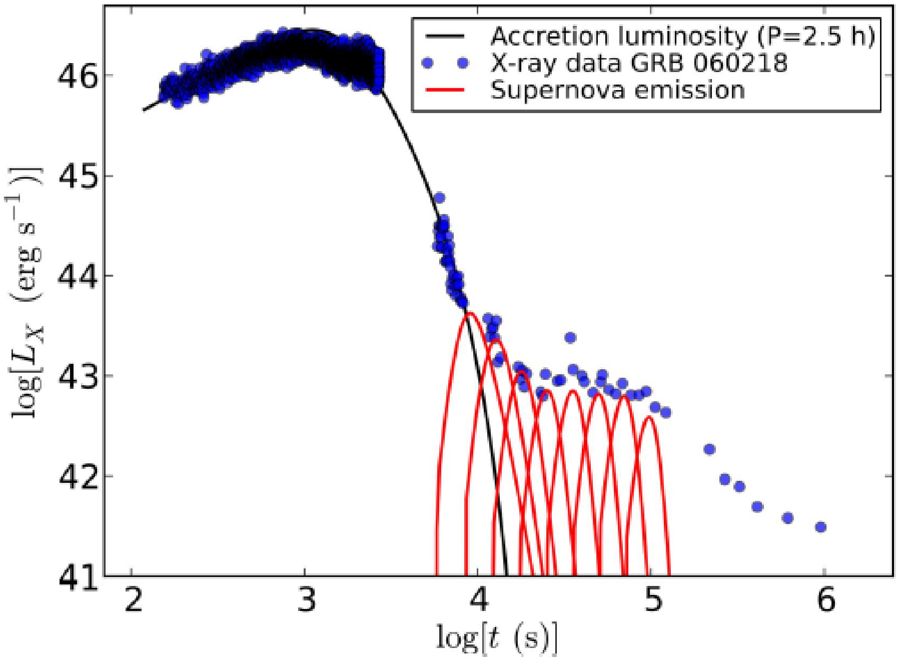


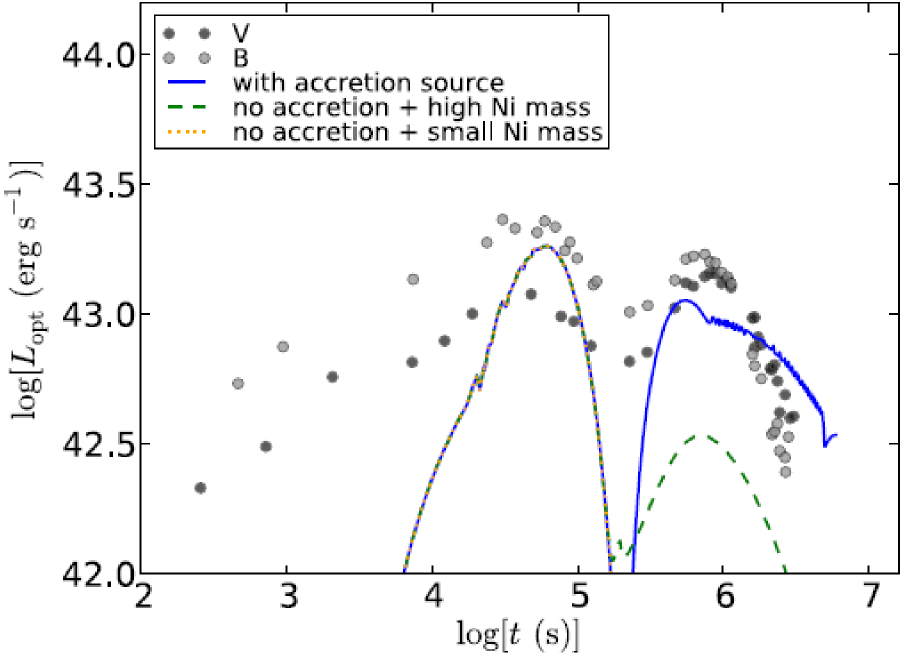
X-ray Flashes and BdHNe



Becerra, Bianco, Fryer, Rueda, Ruffini, ApJ 2016;arXiv:1606.02523

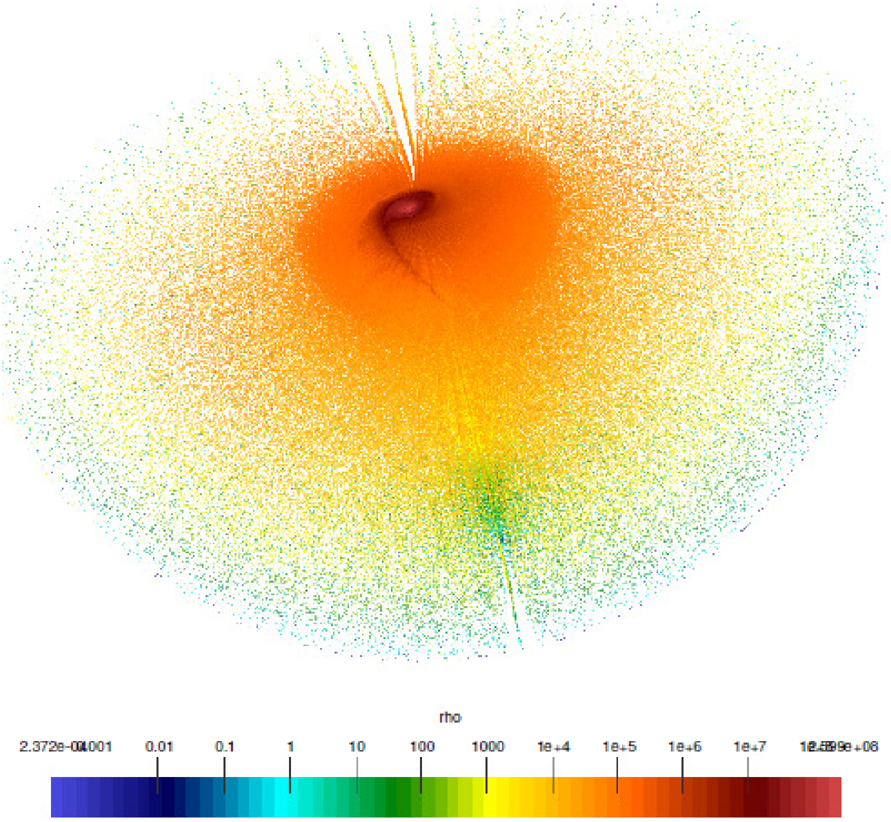
An XRF example (GRB 060218): X-rays and optical emission

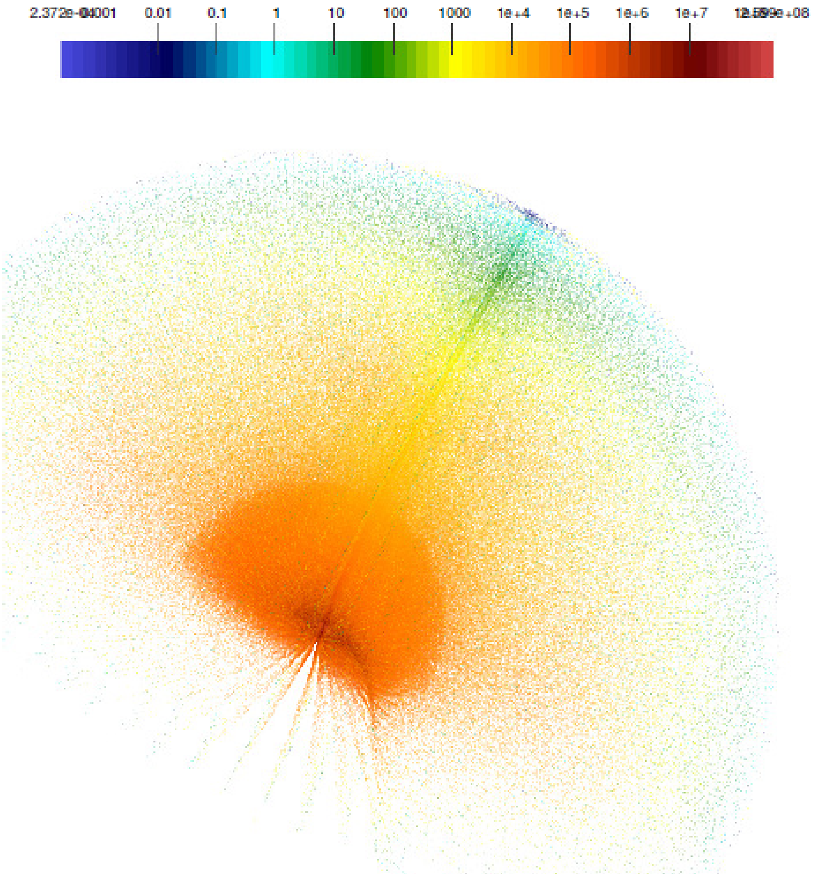




Becerra, Bianco, Fryer, Rueda, Ruffini, ApJ 2016;arXiv:1606.02523

Ejecta density distribution at NS collapse instant

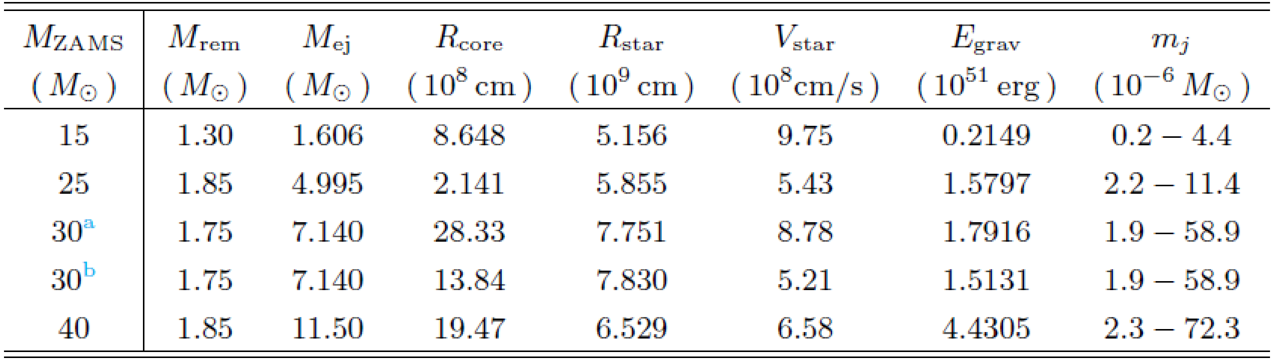




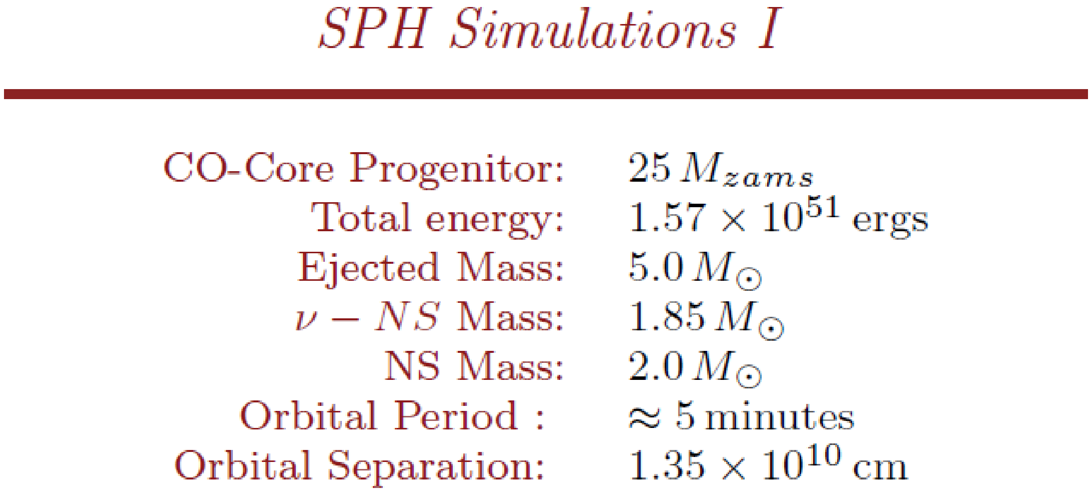
See R. Ruffini, R. Moradi and Yu Wang talks for consequences of the 3D structure

Latest simulations (SPH):
ICRANet-LANL Collaboration

CO core-NS properties



$M_{\rm ZAMS}$ ($M_\odot$)	$M_{\rm rem}$ ($M_\odot$)	$M_{\rm ej}$ ($M_\odot$)	$R_{\rm core}$ (10^8 cm)	$R_{\rm star}$ (10^9 cm)	$V_{\rm star}$ (10^8cm/s)	$E_{\rm grav}$ (10^{51} erg)	m_j ($10^{-6}\,M_\odot$)
15	1.30	1.606	8.648	5.156	9.75	0.2149	0.2 – 4.4
25	1.85	4.995	2.141	5.855	5.43	1.5797	2.2 – 11.4
30[a]	1.75	7.140	28.33	7.751	8.78	1.7916	1.9 – 58.9
30[b]	1.75	7.140	13.84	7.830	5.21	1.5131	1.9 – 58.9
40	1.85	11.50	19.47	6.529	6.58	4.4305	2.3 – 72.3

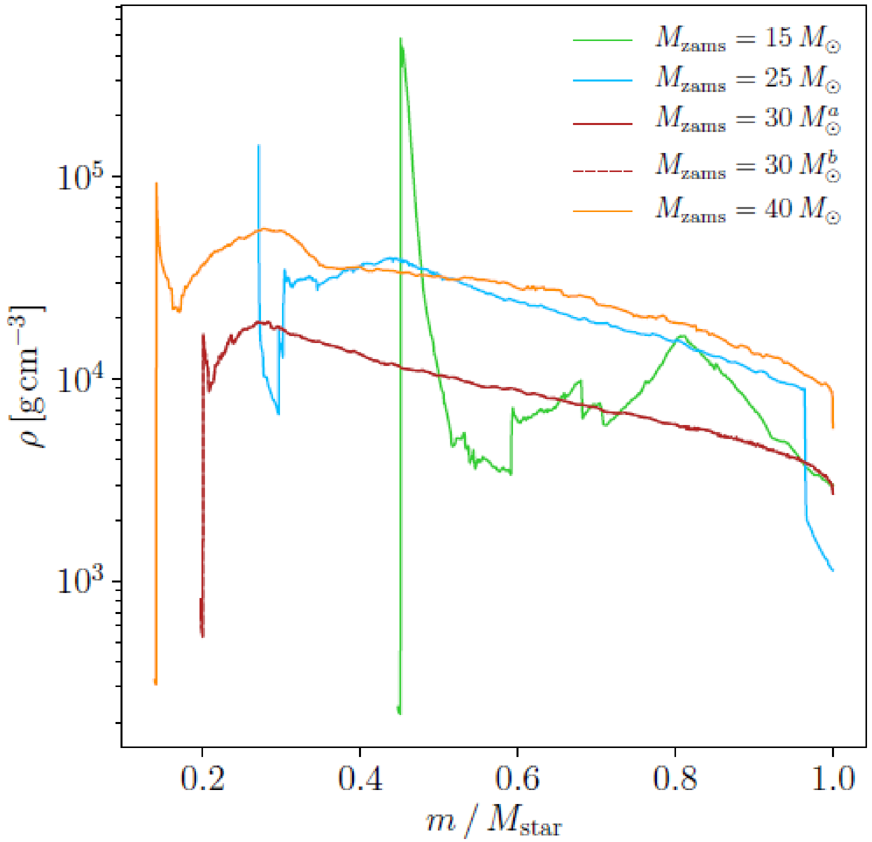


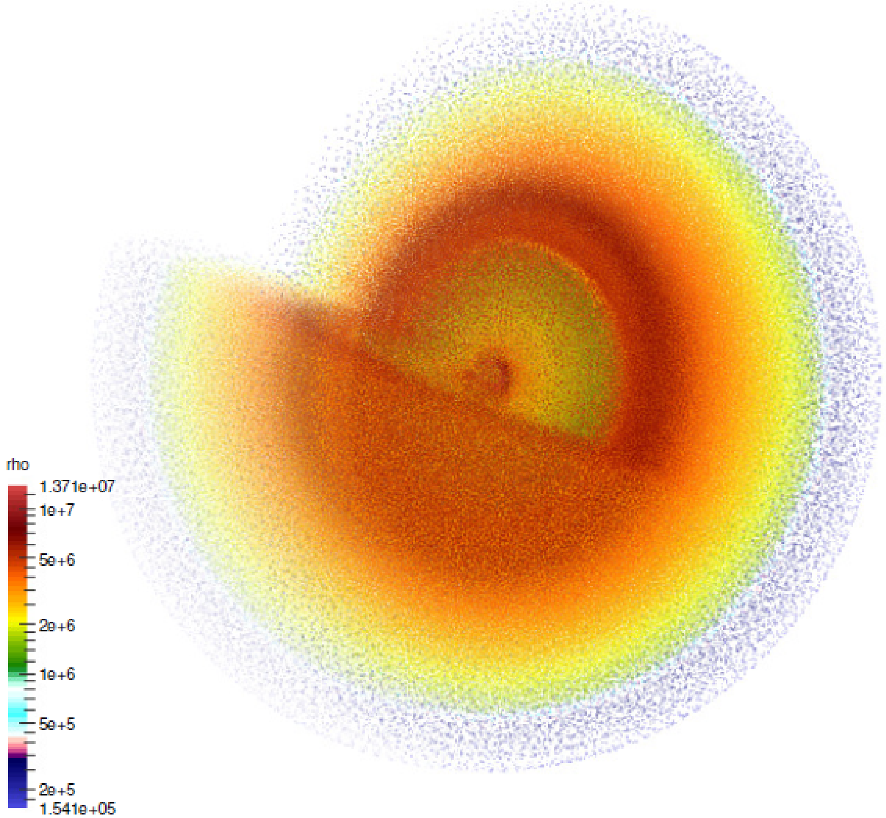
SPH Simulations I

CO-Core Progenitor: $25\,M_{zams}$
Total energy: 1.57×10^{51} ergs
Ejected Mass: $5.0\,M_\odot$
$\nu - NS$ Mass: $1.85\,M_\odot$
NS Mass: $2.0\,M_\odot$
Orbital Period : ≈ 5 minutes
Orbital Separation: 1.35×10^{10} cm

Becerra, Ellinger, Fryer, Rueda, Ruffini; arXiv:1803.04356

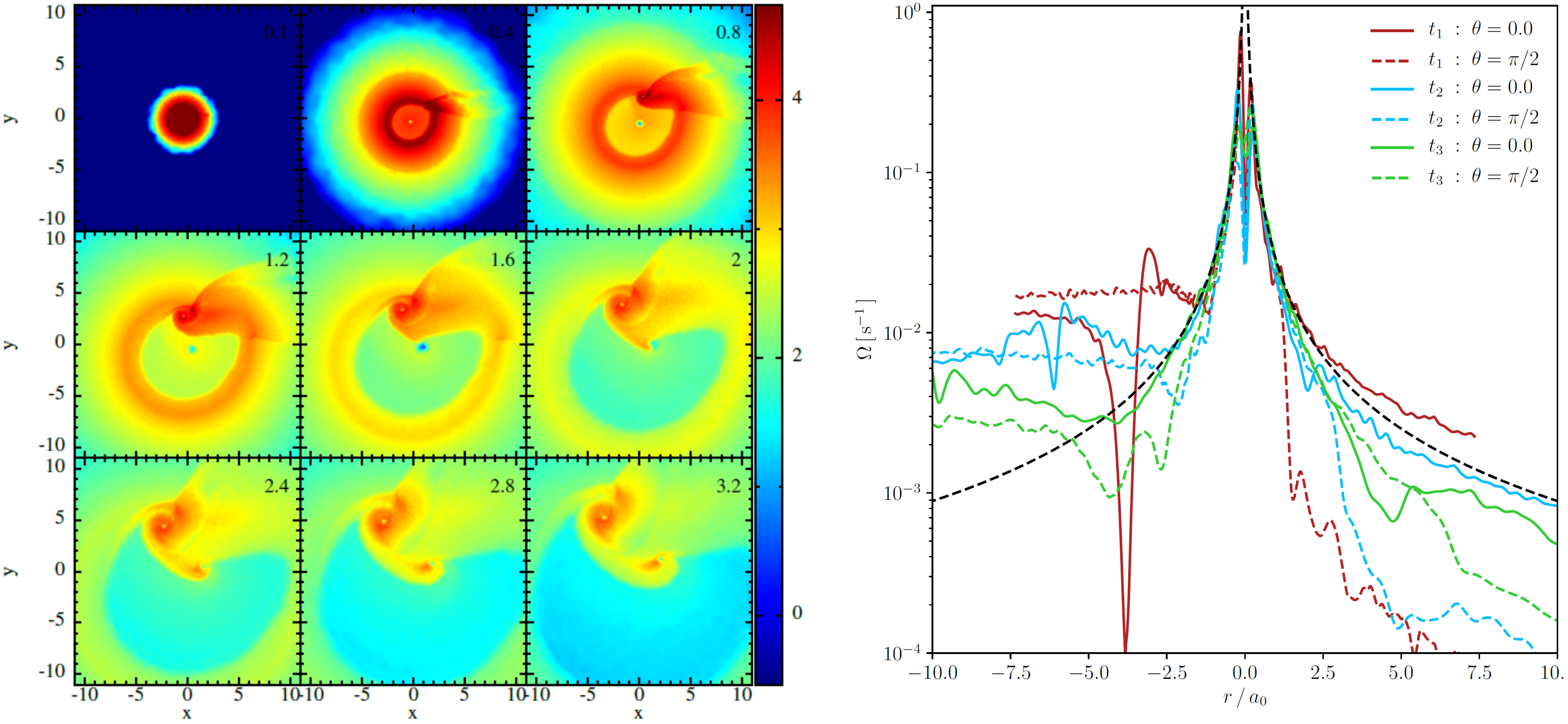
SN at t=0 (shock at CO-core surface)





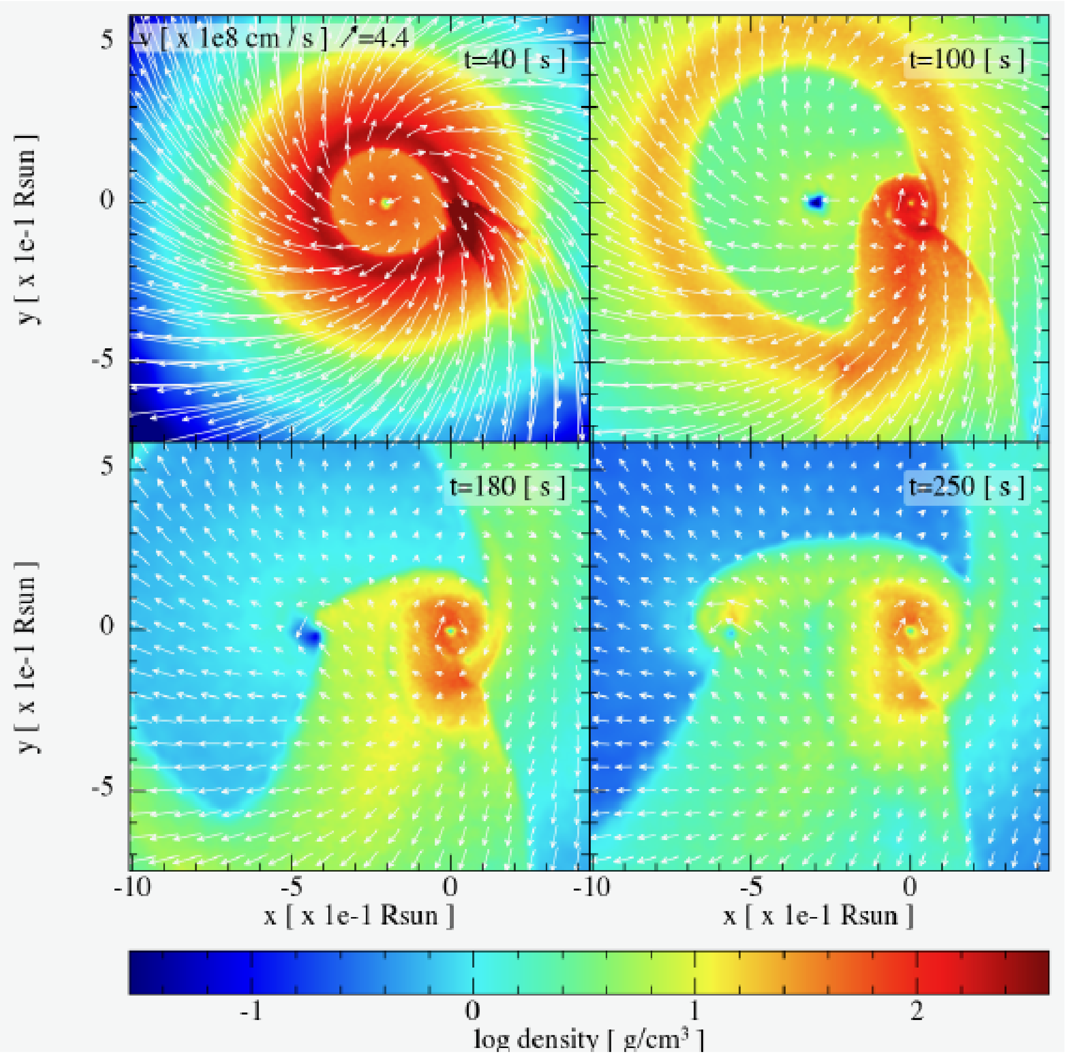
Becerra, Ellinger, Fryer, Rueda, Ruffini; arXiv:1803.04356

BdHNe: orbital plane view



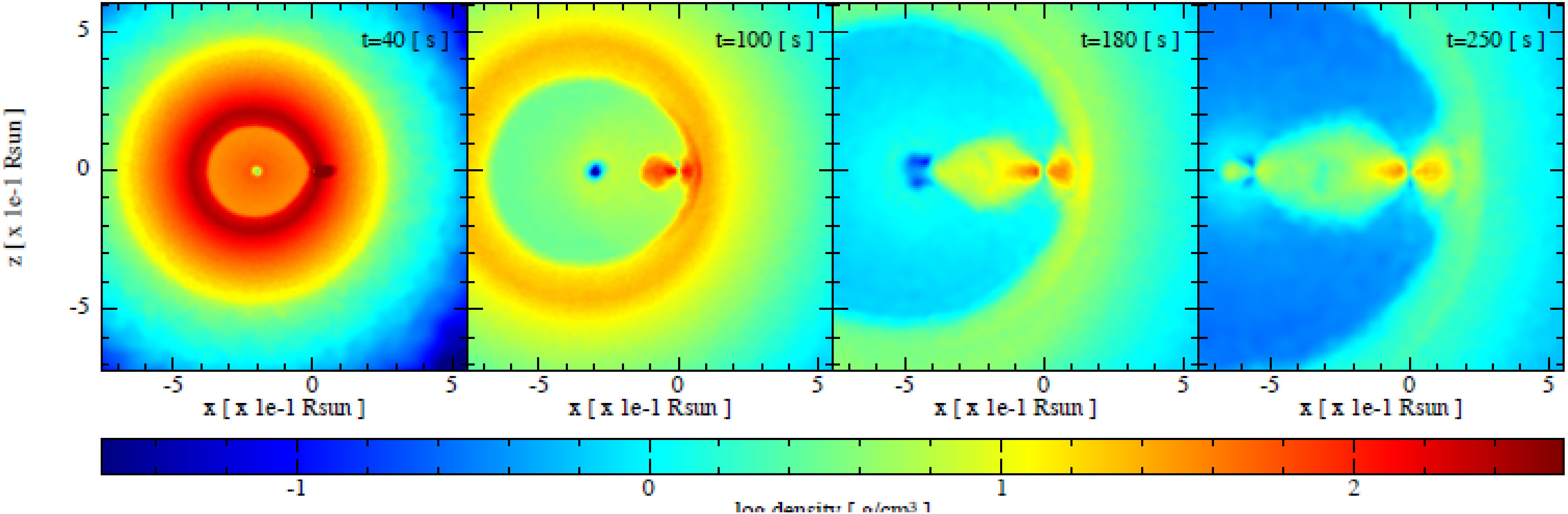
Becerra, Ellinger, Fryer, Rueda, Ruffini; arXiv:1803.04356

BdHN: orbital plane view



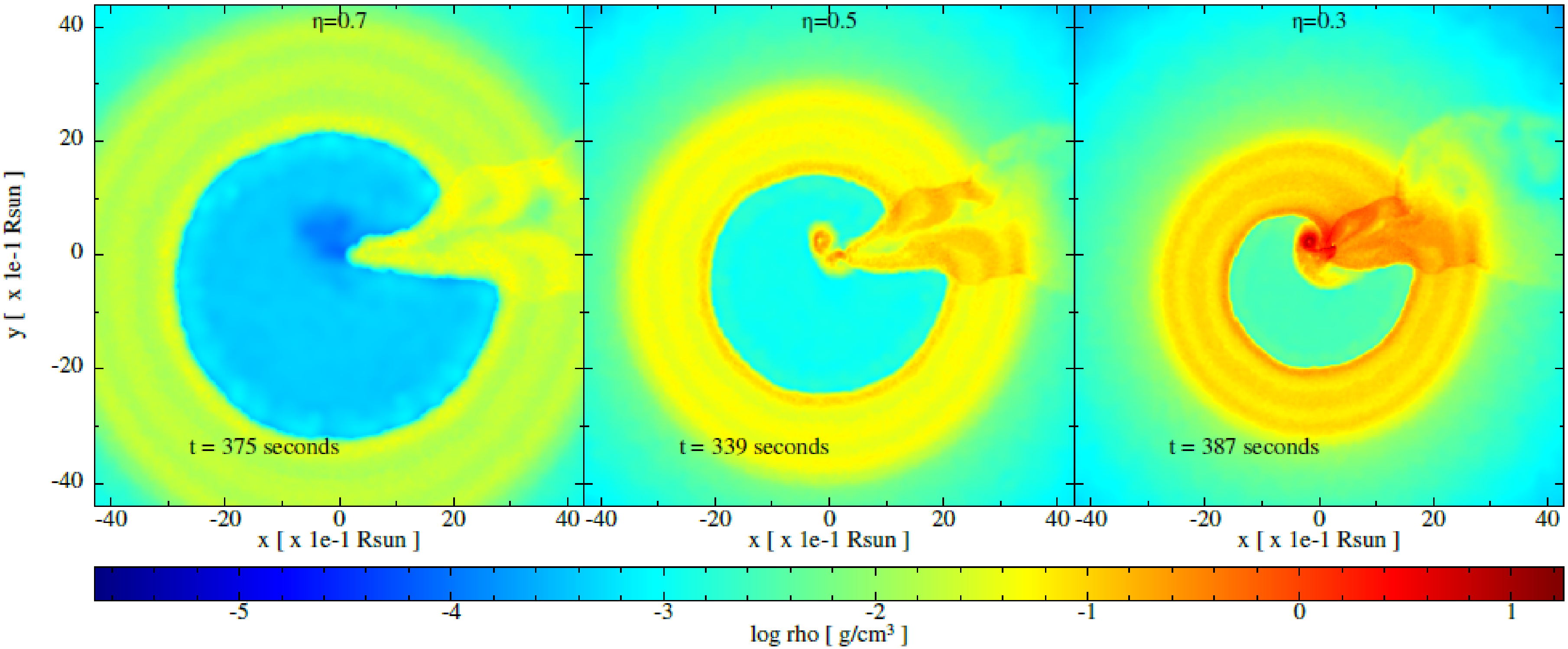
Becerra, Ellinger, Fryer,
Rueda, Ruffini;
arXiv:1803.04356

BdHNe: polar view and disk-like structure



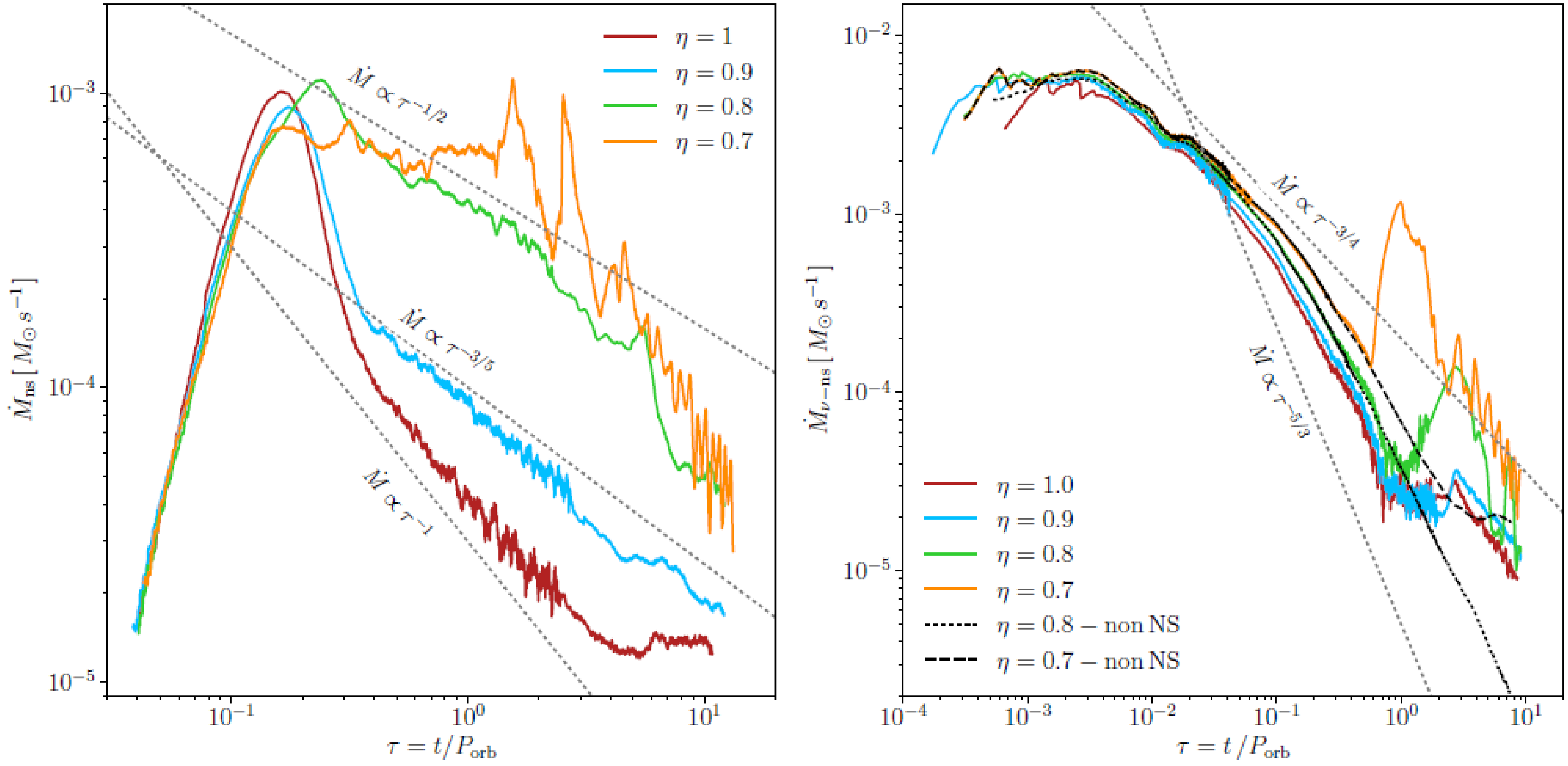
Becerra, Ellinger, Fryer, Rueda, Ruffini; arXiv:1803.04356

BdHNe and the orbital plane view: “fortune cookie” morphology



Becerra, Ellinger, Fryer, Rueda, Ruffini; arXiv:1803.04356

Accretion rate onto the NS and newNS

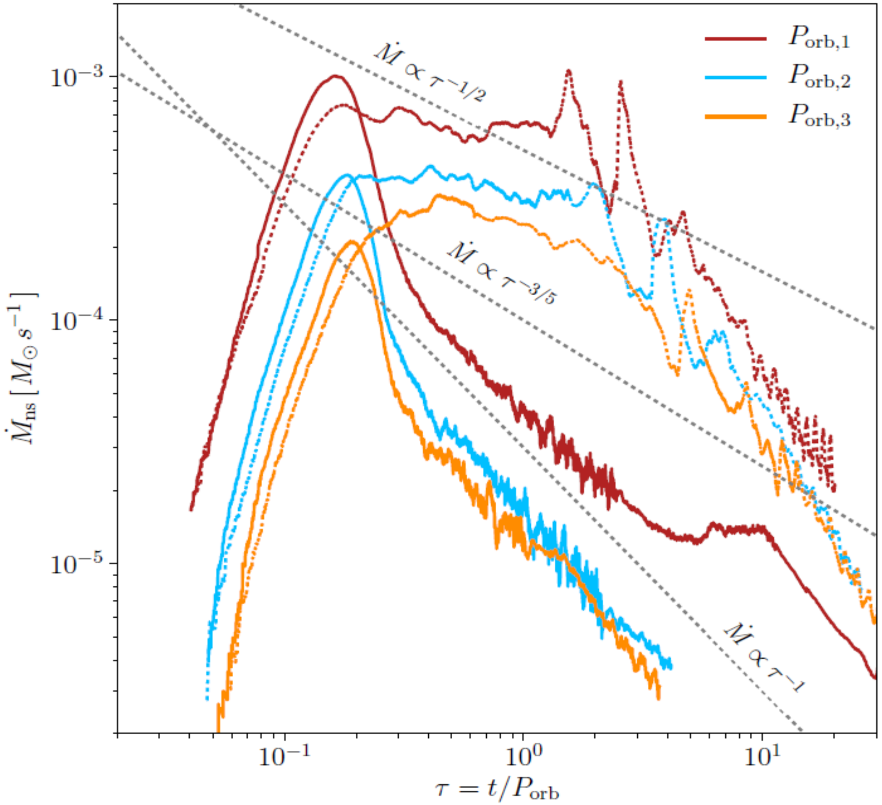


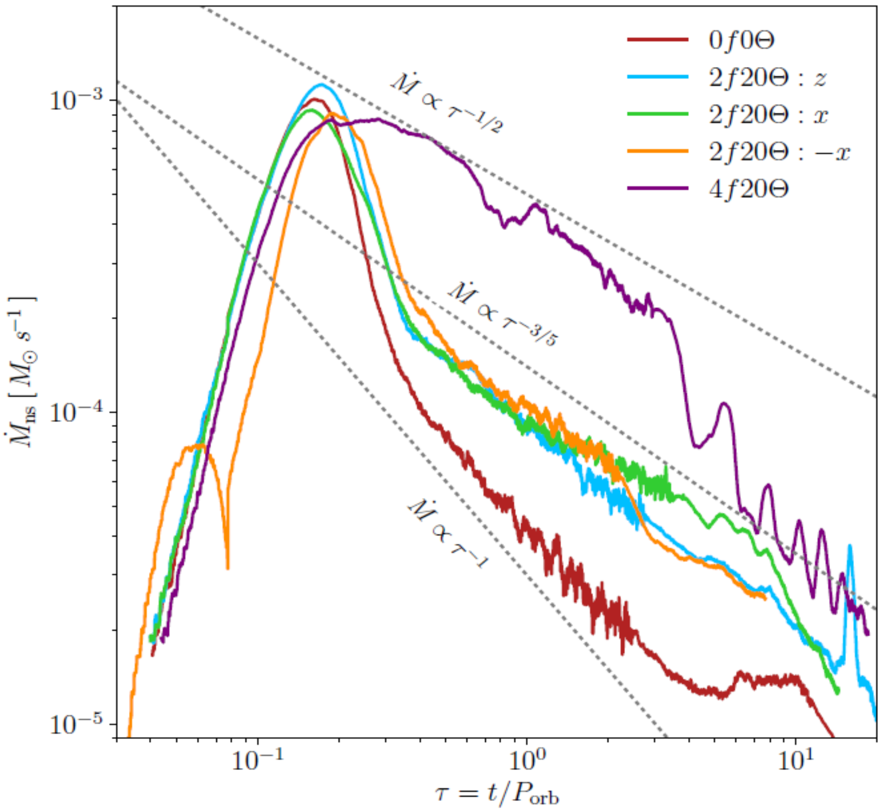
(a) NS star mass accretion rate

(b) νNS mass accretion rate

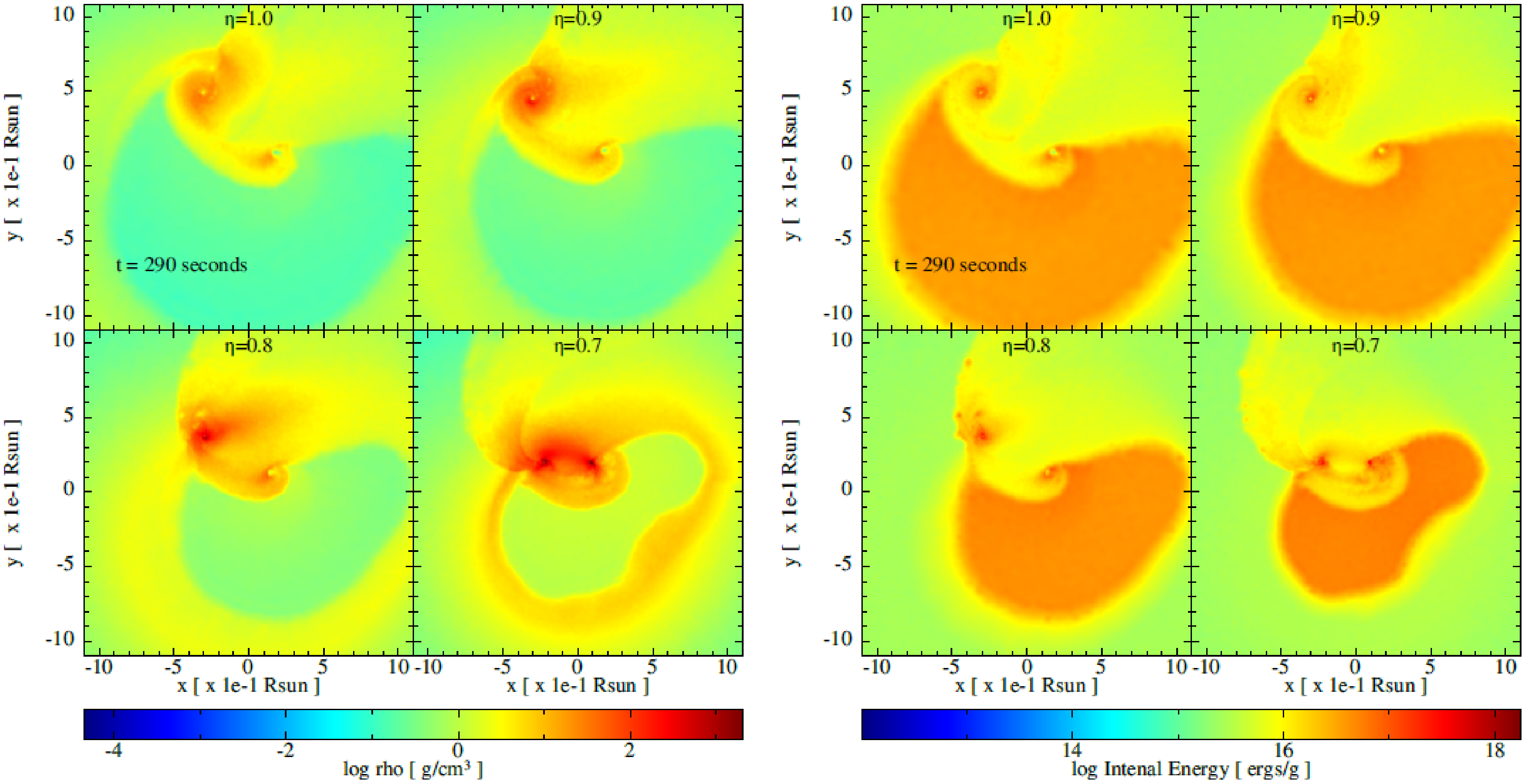
Becerra, Ellinger, Fryer, Rueda, Ruffini; arXiv:1803.04356

Scaling with the orbital period and asymmetric explosion effects





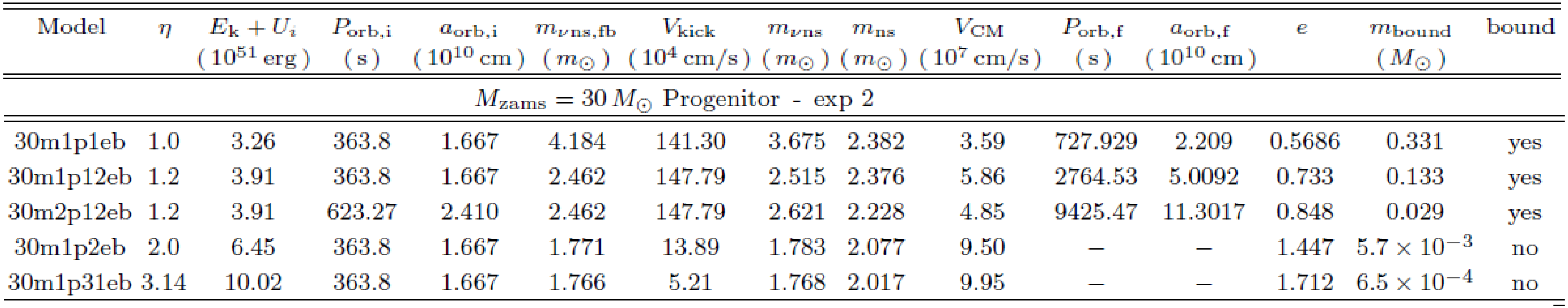
Orbital separation evolution



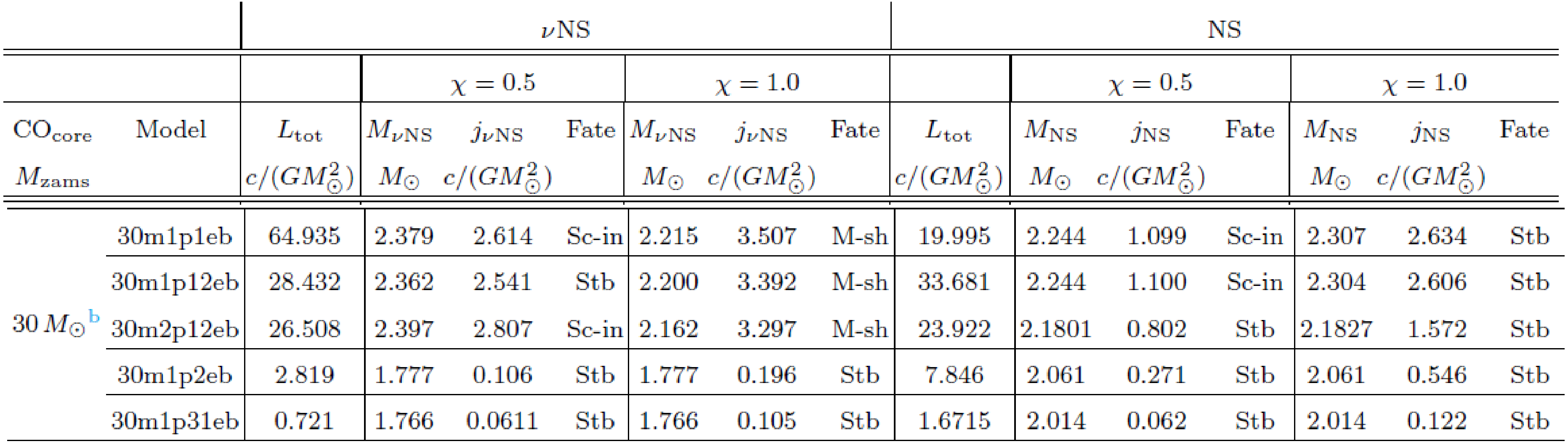
(a) Surface density

(b) Surface specific internal energy

Some results of an specific simulation

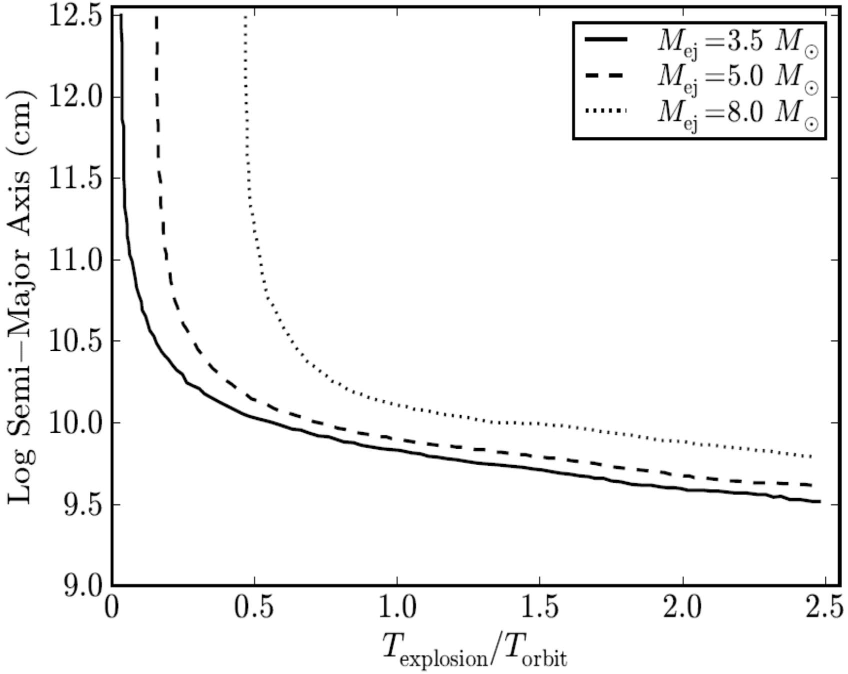


Model	η	$E_k + U_i$ $(10^{51}$ erg$)$	$P_{\rm orb,i}$ (s)	$a_{\rm orb,i}$ $(10^{10}$ cm$)$	$m_{\nu{\rm ns,fb}}$ $(m_\odot)$	$V_{\rm kick}$ $(10^4$ cm/s$)$	$m_{\nu{\rm ns}}$ $(m_\odot)$	$m_{\rm ns}$ $(m_\odot)$	$V_{\rm CM}$ $(10^7$ cm/s$)$	$P_{\rm orb,f}$ (s)	$a_{\rm orb,f}$ $(10^{10}$ cm$)$	e	$m_{\rm bound}$ $(M_\odot)$	bound
$M_{\rm zams} = 30\,M_\odot$ Progenitor - exp 2														
30m1p1eb	1.0	3.26	363.8	1.667	4.184	141.30	3.675	2.382	3.59	727.929	2.209	0.5686	0.331	yes
30m1p12eb	1.2	3.91	363.8	1.667	2.462	147.79	2.515	2.376	5.86	2764.53	5.0092	0.733	0.133	yes
30m2p12eb	1.2	3.91	623.27	2.410	2.462	147.79	2.621	2.228	4.85	9425.47	11.3017	0.848	0.029	yes
30m1p2eb	2.0	6.45	363.8	1.667	1.771	13.89	1.783	2.077	9.50	–	–	1.447	5.7×10^{-3}	no
30m1p31eb	3.14	10.02	363.8	1.667	1.766	5.21	1.768	2.017	9.95	–	–	1.712	6.5×10^{-4}	no

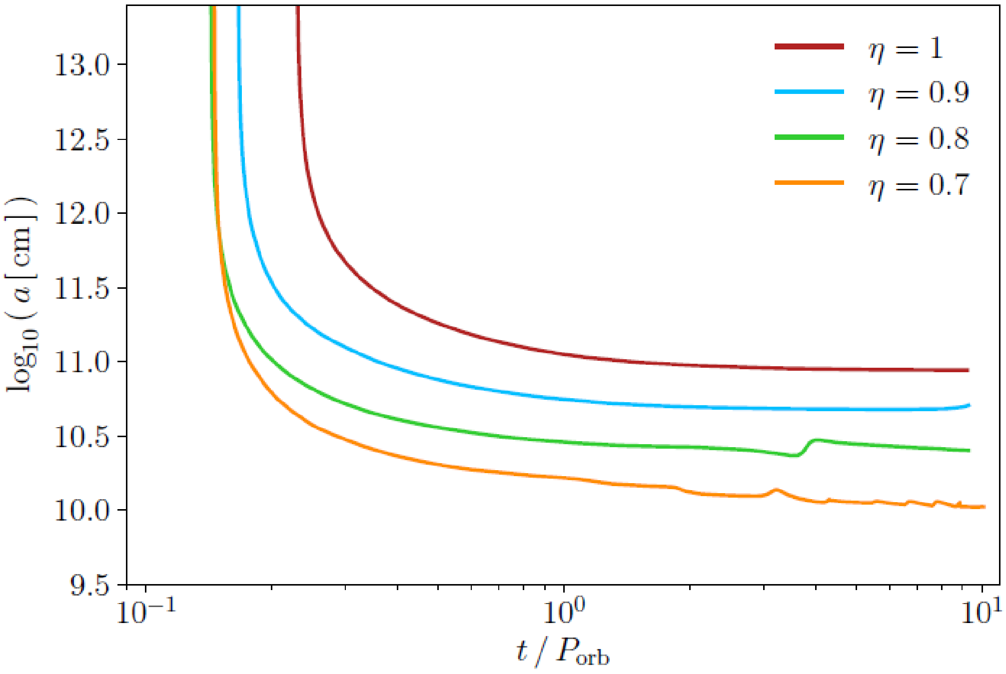


		νNS							NS						
			$\chi = 0.5$			$\chi = 1.0$				$\chi = 0.5$			$\chi = 1.0$		
CO$_{\rm core}$ $M_{\rm zams}$	Model	$L_{\rm tot}$ $c/(GM_\odot^2)$	$M_{\nu{\rm NS}}$ $M_\odot$	$j_{\nu{\rm NS}}$ $c/(GM_\odot^2)$	Fate	$M_{\nu{\rm NS}}$ $M_\odot$	$j_{\nu{\rm NS}}$ $c/(GM_\odot^2)$	Fate	$L_{\rm tot}$ $c/(GM_\odot^2)$	$M_{\rm NS}$ $M_\odot$	$j_{\rm NS}$ $c/(GM_\odot^2)$	Fate	$M_{\rm NS}$ $M_\odot$	$j_{\rm NS}$ $c/(GM_\odot^2)$	Fate
$30\,M_\odot$[b]	30m1p1eb	64.935	2.379	2.614	Sc-in	2.215	3.507	M-sh	19.995	2.244	1.099	Sc-in	2.307	2.634	Stb
	30m1p12eb	28.432	2.362	2.541	Stb	2.200	3.392	M-sh	33.681	2.244	1.100	Sc-in	2.304	2.606	Stb
	30m2p12eb	26.508	2.397	2.807	Sc-in	2.162	3.297	M-sh	23.922	2.1801	0.802	Stb	2.1827	1.572	Stb
	30m1p2eb	2.819	1.777	0.106	Stb	1.777	0.196	Stb	7.846	2.061	0.271	Stb	2.061	0.546	Stb
	30m1p31eb	0.721	1.766	0.0611	Stb	1.766	0.105	Stb	1.6715	2.014	0.062	Stb	2.014	0.122	Stb

NS-BH binaries produced by BdHNe

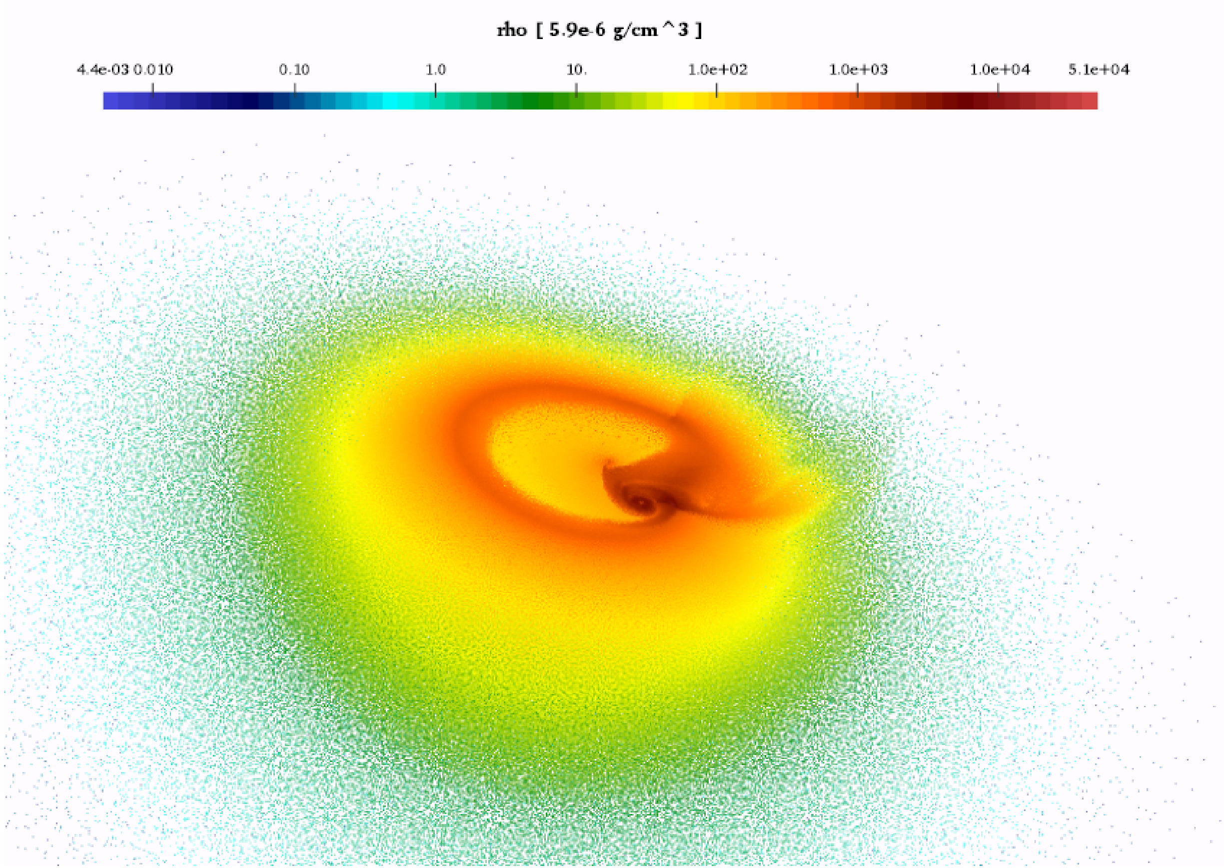


Fryer et al. PRL 2015; arXiv:15015.02809



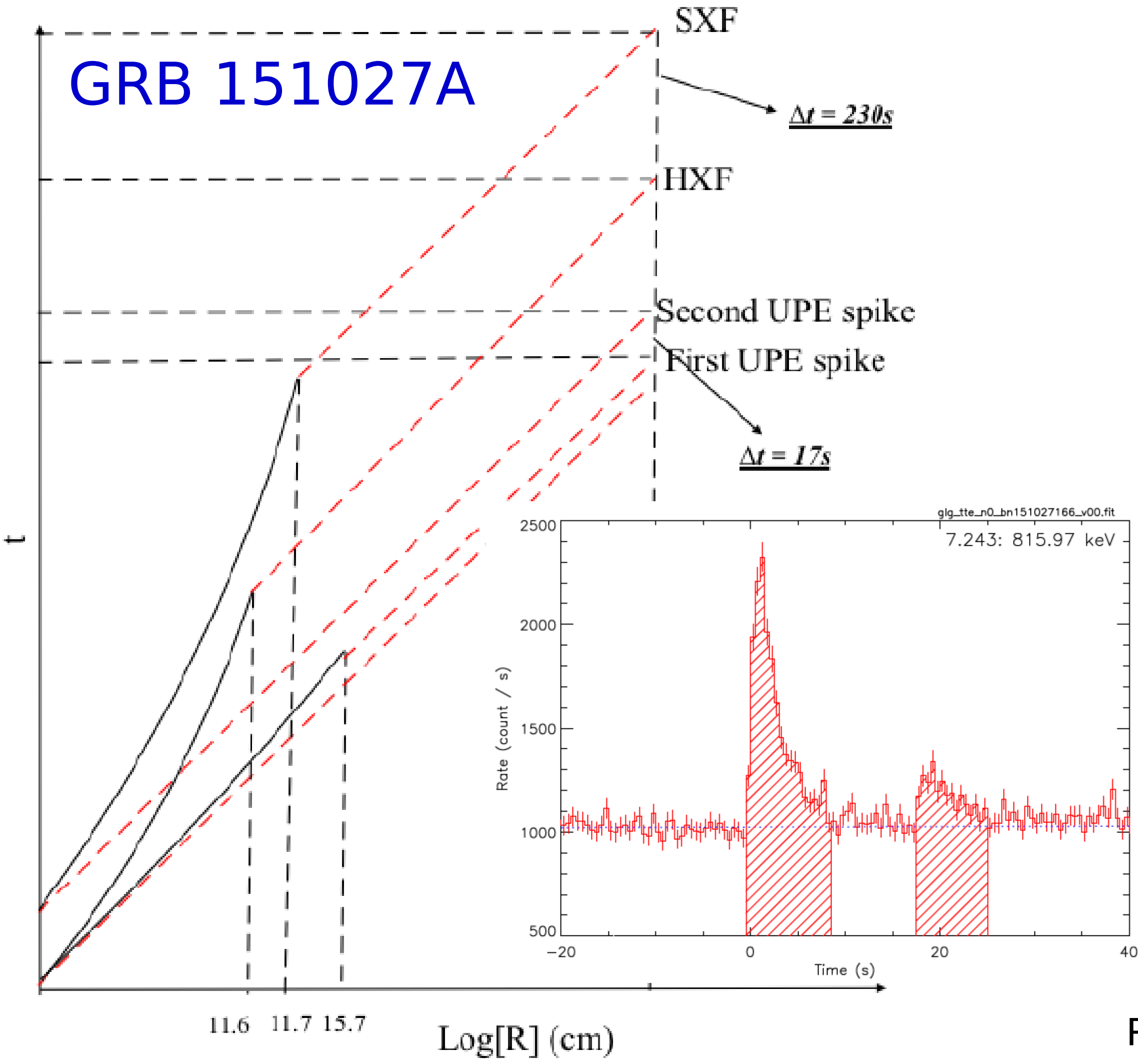
Becerra et al.; arXiv:1803.04356

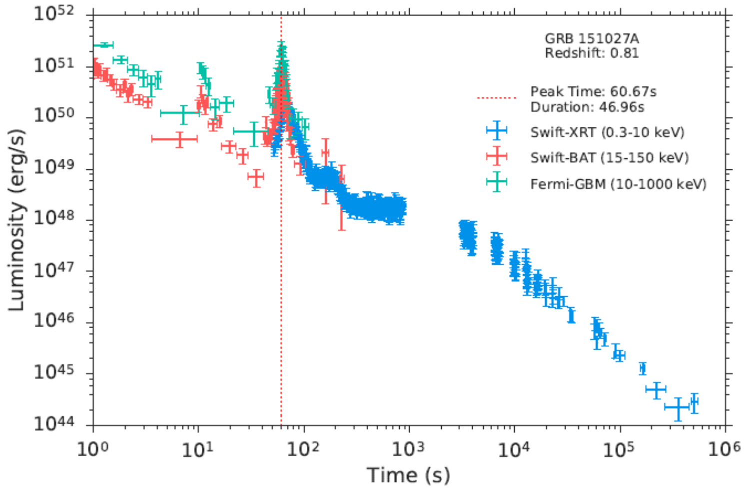
3D view of a BdHN

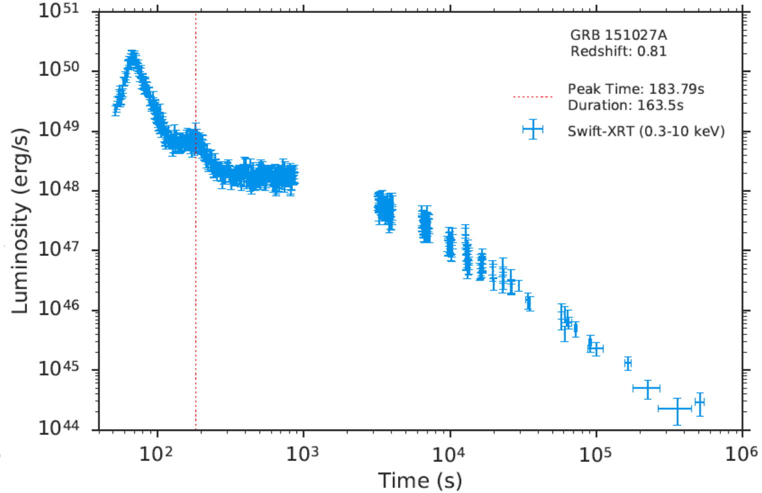


See R. Ruffini, R. Moradi and Yu Wang talks for consequences of the 3D structure

GRB 151027A



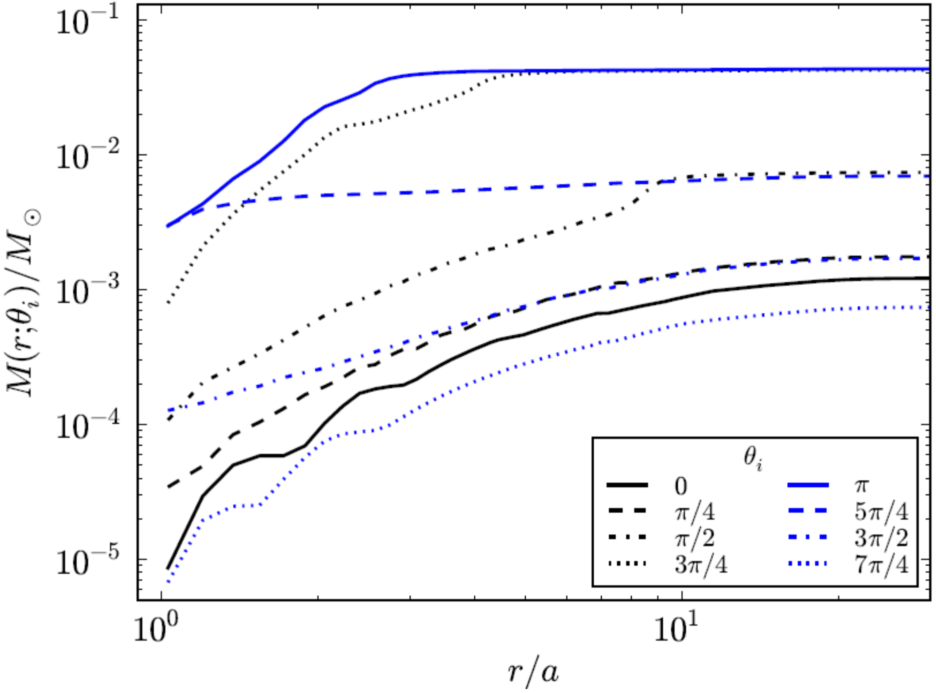


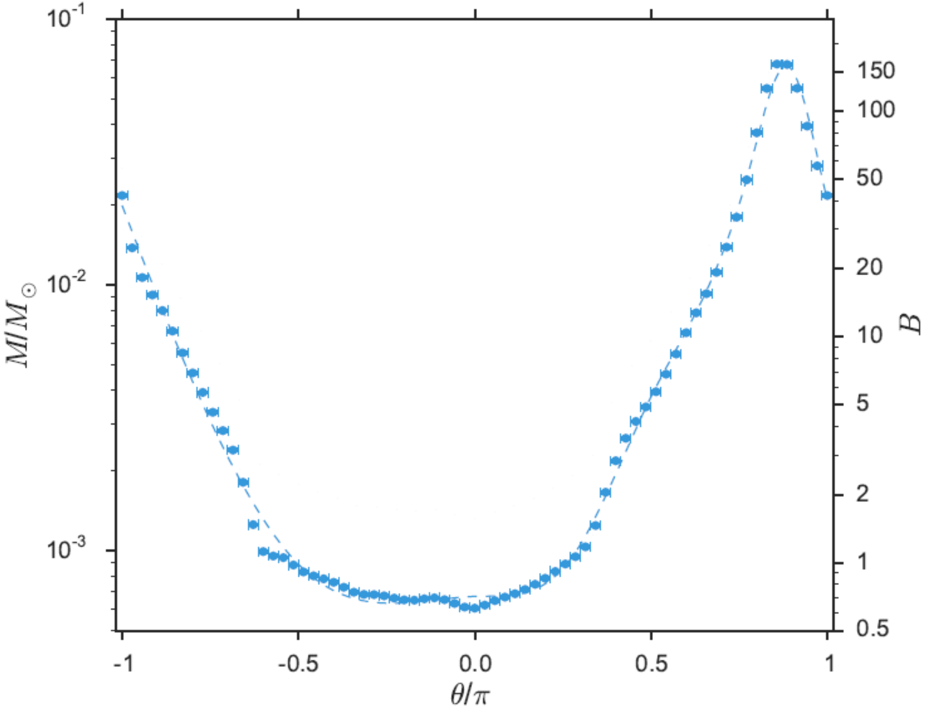


Ruffini, et al.; arXiv:1712.05001

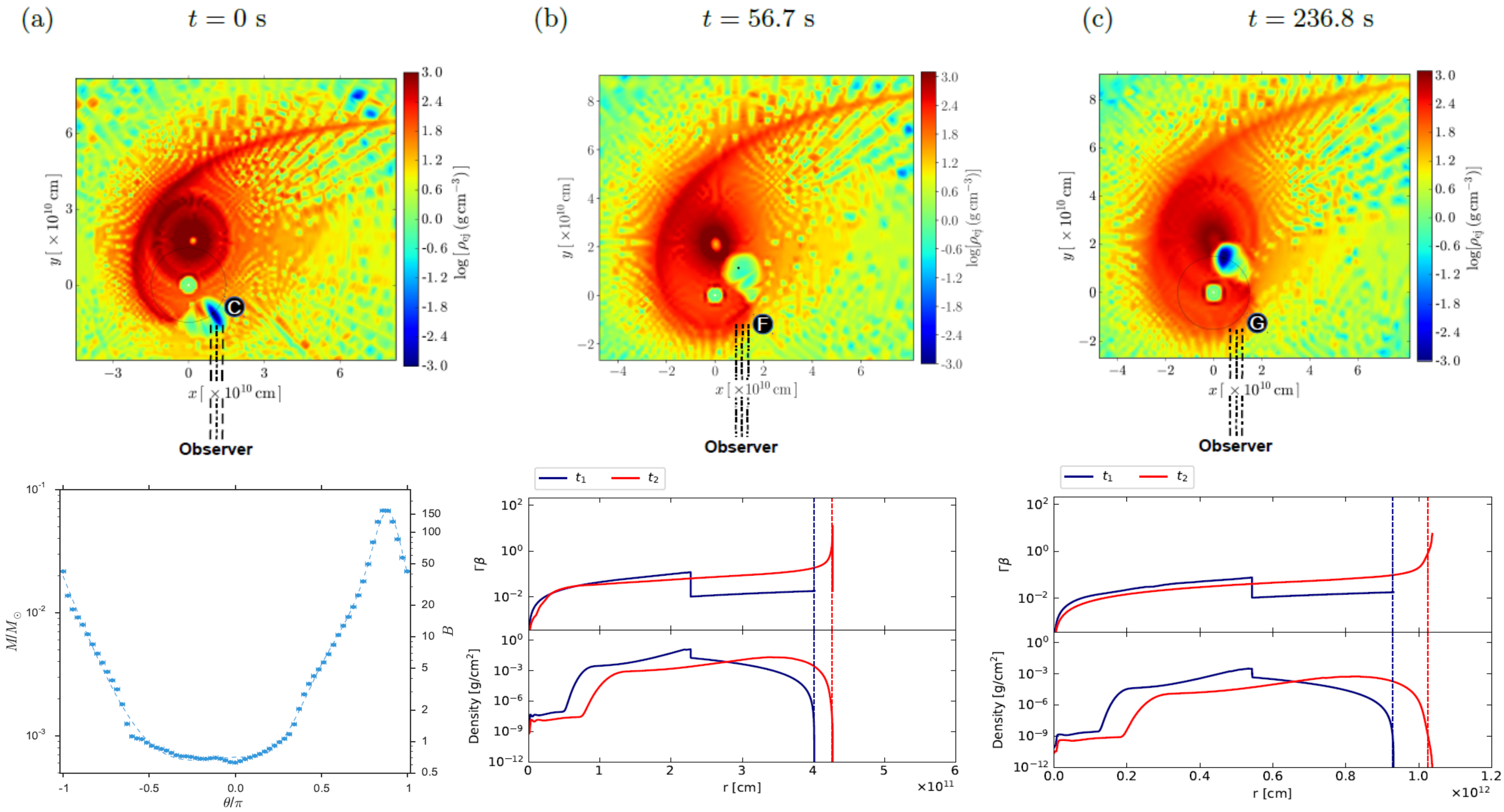
Baryon load on the orbital plane

R. Ruffini, L. Becerra, C. L. Bianco, et al.; arXiv:1712.05001; Ruffini et al. ApJ 852, 53 (2018)

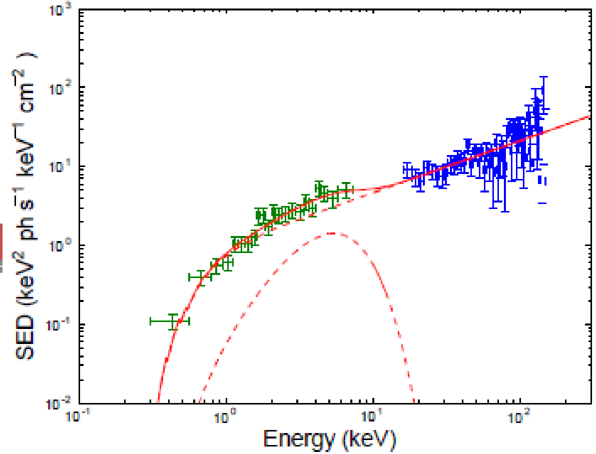


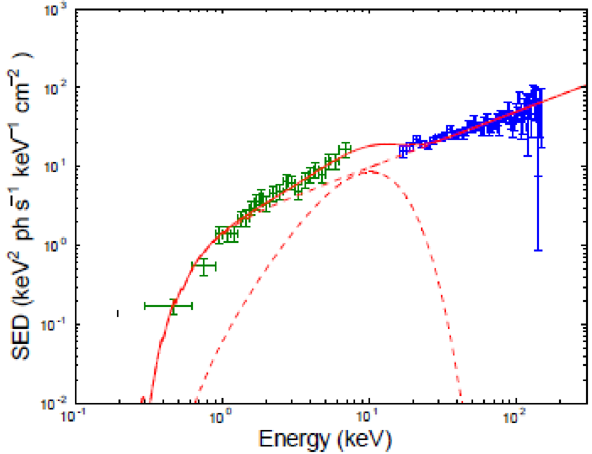


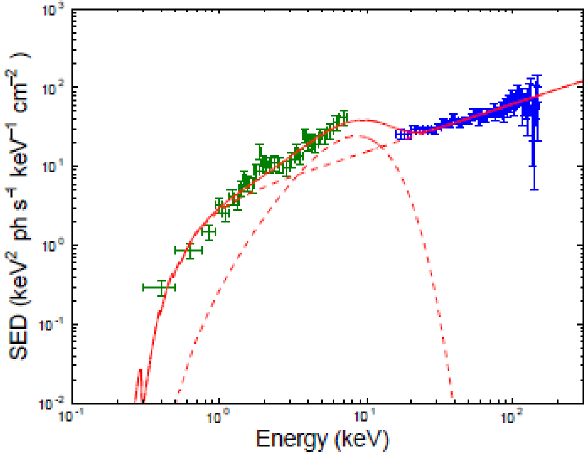
Baryon load parameter = B = plasma energy / baryon target mass-energy

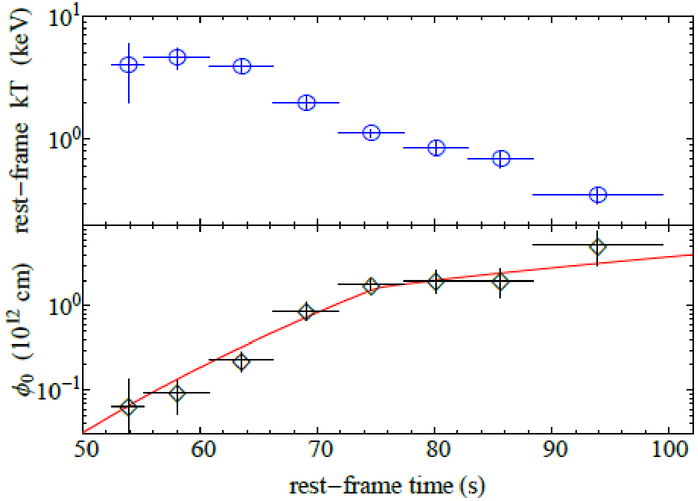


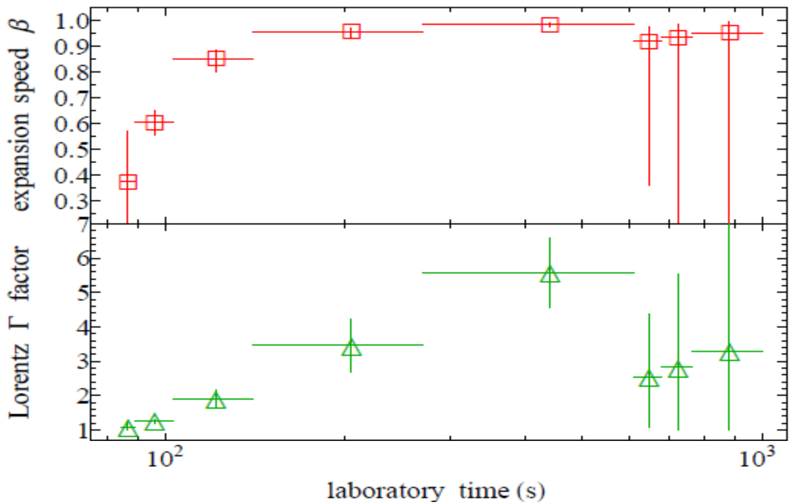
Ruffini, et al.; arXiv:1712.05001; see R. Ruffini's talk and D. Melon-Fuksman talk











Ruffini, et al.; arXiv:1712.05001