UNIVERSITY OF TRENTO - Italy

Trento Institute for
Fundamental Physics
and Applications

Electromagnetic Counterparts of LIGO-Virgo Events

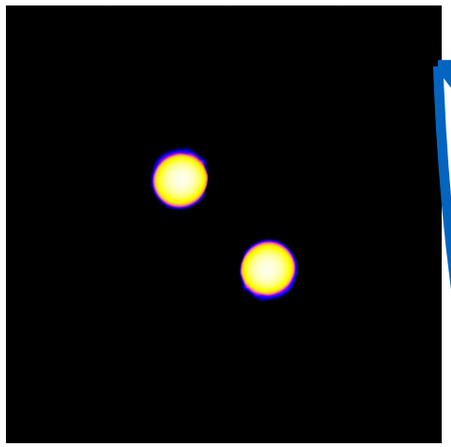
Bruno Giacomazzo
University of Trento and INFN-TIFPA

WARNING

- This talk will mainly cover NS-NS and NS-BH mergers
- Two slides on BH-BH EM counterparts
- No time to mention Supernovae, NS accretion induced collapse, etc… (GW signal much smaller)

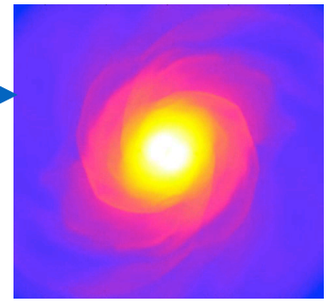
NS-NS & NS-BH

NS-NS

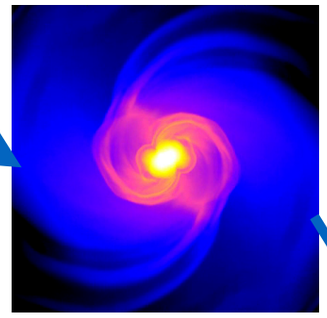


Low-Mass NS-NS

STABLE NS + Torus

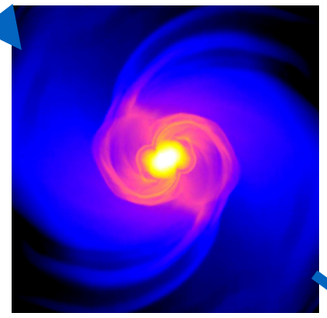


SMNS



<~1 hour

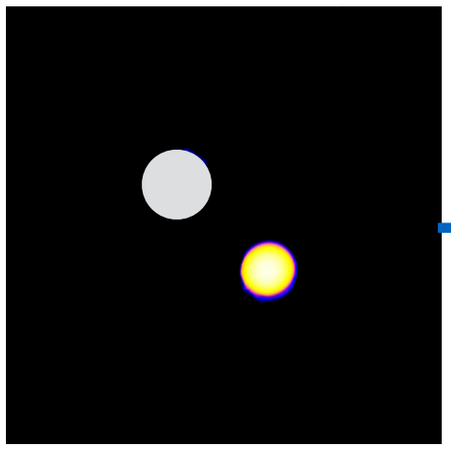
HMNS



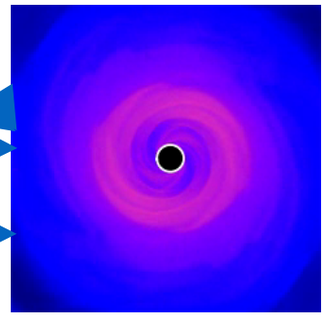
<~1s

High-Mass NS-NS

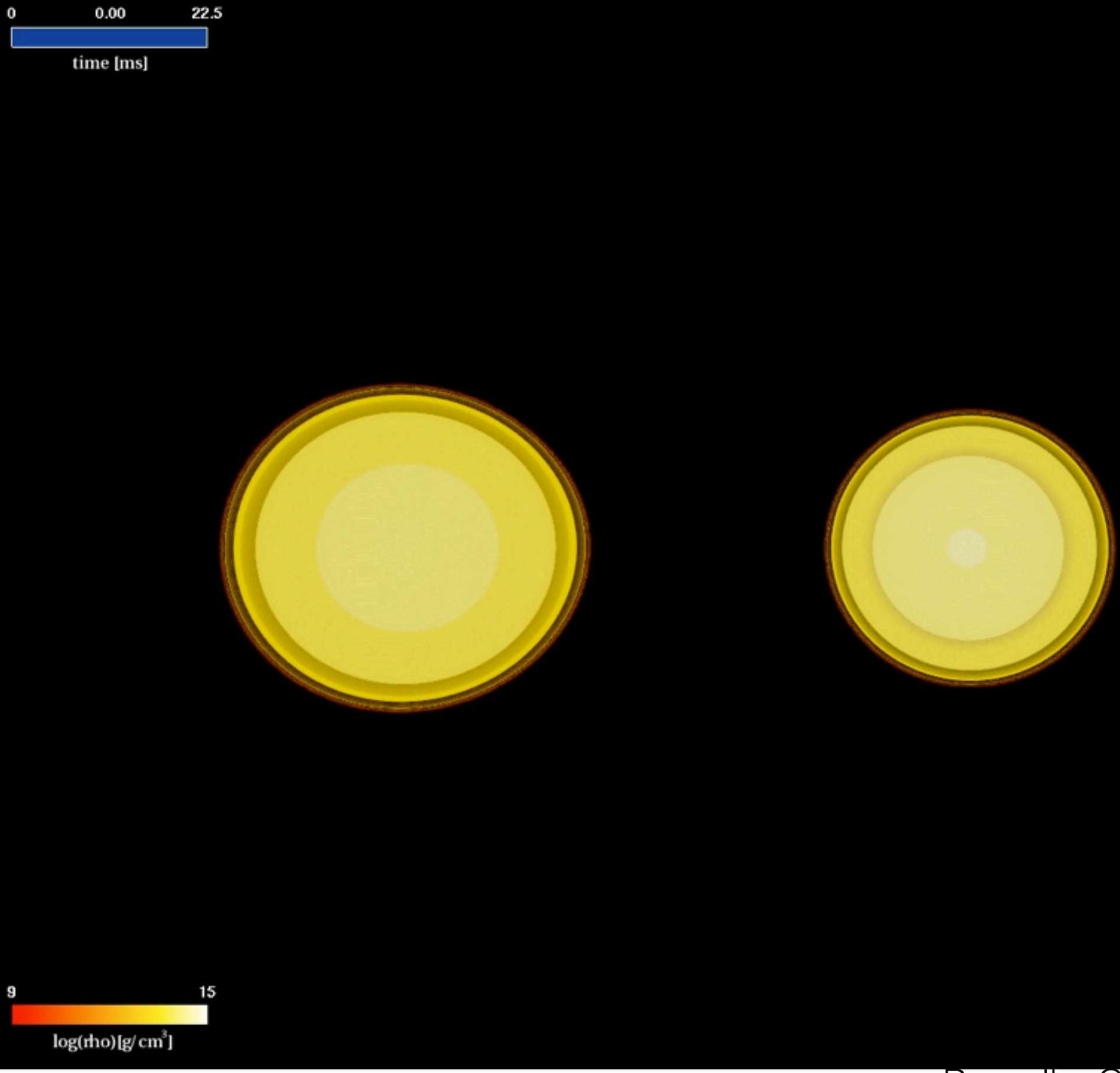
NS-BH



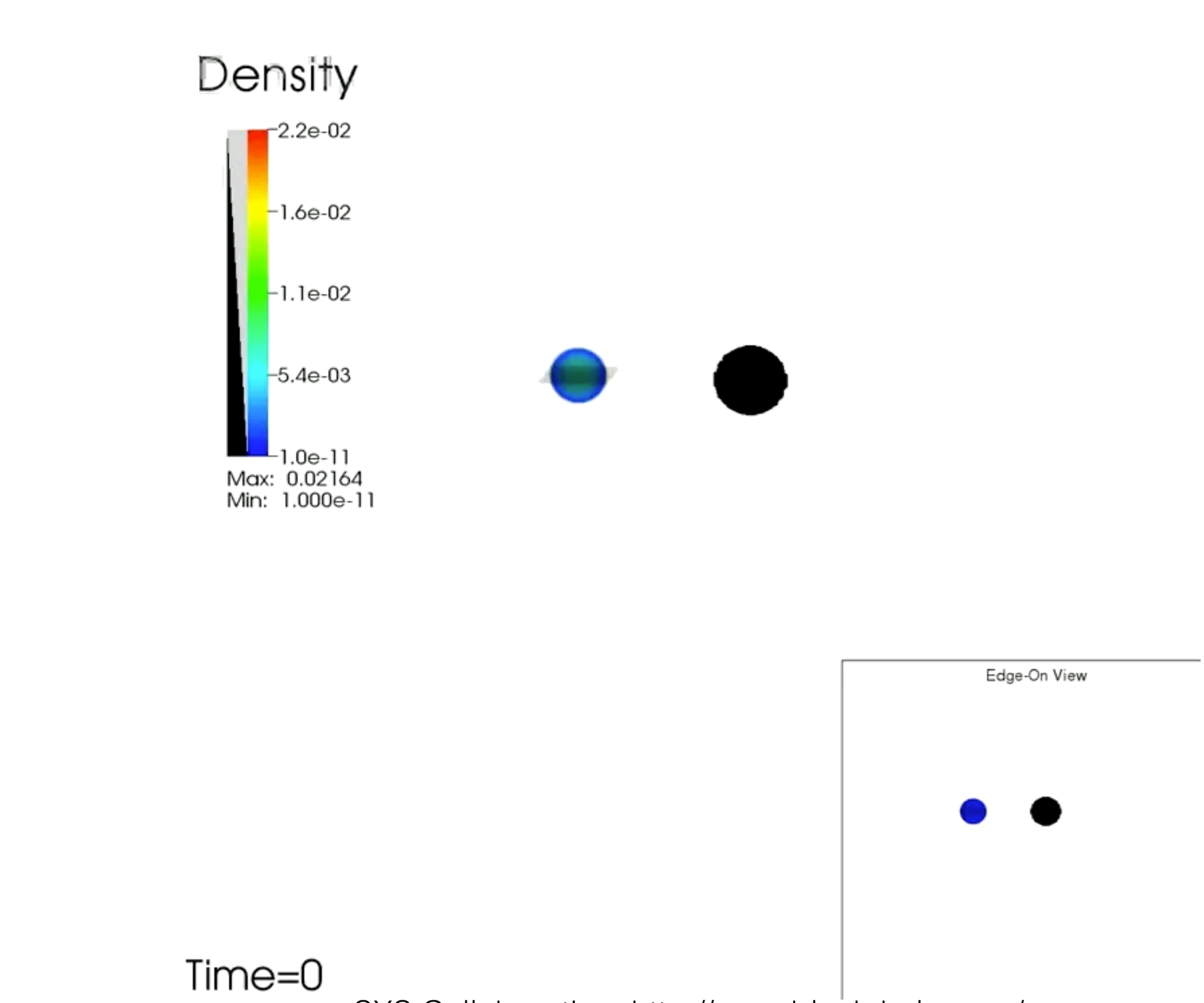
BH + TORUS



sim. & vis.: Wolfgang Kastaun

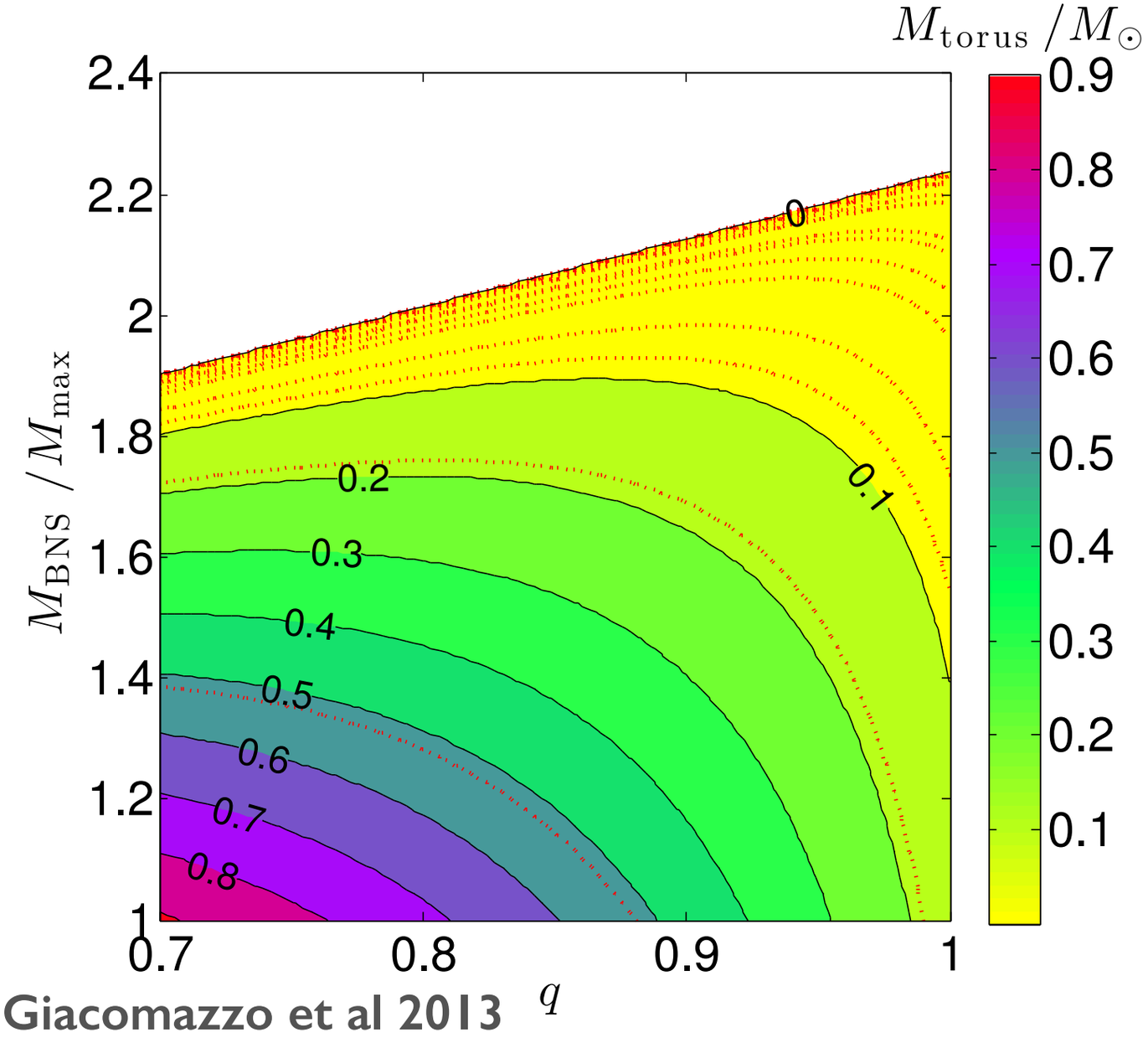


Rezzolla, Giacomazzo, et al 2010



SXS Collaboration: http://www.black-holes.org/

NS-NS: Disk Formation



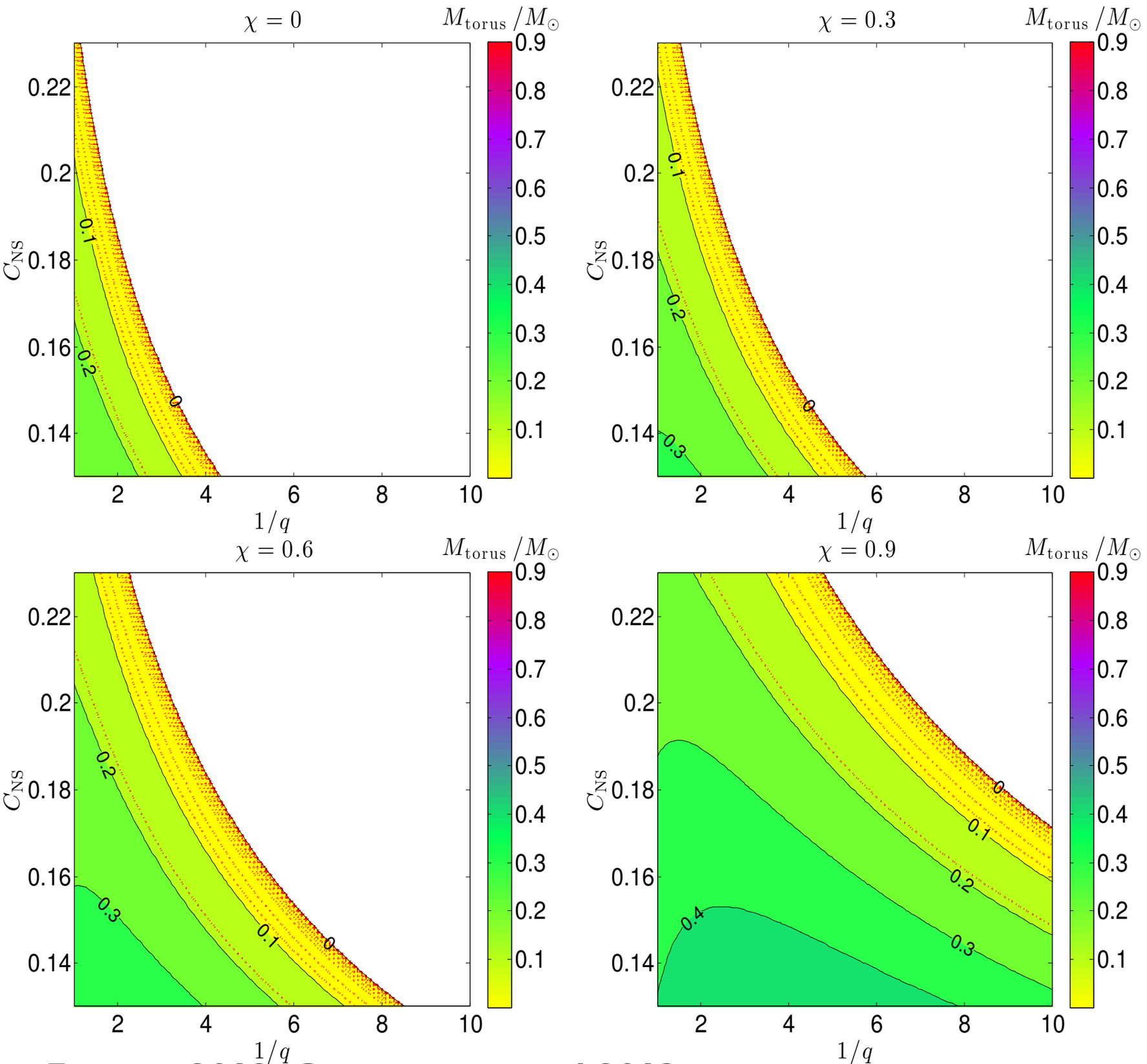
Giacomazzo et al 2013

More massive disks in case of no-prompt collapse

Strongly dependent on NS EOS

Very easy to form disks of ~0.1 solar masses

NS-BH: Disk Formation



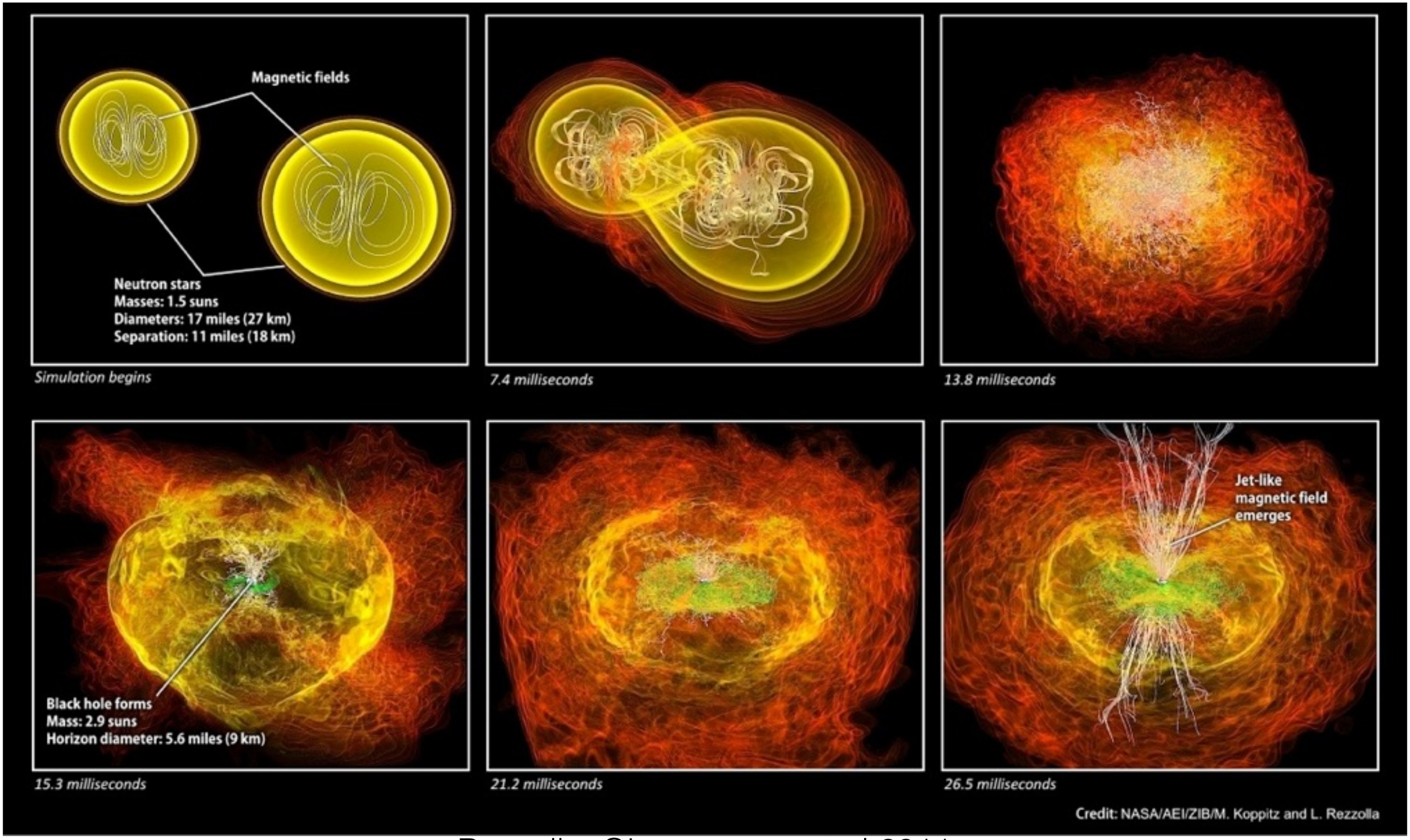
Rapidly rotating BHs are required

Many systems may not be able to form disks

If disk is formed GW signal clearly differs from BH-BH GW

Foucart 2012, Giacomazzo et al 2013

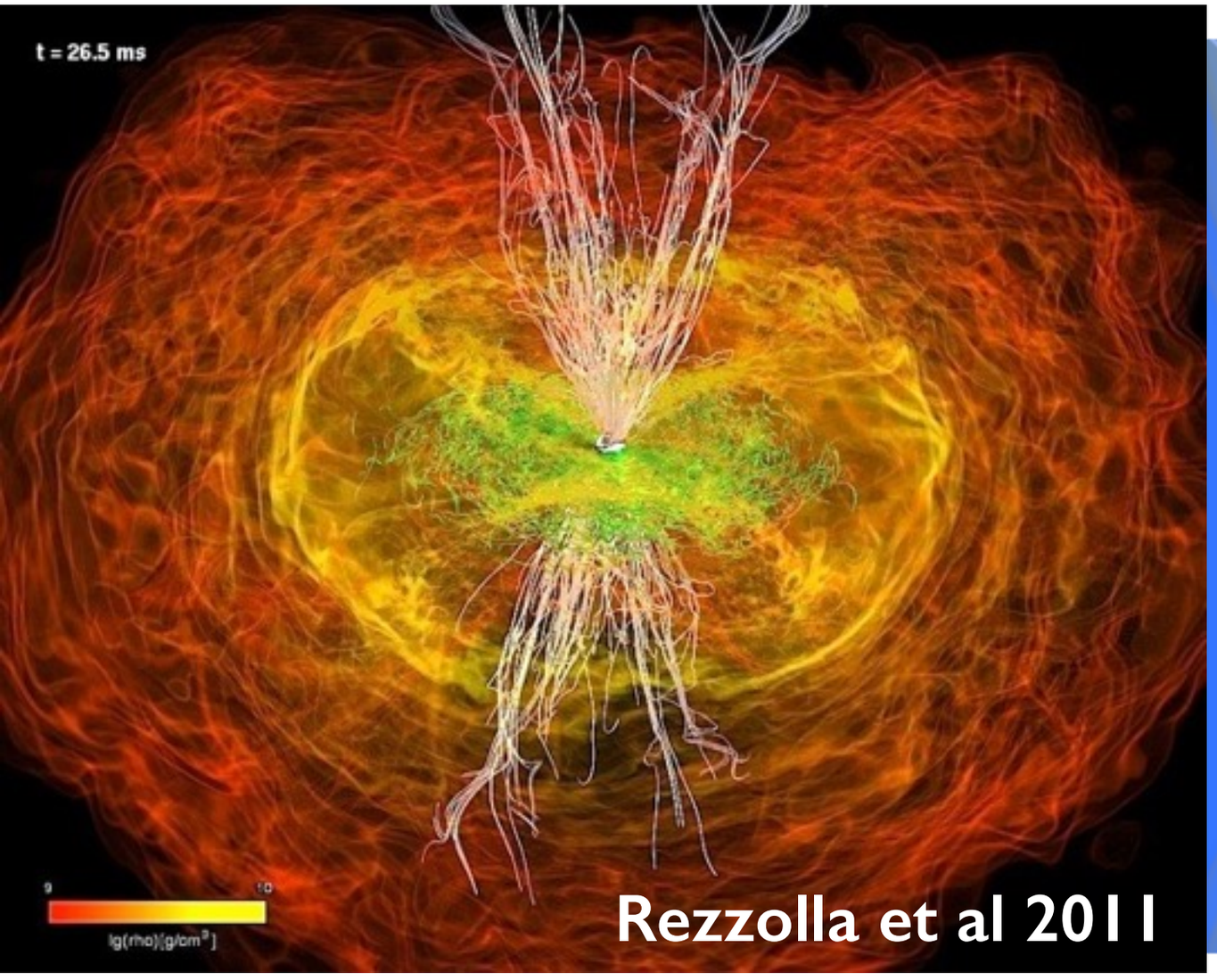
Jet Formation



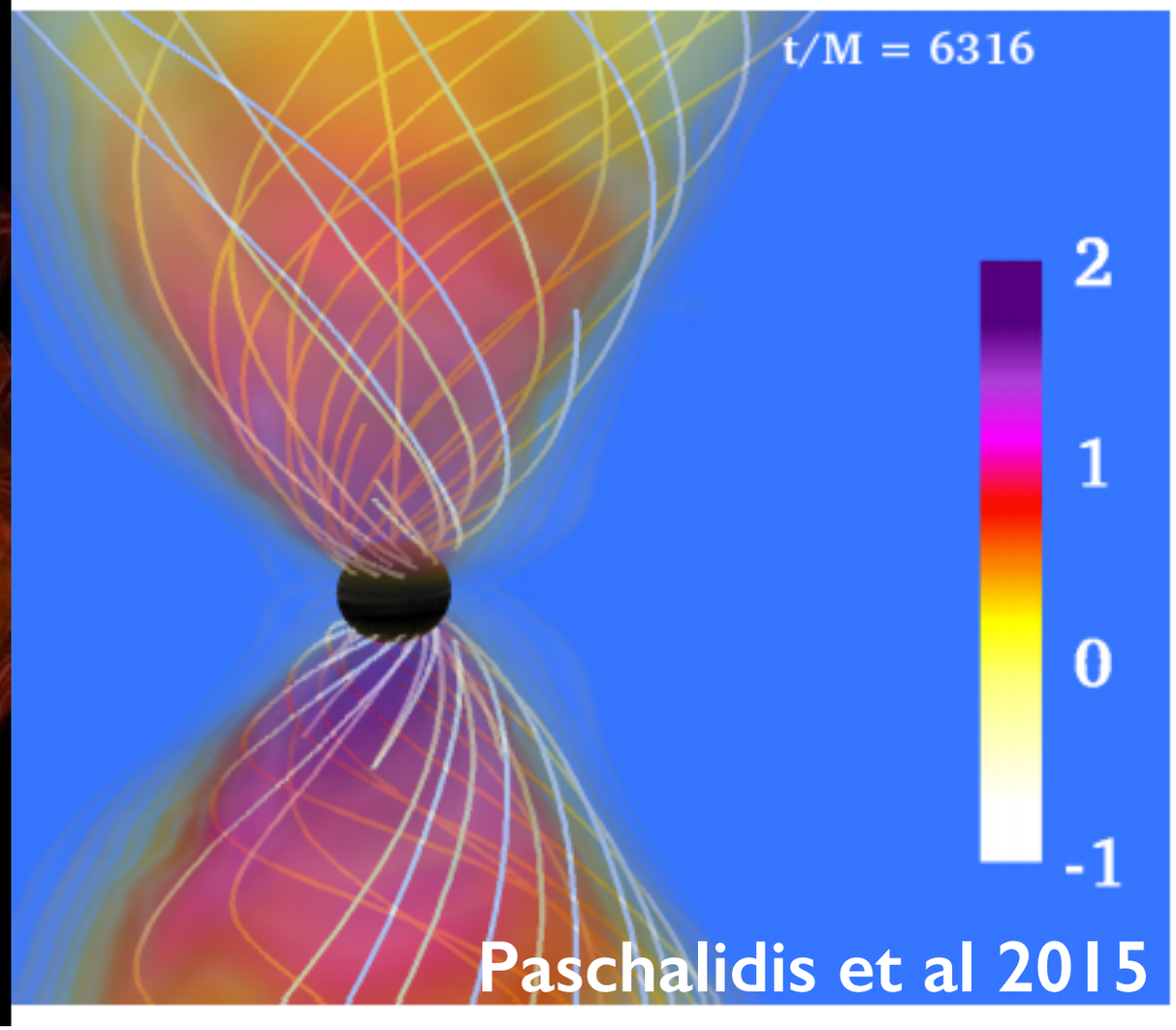
Rezzolla, Giacomazzo, et al 2011

Jet Formation

NS-NS

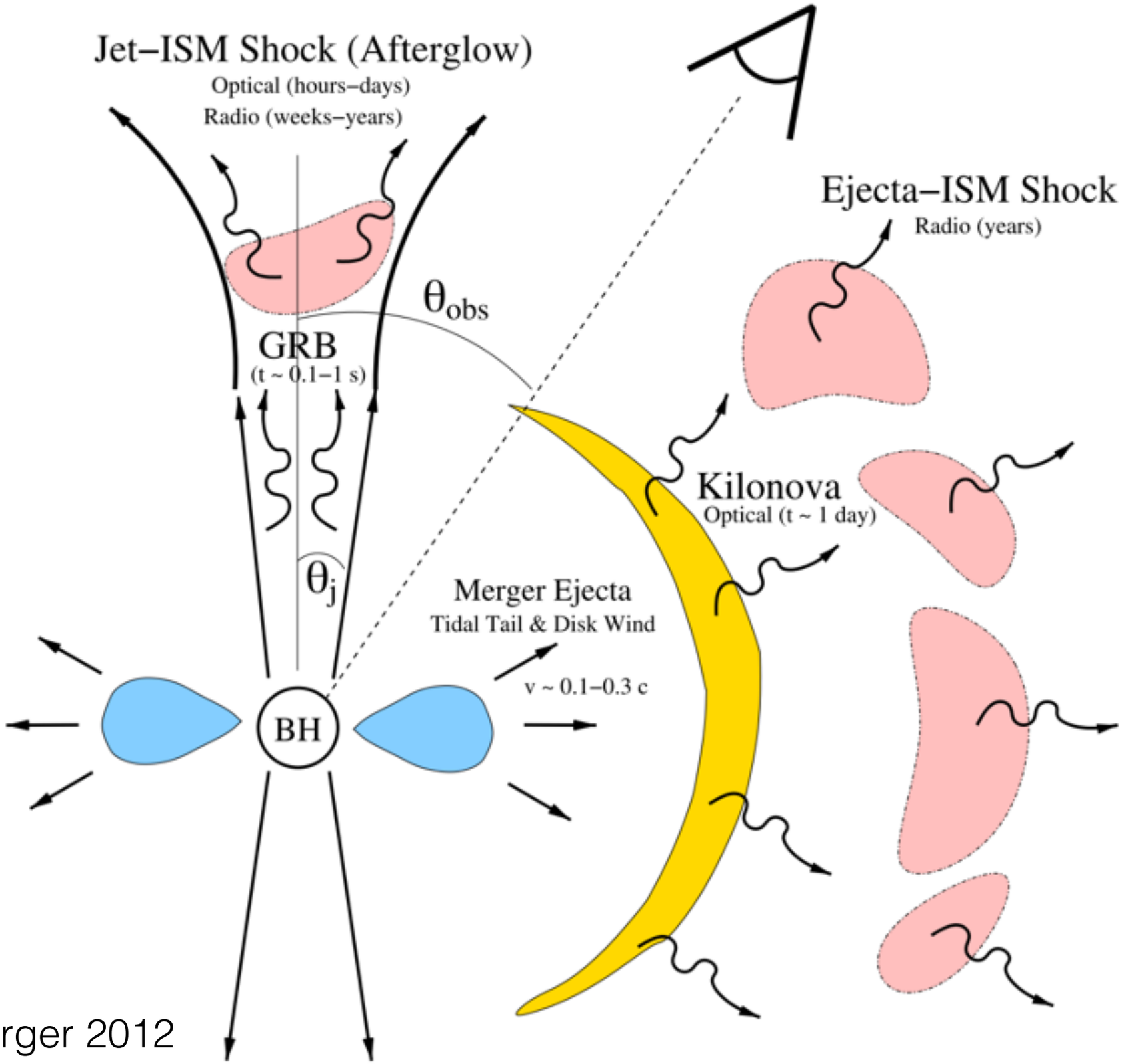


NS-BH



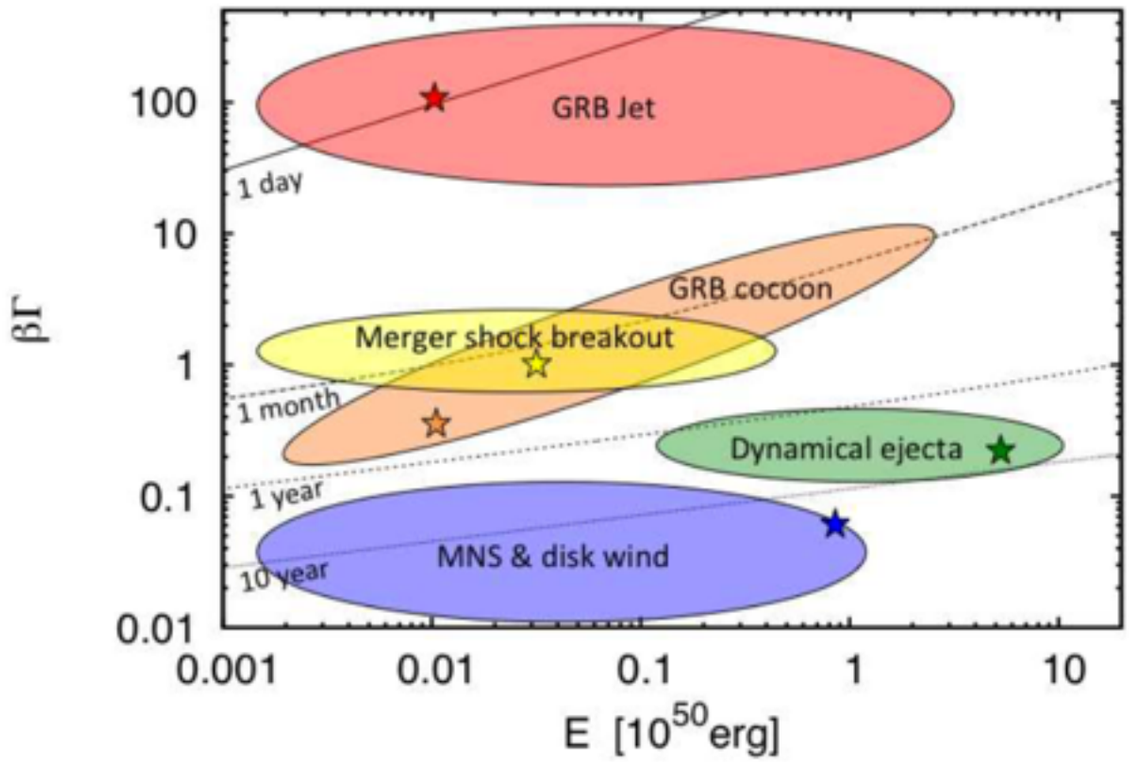
WARNING: actual jet observed only in NS-BH merger (only 1 sim), NS-NS still debated. Role of magnetic fields is crucial.

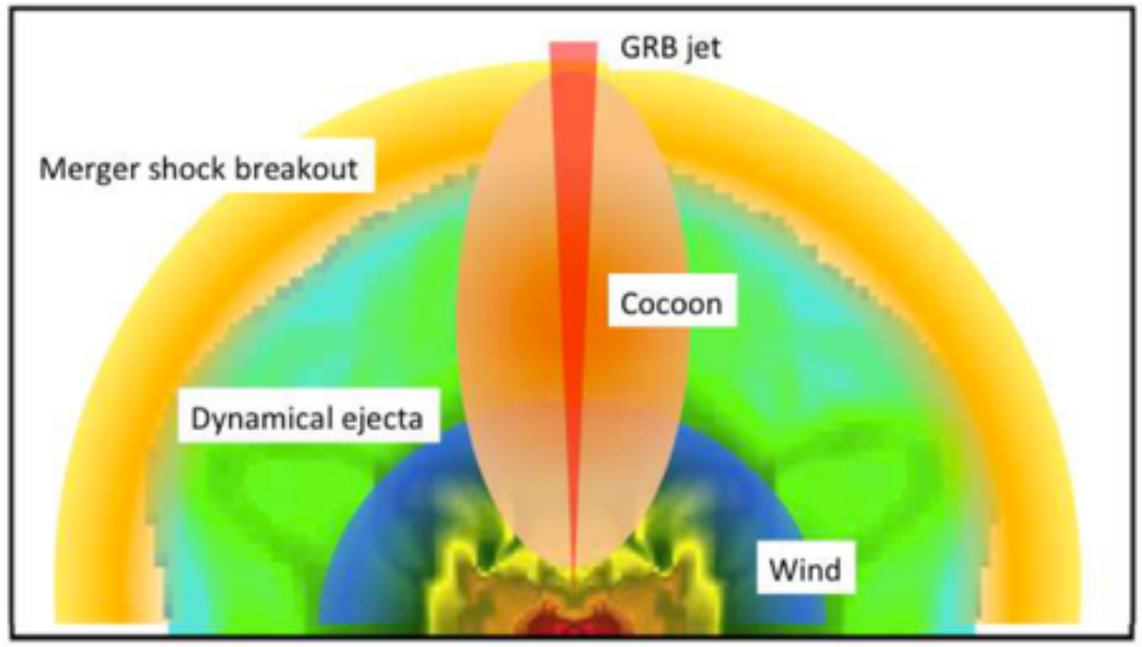
Other EM Counterparts



Metzger&Berger 2012

Radio Emission from Ejecta



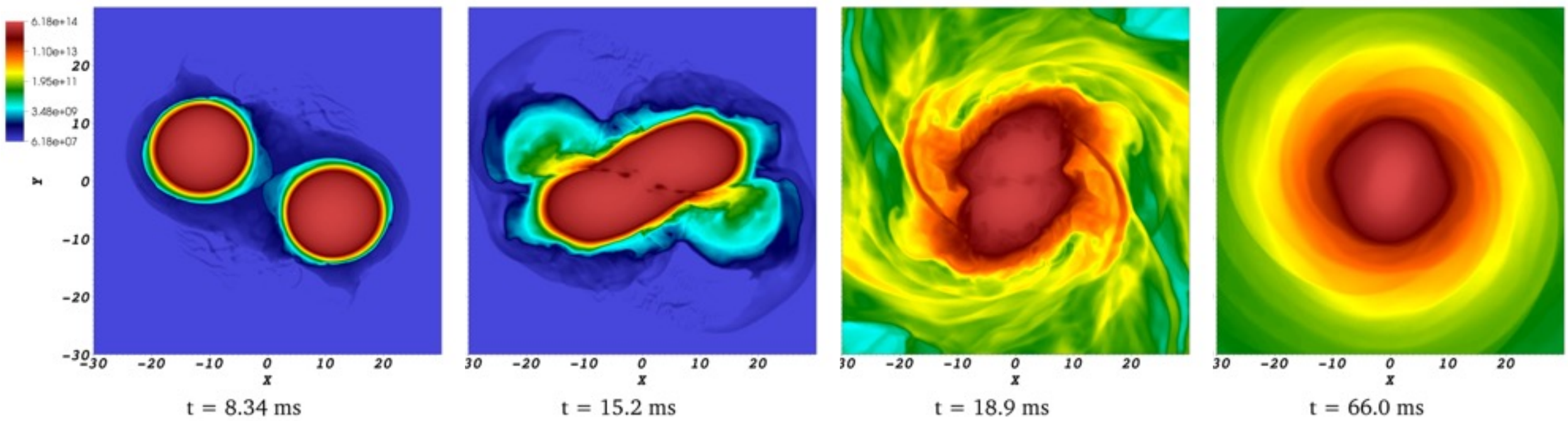


Hotokezaka & Piran 2015

- Dynamical and wind ejecta between ~10^{-4} - ~10^{-2} $M_\odot$
- Tidal Ejecta from NS-NS and NS-BH similar
- Ejecta from NS-NS merger hotter (shocks at merger produce most of ejecta in NS-NS)

Long-Lived Magnetar Formation

- Maximum NS mass >2 supports long-lived NS formation after merger
- It will affect GRB engine
- Much longer GW emission and bright EM counterparts
- A long-lived (or stable) magnetar could be used to explain X-ray plateaus and extended emissions from SGRBs (e.g., Rowlinson et al 2013).



Giacomazzo & Perna 2013

TIME-REVERSAL SGRB MODEL

(Ciolfi & Siegel 2015)

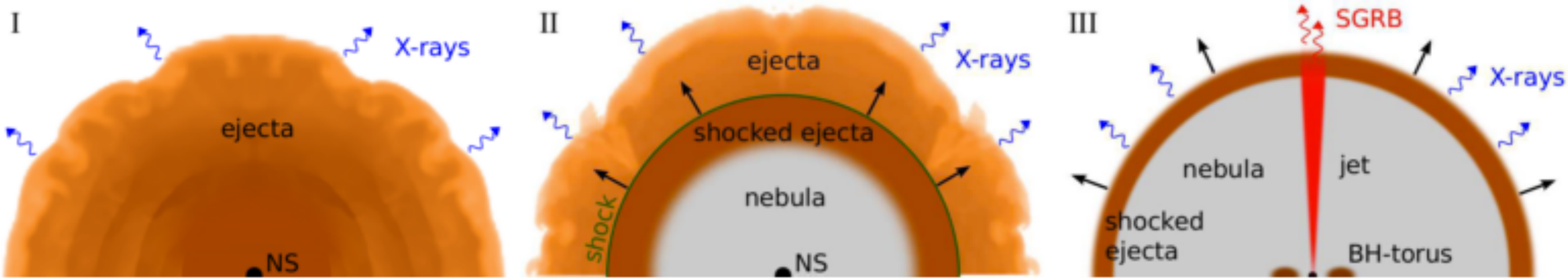
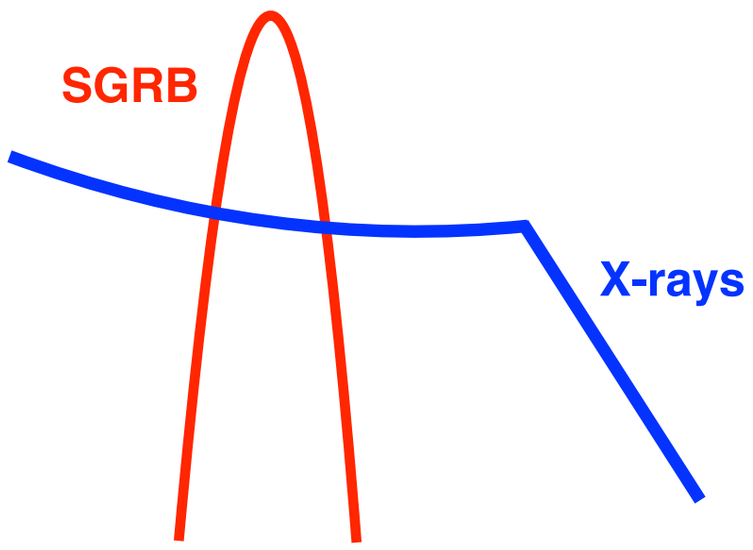


Figure 1. Evolution phases: (I) The differentially rotating supramassive NS ejects a baryon-loaded and highly isotropic wind; (II) The cooled-down and uniformly rotating NS emits spin-down radiation inflating a photon-pair nebula that drives a shock through the ejecta; (III) The NS collapses to a BH, a relativistic jet drills through the nebula and the ejecta shell and produces the prompt SGRB, while spin-down emission diffuses outwards on a much longer timescale.

Ciolfi & Siegel 2015



X-ray afterglow emitted by magnetar

SGRB emitted by BH after magnetar collapse

(GW inspiral - X-ray - SGRB)

Magnetars may be formed from BNS mergers
(Giacomazzo & Perna 2013, Giacomazzo et al 2015)

EM emission from the long-lived NS remnant

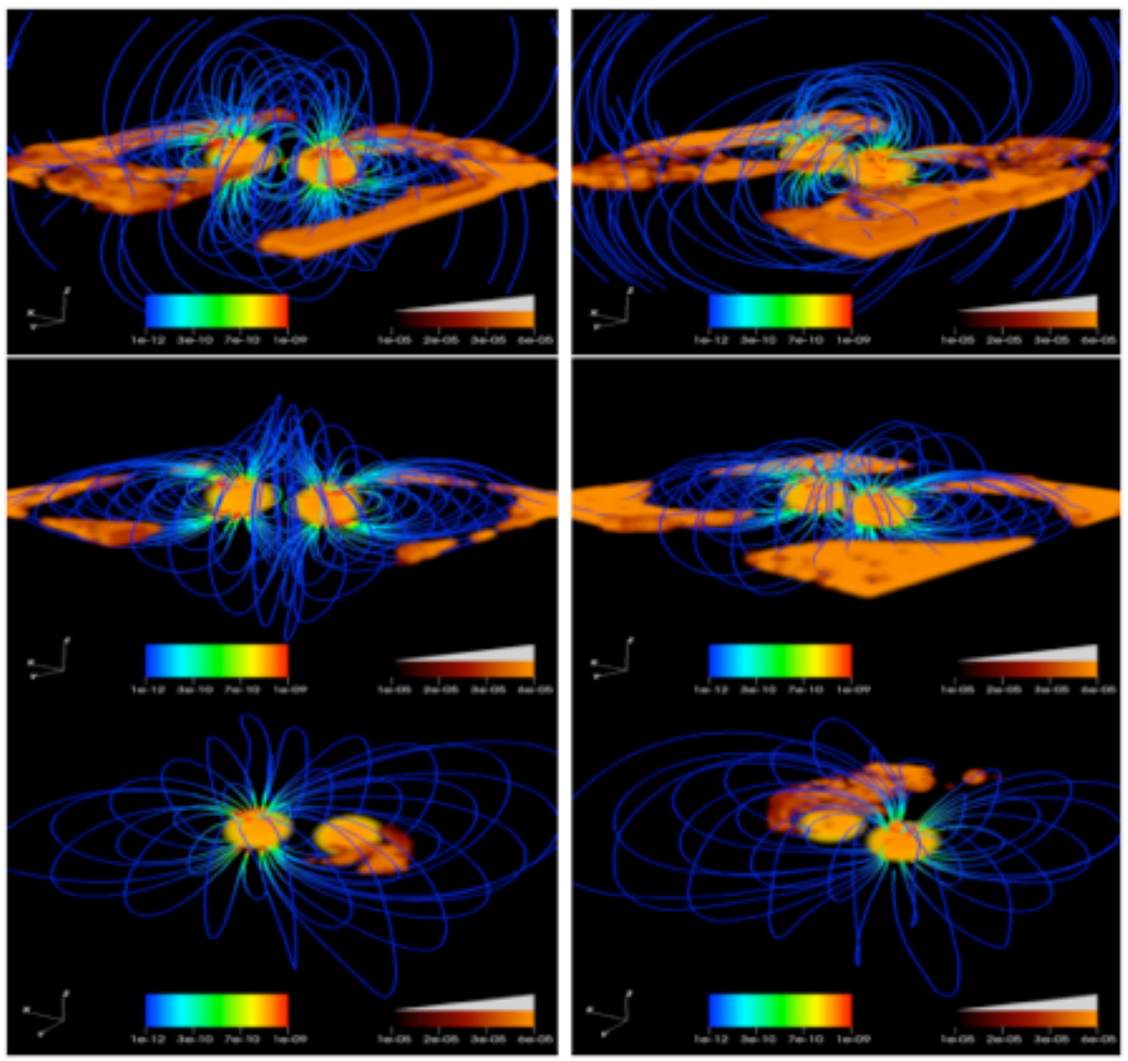
Siegel & Ciolfi 2015b, 2015c

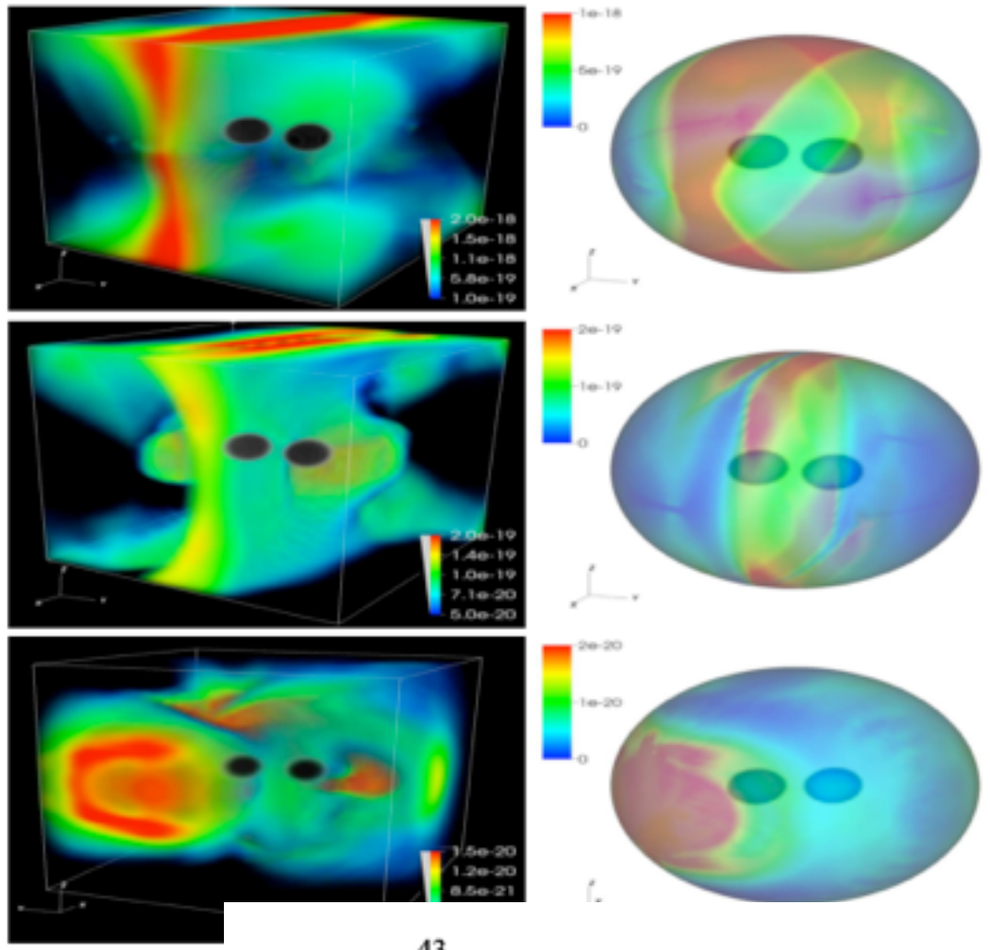
- signal peaks at 10^2-10^4 s (similar range for duration)
- luminosities 10^{46}-10^{49} erg/s

	BRIGHT	ISOTROPIC	LONG-LASTING	HIGH OCCURRENCE	DISTINGUISH BNS AND NS-BH
SGRB	✓	✗	✗	✗	✗
MACRONOVA	✓	✓	✓	✓	✗
NS SPIN-DOWN	✓	✓	✓	✓	✓

very promising EM counterpart!

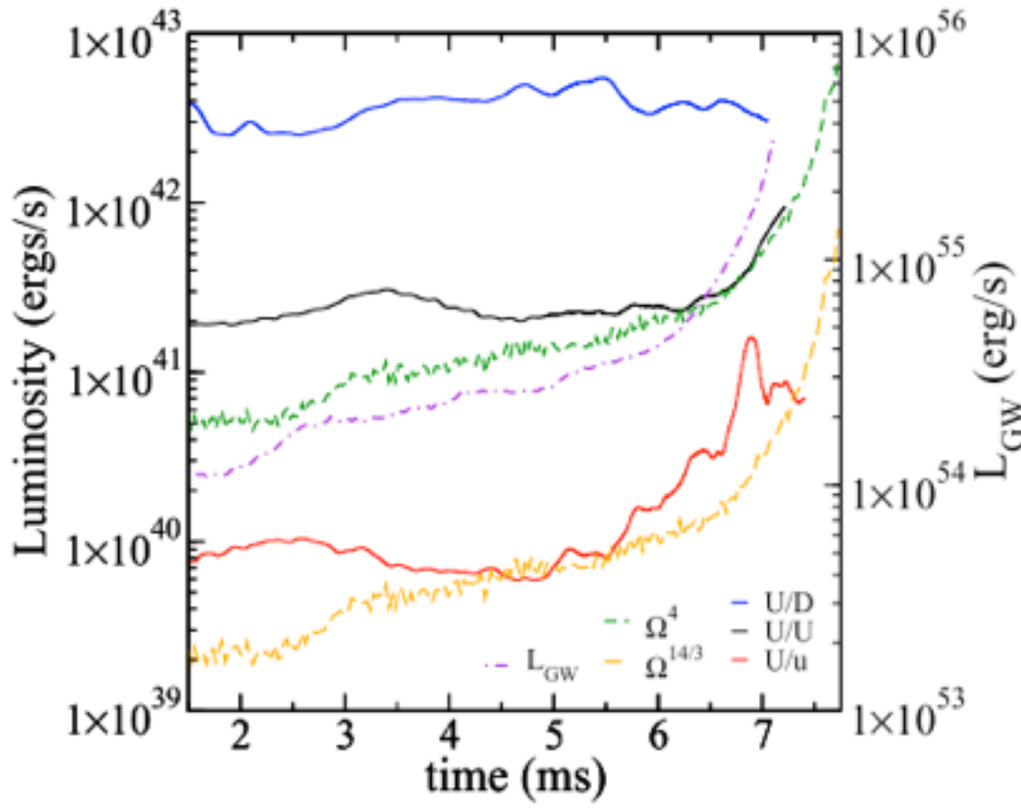
NS-NS EM Precursors



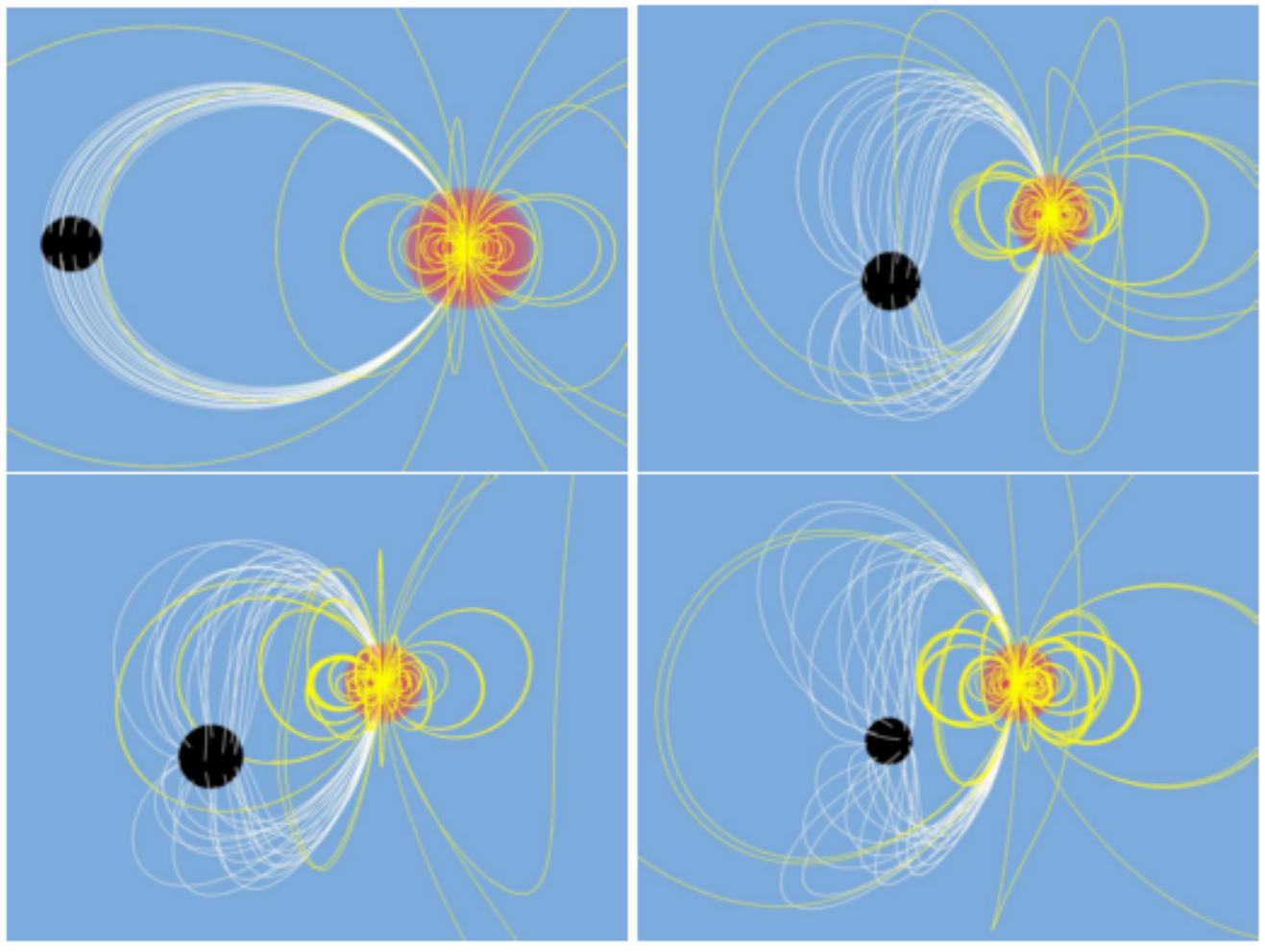


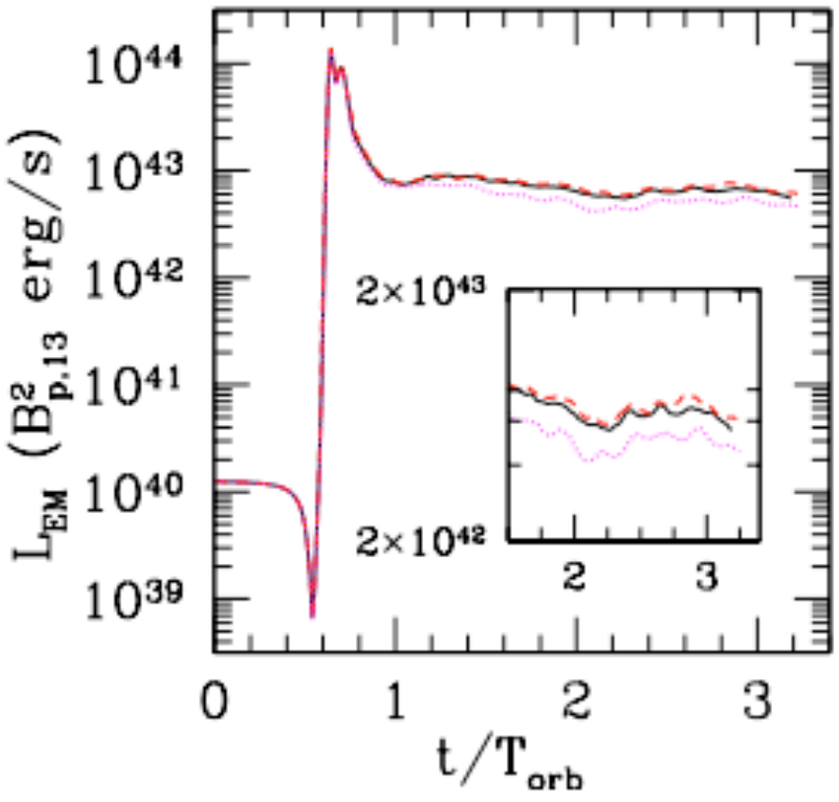
Palenzuela et al 2013

Resistive MHD simulations (full GR)
EM emission during inspiral (~1e43 erg/s)
Emission depends on initial configuration



NS-BH EM Precursors



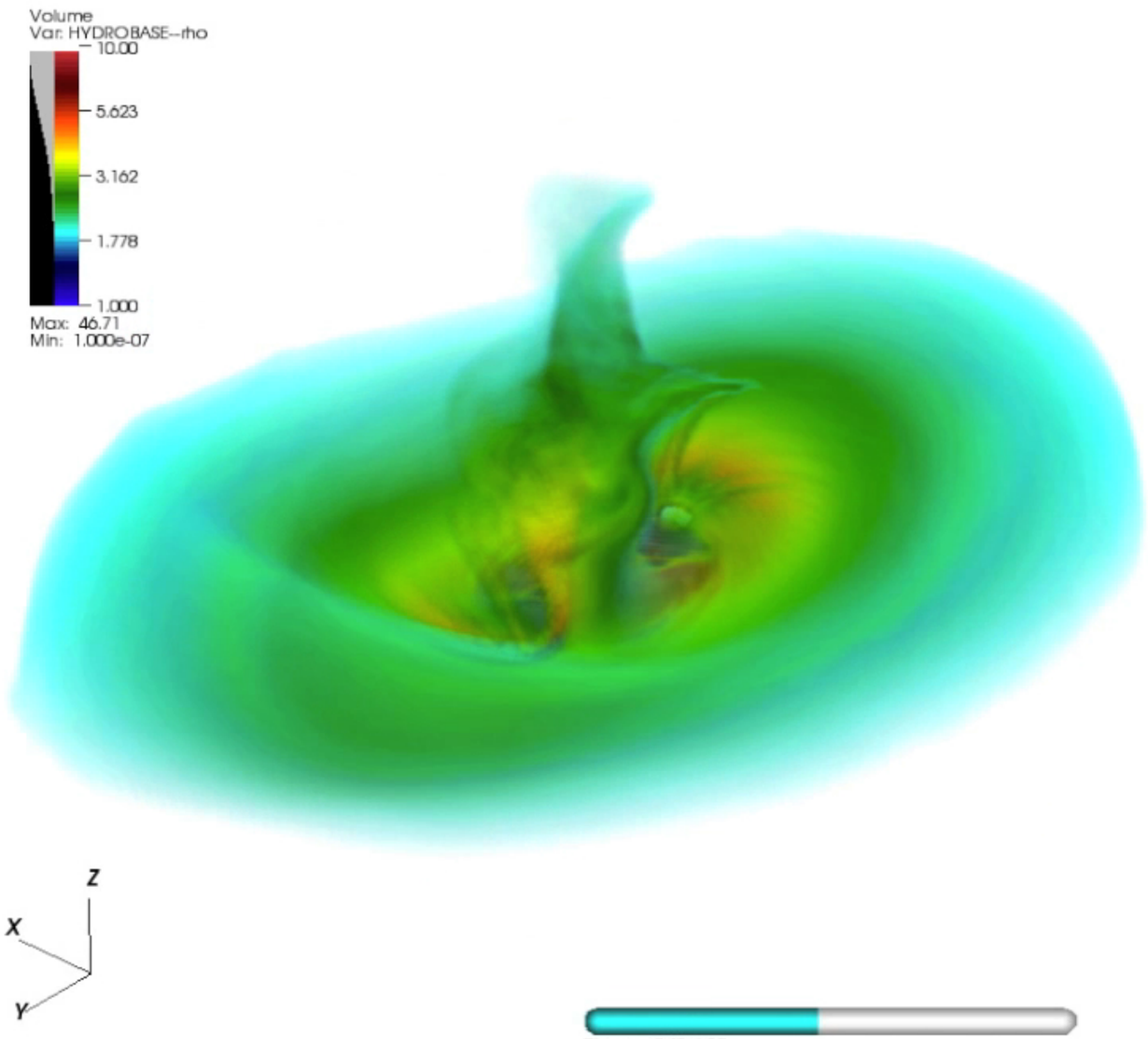


Paschalidis et al 2013

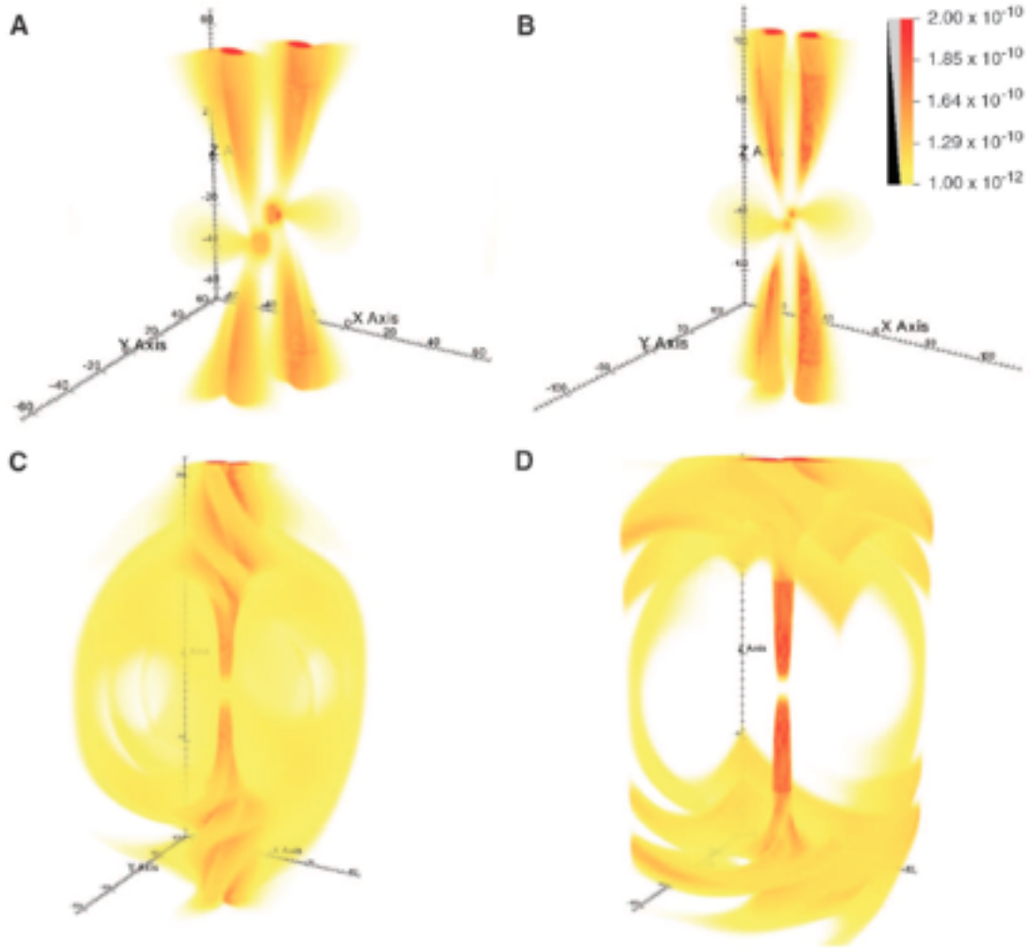
Force Free simulations of NS-BH mergers show also 1e43 erg/s emission (but for larger fields, ~1e13G)
Emission within ~60° from orbital plane (possible lighthouse effect)

BH-BH EM counterparts?

Supermassive BH-BH? Yes!



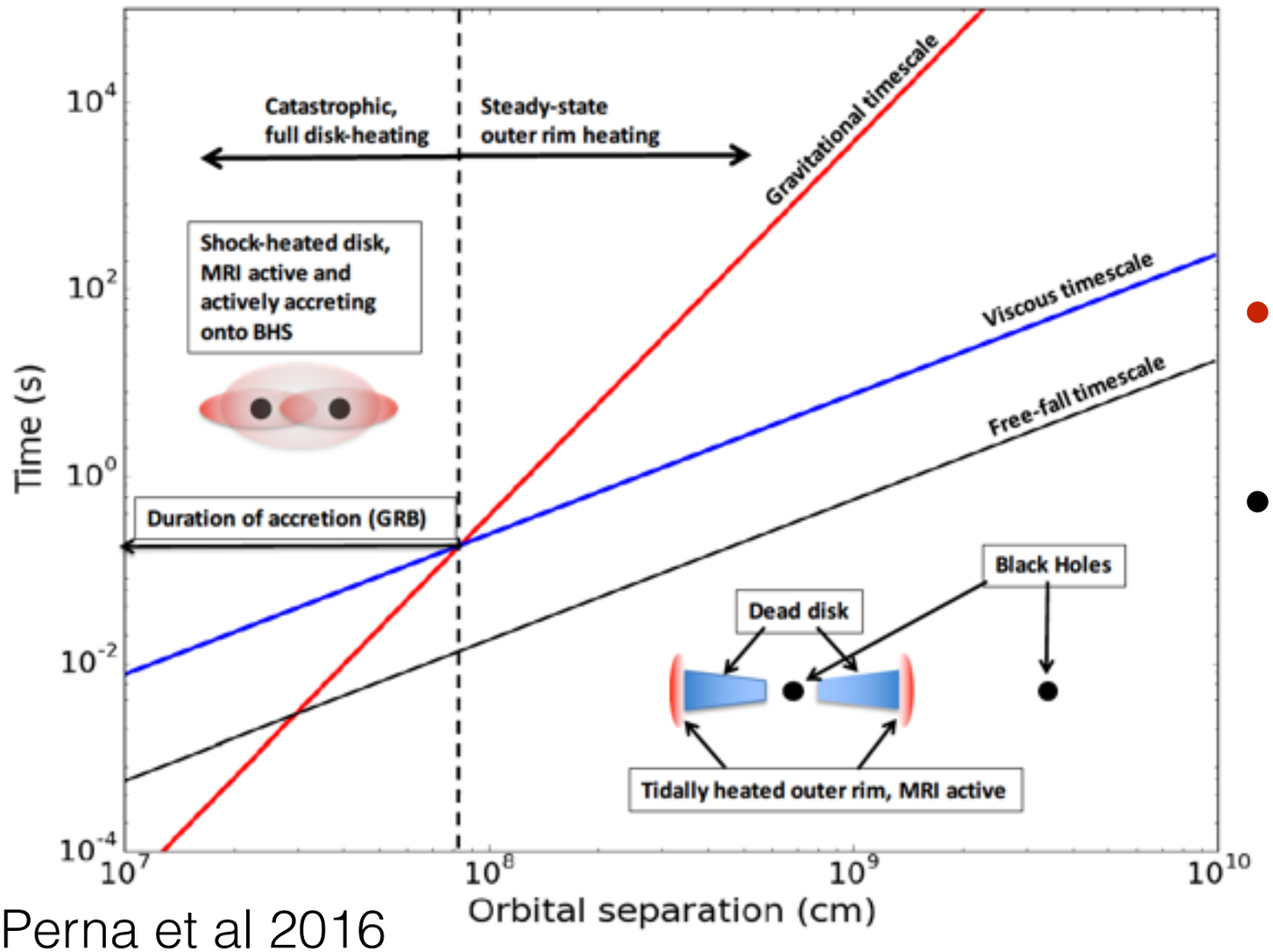
Giacomazzo et al 2012



Palenzuela et al 2010, Science 329, 927

For a recent review see Schnittman 2013: http://arxiv.org/abs/1307.3542

Solar Mass BH-BH? maybe?



Perna et al 2016

- Fermi GBM detected gamma-ray emission after GW150914 ($L \sim 10^{49}$ erg/s)
- No other EM detection by other satellites
- Solar mass BH-BH were not expected to have disks at merger, but necessary to explain EM counterpart

Conclusions

- NS-NS merger offer a very rich phenomenology with several possible EM counterparts

- NS-BH may also produce bright EM counterparts, but only if NS is disrupted before merger

- NS-NS and NS-BH EM counterparts are strongly connected with GW signal (e.g., NS EOS)

- BH-BH mergers: EM emission strongly debated in case of Virgo-LIGO sources (no problem for eLISA)