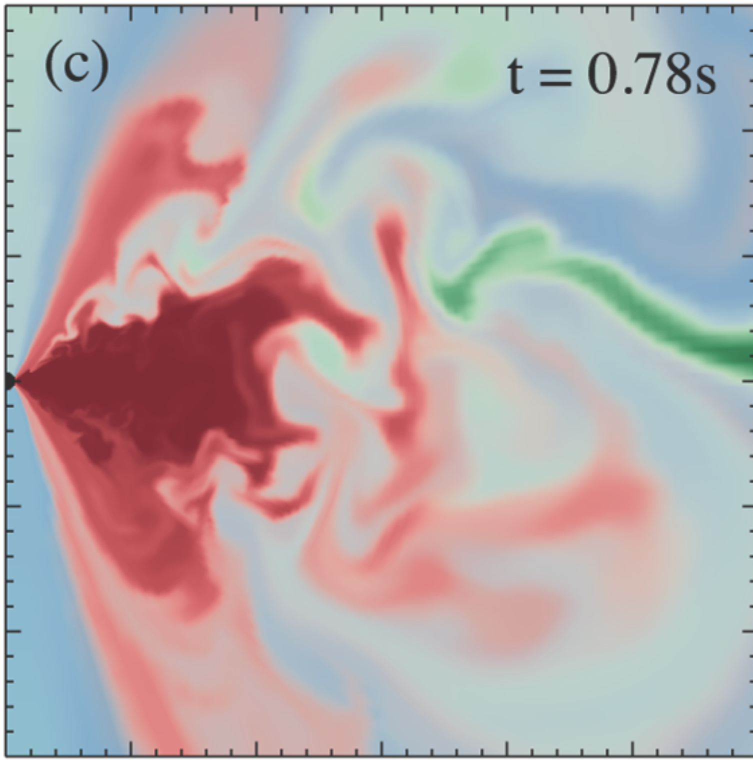
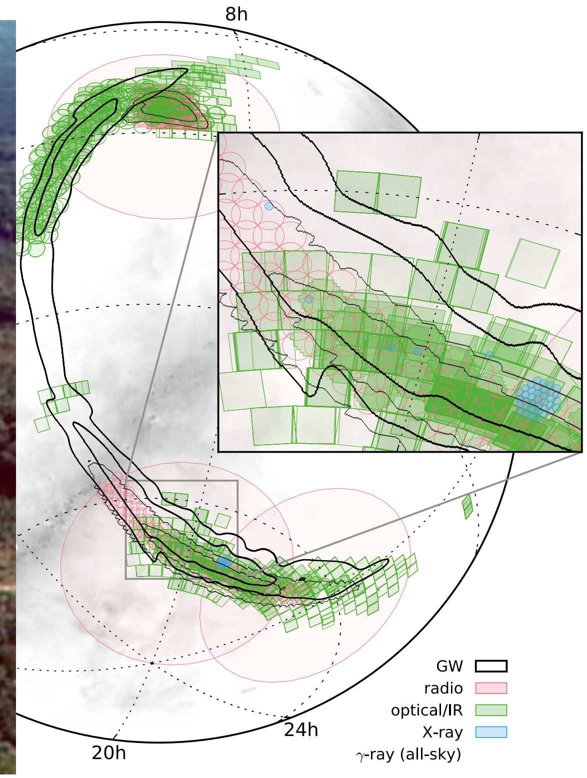


Outflows from NS merger remnant accretion disks

Rodrigo Fernández (University of Alberta)

Overview

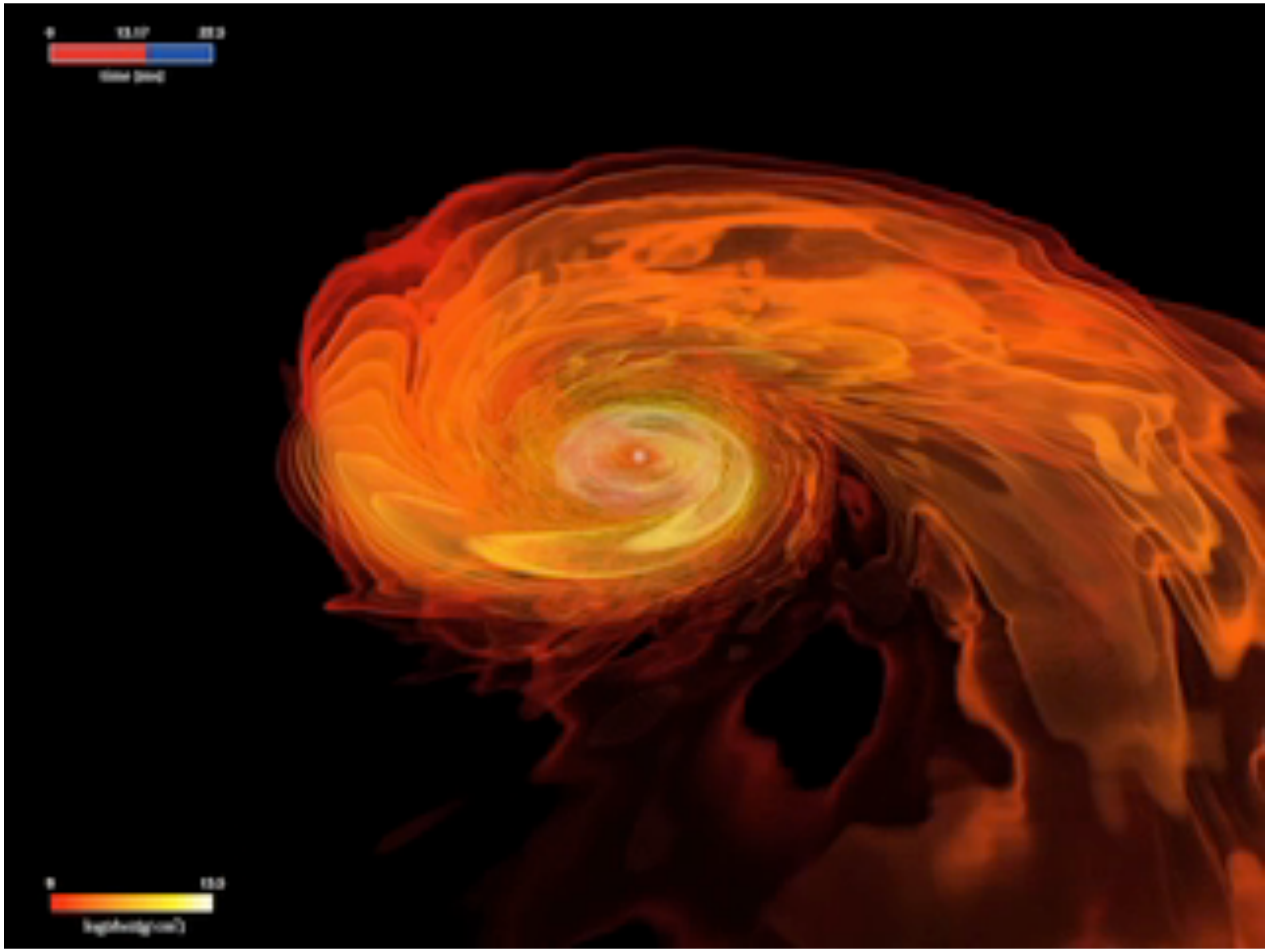
1. Overview of disk evolution

2. Nucleosynthesis and Kilonova contribution

3. Current Status of disk outflow research

Dynamical Phase: Merger

Unequal mass NS-NS merger:



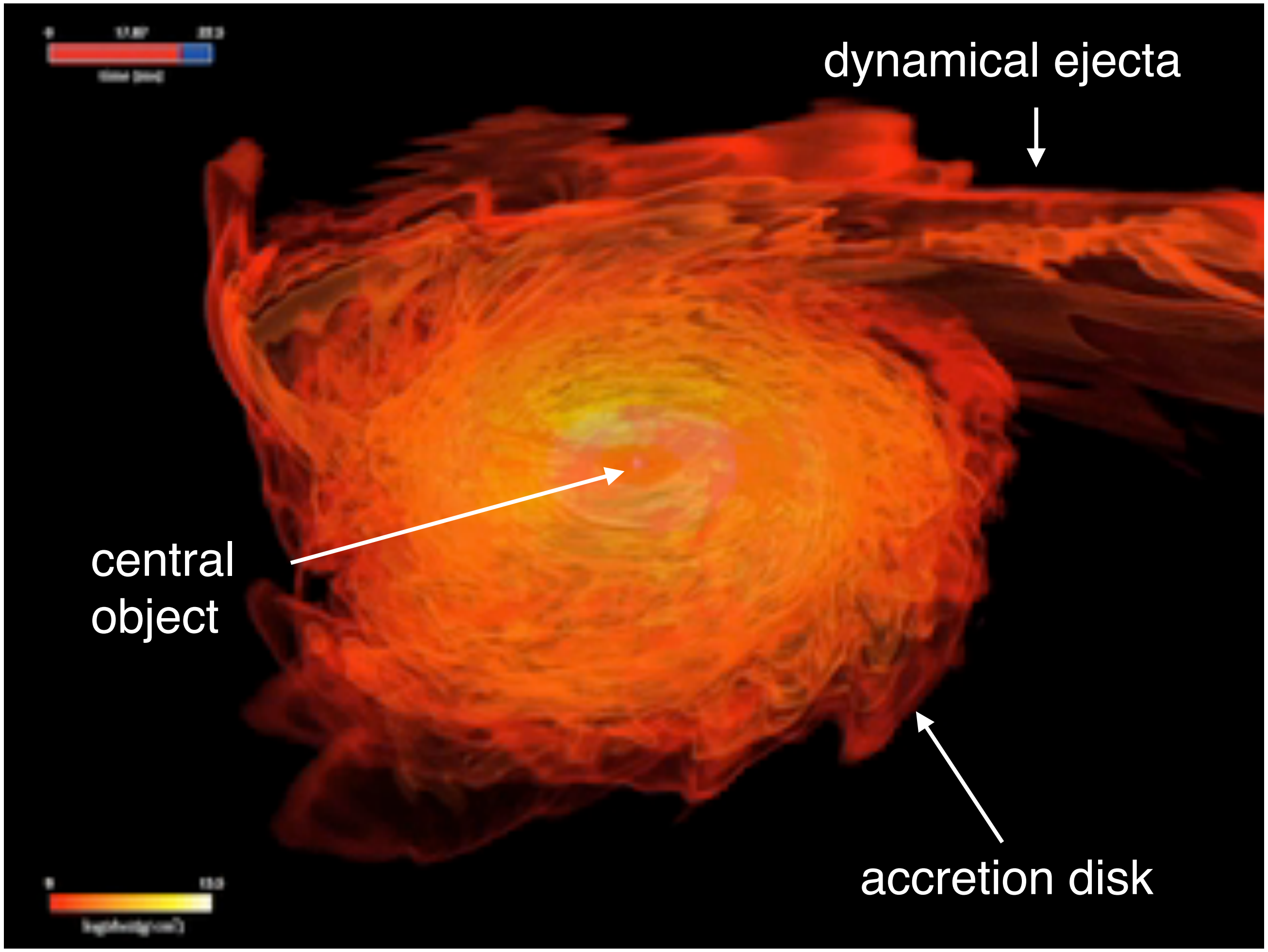
Rezzolla+ (2010)

Phases:

- inspiral
- merger
- remnant + ejecta

Dynamical Phase: Merger

Unequal mass NS-NS merger:



Rezzolla+ (2010)

Phases:

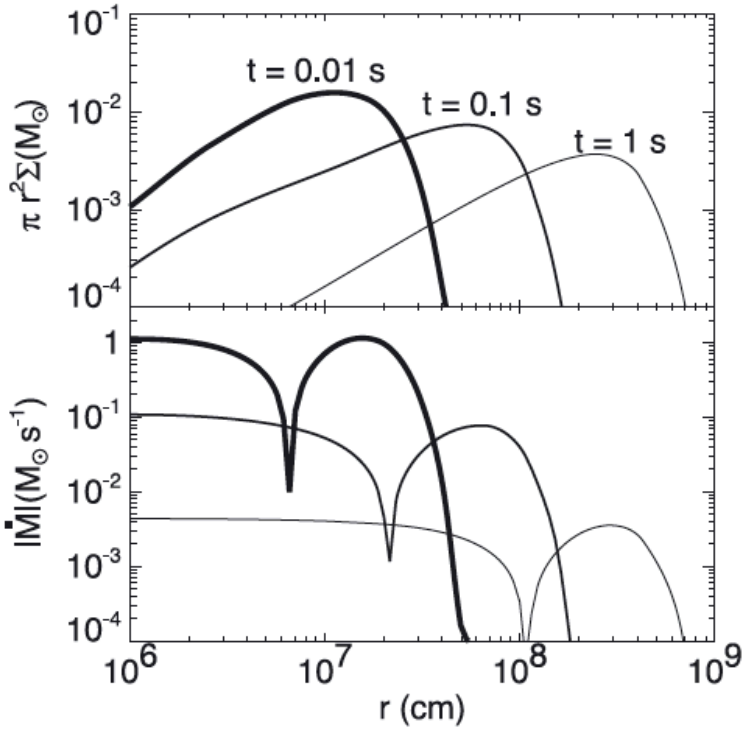
- inspiral
- merger
- remnant + ejecta
- relativistic jet (?)

Large body of work:

MPA, Kyoto, Caltech-Cornell-CITA
Princeton, Frankfurt, Trento,
Stockholm, Illinois, Perimeter, etc.

Disk evolution

Evolution of surface density and accretion rate



Metzger+ (2008)

also Popham+ (1999), Chen & Beloborodov (2003)

$$t_{\rm orb} \simeq 3 R_{50}^{3/2} M_3^{-1/2} \ {\rm ms}$$

$$t_{\rm visc} \simeq 1 \alpha_{0.03}^{-1} R_{50}^{3/2} M_3^{-1/2} \, (H/3R) \ {\rm s}$$

$$t_{\rm therm} \simeq \frac{c_s^2}{v_K^2} t_{\rm visc} \lesssim t_{\rm visc}$$

- Disk evolves on timescales long compared to the dynamical (orbital) time, due to viscous processes

- Weak interactions freeze-out as the disk spreads viscously: final Ye

- Gravitationally-unbound outflows driven by:

  - Neutrino heating (on thermal time)

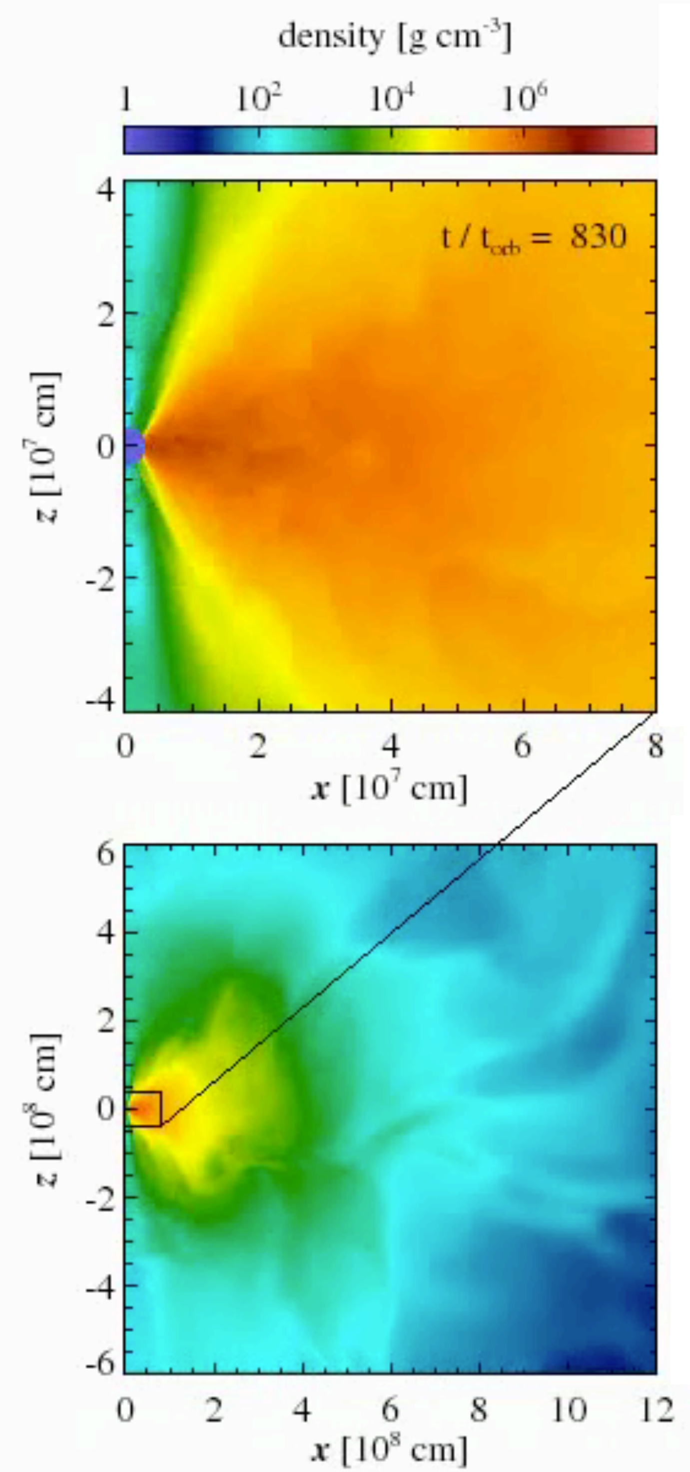
    Ruffert & Janka (1999), Dessart+ (2009)

  - Viscous heating and nuclear recombination (on viscous time)

$$\frac{E_\alpha}{G M_{\rm BH}/R} \simeq 1 R_{600} M_3^{-1}$$ Metzger+ (2008)

  - MHD stresses

    Kiuchi (2015), Siegel (2017)



Wind from remnant accretion disk

- Neutrino cooling shuts down as disk spreads on accretion timescale (~300ms)
- Viscous heating & nuclear recombination are unbalanced
- Fraction ~10-20% of initial disk mass ejected, ~1E-3 to 1E-2 solar masses
- Material is neutron-rich (Ye ~ 0.2-0.4)
- Wind speed (~0.05c) is slower than dynamical ejecta (~0.1-0.3c)

RF & Metzger (2013), MNRAS

Just et al. (2015), MNRAS

RF et al. (2015), MNRAS

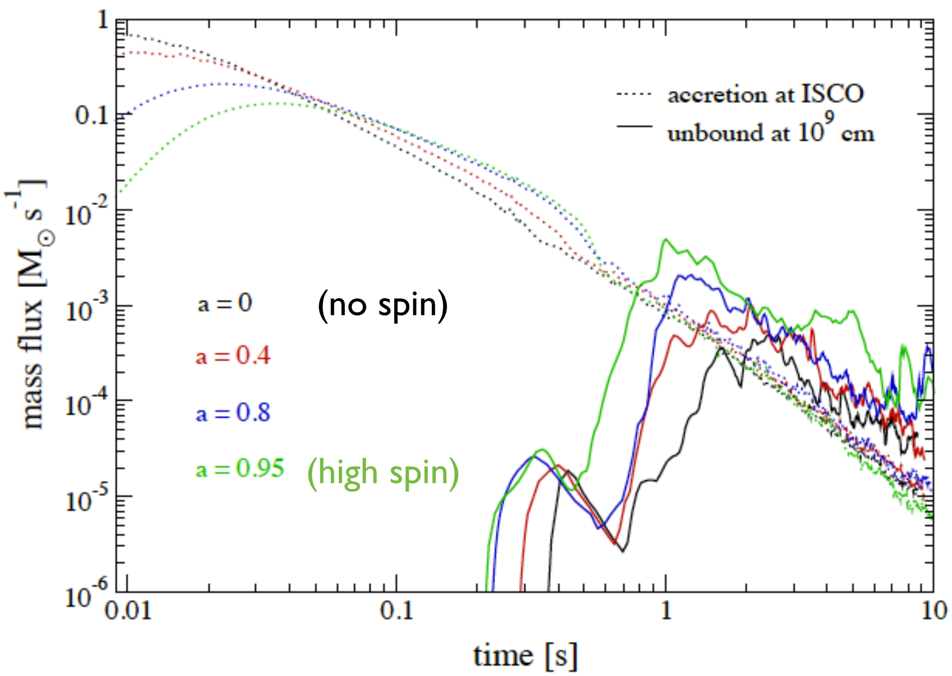
Setiawan et al. (2005)

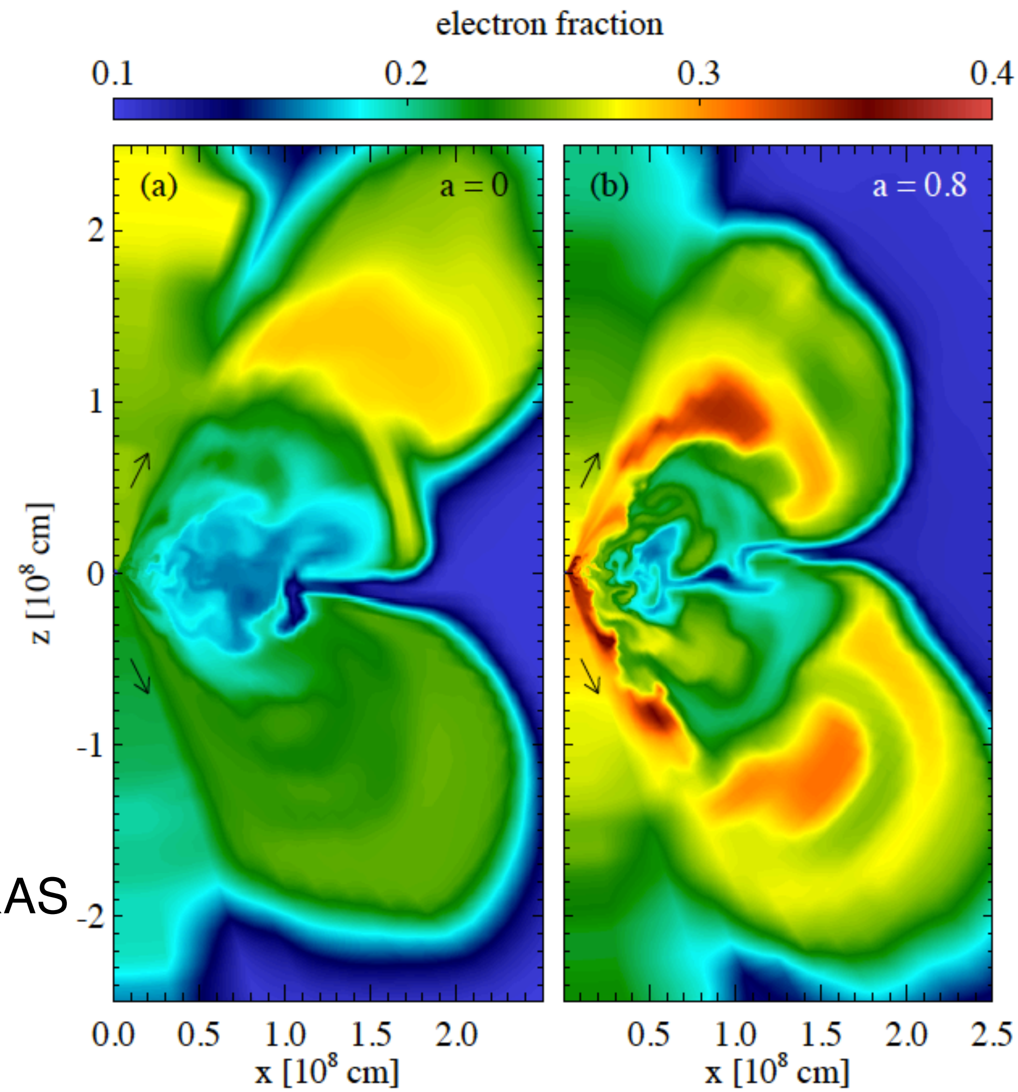
Lee, Ramirez-Ruiz, & Lopez-Camara (2009)

Metzger (2009)

Effect of BH spin on disk wind

Mass ejection as a function of time (solid lines):

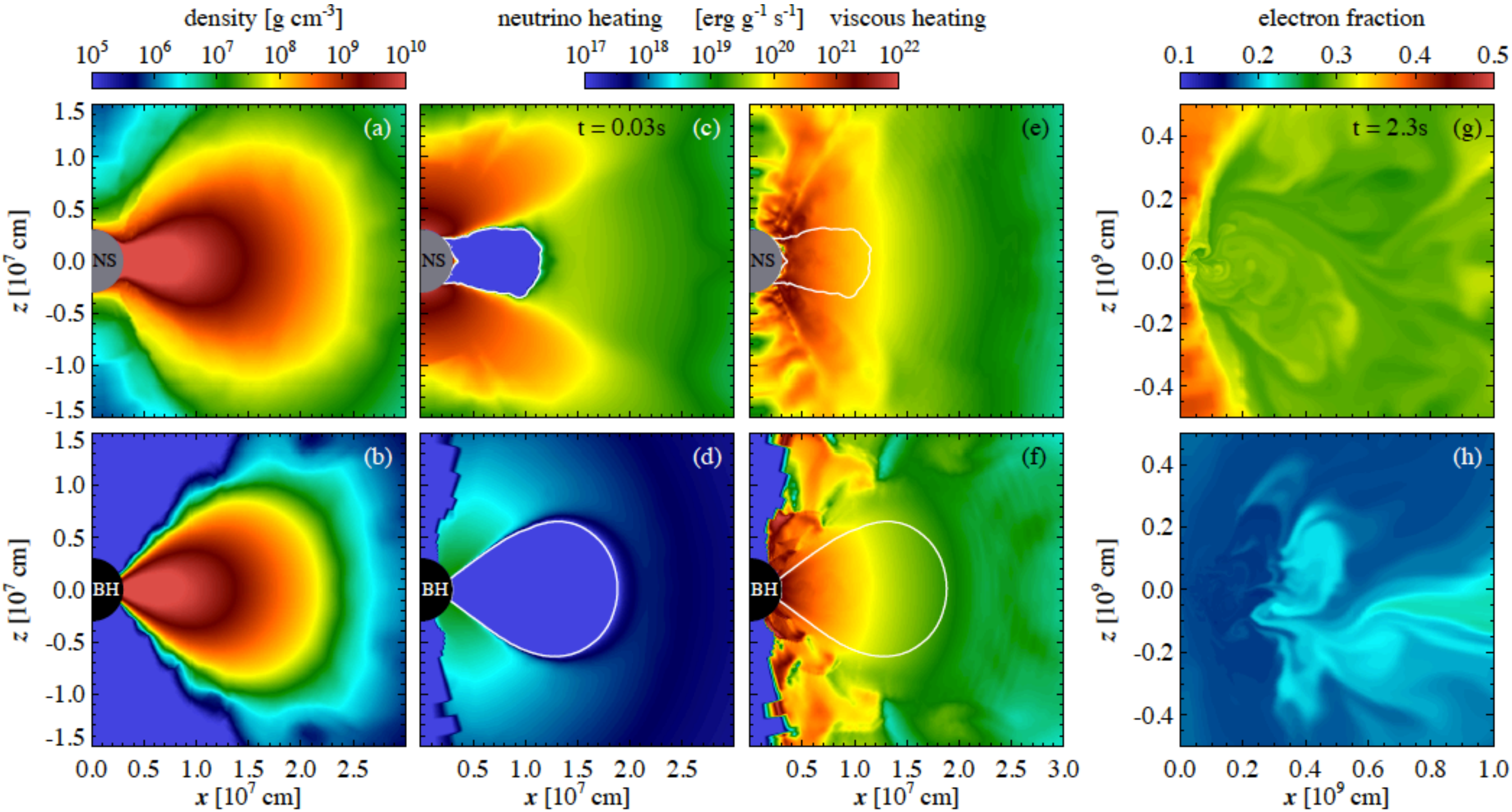




RF, Kasen, Metzger, Quataert (2015), MNRAS

(see also Just et al. 2015)

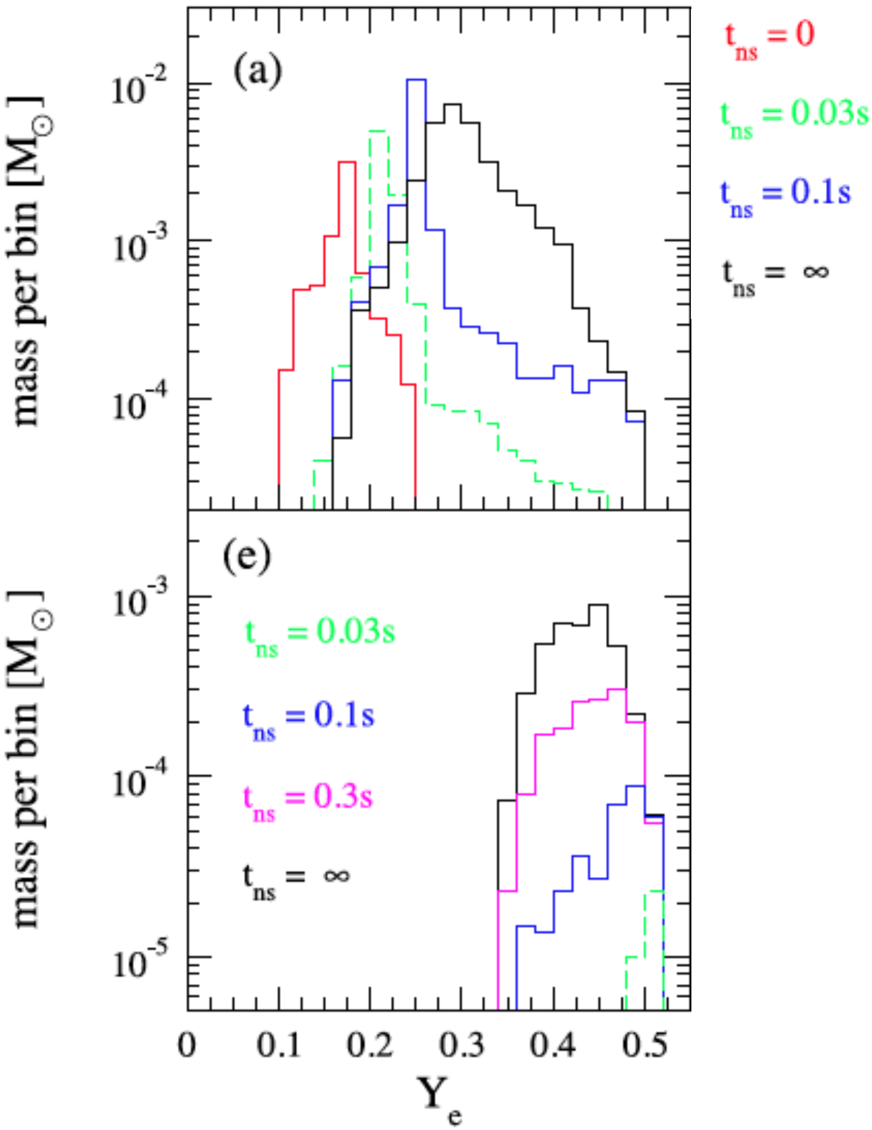
Hypermassive NS versus BH

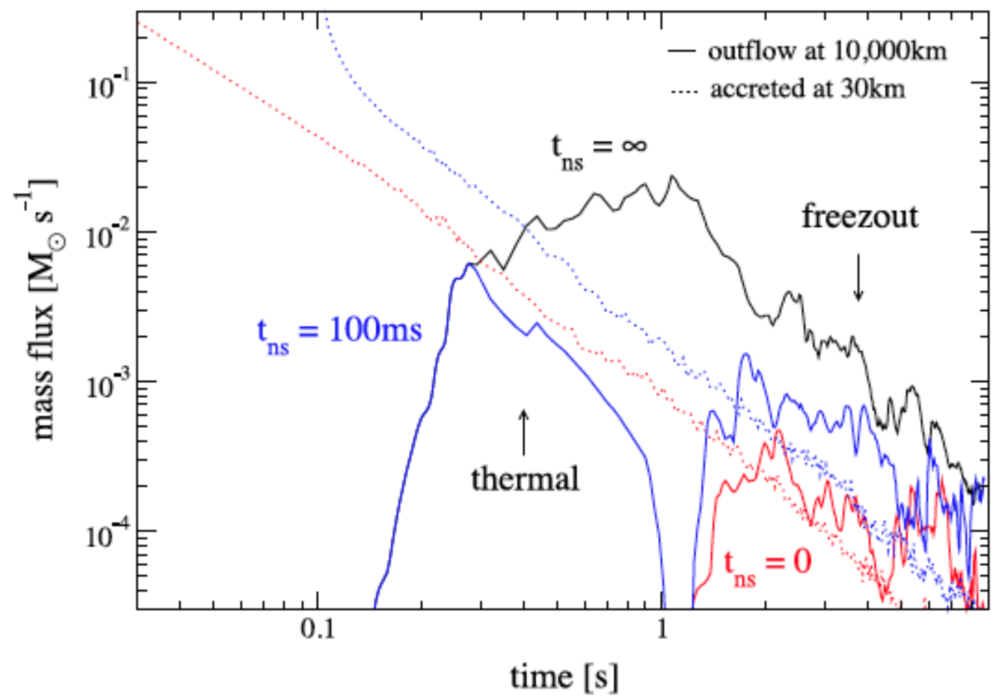


See also: Dessart+ (2009) Martin+ (2015)
Perego+ (2014) Fujibayashi+ (2017a,b)

Metzger & RF (2014)

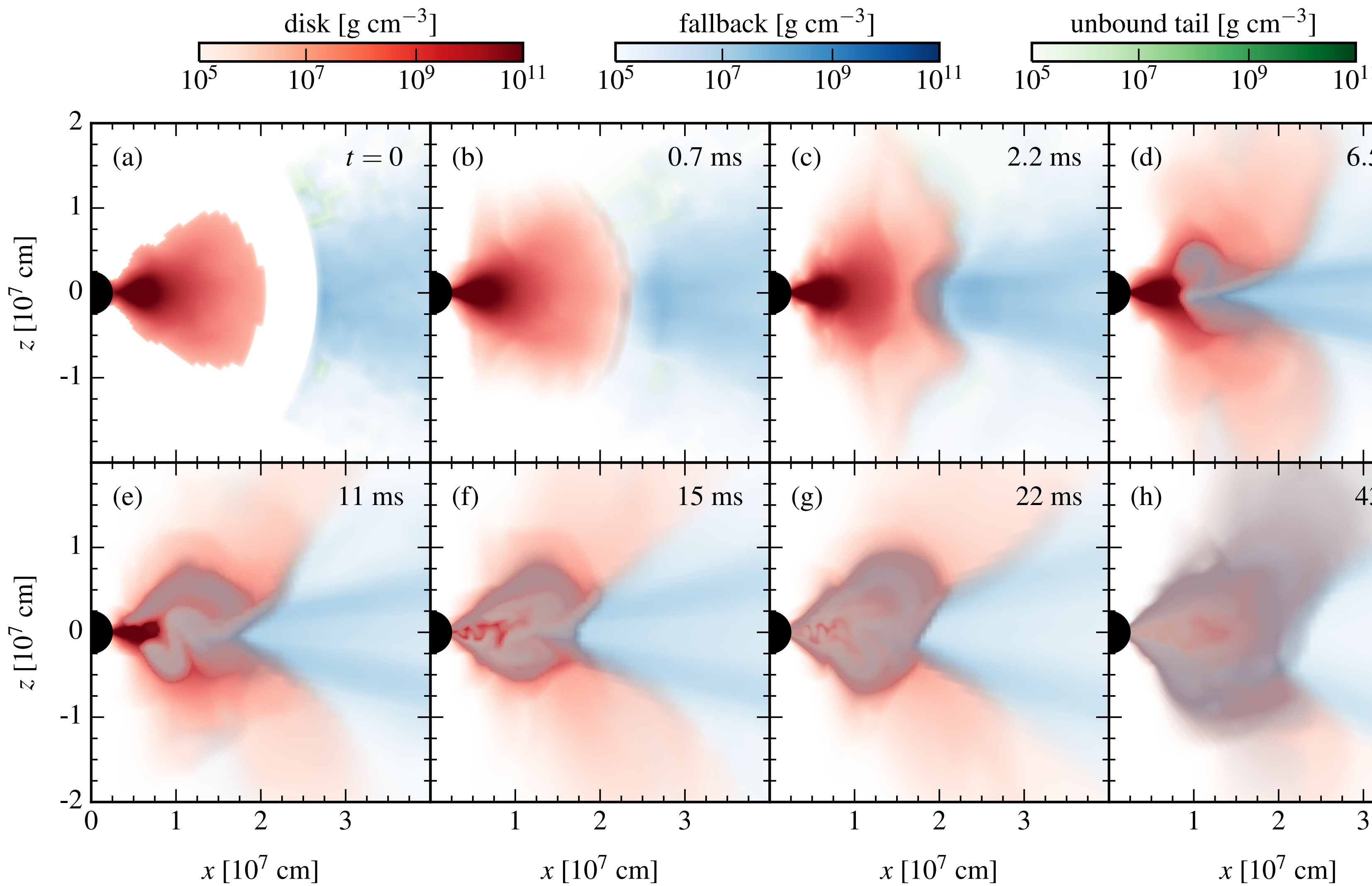
Disk around HMNS





Metzger & RF (2014)

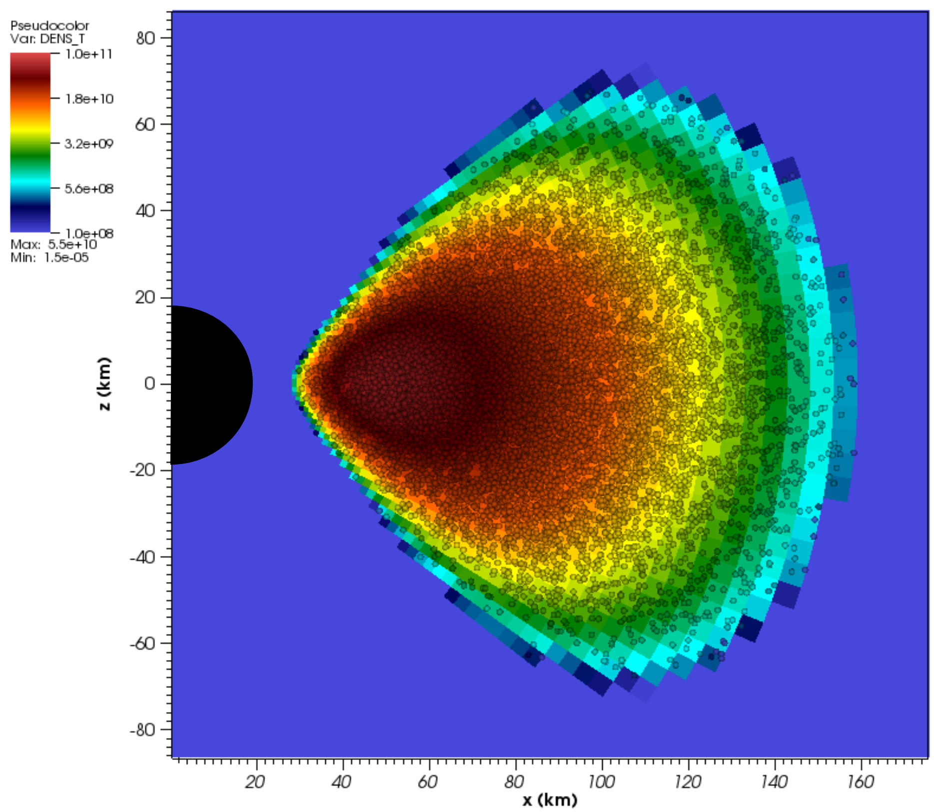
Interplay of disk wind and dynamical ejecta



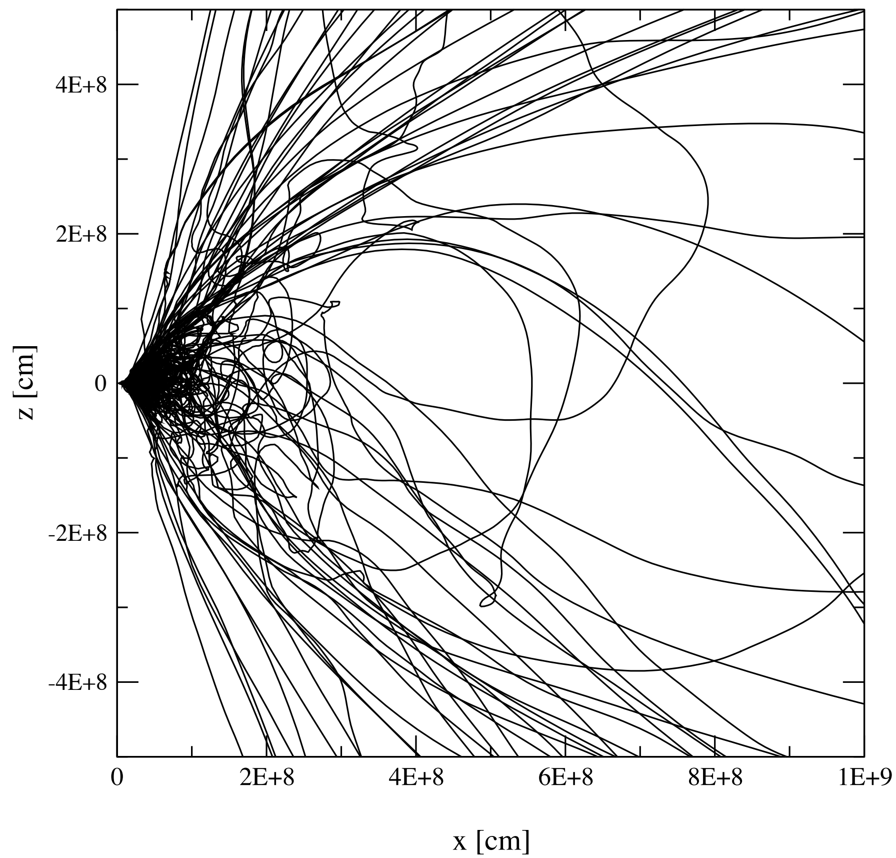
RF, Foucart, Kasen, Lippuner, et al. (2017)

Nucleosynthesis with Tracer Particles

Passive tracers follow density distribution



Disk is convective

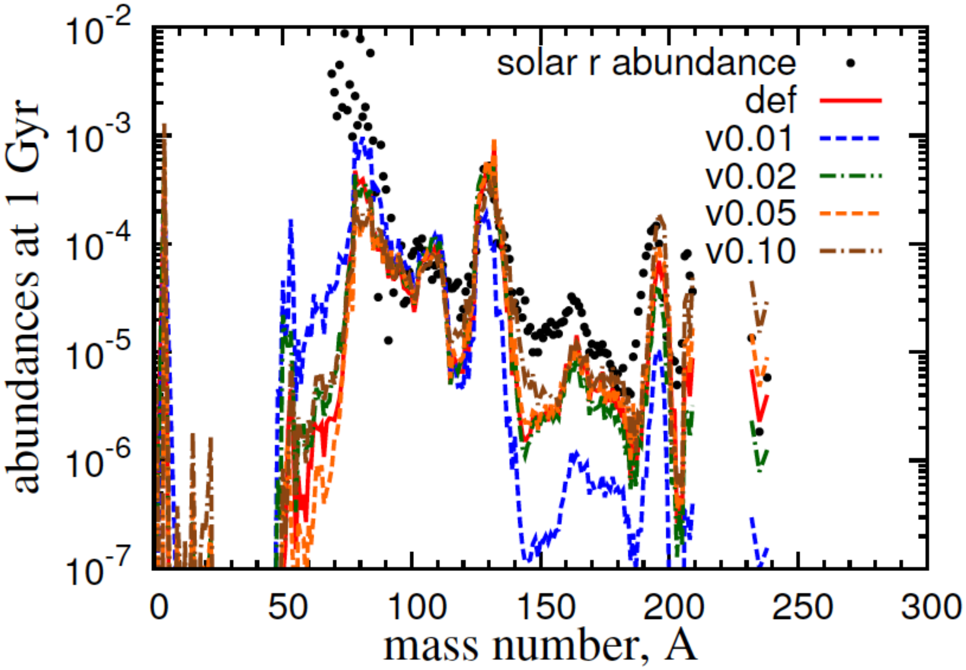


M-R Wu, RF, Martinez-Pinedo & Metzger (2016)

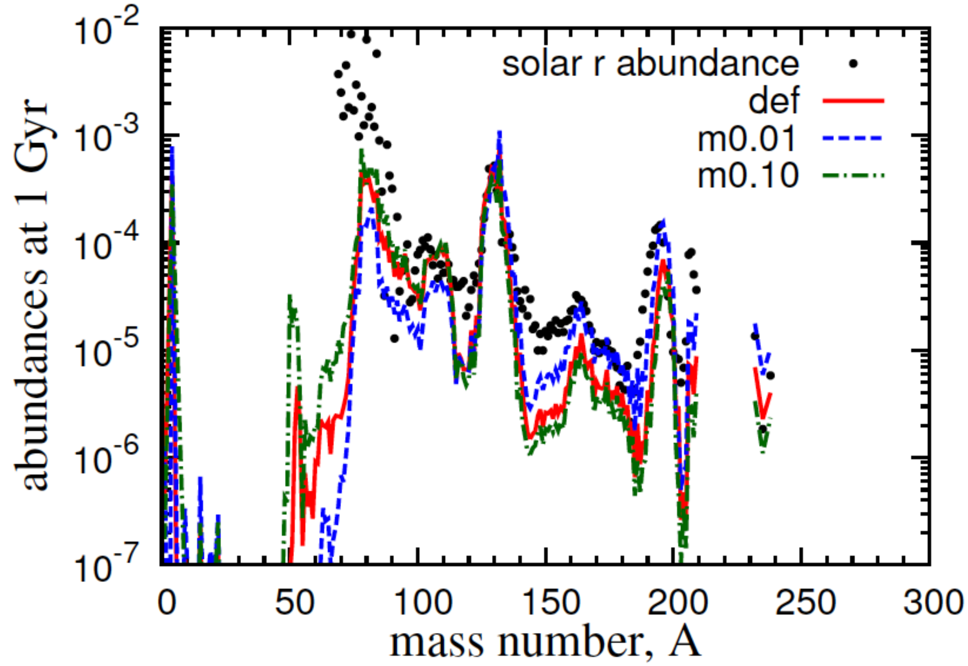
- Nuclear network: ~7000 isotopes, include neutrino effects
- Non-spinning BH, parameter dependencies

Black Hole Accretion Disks

Varying disk viscosity:



Varying disk mass:



M-R Wu, RF, Martinez-Pinedo & Metzger (2016)

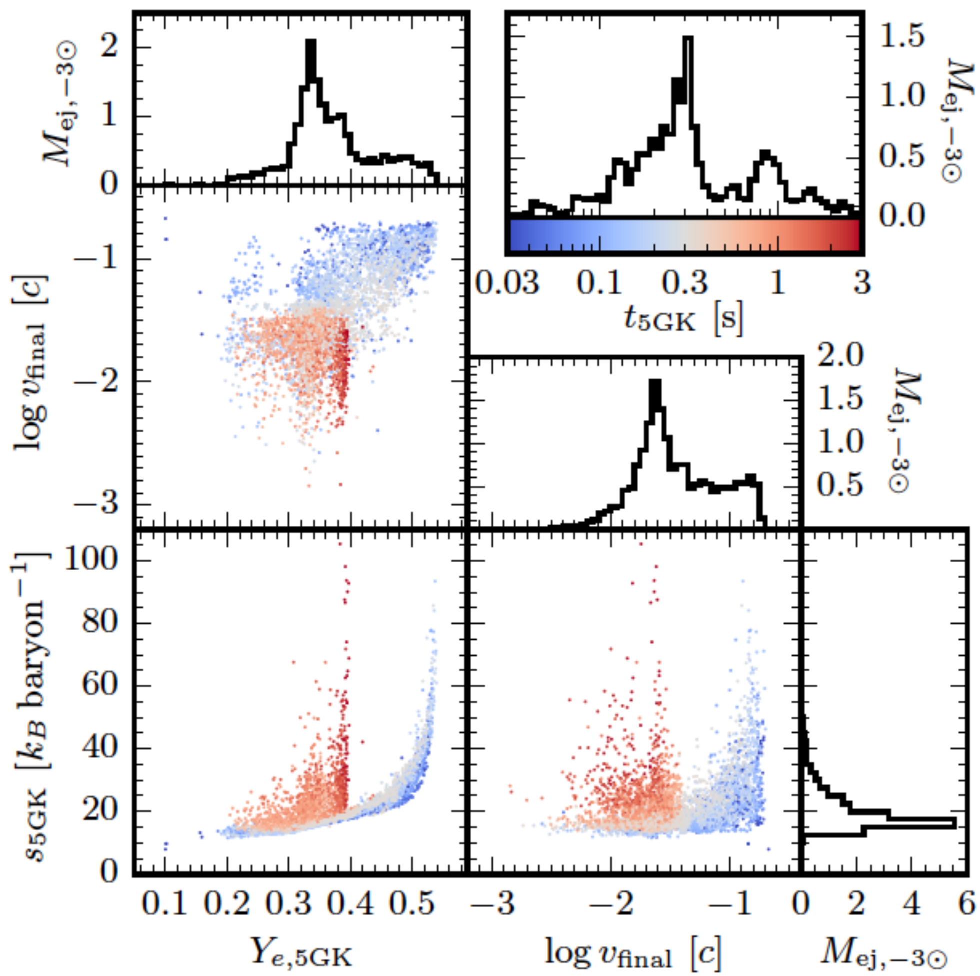
- Most sensitive to viscosity: expansion time vs weak interaction time

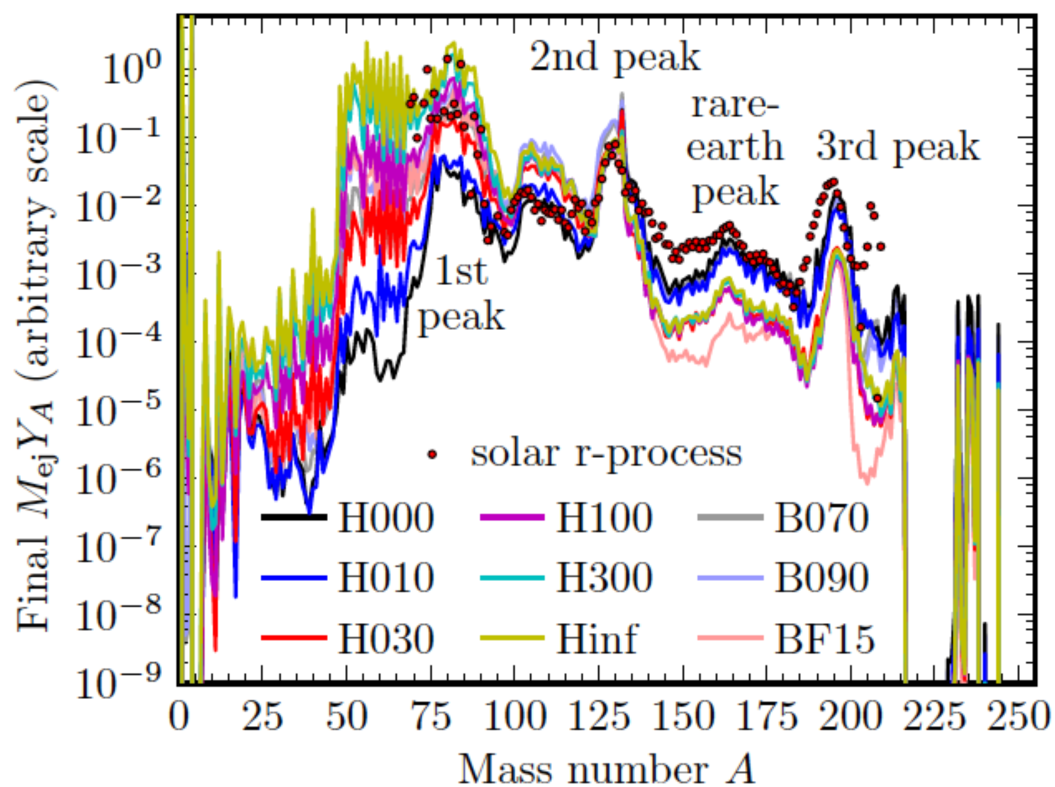
- Also sensitive to disk mass and degeneracy: neutrinos & equilibrium Ye

- Not very sensitive to initial Ye

- See also Just et al. 2015

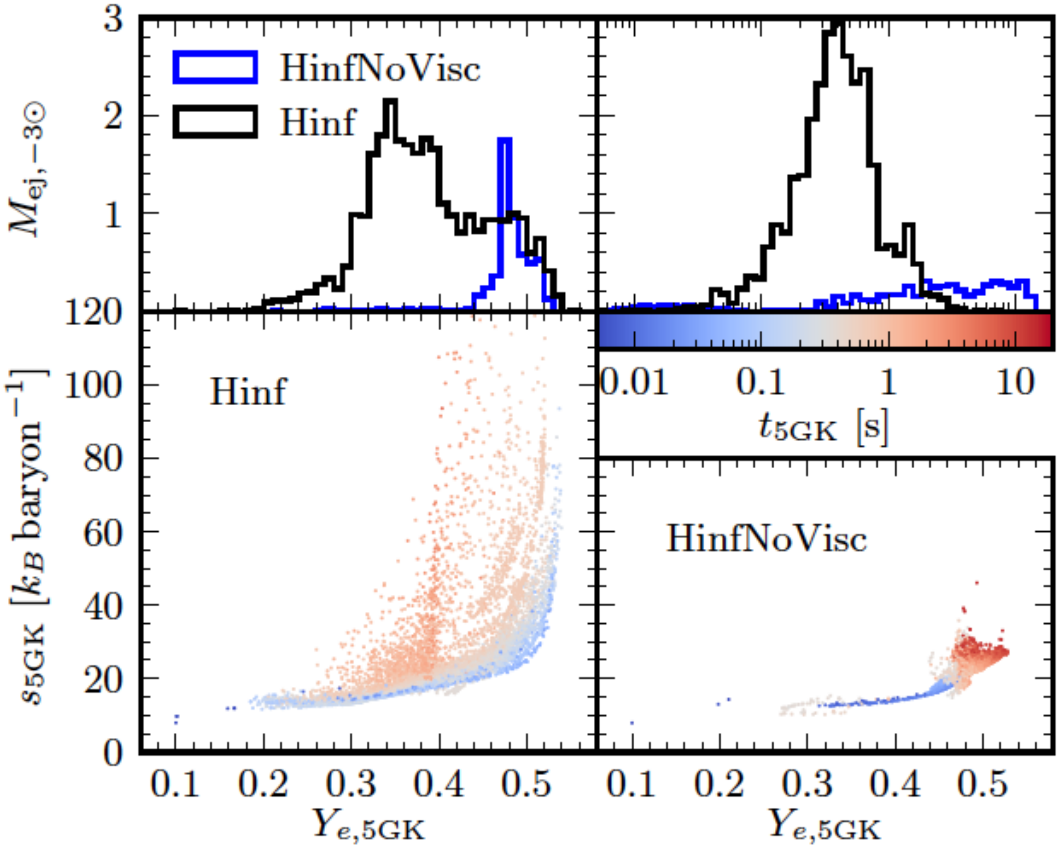
HMNS disks

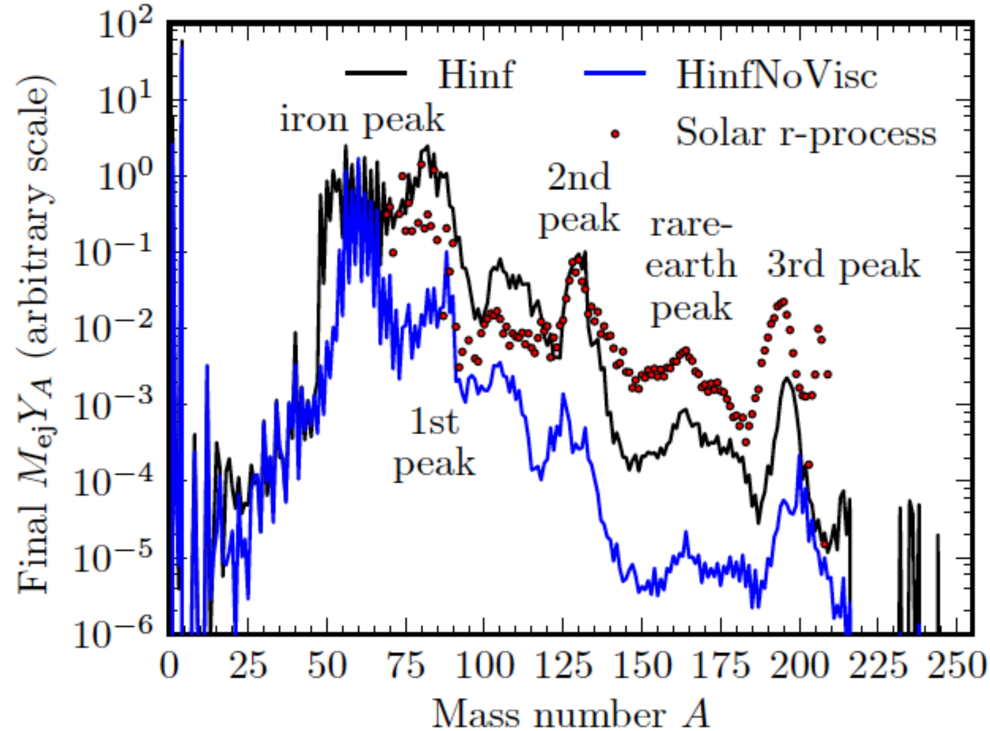




Lippuner, RF, Roberts, et al. (2017)

HMNS disks

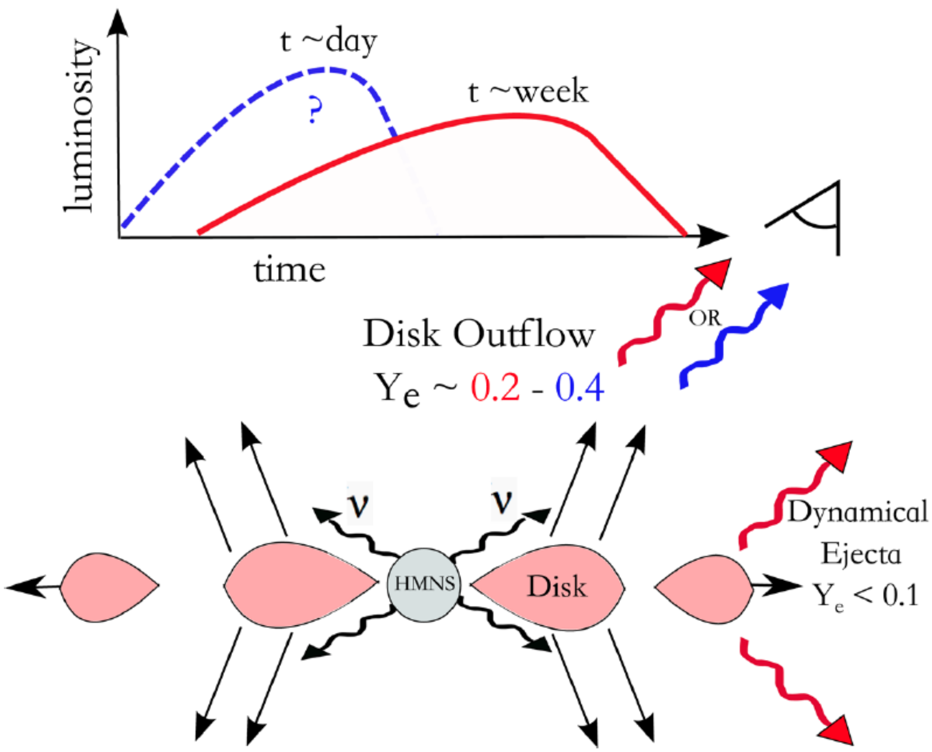




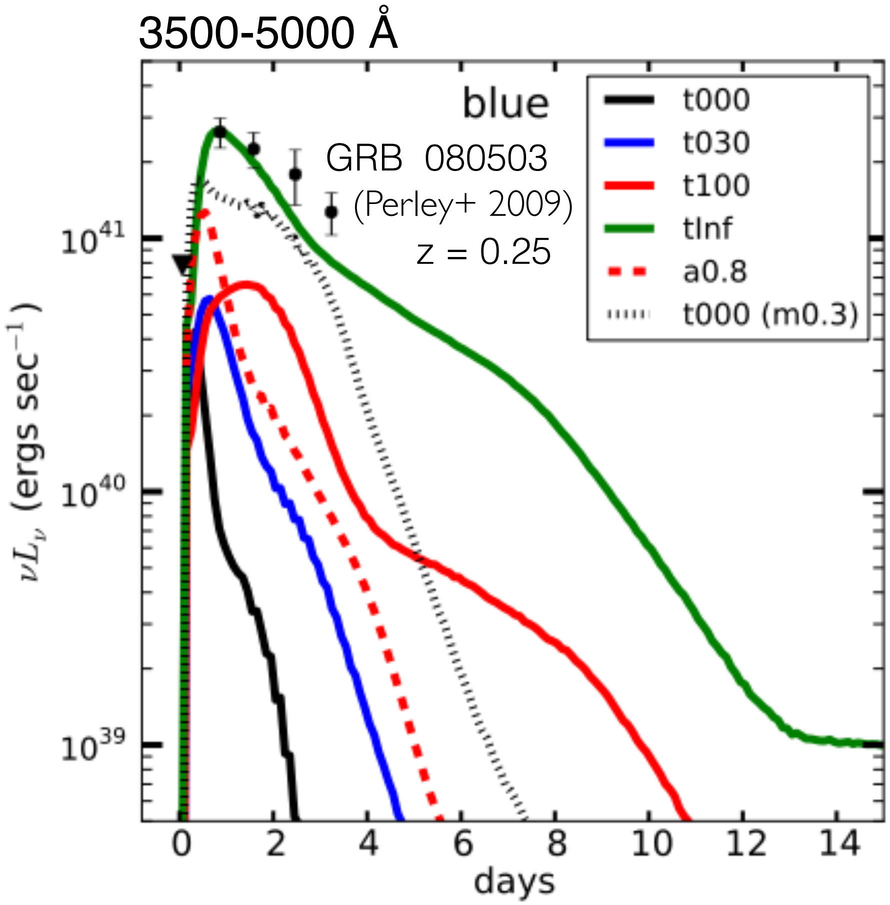
Lippuner, RF, Roberts, et al. (2017)

HMNS lifetime and kilonova

Longer lifetime → more neutrino irradiation → less neutrons → smaller opacity → bluer emission



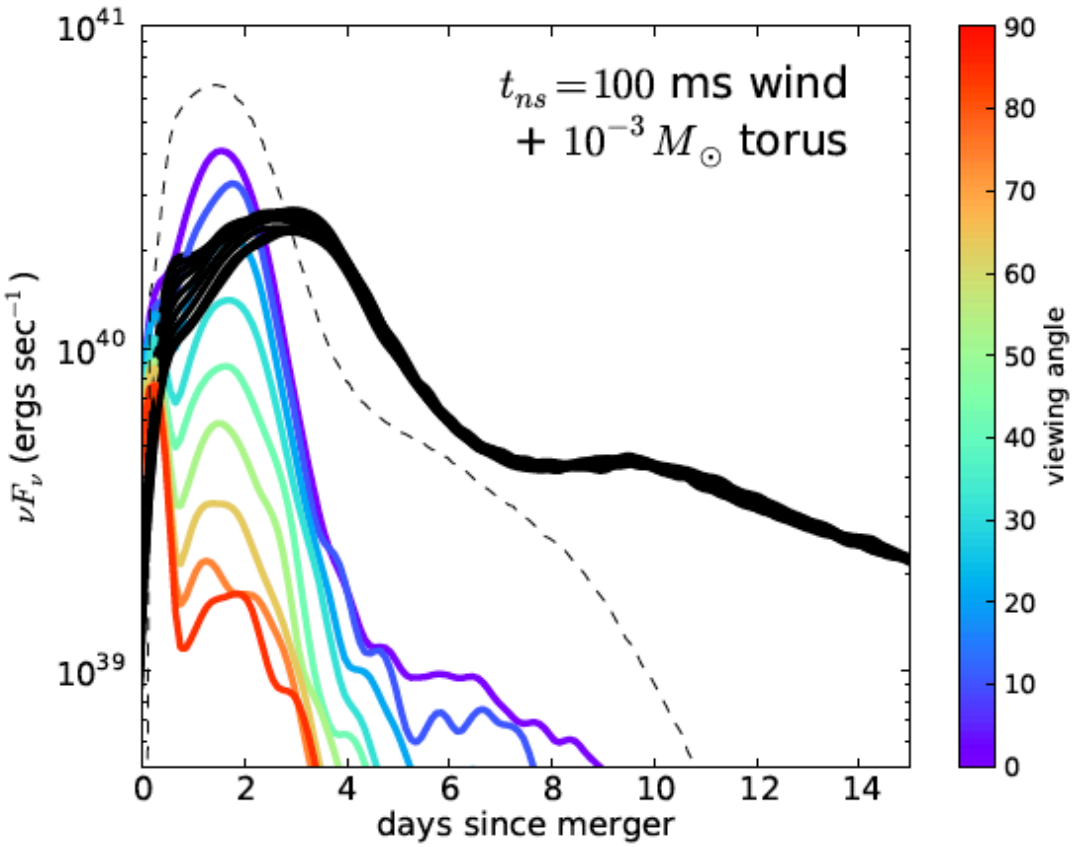
Metzger & RF (2014)



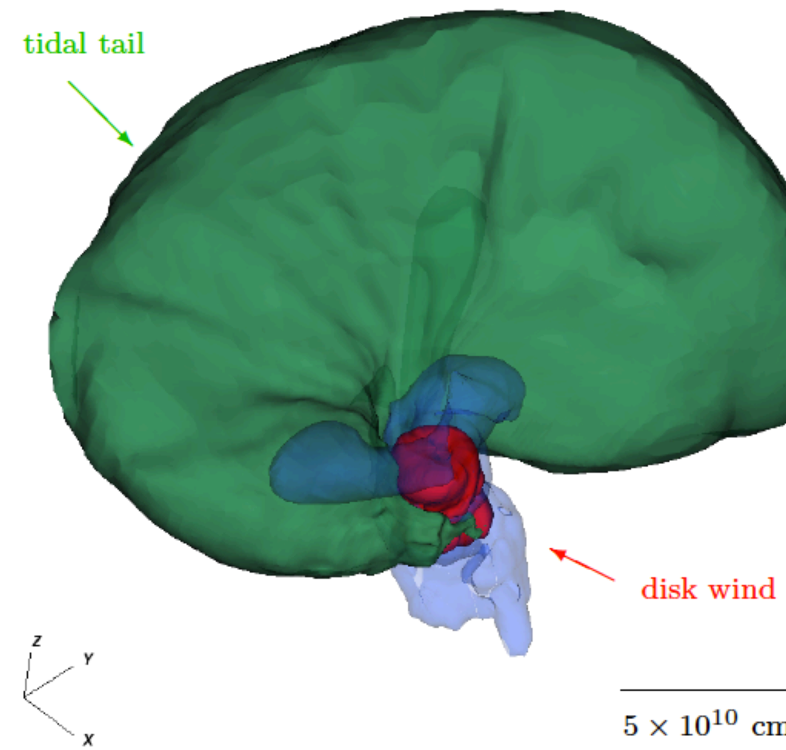
Kasen, RF, & Metzger (2015)

Viewing angle dependence

3500 - 5000 A light curve as fn. of viewing angle



BH-NS merger remnant:



Kasen, RF, & Metzger (2015)

RF, Quataert, Schwab, Kasen & Rosswog (20

Summary

1. A significant amount of material (>10% of initial disk mass) is ejected from the accretion disk on various timescales, for GW170817 it is thought to be the dominant contribution to the kilonova

2. Biggest effect is the presence of a HMNS. Strong neutrino irradiation generates lanthanide-poor outflows: blue kilonova.

3. Outstanding issues: inclusion of MHD, neutrino transport, proper treatment of the HMNS. Can the disk account for the high speed of the blue kilonova ejecta in GW170817?

Thanks to: UNIVERSITY OF ALBERTA NSERC CRSNG NERSC U.S. DEPARTMENT OF ENERGY Office of Science