PennState
Eberly College of Science

CoRe collaboration

Neutron Rich Outflows from NS Mergers and AICs

David Radice – March 26, 2026

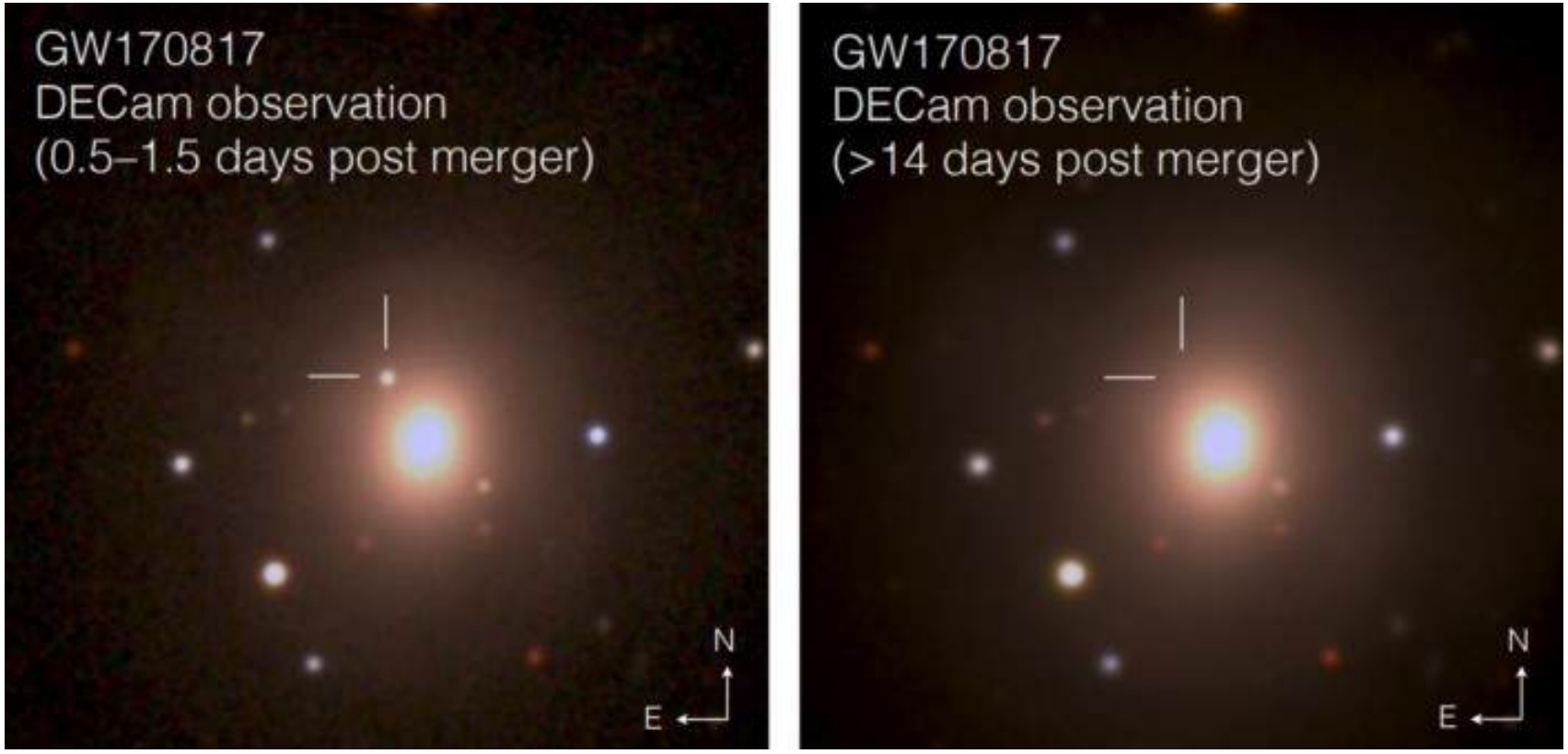
NP3M

N3AS Network for Neutrinos, Nuclear Astrophysics, and Symmetries
PHYSICS FRONTIER CENTER

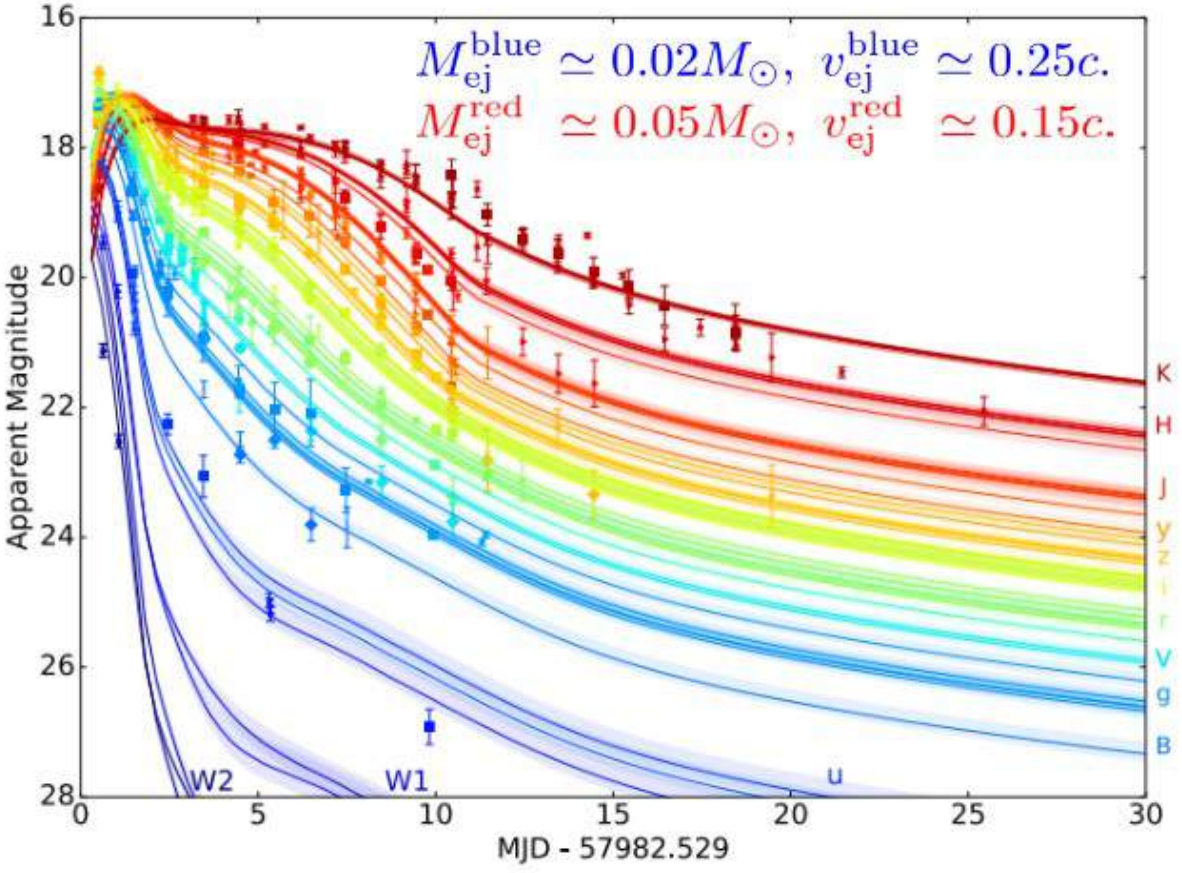
NSF

NASA

R-process in neutron star mergers

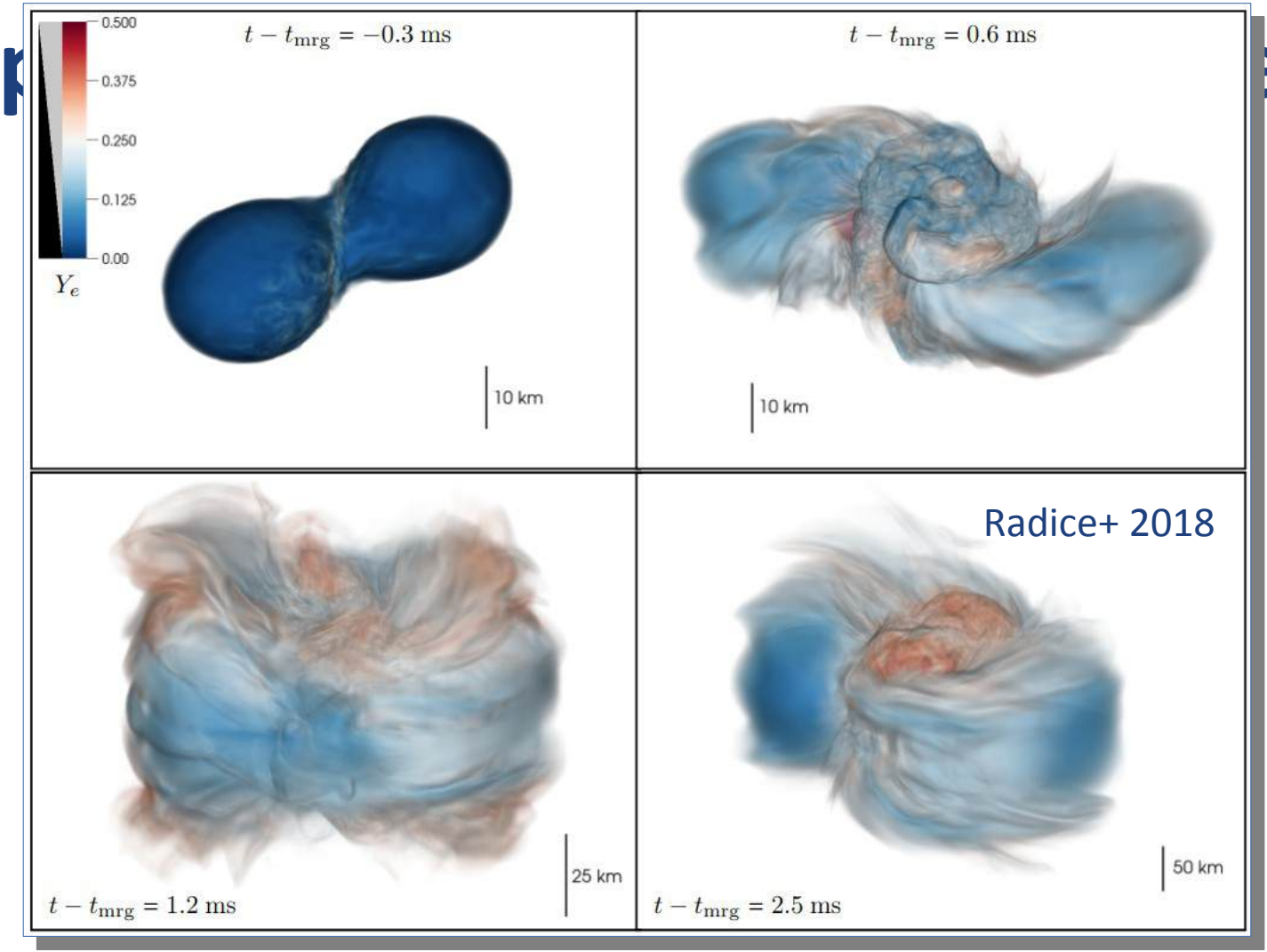


R-process in neutron star mergers



From Villar+ 2017

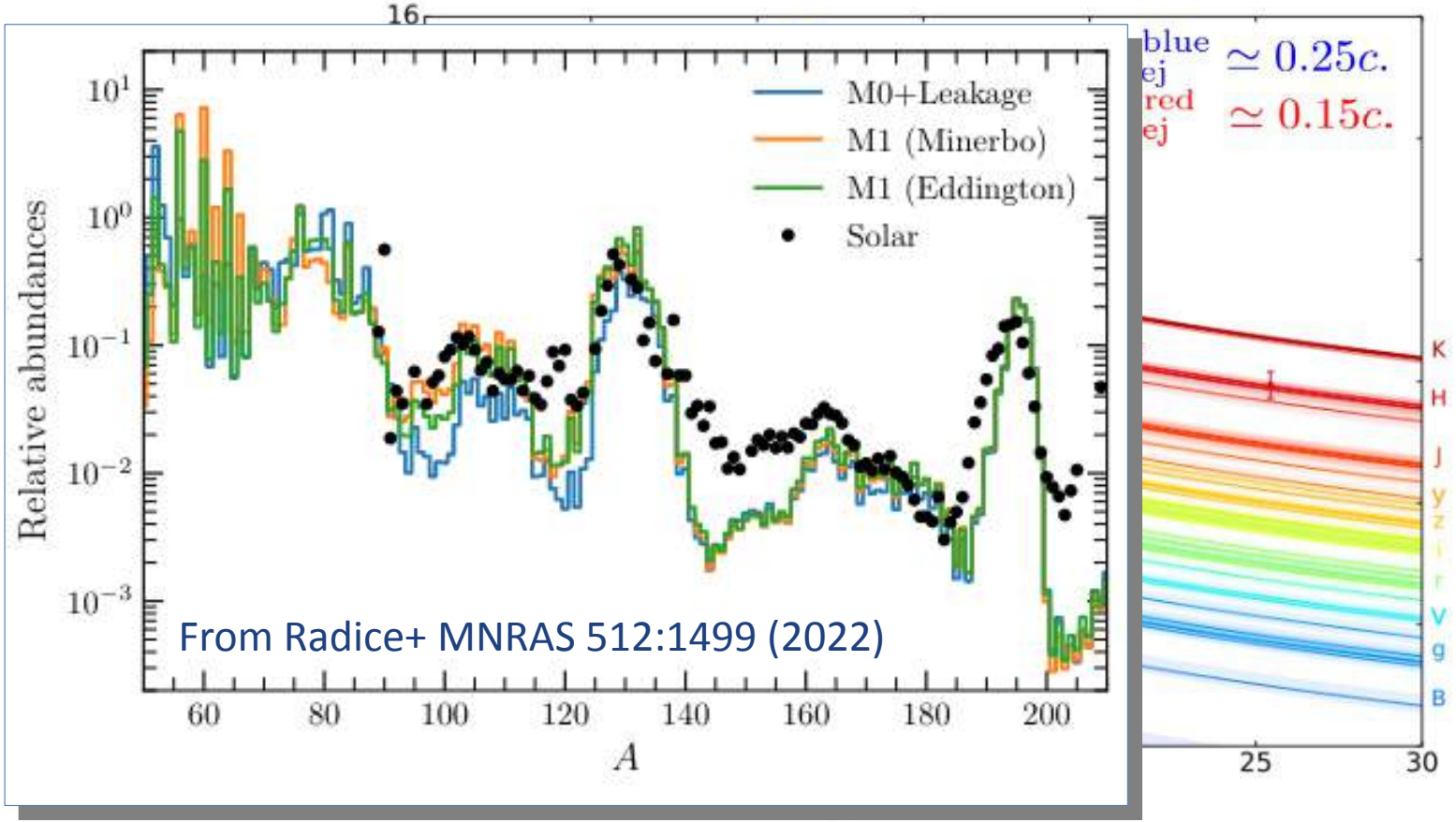
R-p ers



Radice+ 2018

From Villar+ 2017

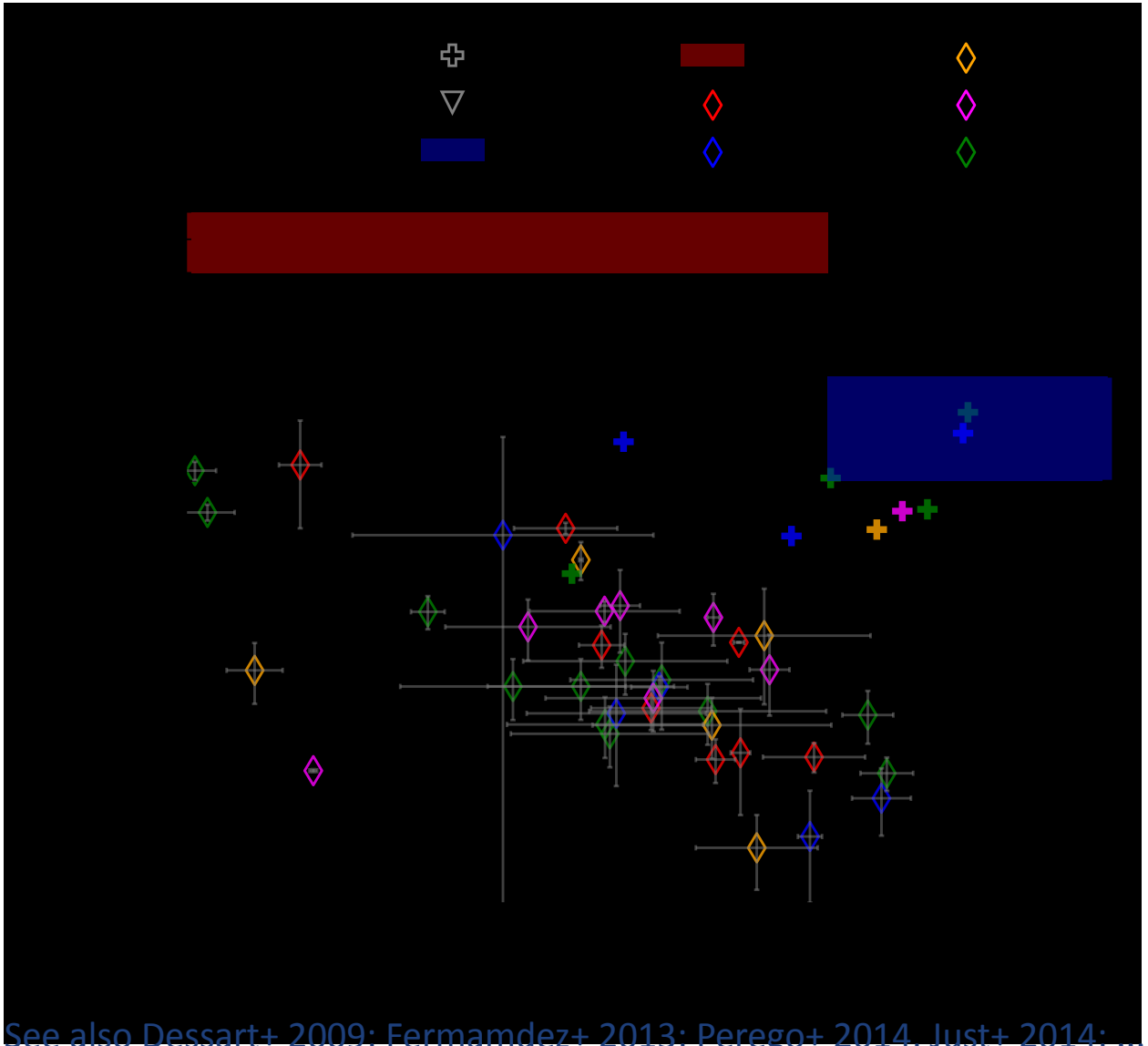
R-process in neutron star mergers



From Villar+ 2017

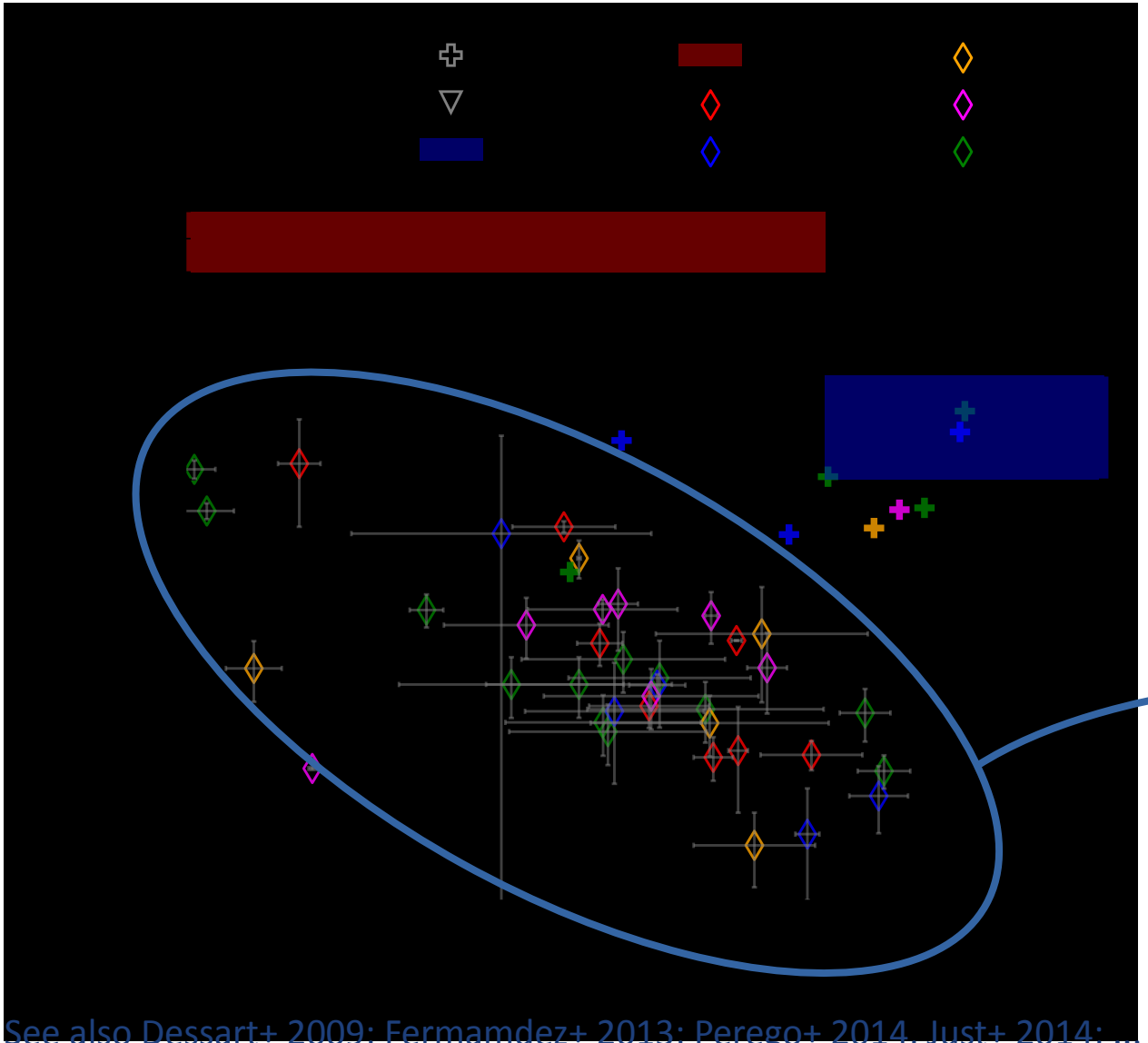
Problem solved?

- NS mergers make r-process elements, but in what quantity and quality? Are they the only source?
- What about low-/high-metallicity trends, dwarf galaxies, ever decreasing LIGO rates (😢), etc.?
- Theory models are incomplete and affected by systematic uncertainties



See also Dessart+ 2009; Fermamdez+ 2013; Perego+ 2014, Just+ 2014; ...

From Nedora+, ApJ 906:98 (2021)



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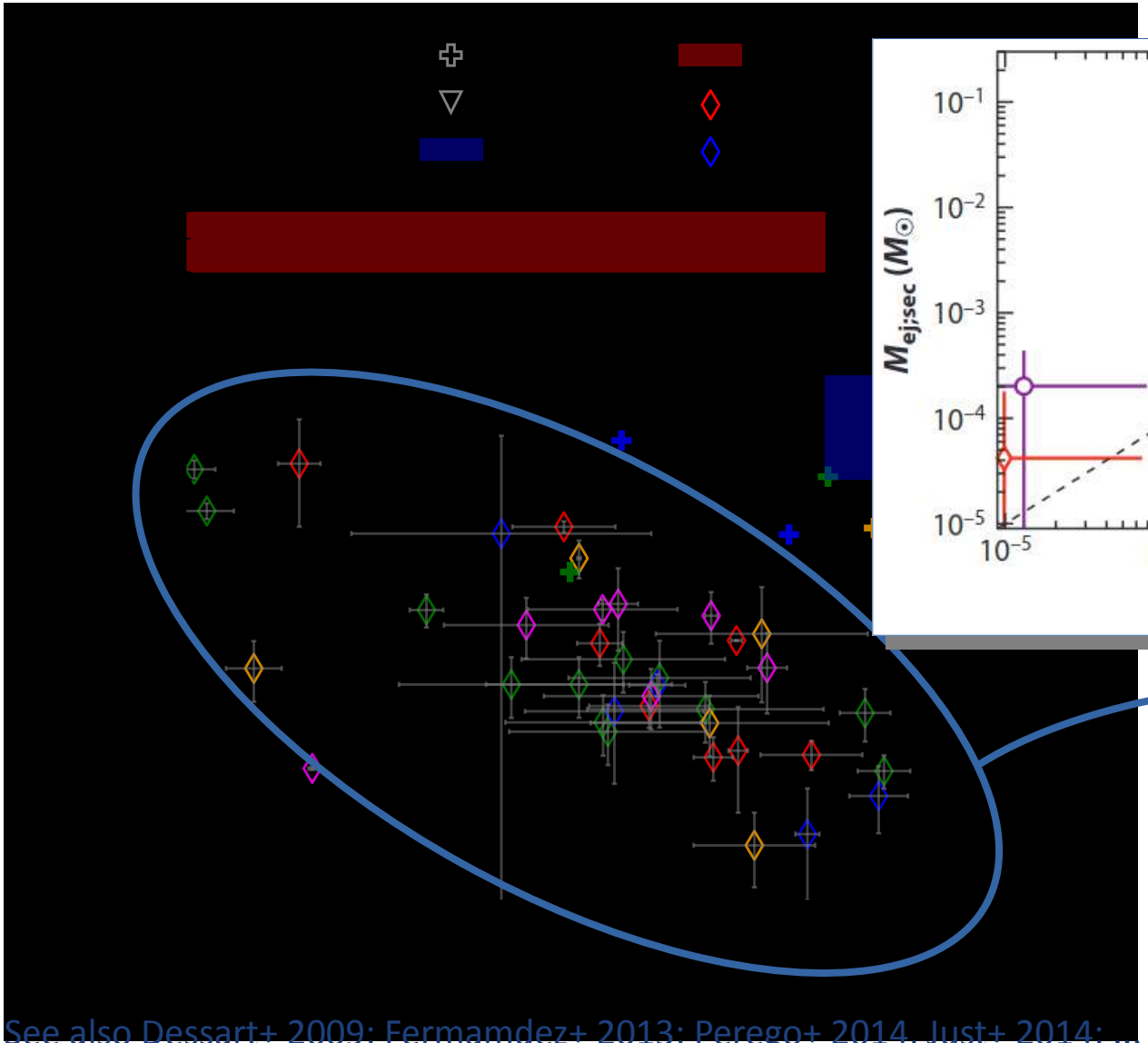
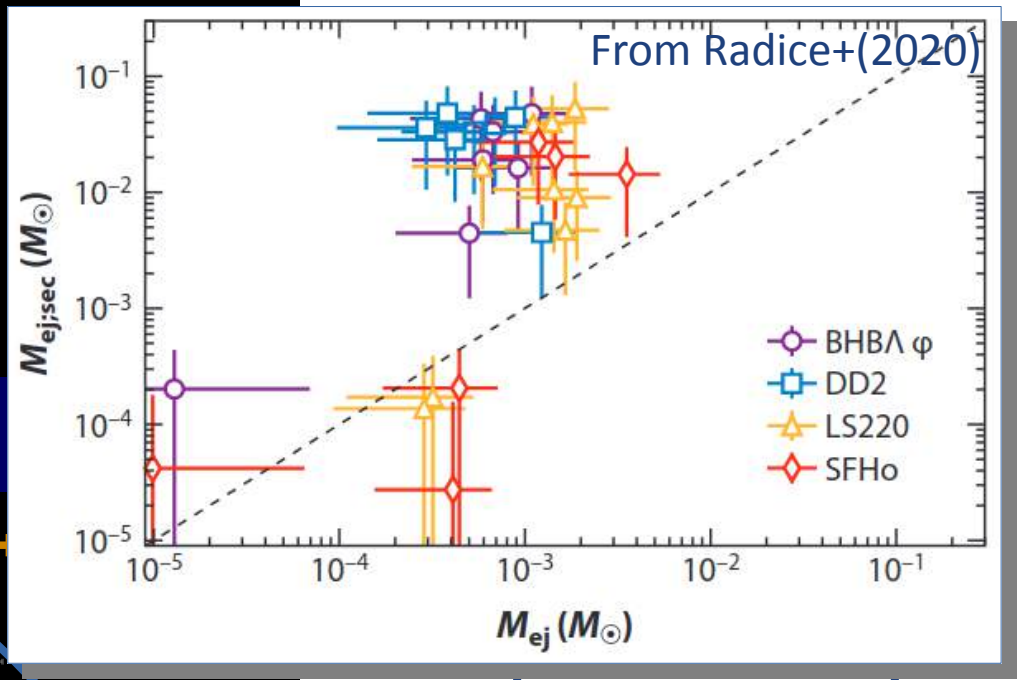
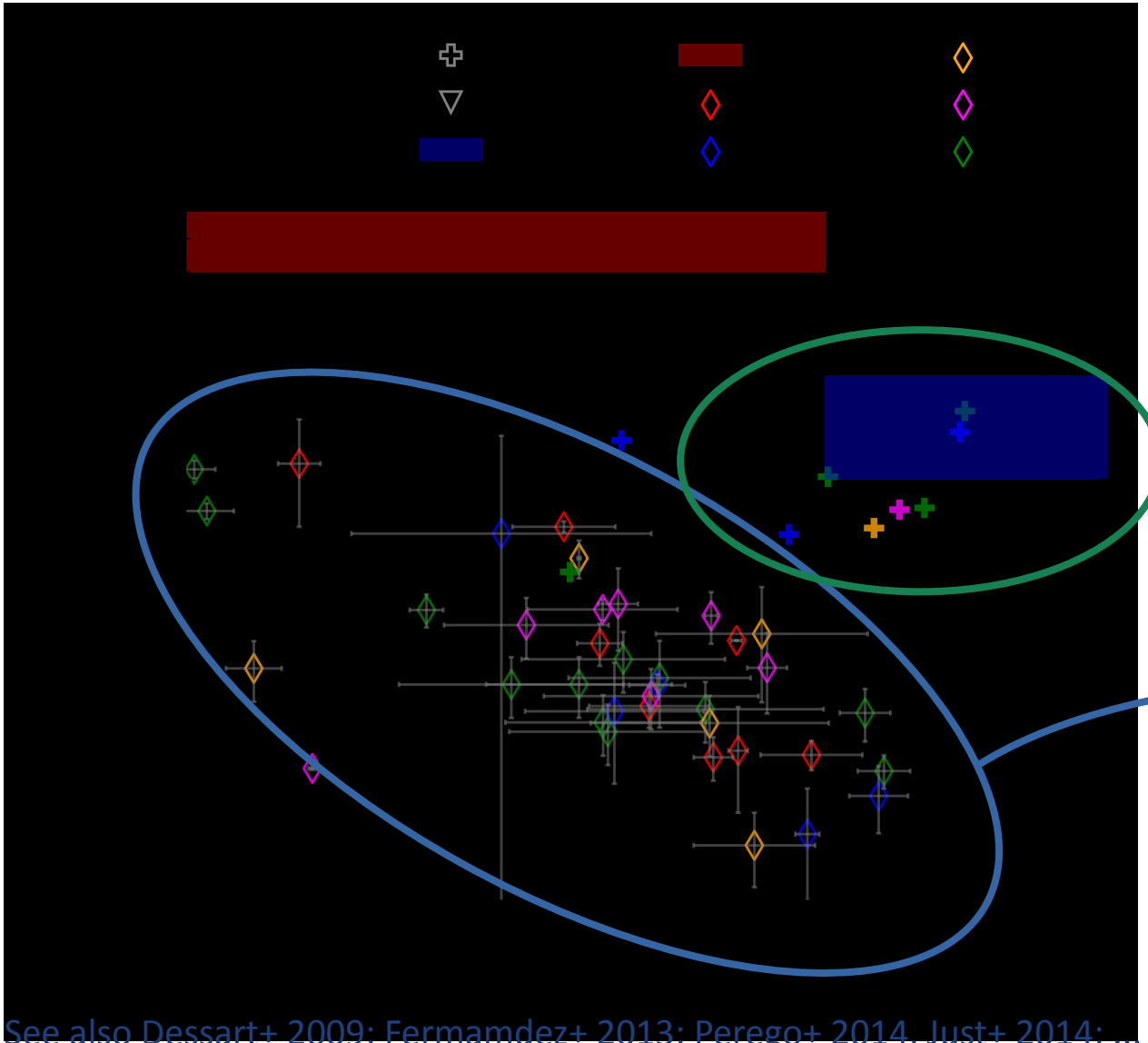




Dynamical ejecta

See also Dessart+ 2009; Fermamdez+ 2013; Perego+ 2014, Just+ 2014; ...

From Nedora+, ApJ 906:98 (2021)

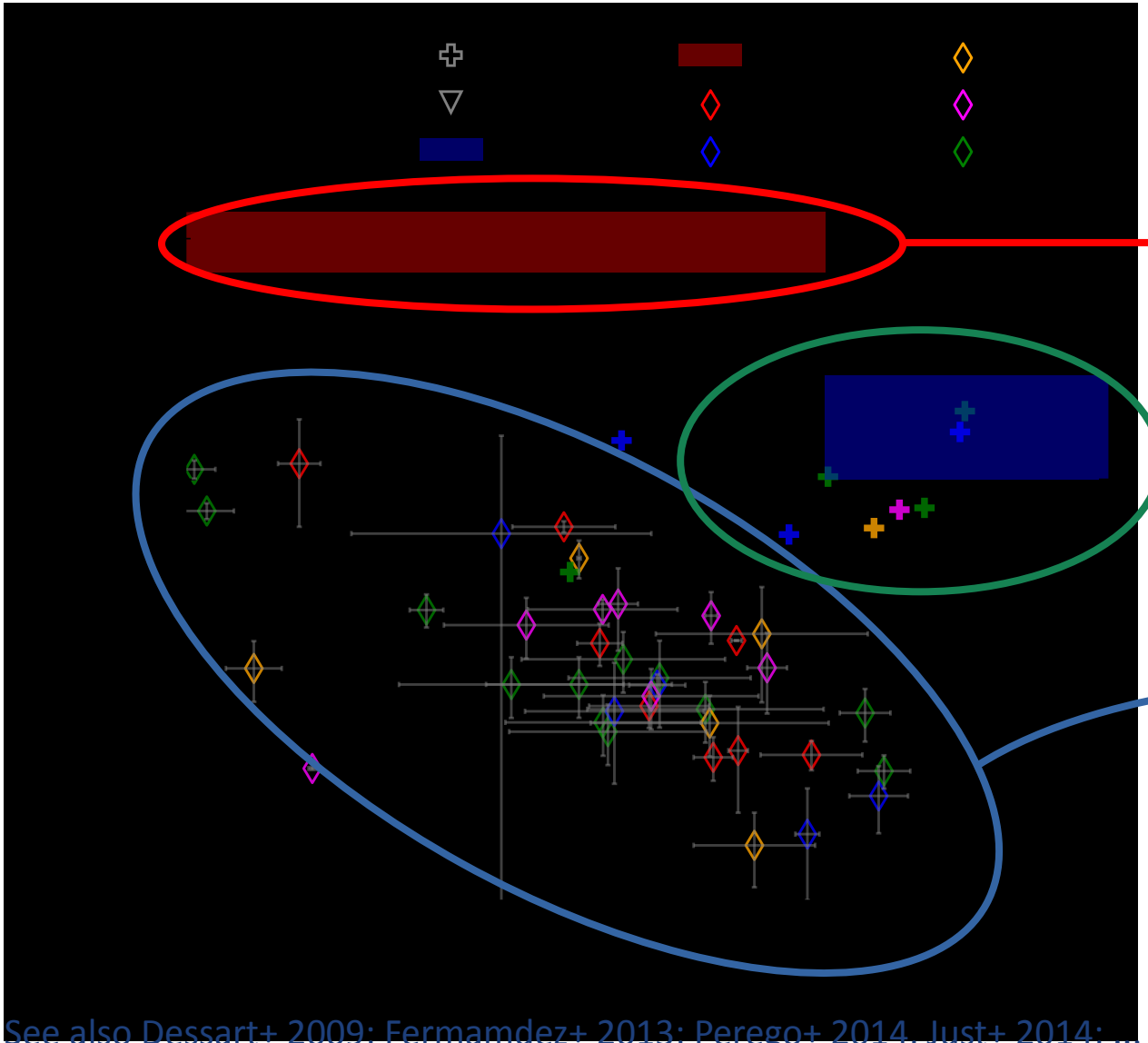


Spiral-wave wind?

Dynamical ejecta

See also Dessart+ 2009; Fermamdez+ 2013; Perego+ 2014, Just+ 2014; ...

From Nedora+, ApJ 906:98 (2021)



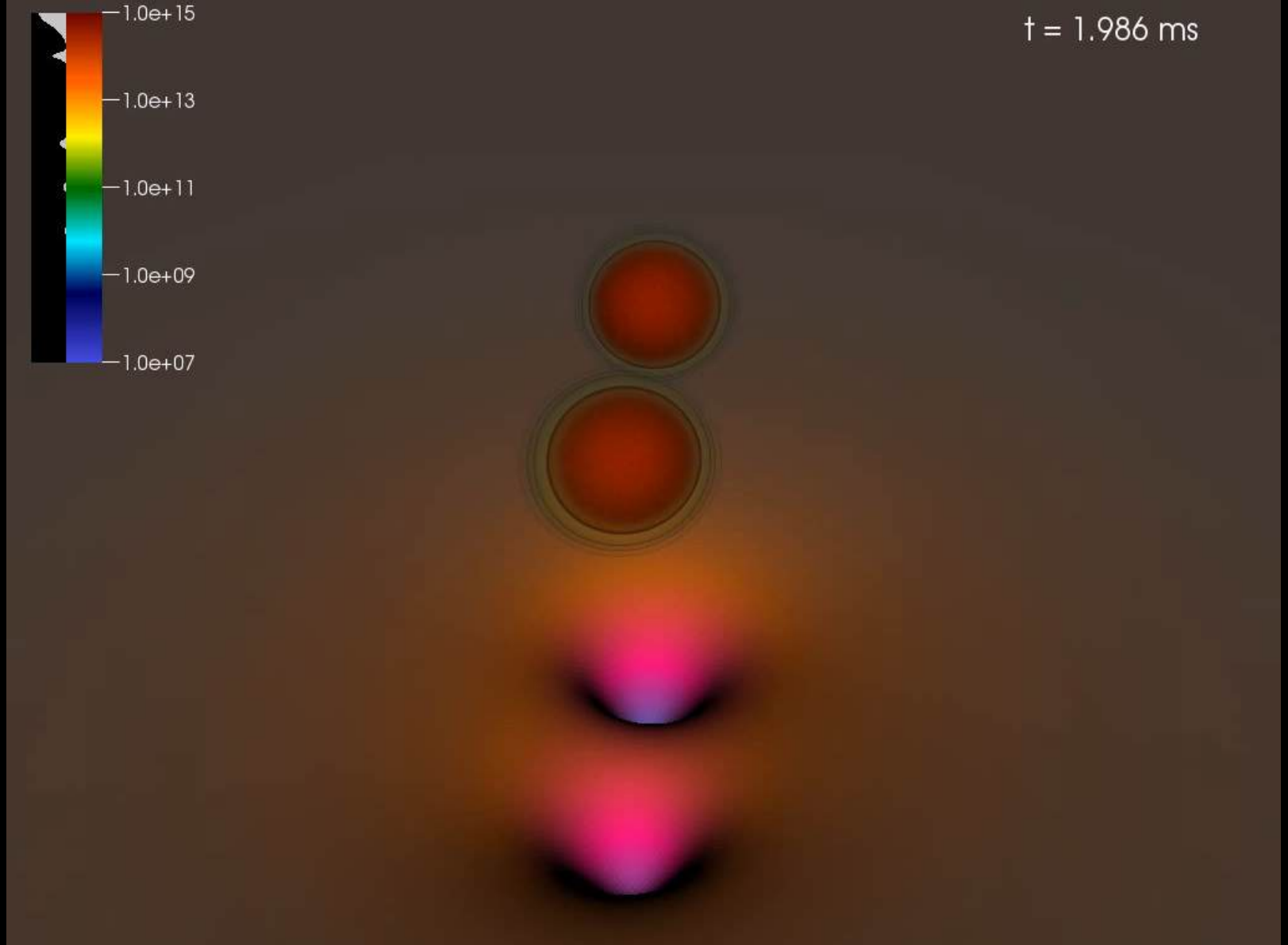
Disk recombination wind?!?

Spiral-wave wind?

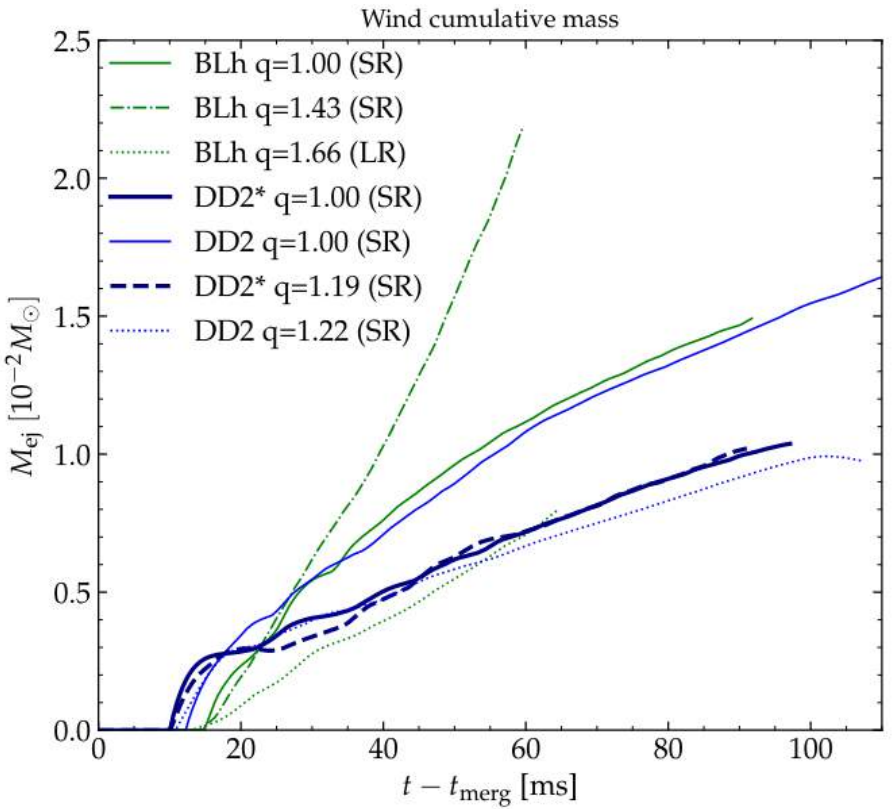
Dynamical ejecta

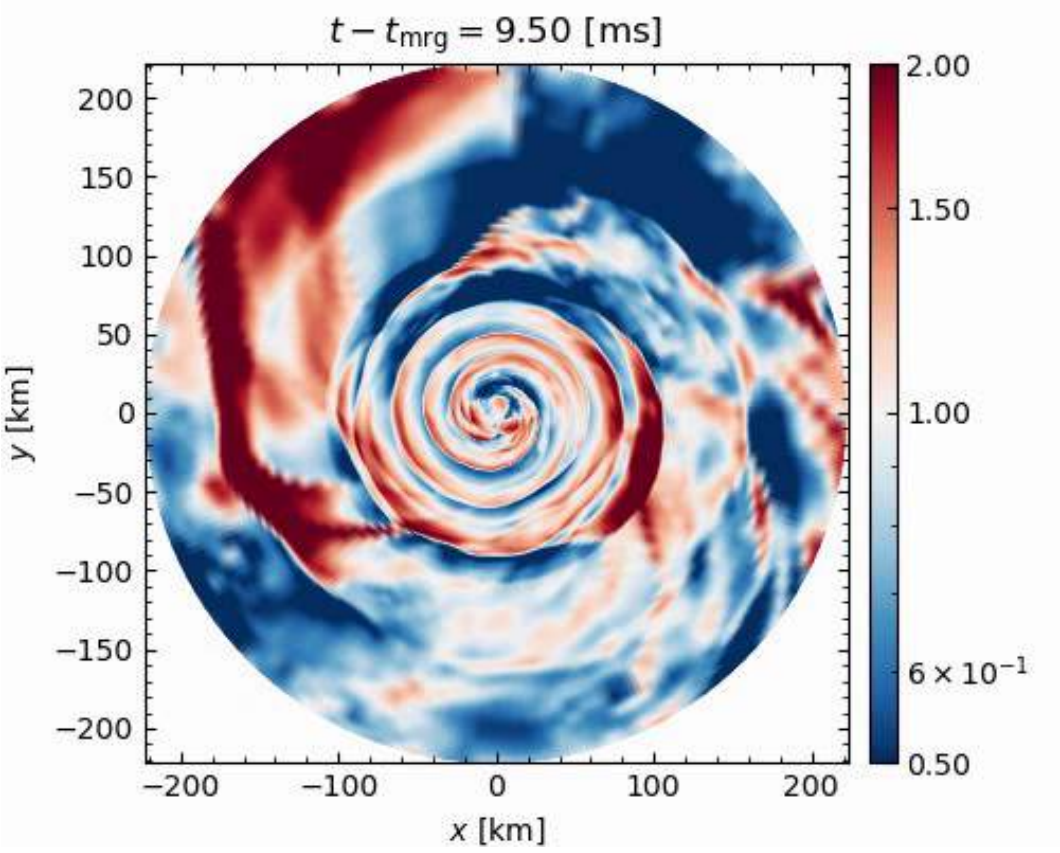
See also Dessart+ 2009; Fermamdez+ 2013; Perego+ 2014, Just+ 2014; ...

From Nedora+, ApJ 906:98 (2021)


1.0e+15
1.0e+13
1.0e+11
1.0e+09
1.0e+07
t = 1.986 ms

Spiral-wave wind

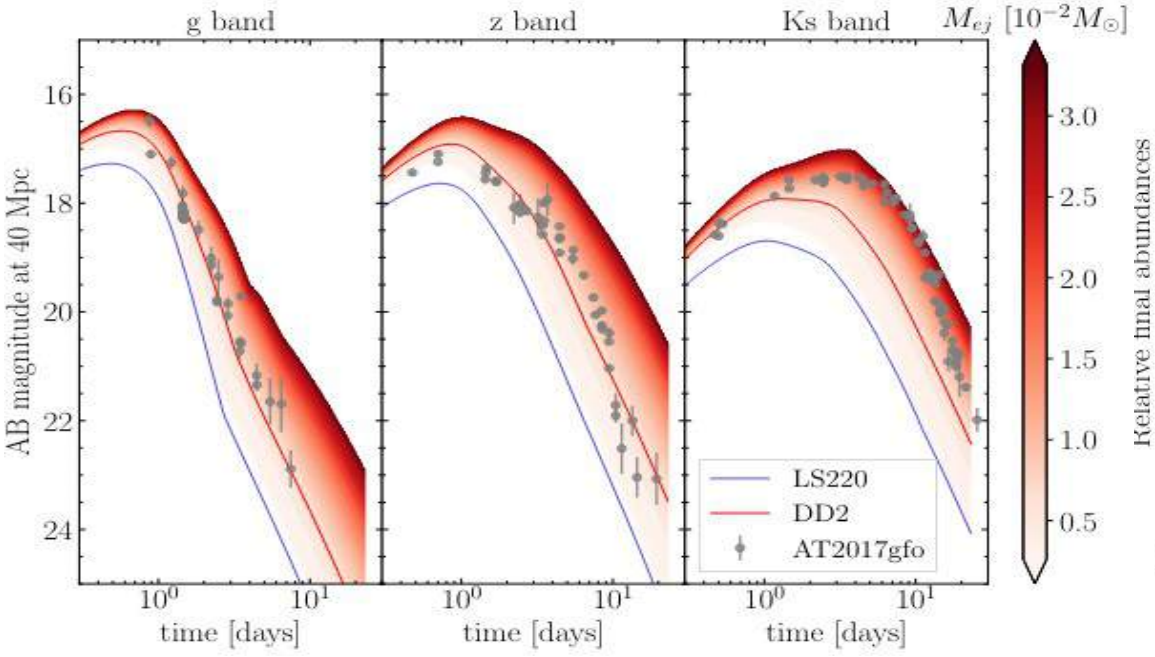


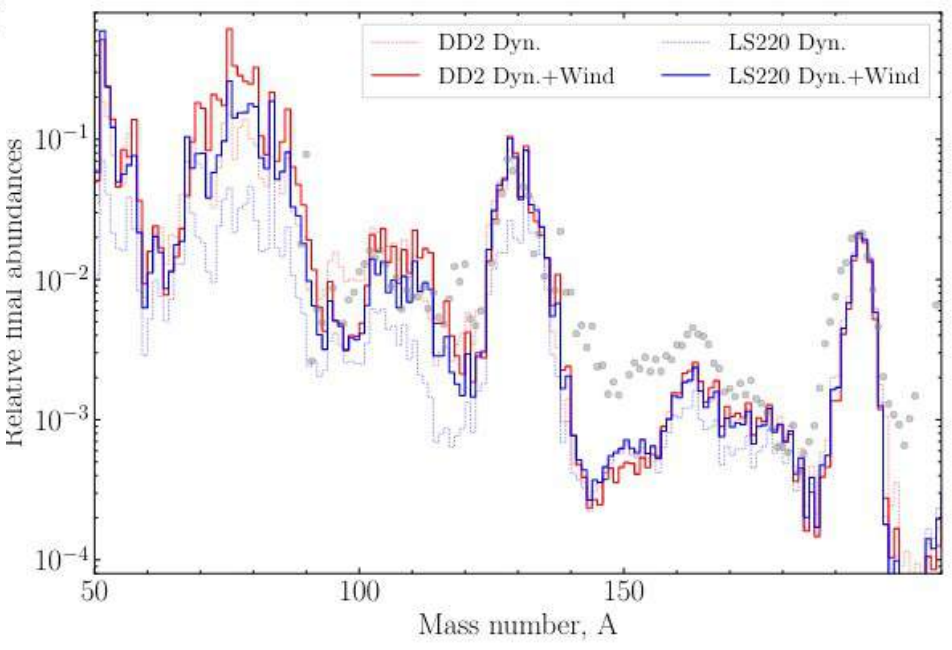


See also Siegel+ 2017; Fujibayashi+ 2018-2023;
Radice+ 2018; Mösta+ 2020; Curtis+ 2023; Combi+ 2023; ...

Nedora+ ApJ 906:98 (2021);
Radice+ ApJ 959:46 (2023)

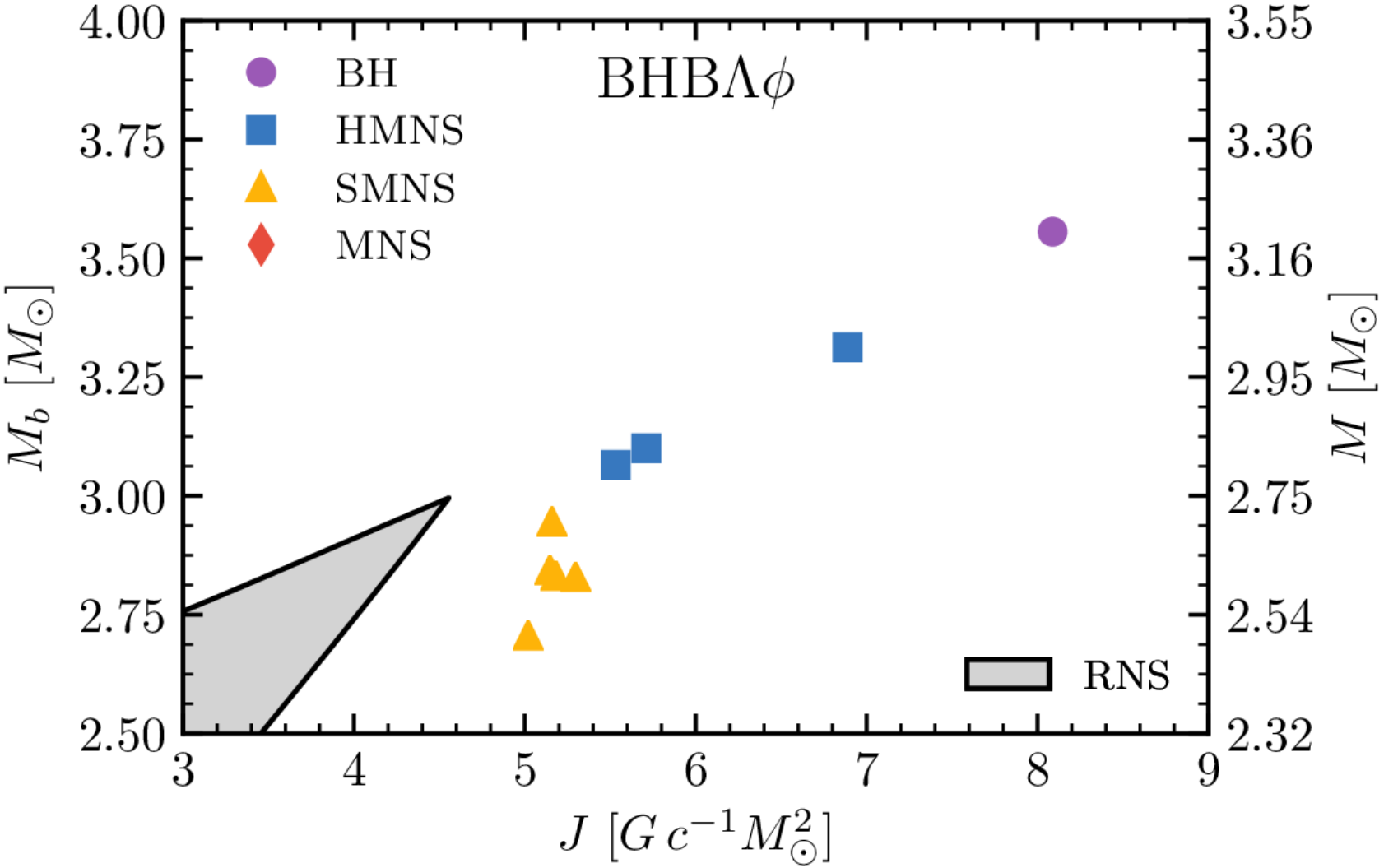
Numerical relativity results



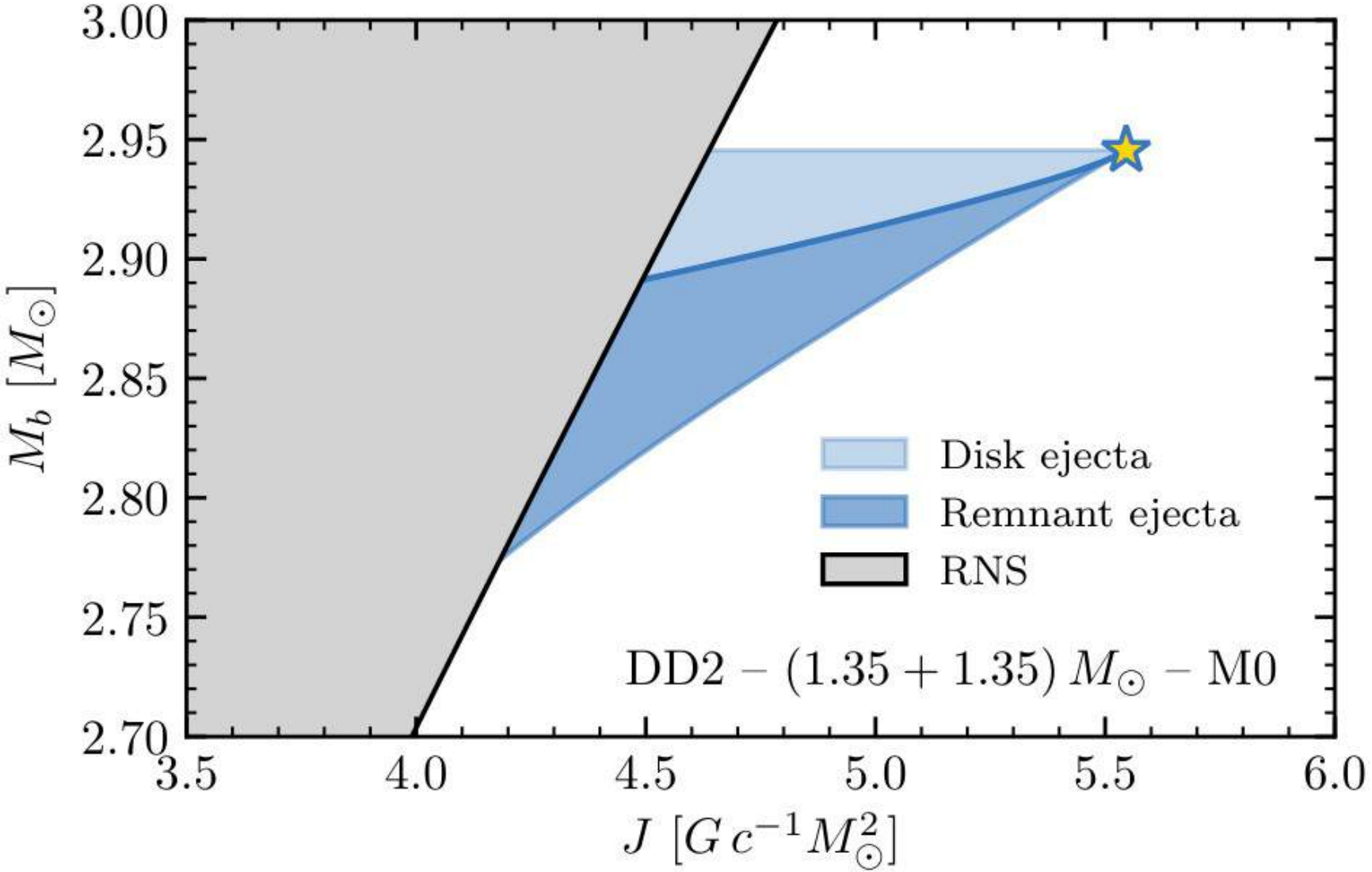


Postmerger winds naturally explain blue kilonova emission!

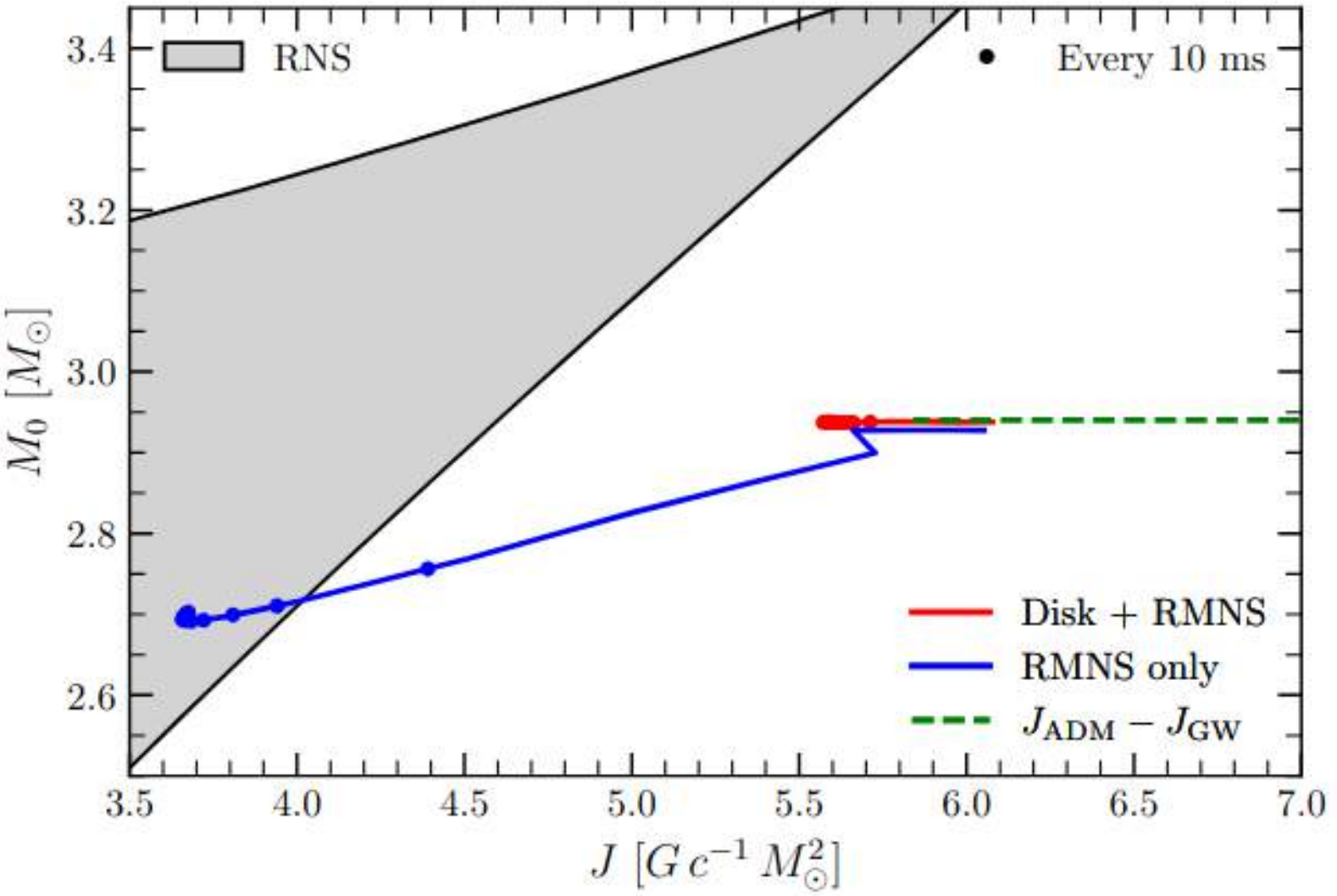
From Nedora+, ApJL 886:L30 (2019) & ApJ 906:98 (2021)



From Radice+ MNRAS 481:3670 (2018)

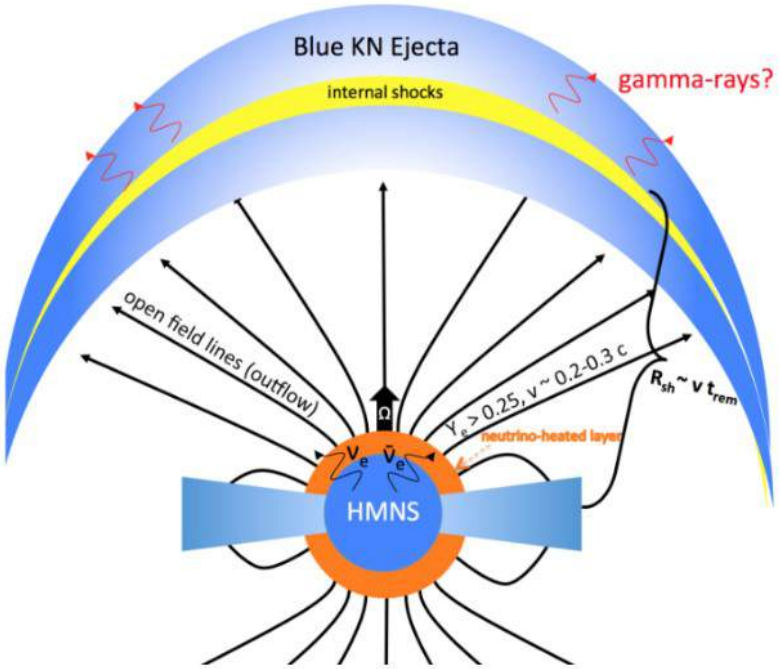


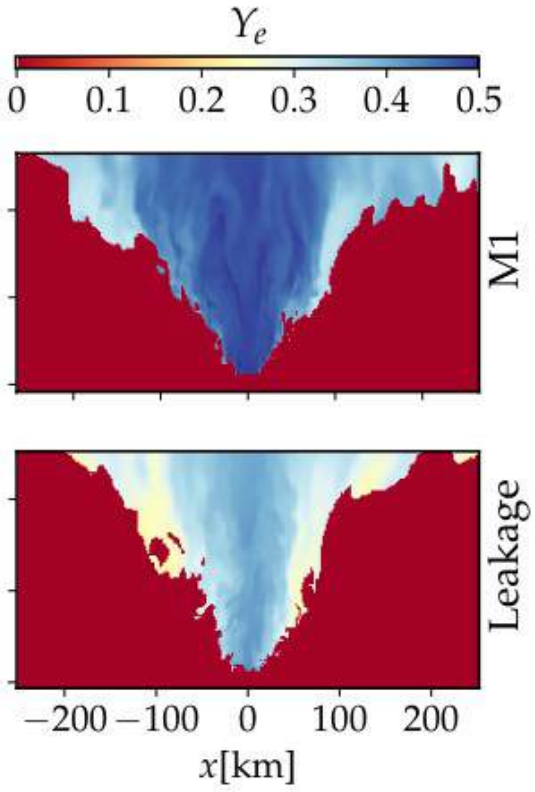
From Radice+ MNRAS 481:3670 (2018)

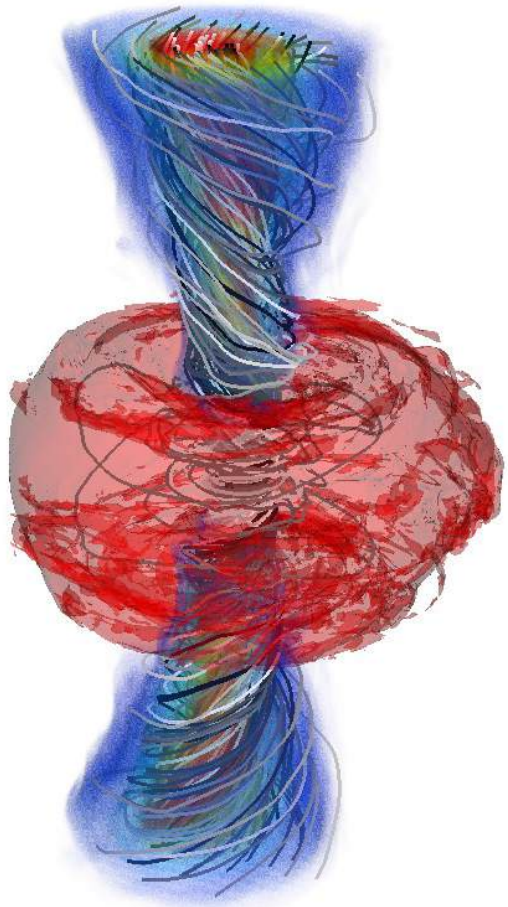


From Radice & Bernuzzi, ApJ 959:46 (2023)

What about magnetic fields?





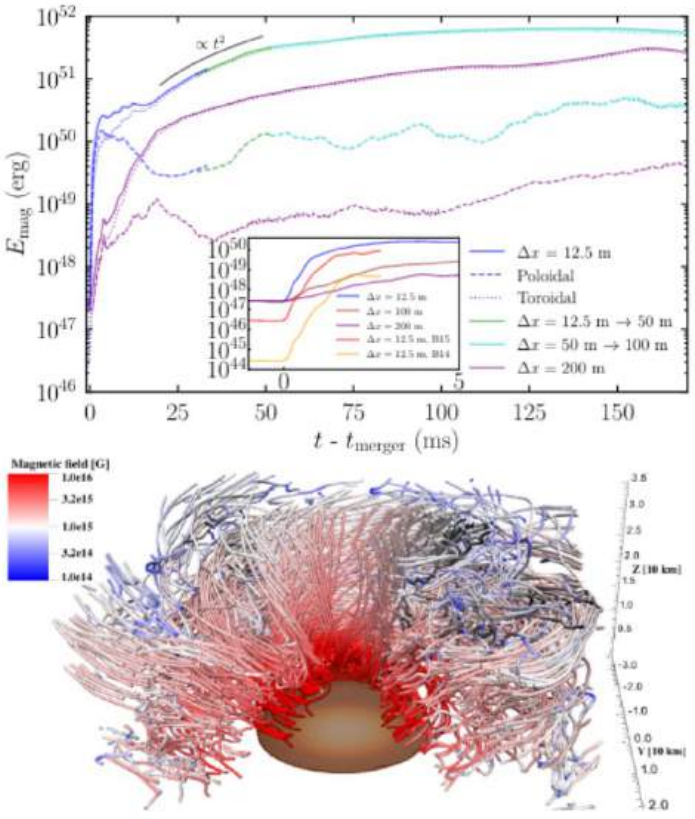


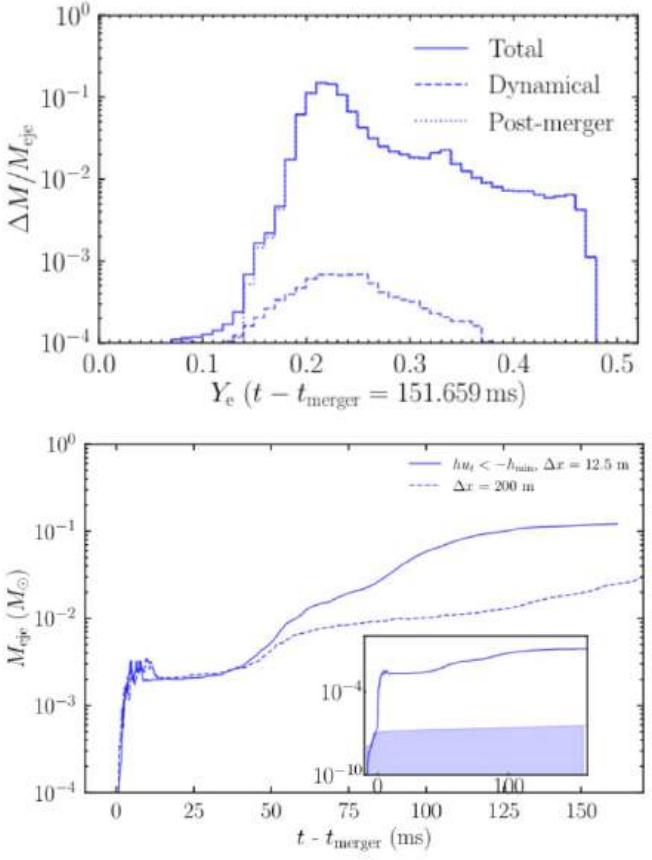
Metzger+, ApJ 856:101 (2018)

Curtis+, ApJL 961:L26 (2023)

Moesta+, ApJL 901:L37 (2020)

Magnetized winds

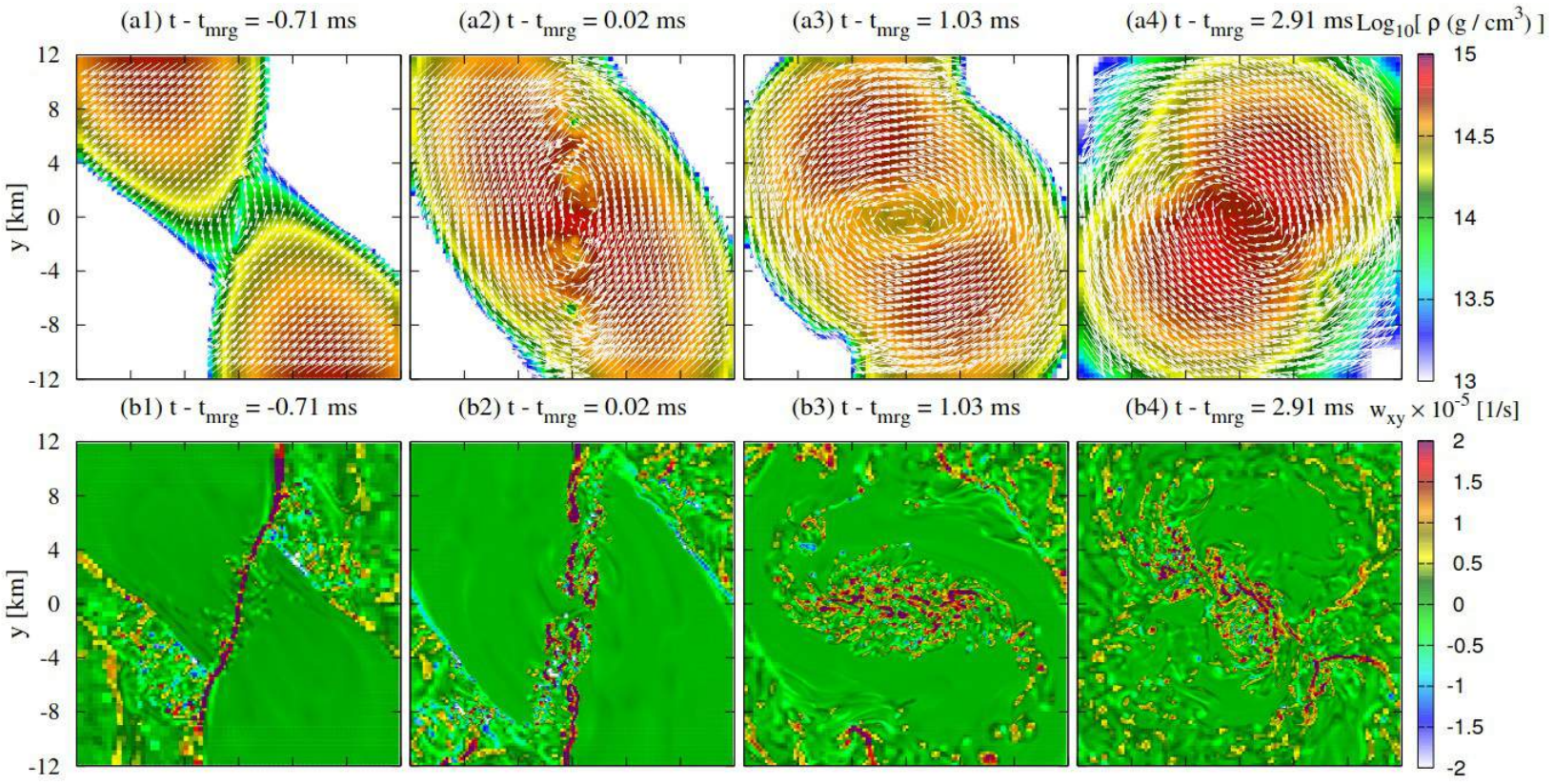




See also Siegel & Combi, PRL 131:231402 (2023)

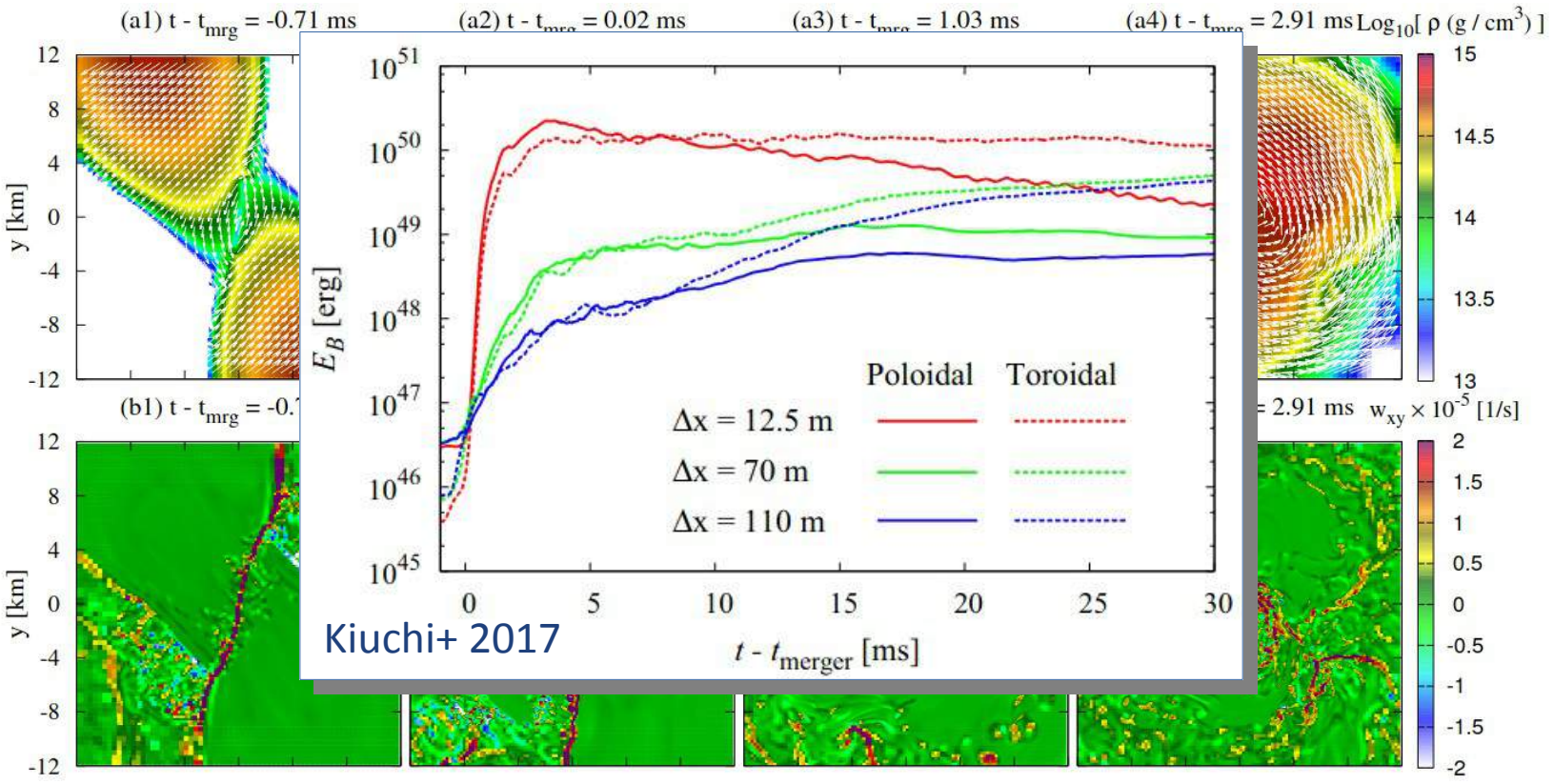
From Kiuchi+, Nat. Astoron. 8:298 (2024)

Field amplification by the KHI



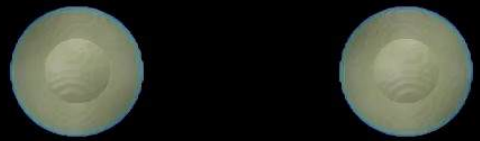
From Kiuchi et al. (2015)

Field amplification by the KHI

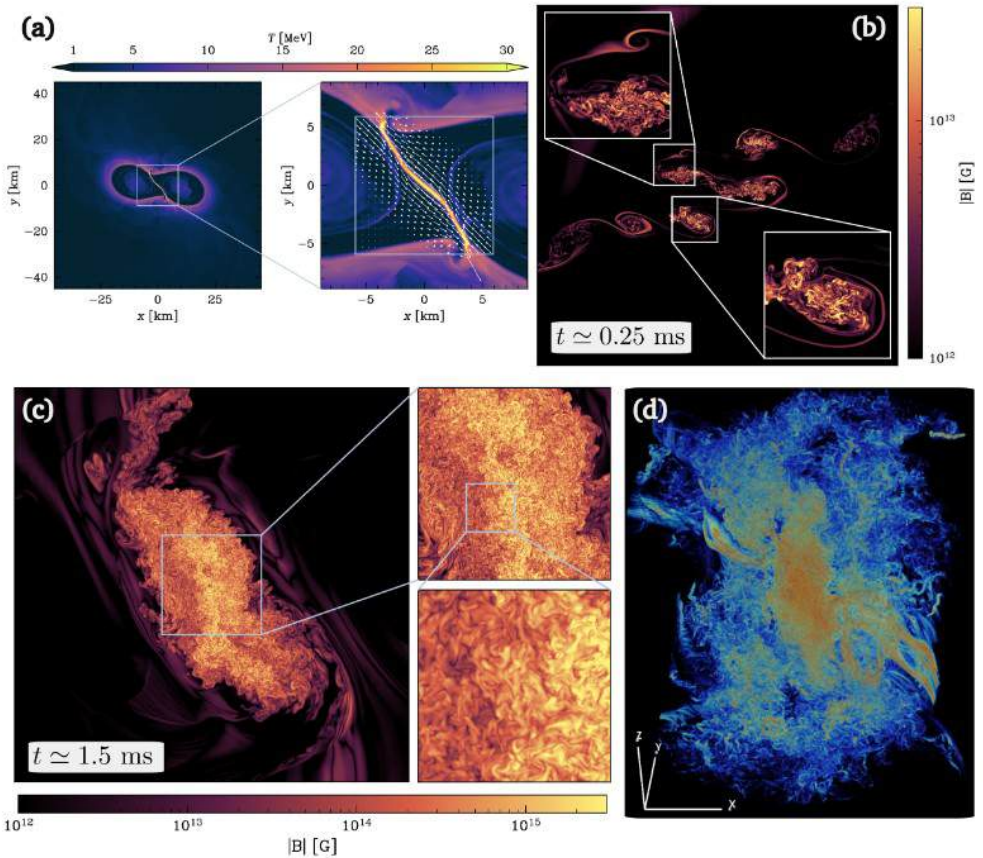


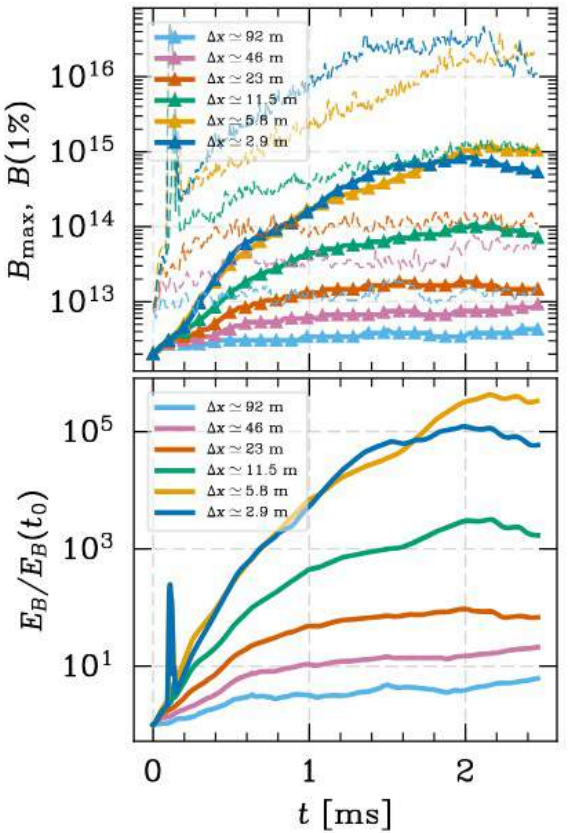
From Kiuchi et al. (2015)

t = 0.00 ms



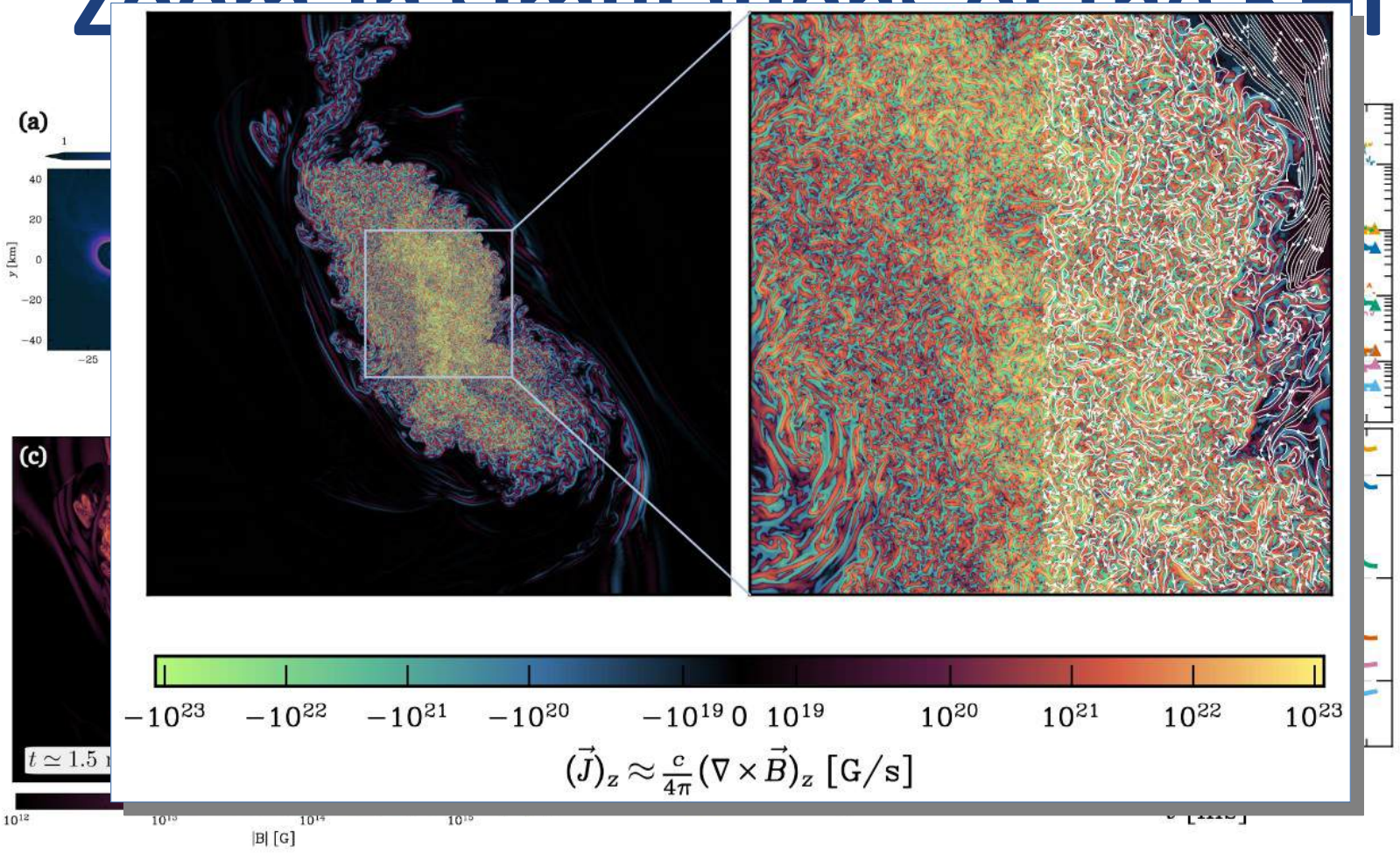
Zoom-in simulations of the KHI





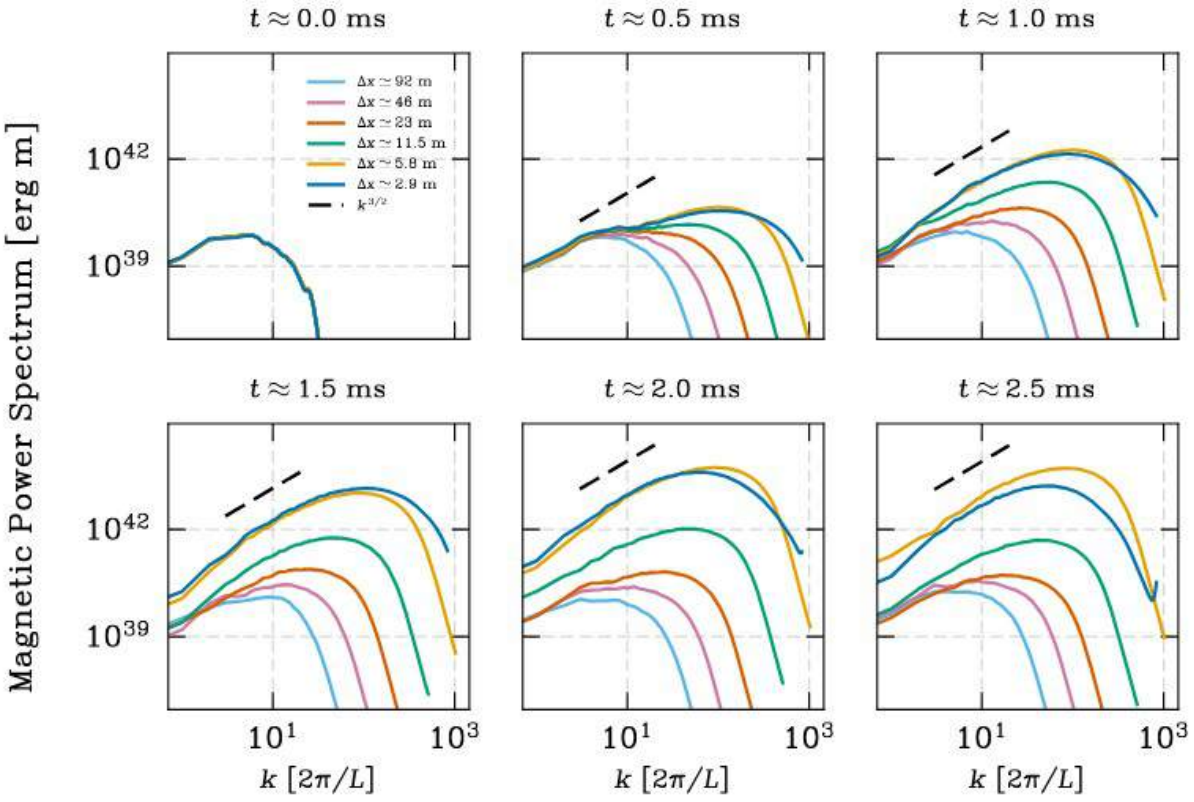
From Gutierréz+, arXiv:2601.20953

Zoom in simulations of the KHI



From Gutierréz+, arXiv:2601.20953

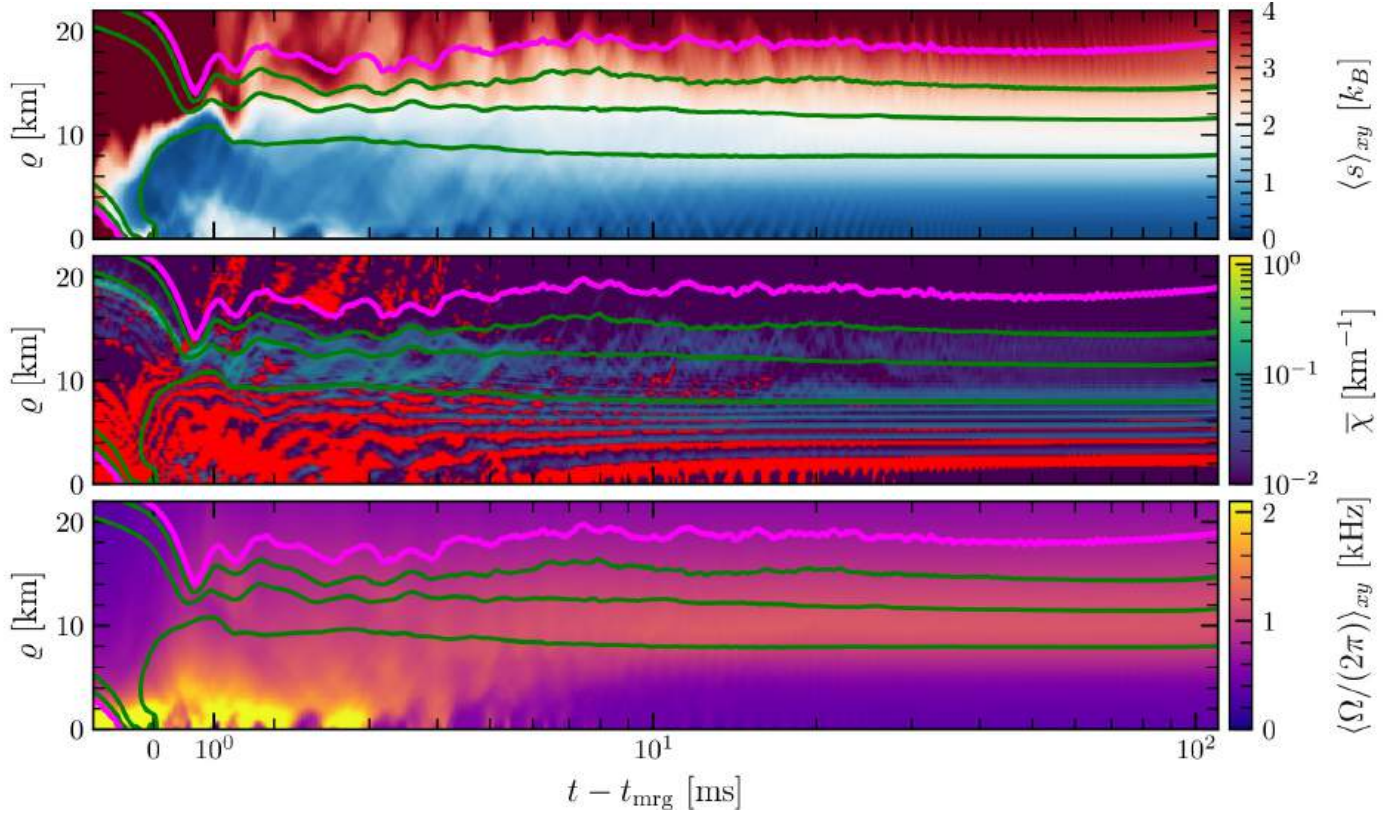
Turbulent dynamo action



See also Price & Rosswog 2006; Obergaulinger+ 2010; Zrake+2013 Kiuchi+ 2014, 2025; ...

From Gutierréz+, arXiv:2601.20953

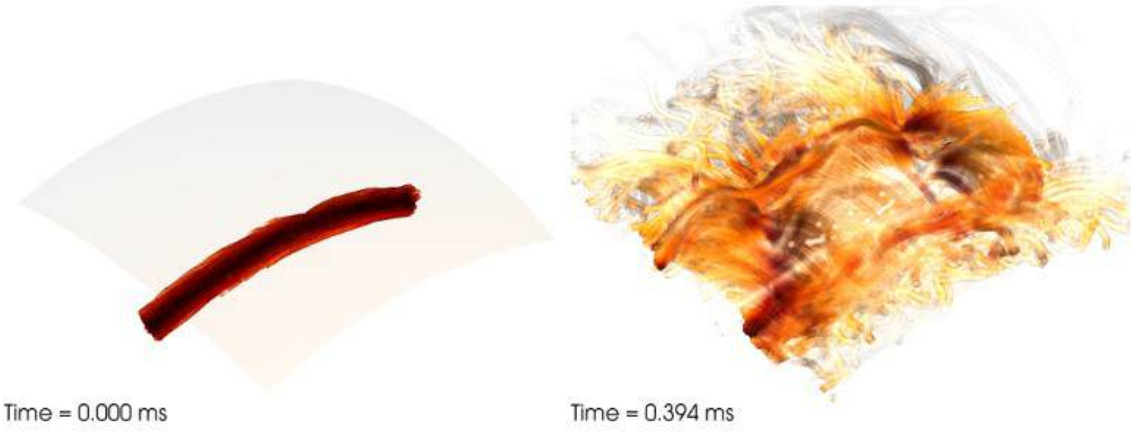
Maybe we can bury the field?



From Radice & Bernuzzi, ApJ 959:46 (2023); 995:229 (2025) (erratum)

Flux emergence in NS mergers

$B_{max} = 7 \times 10^{17}$ G

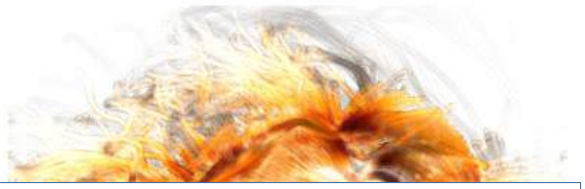


$B_{max} = 1 \times 10^{17}$ G

See also Siegel+ 2023, Musolino+ 2025, ...

From Fields+, PRD 113:043056 (2026)

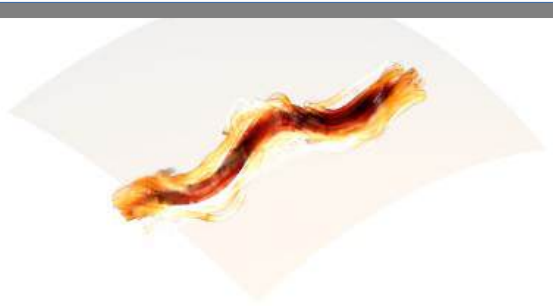
Flux emergence in NS mergers



$B_{max} =$

- Most of the field is buried within the remnant
- Some of the field will leak as the disk is formed. How much?
- Can only rely on the accretion disk field to do interesting things

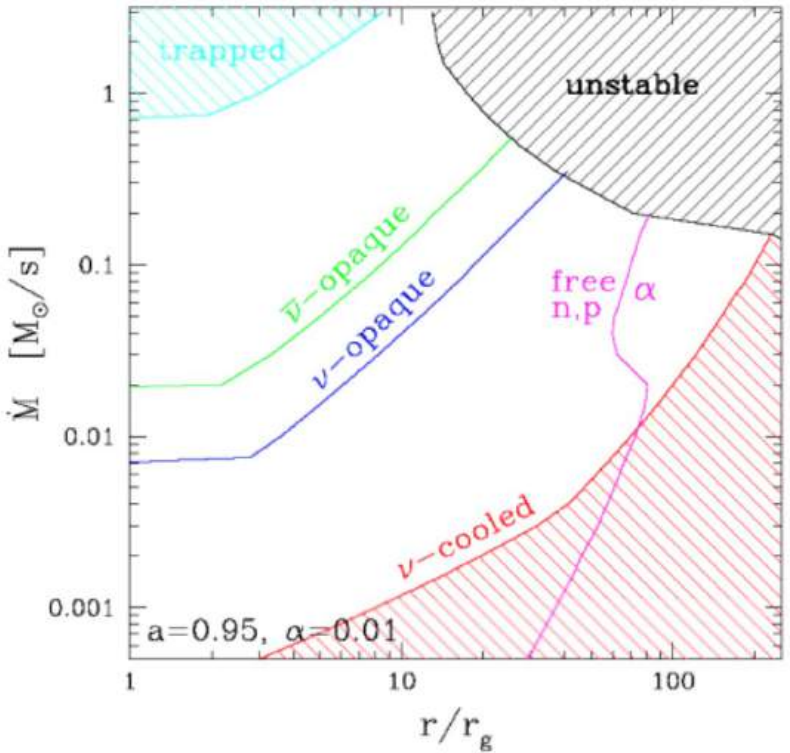
$B_{max} = 1 \times 10^{17}$ G



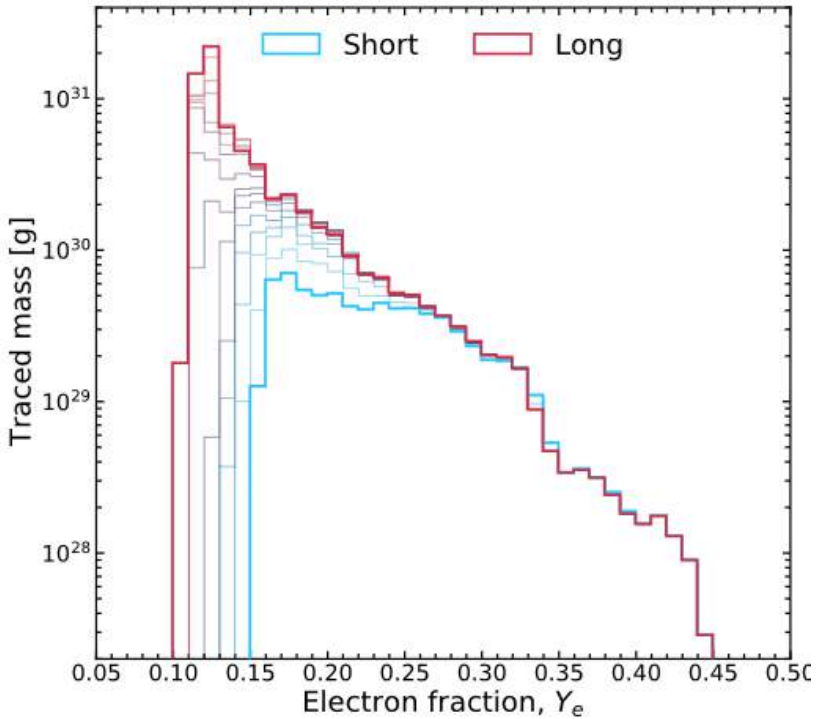
See also Siegel+ 2023, Musolino+ 2025, ...

From Fields+, PRD 113:043056 (2026)

Late times: disk evaporation



From Beloborodov AIP Conf.Proc. 1054 (2008)

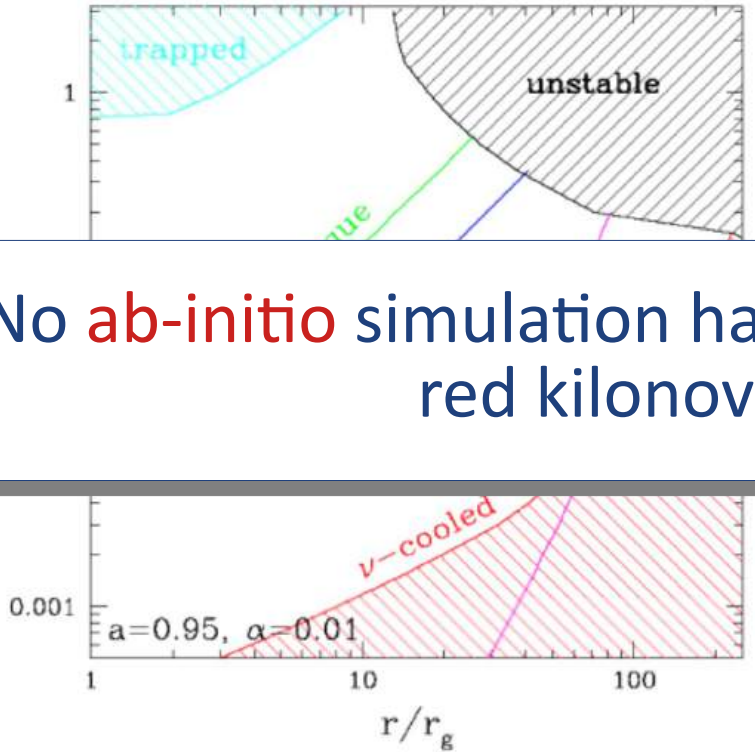


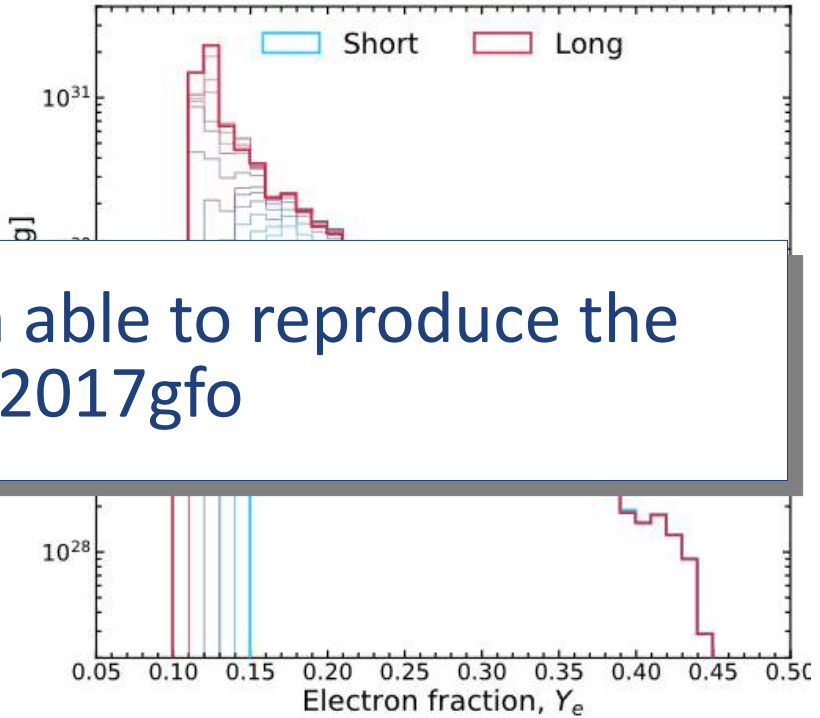
From Sprouse+ ApJ 962:79 (2024)

See also Beloborodov (2003); Fernandez+ (2013); Metzger+ (2014); Perego+ (2014); Siegel+ (2017); ...

See Oliver's talk!

Late times: disk evaporation





No ab-initio simulation has been able to reproduce the red kilonova in AT2017gfo

From Beloborodov AIP Conf.Proc. 1054 (2008)

From Sprouse+ ApJ 962:79 (2024)

See also Beloborodov (2003); Fernandez+ (2013); Metzger+ (2014); Perego+ (2014); Siegel+ (2017); ...

See Oliver's talk!