HIGH-MASS MAGNETIZED BINARY NEUTRON STAR MERGERS

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INTRODUCTION

IMPORTANCE OF NEUTRON STAR MERGERS

- Gravitational waves

One of the most promising sources of GWs

- Equation of state of neutron stars

GW signals are affected by stiffness of neutron stars

- Short gamma-ray bursts

Black hole and surrounding disk formed after coalescence may produce bursts of gamma-rays

NUMERICAL CODE

WhiskyMHD

- WhiskyMHD(B. Giacomazzo & L. Rezzolla, 2007)
  - ideal MHD
  - HLLE, PPM
  - vector potential with a modified Lorenz gauge

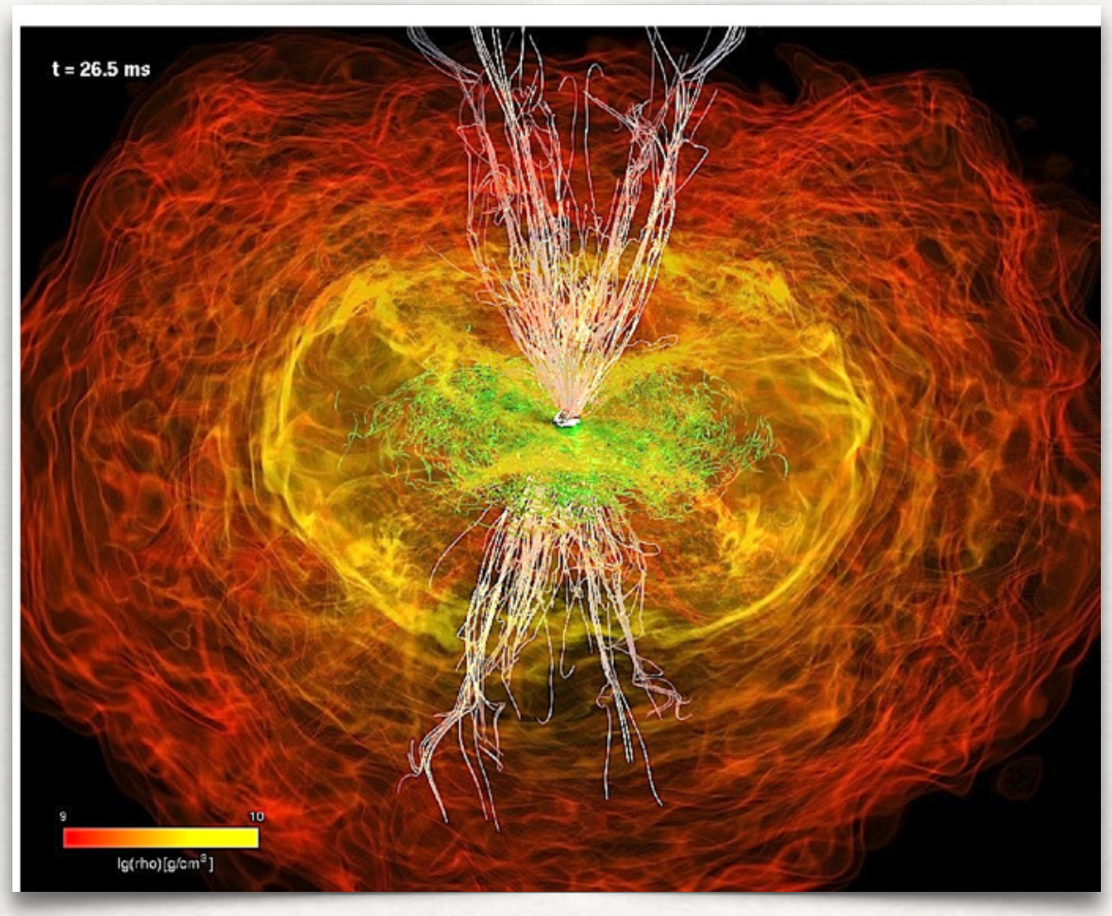
  Important for reducing artifacts on mesh refinement boundary

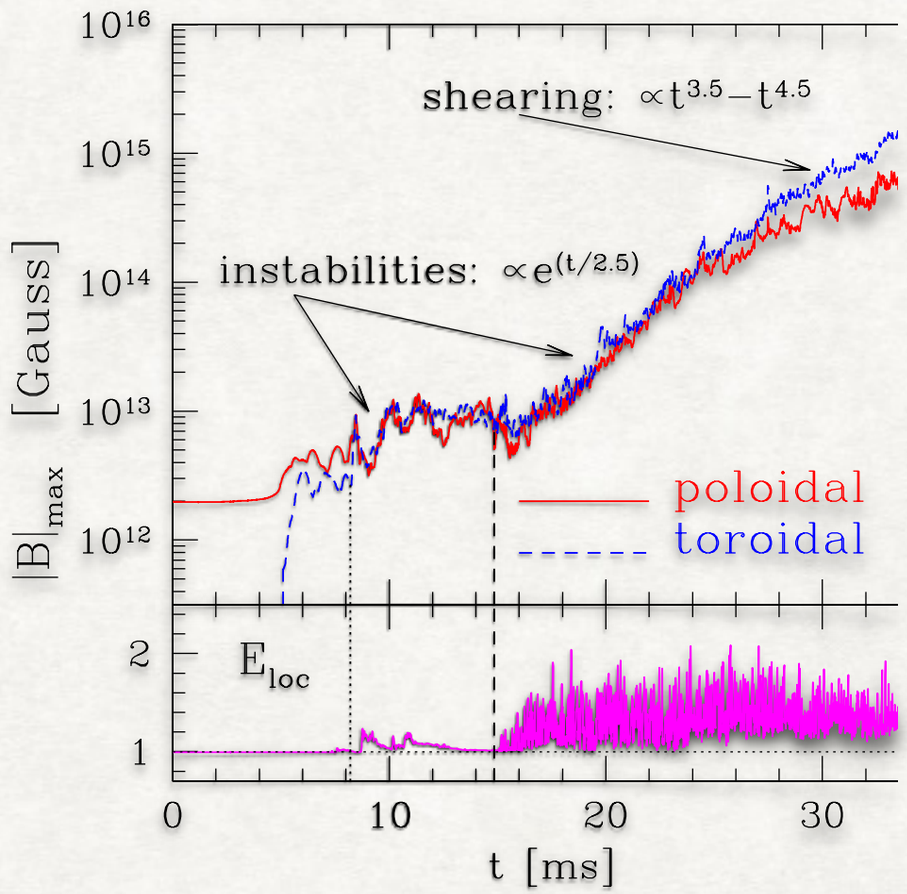
- Einstein Toolkit(einsteintoolkit.org)
  - open source
  - space-time evolution(via McLachlan, BSSNOK)
  - adaptive mesh refinement(Carpet)

PREVIOUS RESULT

"Missing Link" Paper(L. Rezzolla et al, 2012)

Binary neutron star merger simulation using WhiskyMHD, where for the first time strongly collimated magnetic field emerges along the black hole spin axis.





1.5M_sun-1.5M_sun, Ideal fluid EOS, initial B field ~10^12G inside stars

INITIAL DATA

Similarities with the “Missing Link” paper:

1.5M_sun-1.5M_sun, Ideal fluid EOS, initial B field strength of ~10^12 G

Different numerical setups:

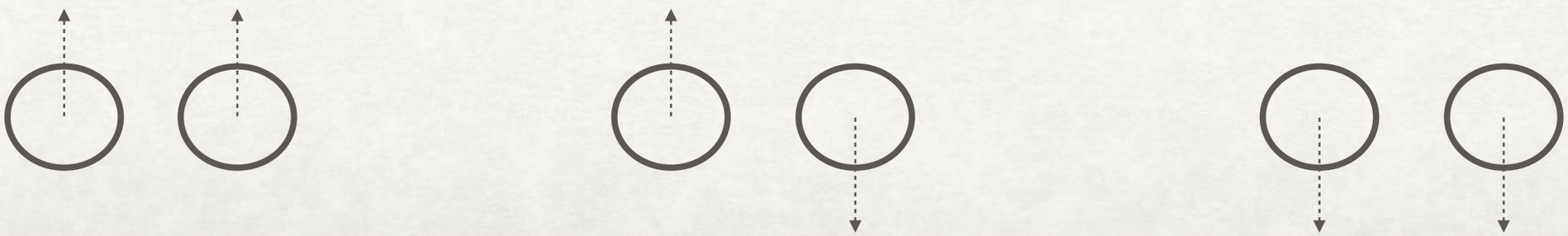
1. Use of Lorenz gauge for evolving B field
2. Larger computational domain(1400km vs 375km)
3. Lower atmosphere(~10^4 g/cm^3 vs ~10^7 g/cm^3)

We use 3 different magnetic field configurations;

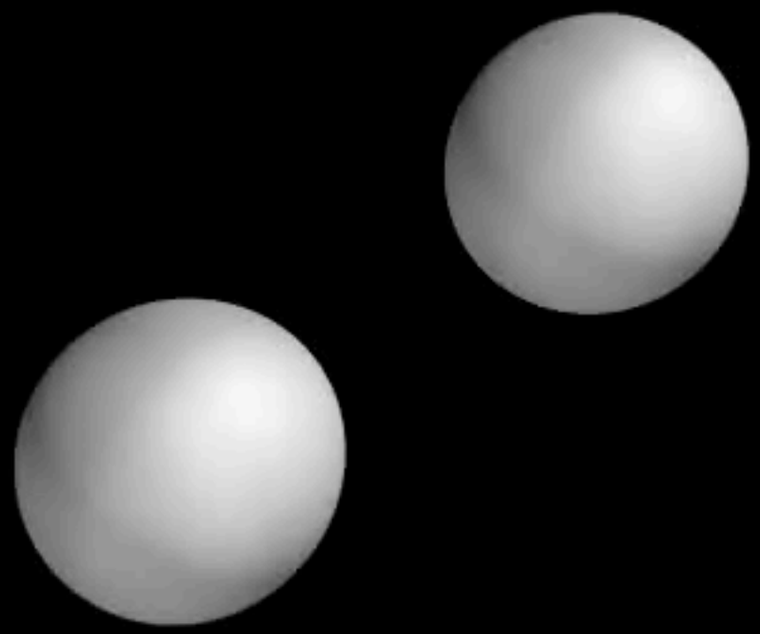
A. Up-Up(initial B field of both stars aligned with orbital rotational axis)

B. Up-Down(B field of one star aligned with rotational axis, the other anti-aligned)

C. Down-Down(B field of both stars anti-aligned with rotational axis)



t = 0.0 ms



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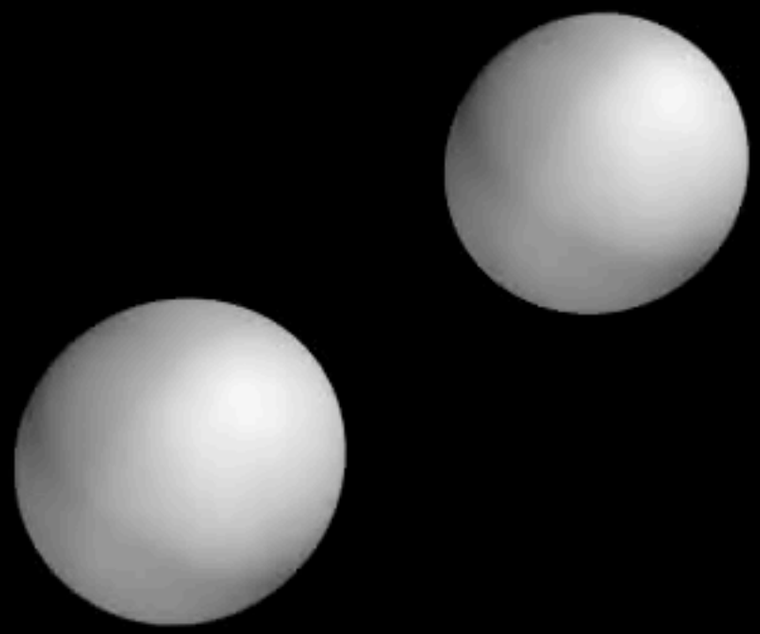


t = 0.0 ms

log(B)

14.1

13.6

13.0

12.5

12.0

11.5

10.9

10.4

t = 0.0 ms

log(B)

14.1

13.6

13.0

12.5

12.0

11.5

10.9

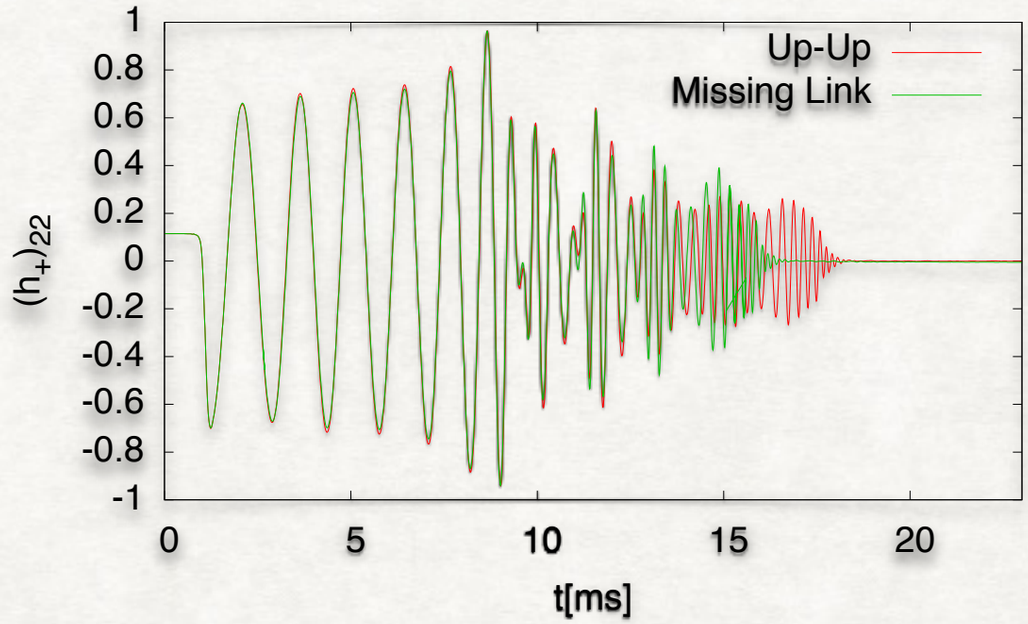
10.4

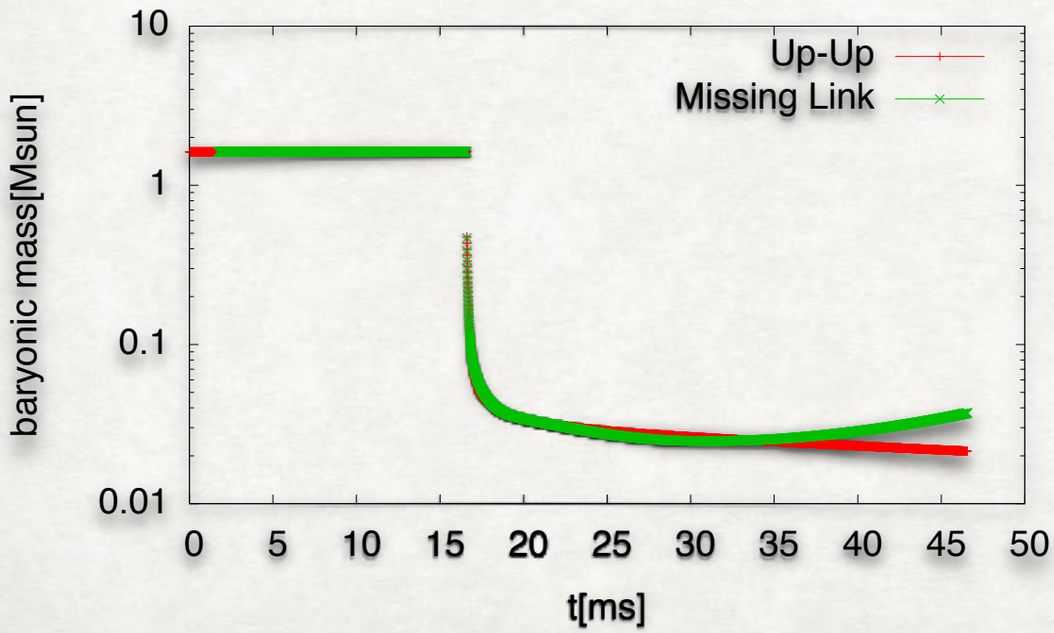
60
40
20
0
−20
−40
−60
z [km]
−60
−40
−20
0
20
40
60
x [km]
0.60
0.45
0.30
0.15
0.00
−0.15
−0.30
−0.45
−0.60
v^z [c]
$t = 43.164$ ms

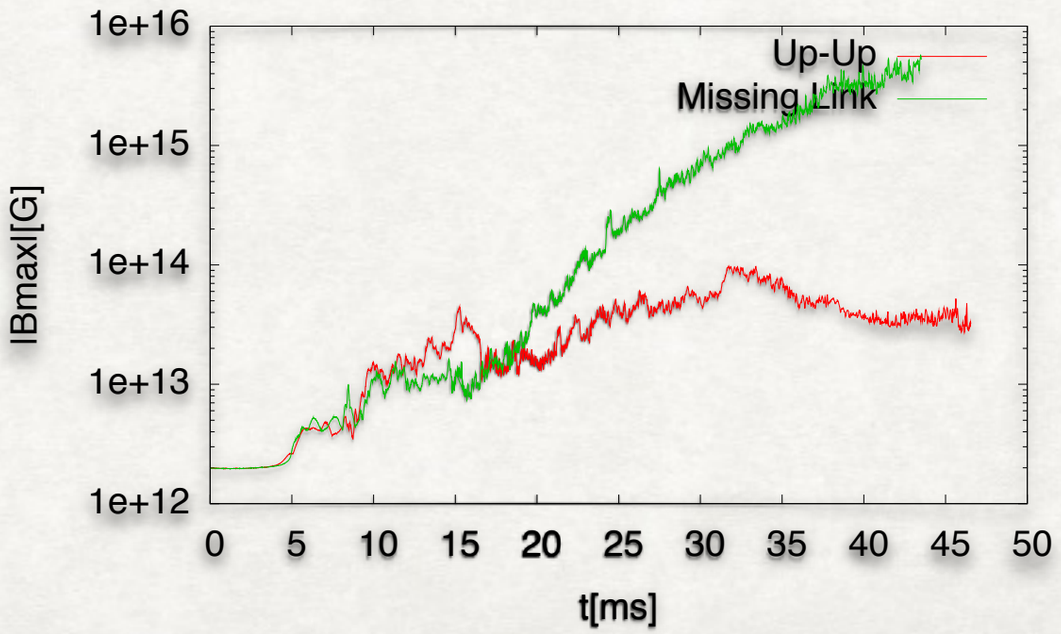
COMPARISON OF RESULTS

Between New And Original Missing Link Simulation

- Different life time of HMNS
- Different B field amplification
- Rest mass conservation







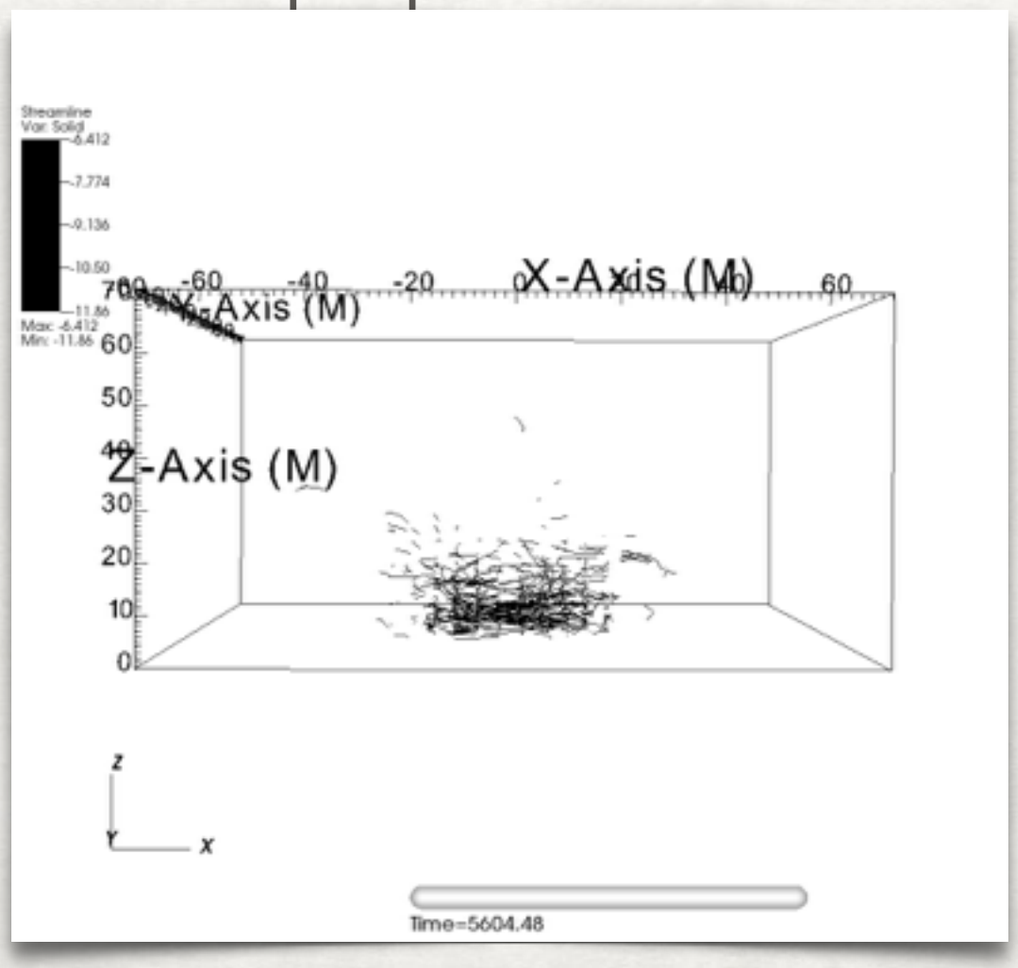
Magnetic Field Line Comparison

- About ~10ms after formation of black hole for both cases

Found very weak poloidal field near the black hole spin axis.

Found toroidal field weaker than original simulation.

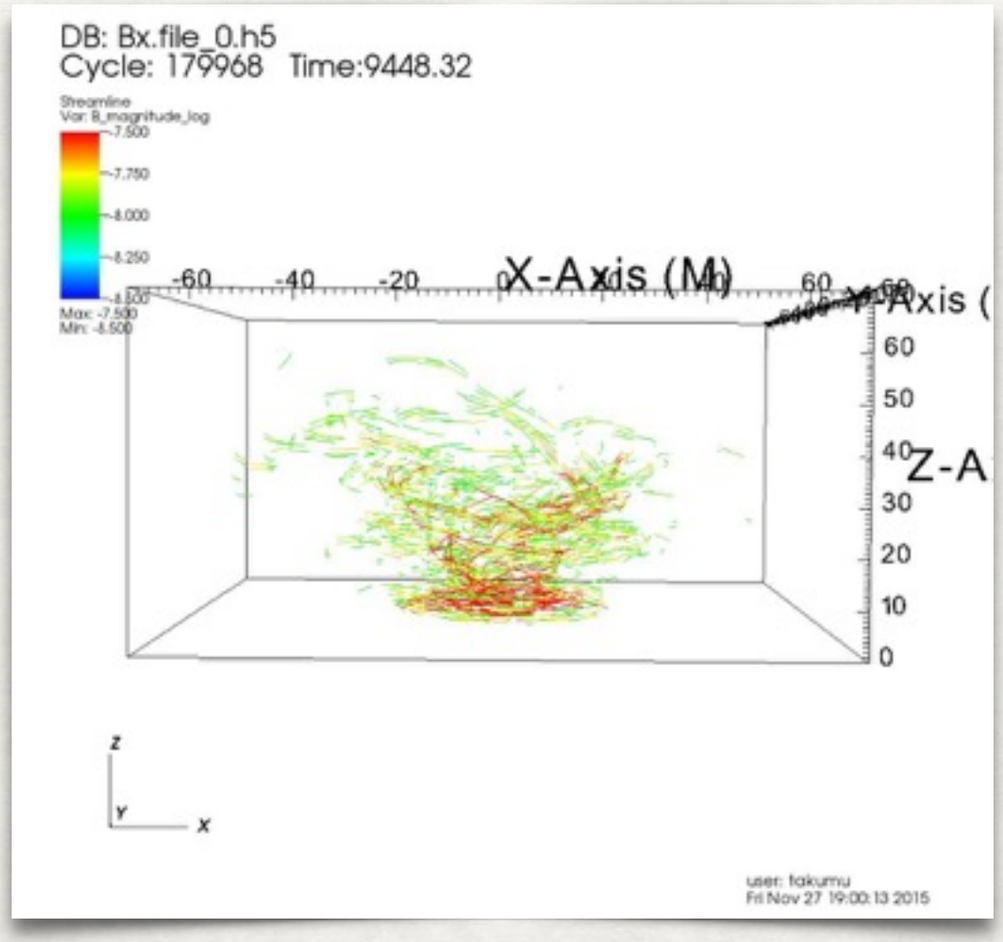
Up-Up simulation

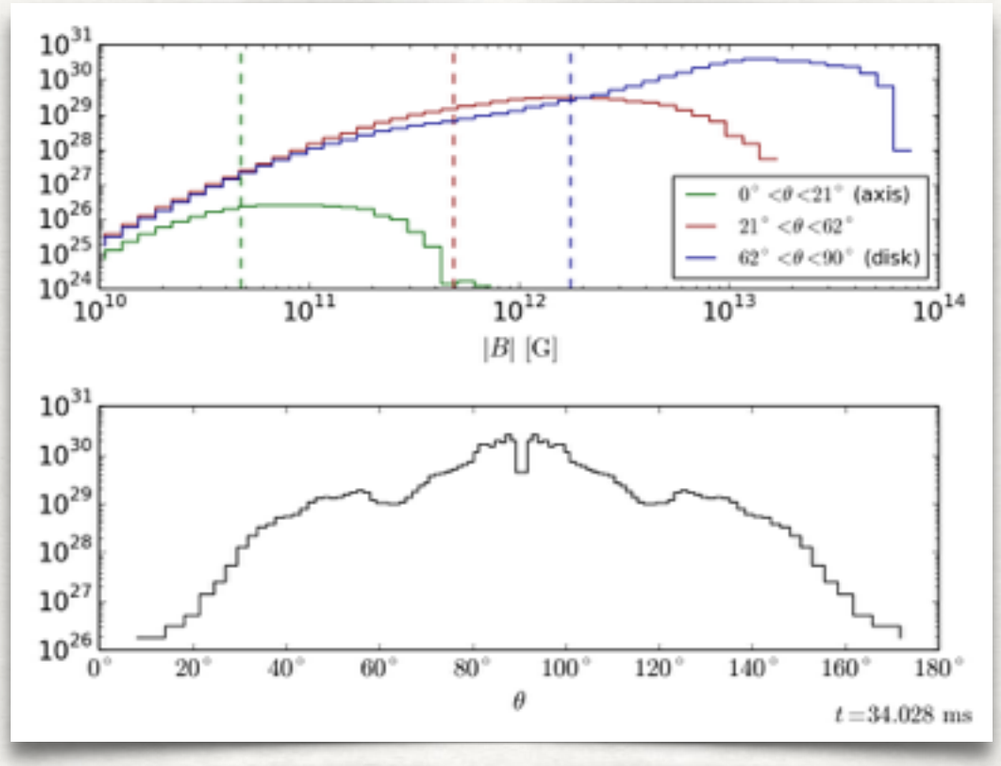


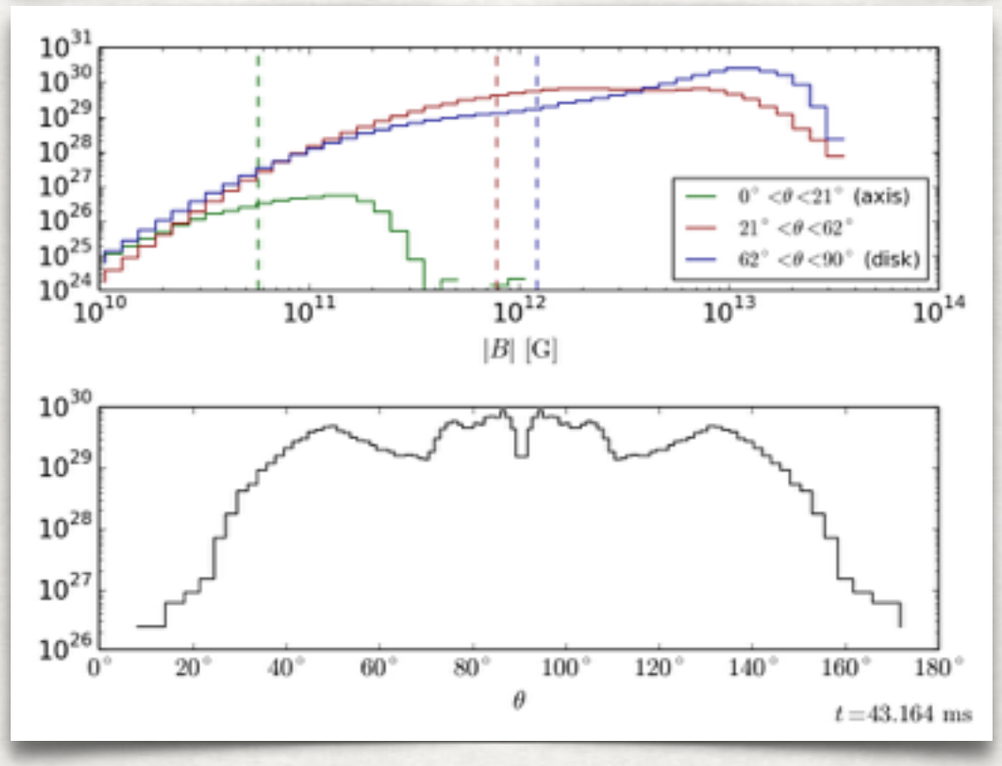
Missing Link simulation

Magnetic Field Evolution For Up-Up Case

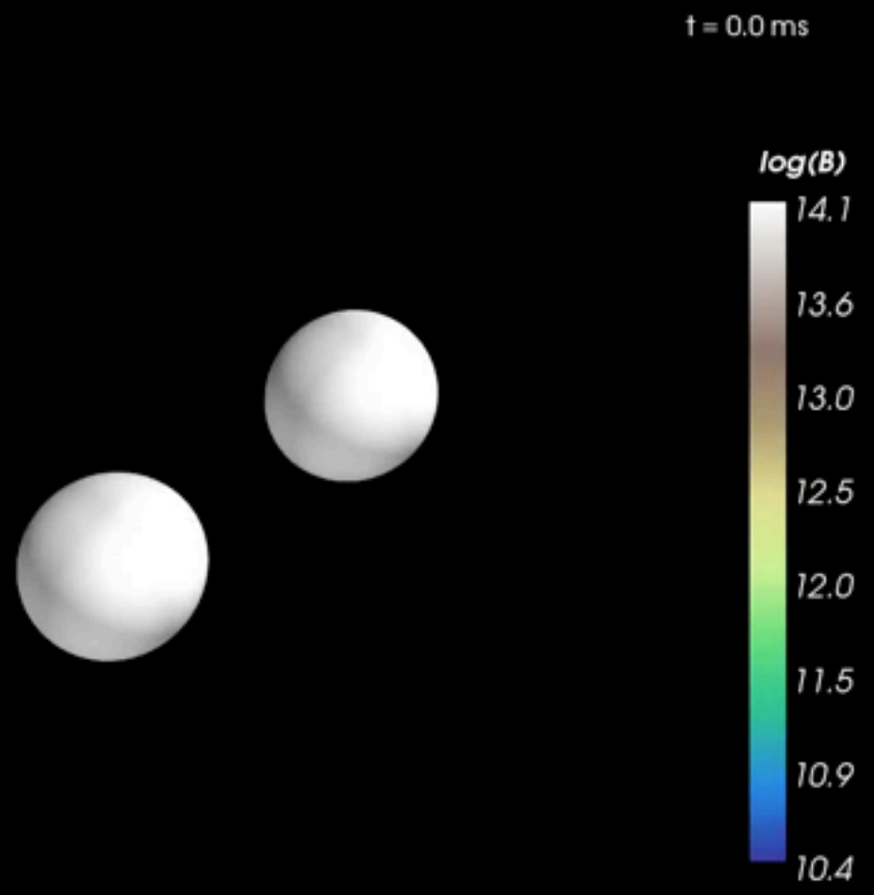
Conical structure of field lines seems emerging… In the way of producing jet?



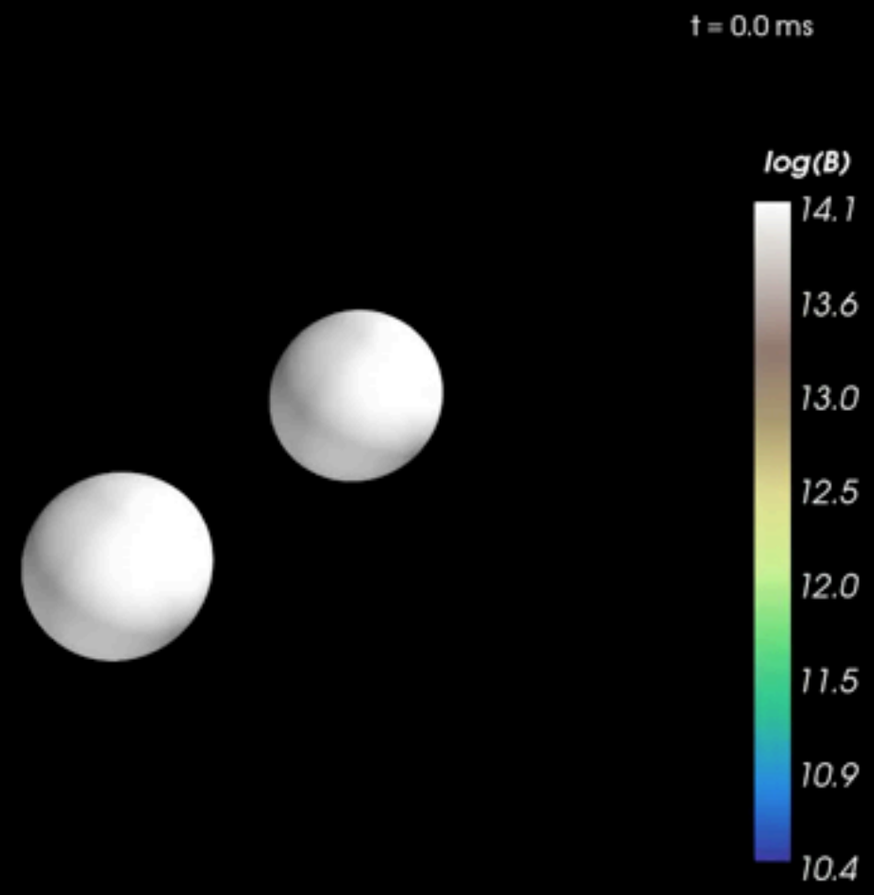




Up–Up



Down–Down



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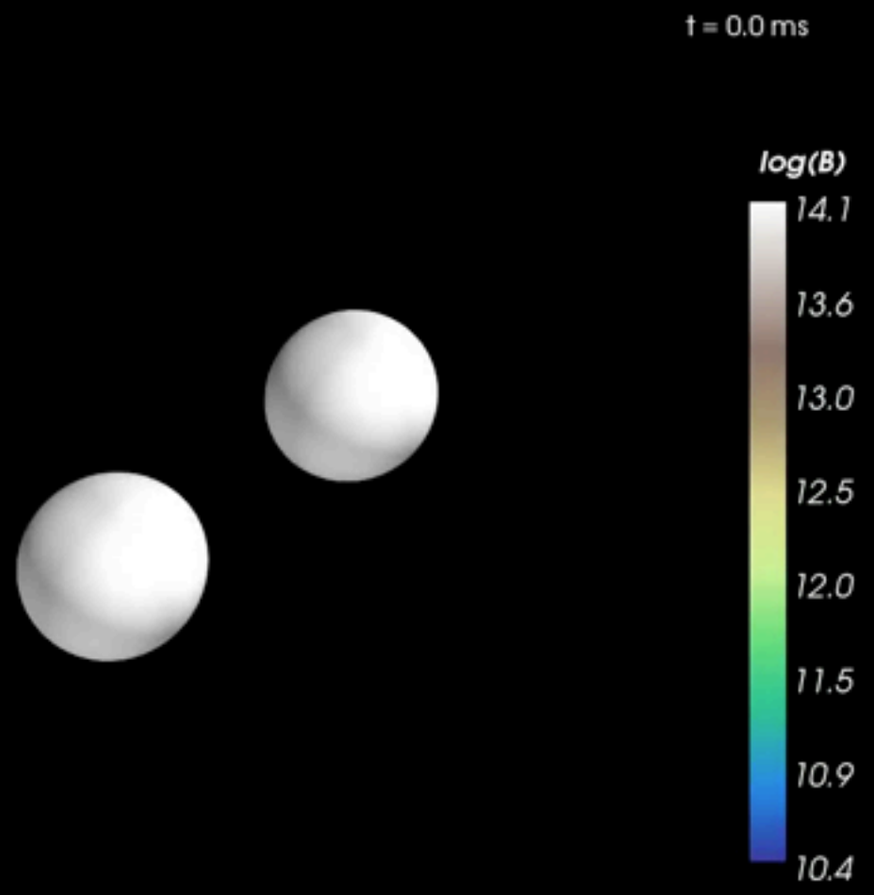

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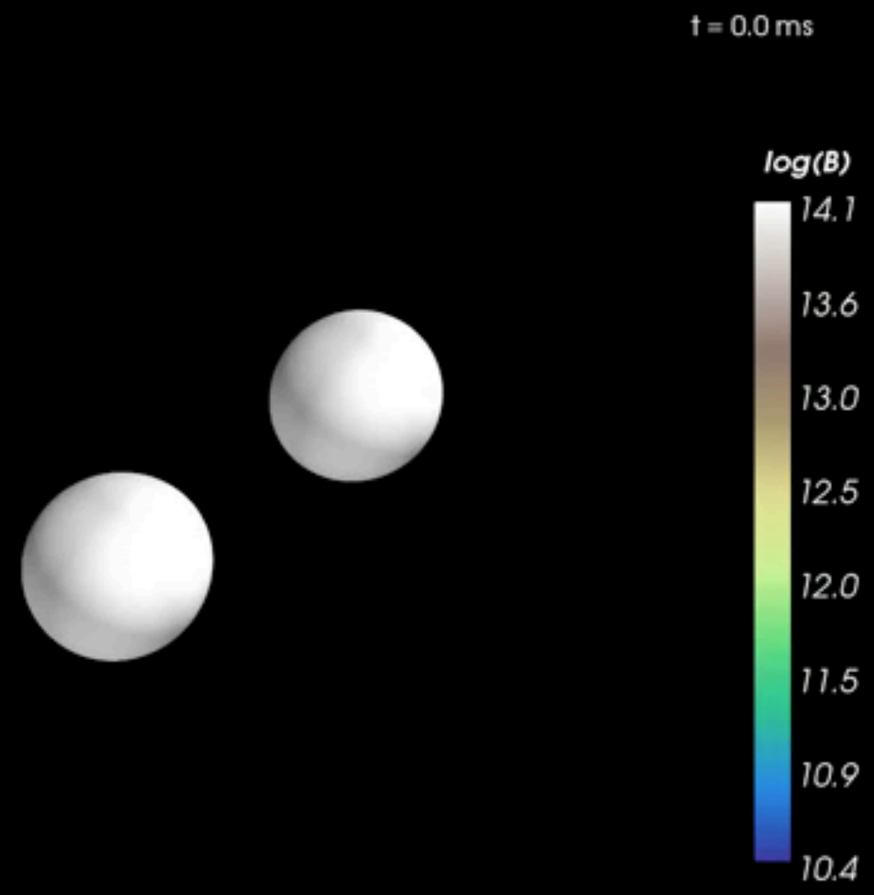

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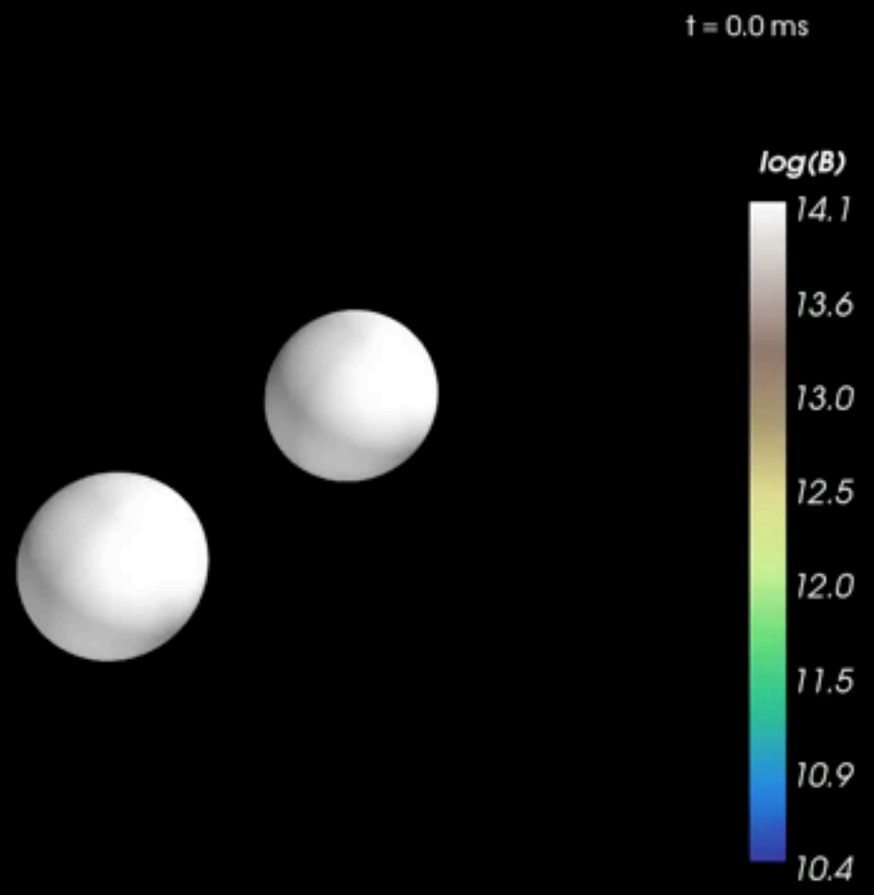
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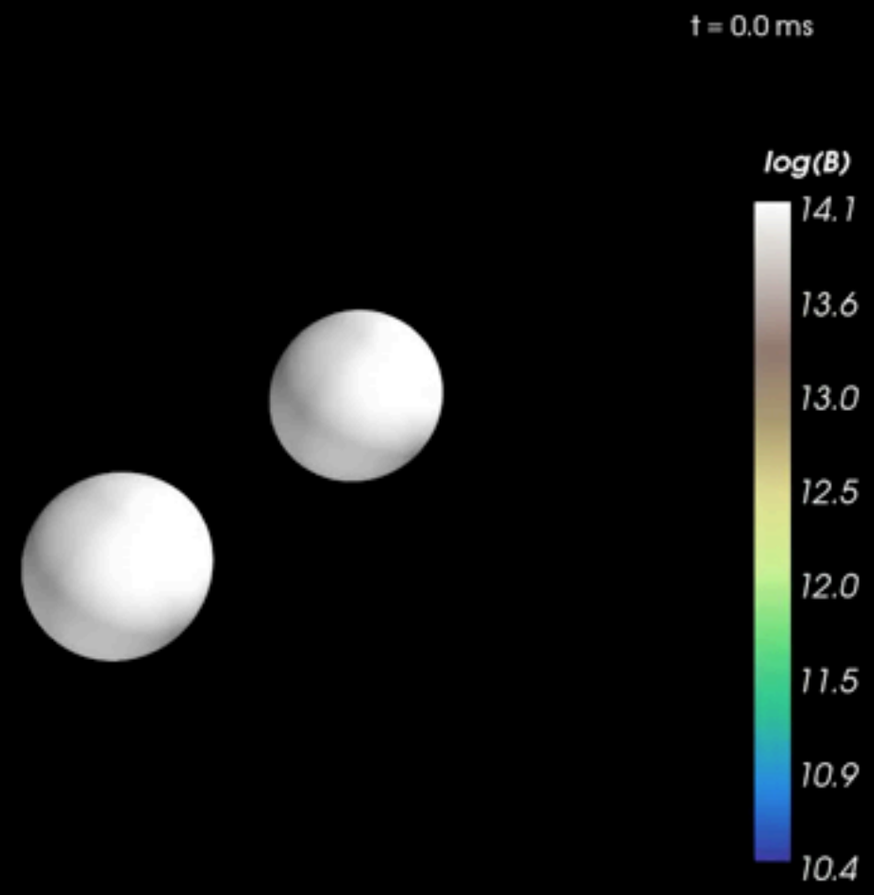
Up–Down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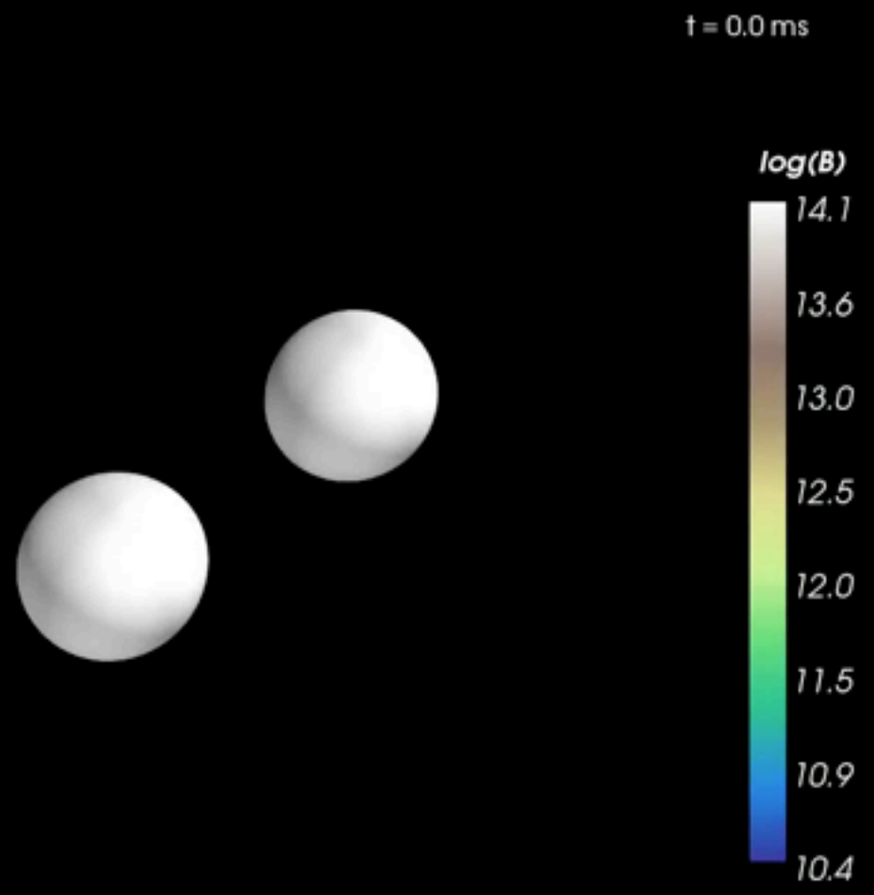
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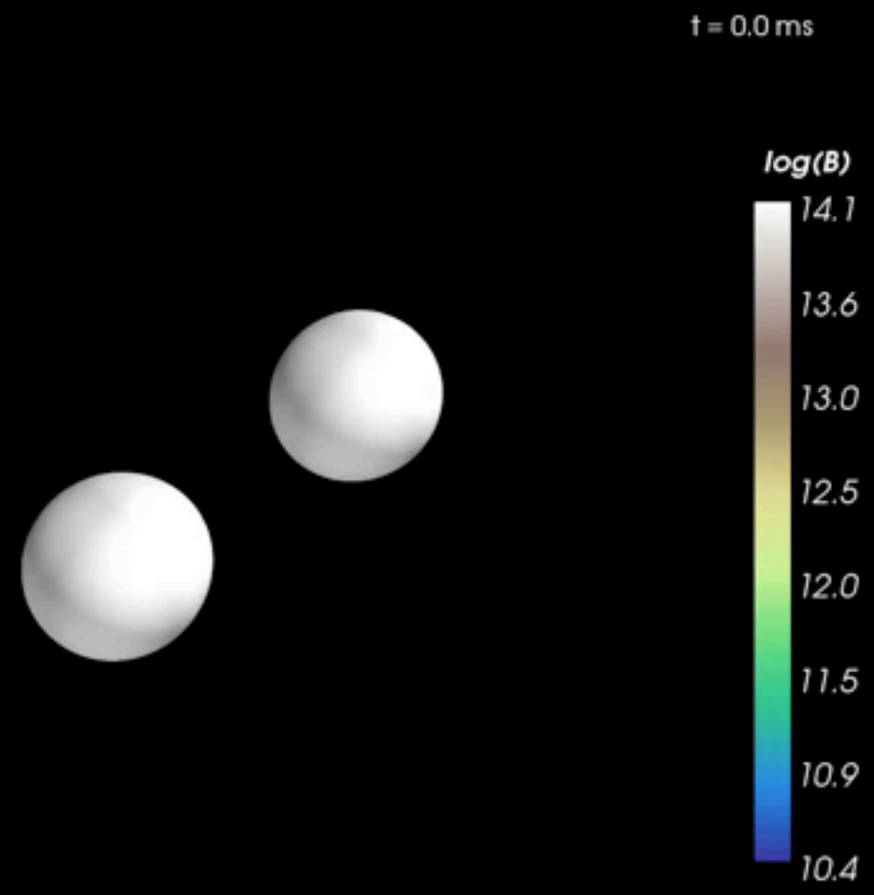
Up–Down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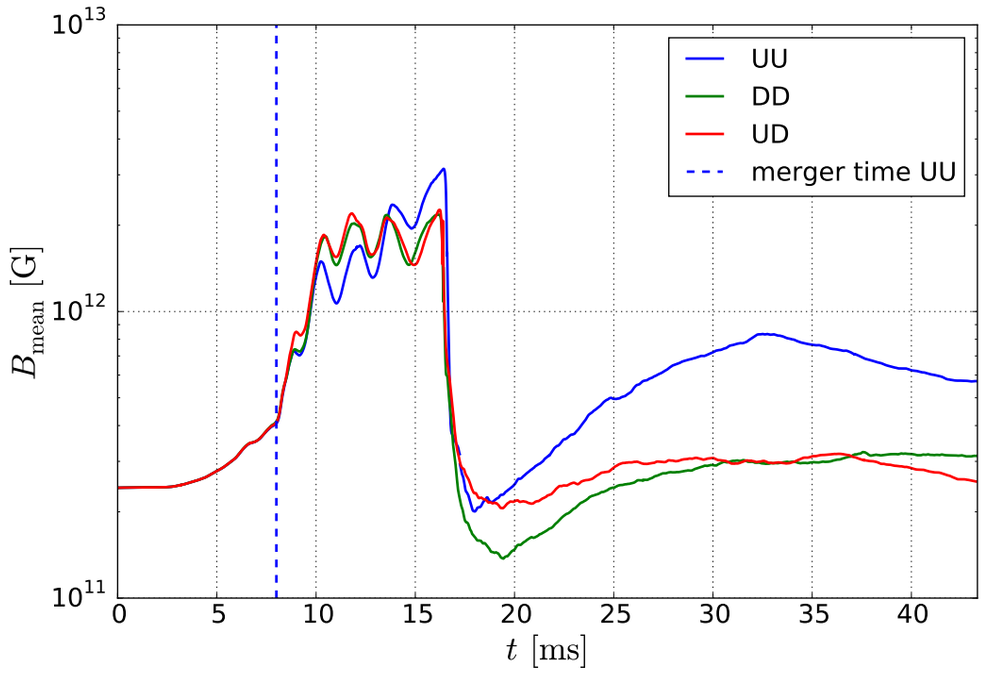
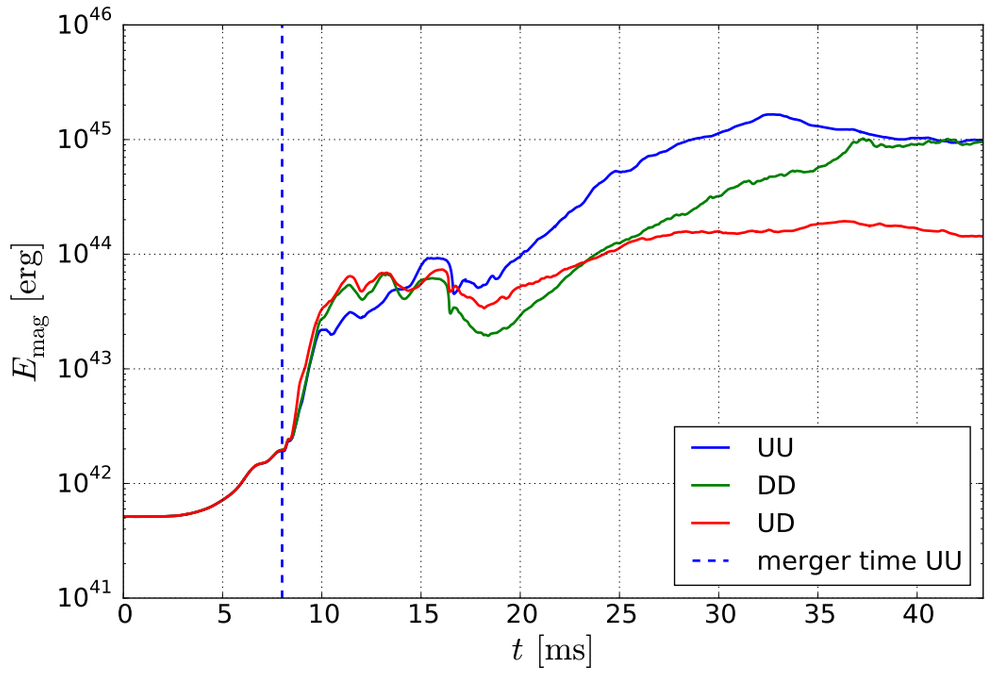
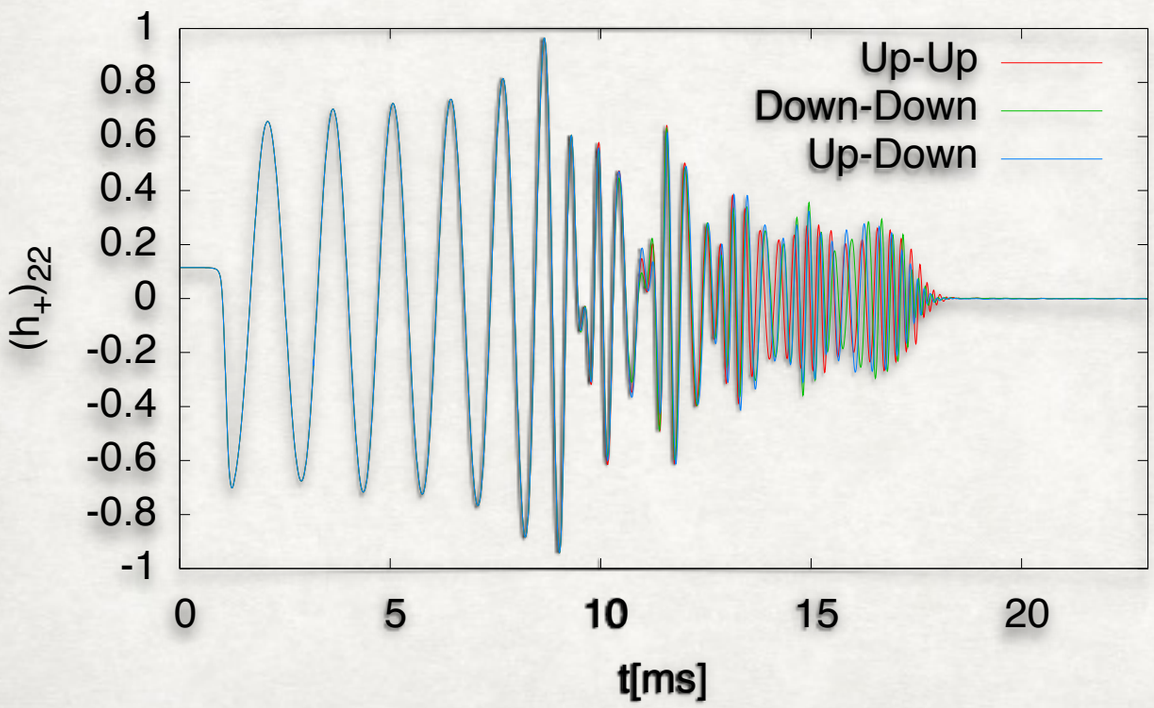
Comparison Among Up-Up, Down-Down, Up-Down Cases







Difference in B field, but not great

difference in GWs.

CONCLUSION

- Up-Up configuration: no strong field along the black hole spin axis
- But conical structure of magnetic field lines can be seen, which might lead to SGRBs
- Magnetic field configuration has weaker effect on matter dynamics
- But has significant effect on magnetic field amplification

-Currently investigating also unequal-mass models and also the role of a different equation of state (H4)