Compact Object Mergers: NS-NS and NS-BH as emitters of GW, EM, and νs in the age of aLIGO, Virgo, and Kagra

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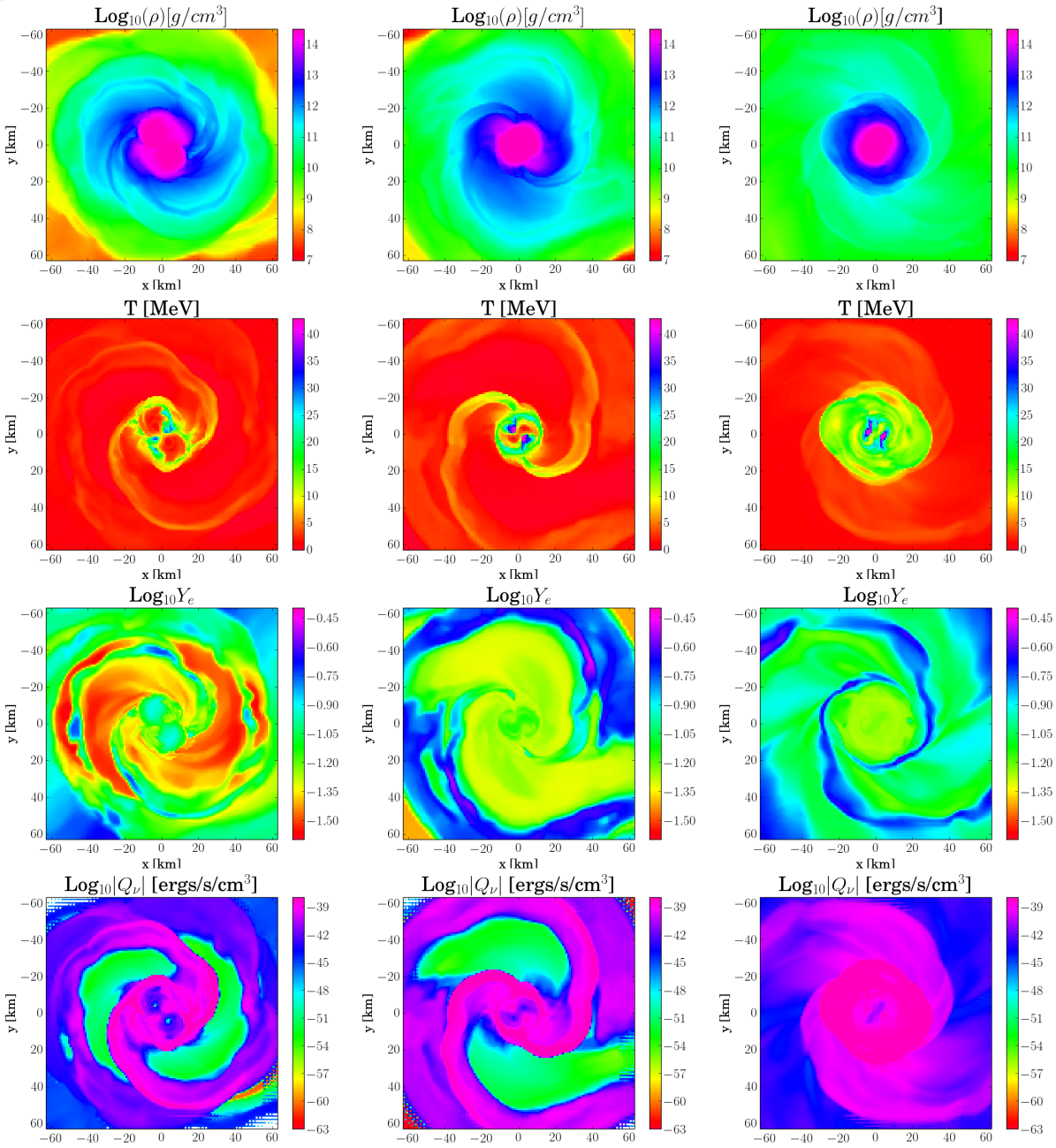
Motivation

- Understand binary mergers better
  - as engines of sGRB
  - as sites of r-process nucleosynthesis (e.g. SGRB 130603B)
  - as drivers of kilonovae
- Understand dynamics generally:
  - jet production...Blandford-Znajek, etc
  - magnetic instabilities...Kelvin-Helmholtz, MRI, etc
- Extract as much science as possible from aLIGO wave detection/observation
  - Determine properties of NS EoS from GW
  - Find possible EM counterparts
  - Multimessenger astronomy via neutrino detection

- Computational
  - Parallel–to use many cores, processors, nodes
  - Adaptive–AMR to refine when and where needed
  - boundaries–good conditions or compactified, etc
- Dynamical Gravity
  - Track the binary components
  - Gravity plays a dynamical role...GR
  - Accurate wave-zone GW extraction/characterization
- Fluid
  - Astrophysical relevance demands matter
  - GR fluid w/ shocks
  - **Realistic EOS**
- Electromagnetism
  - Couplings to matter: **MHD**, electrovac, force-free, resistive
  - Connection of global EM-field to observation: PIC, etc
- Microphysics
  - Neutrino interactions–**Leakage,** Monte-Carlo, full Boltzmann
  - Photon–radiation hydrodynamics

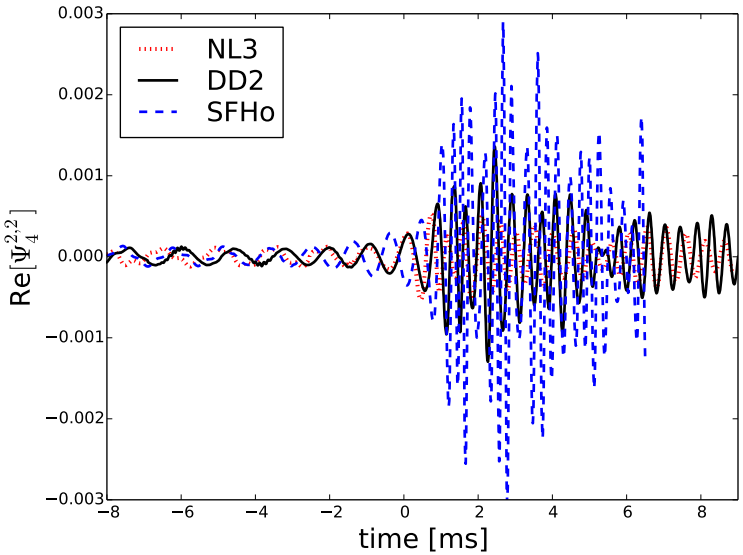
effects of EoS on BNS merger

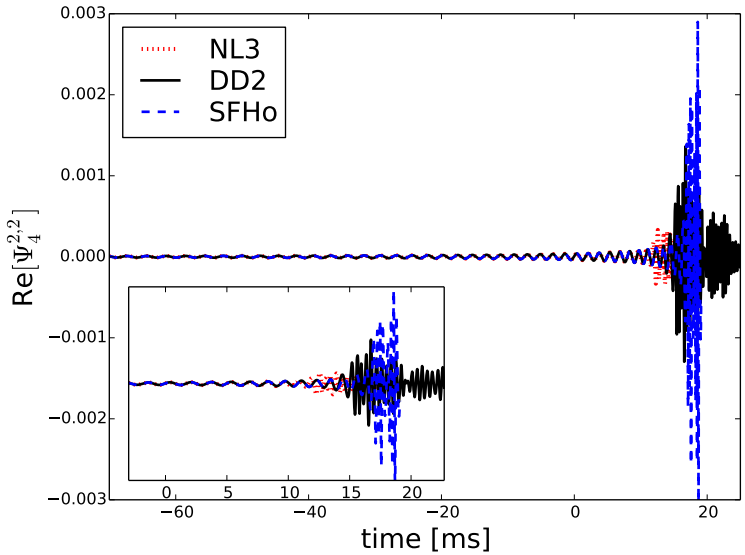


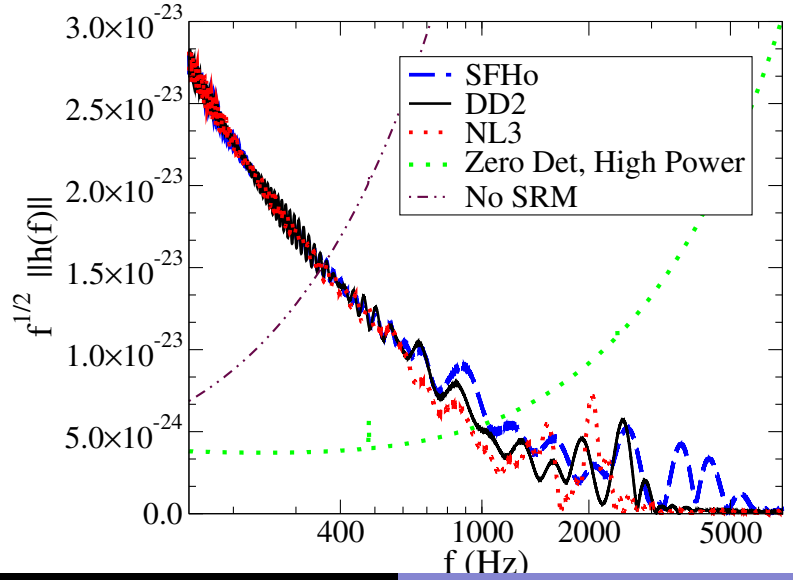
Equatorial Plane

- Left—NL3
- Middle—DD2
- Right—SFHo

GW Waveforms

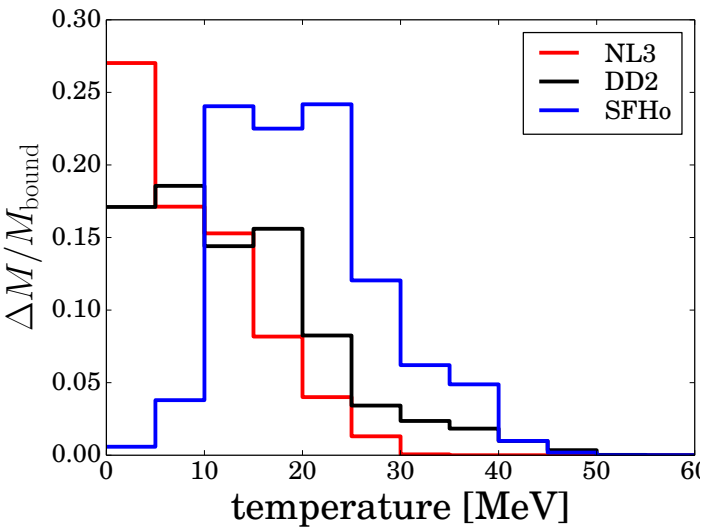


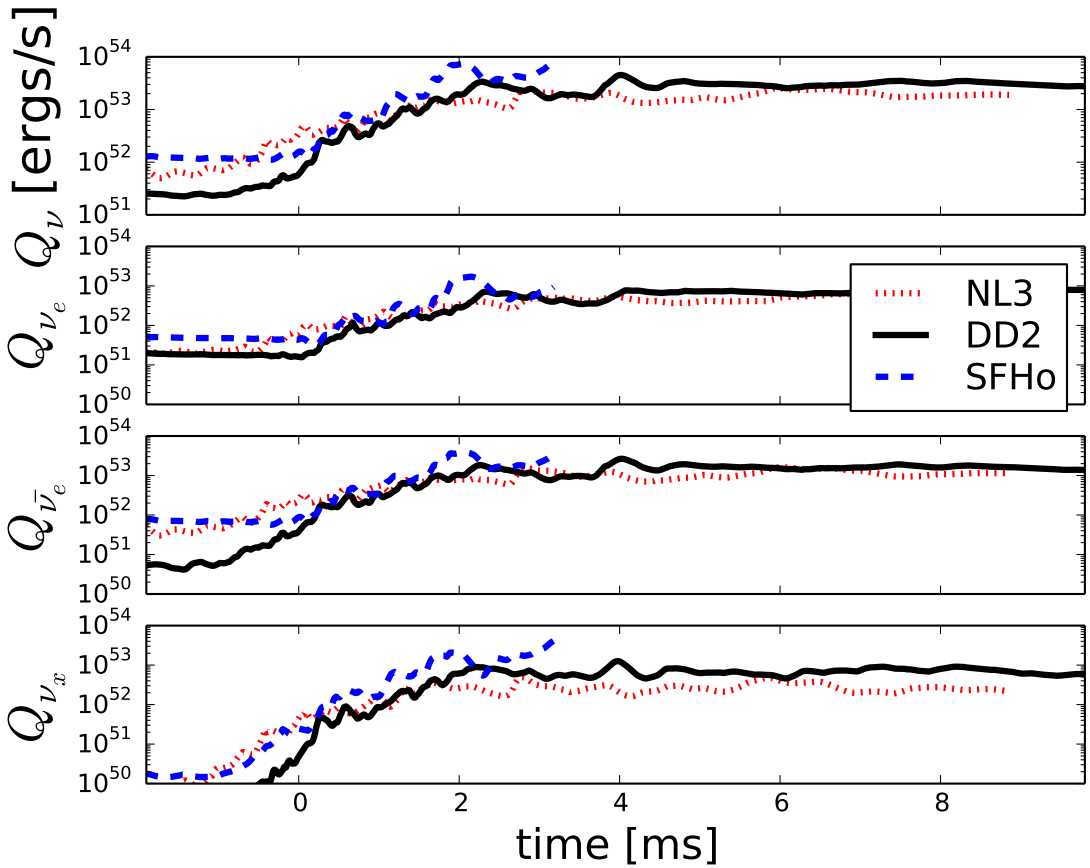




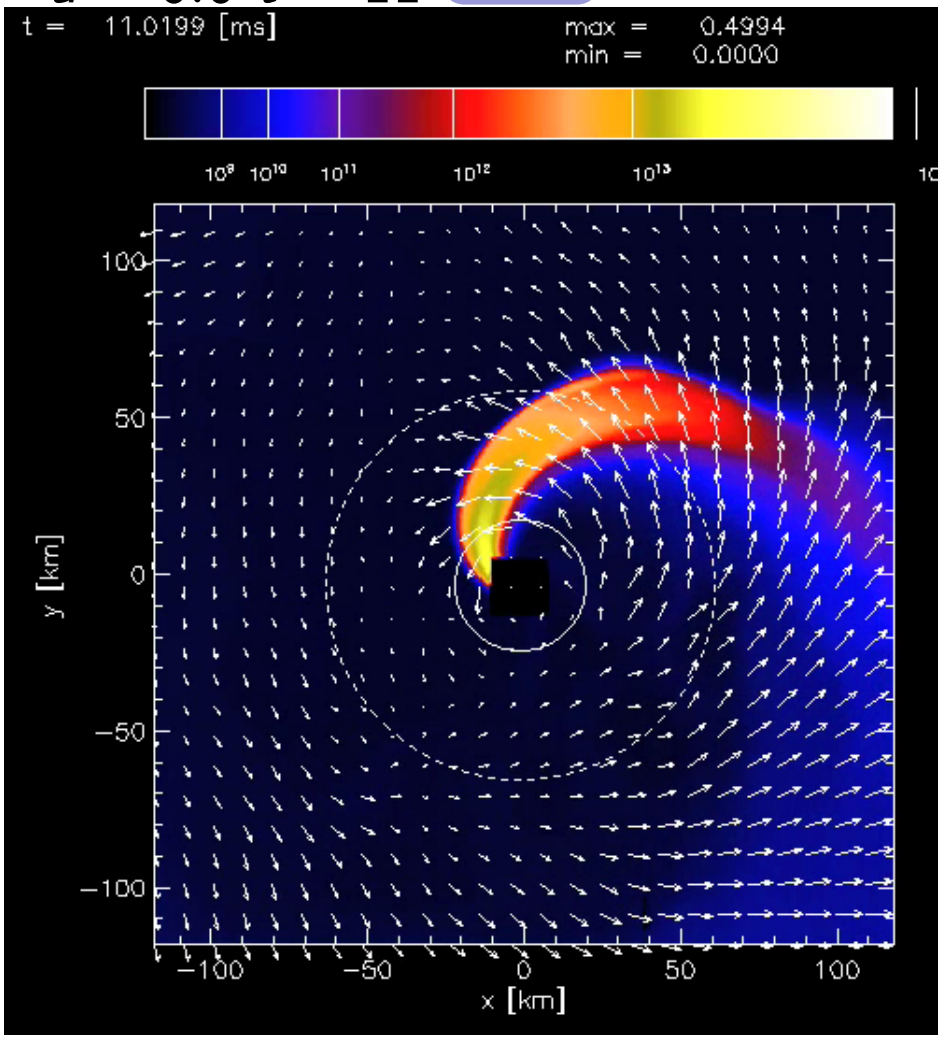
Neutrino Emission

- Softest EoS most luminous because high temperature

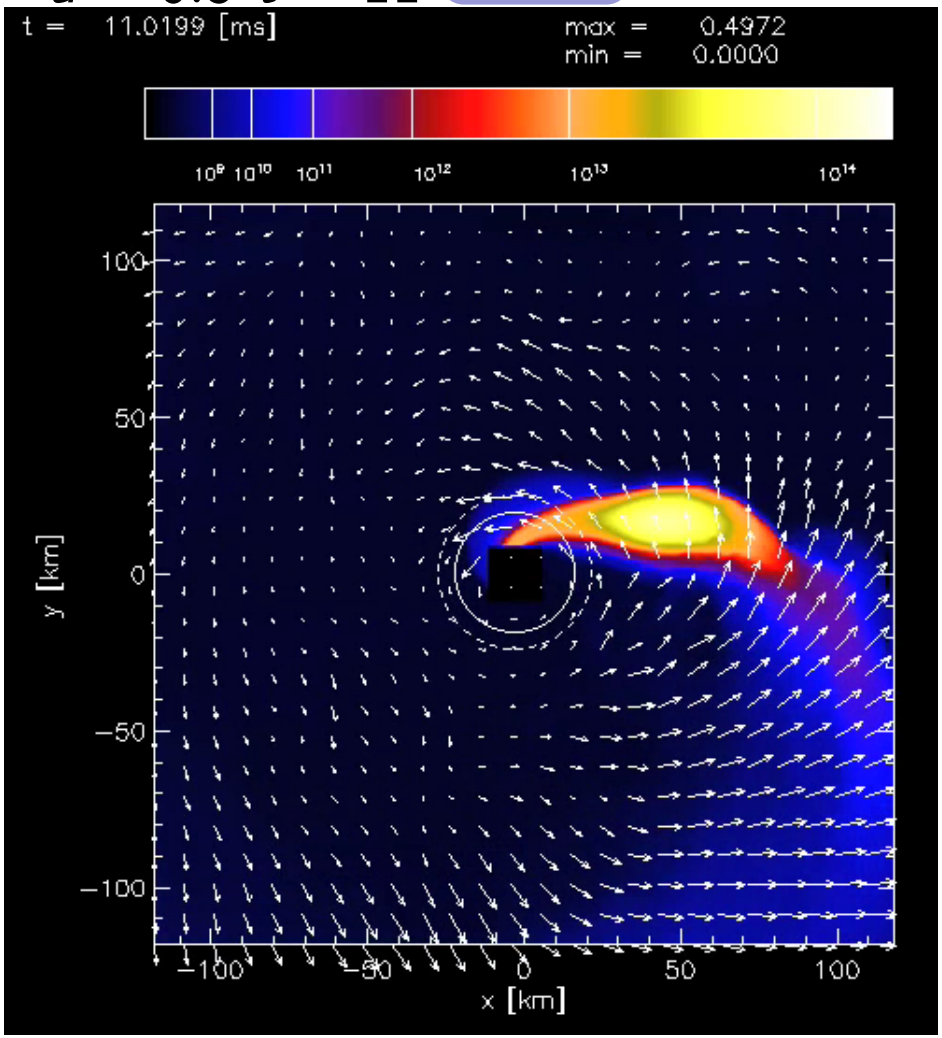




$a = 0.0$ $t = 11$ ▸ $a = 0$

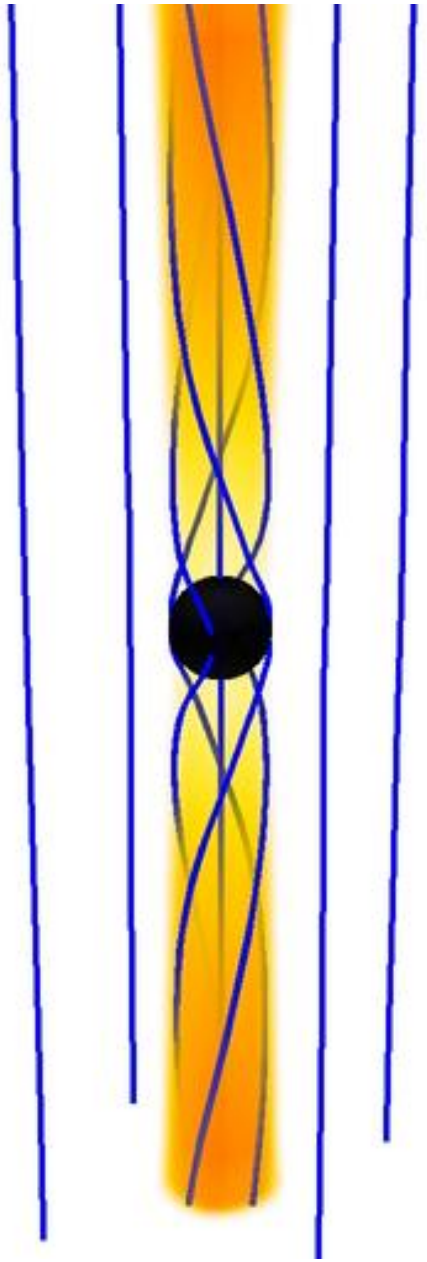


$a = 0.5$ $t = 11$ ▸ $a = 0.5$

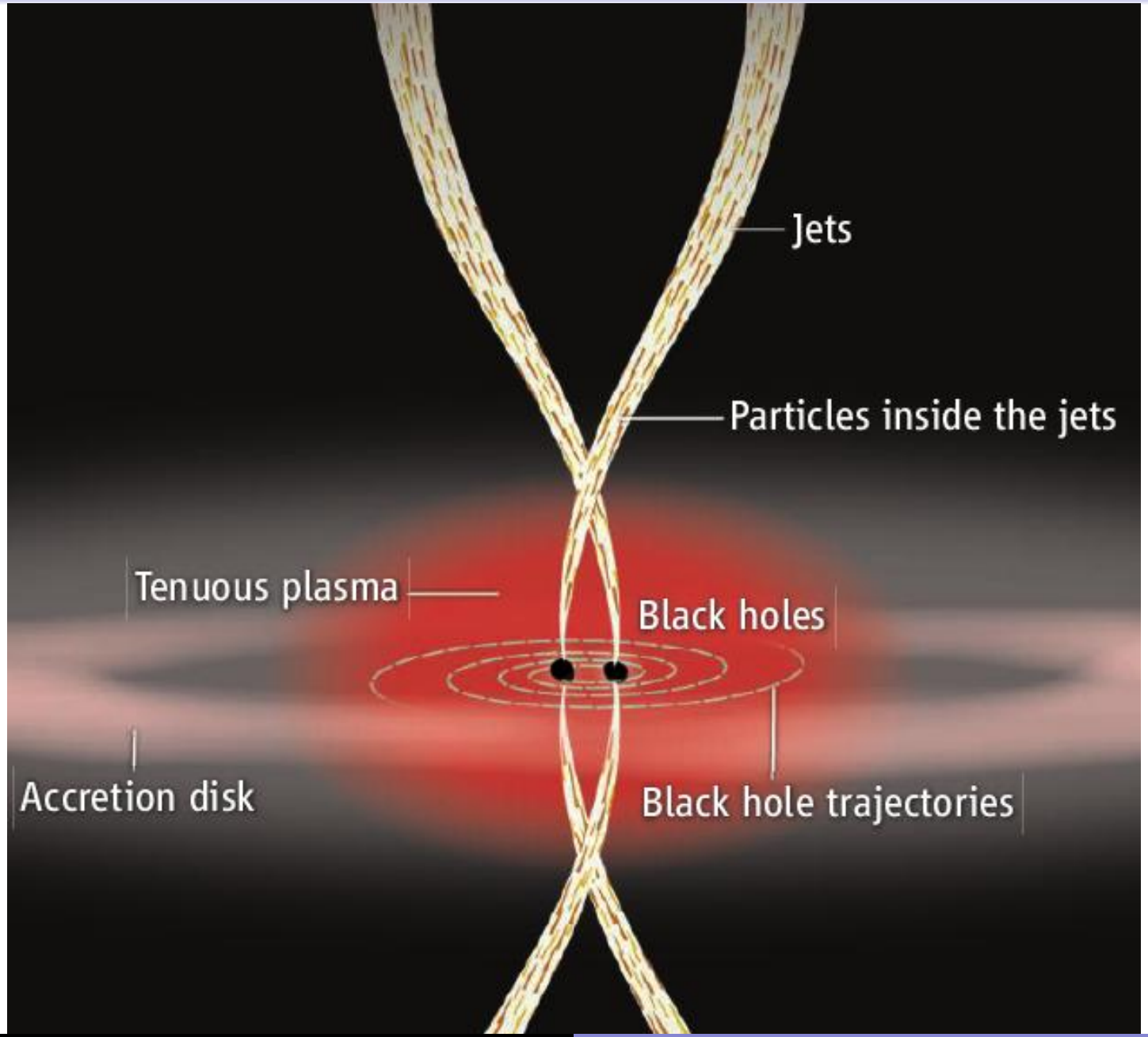


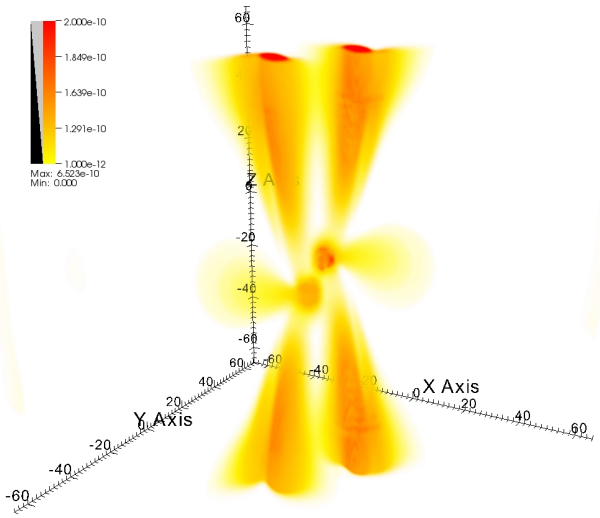
Blandford-Znajek Mechanism for Kerr BH

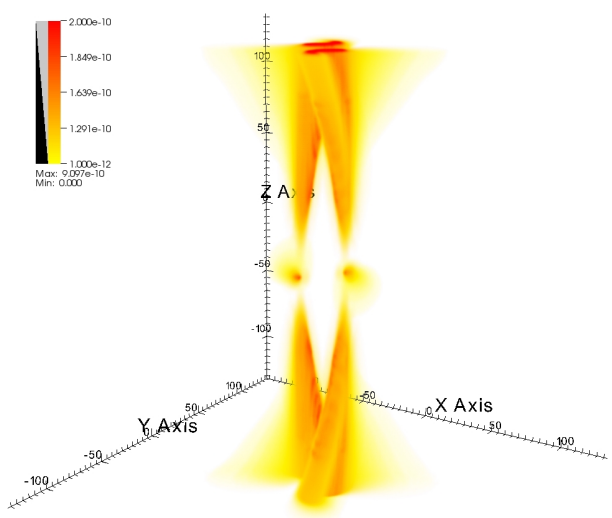
- orange shading–Poynting Flux
- blue lines–magnetic field lines
- Energy extracted:
  - ergoregion of Kerr BH drags field lines
  - tension on field lines propagates
  - Alfvén waves carry energy out



What happens when one relaxes assumption of axisymmetry and fixed metric?


Jets
Particles inside the jets
Tenuous plasma
Black holes
Accretion disk
Black hole trajectories


2.000e-10
1.849e-10
1.639e-10
1.291e-10
1.000e-12
Max: 6.523e-10
Min: 0.000
Z Axis
X Axis
Y Axis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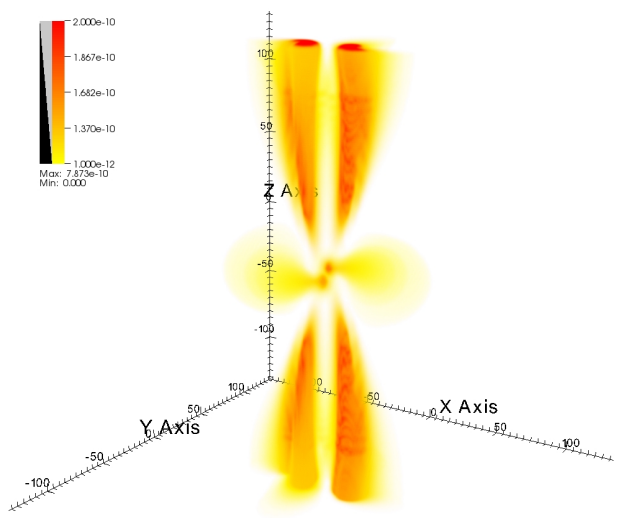
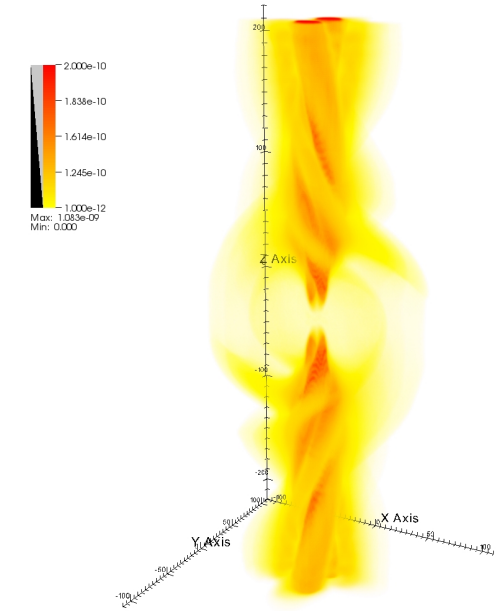
1.849e-10
1.639e-10
1.291e-10
1.000e-12
Max: 9.007e-10
Min: 0.000
Z Axis
X Axis
Y Axis


2.000e-10
1.867e-10
1.682e-10
1.370e-10
1.000e-12
Max: 7.873e-10
Min: 0.000
Z Axis
X Axis
Y Axis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1.245e-10
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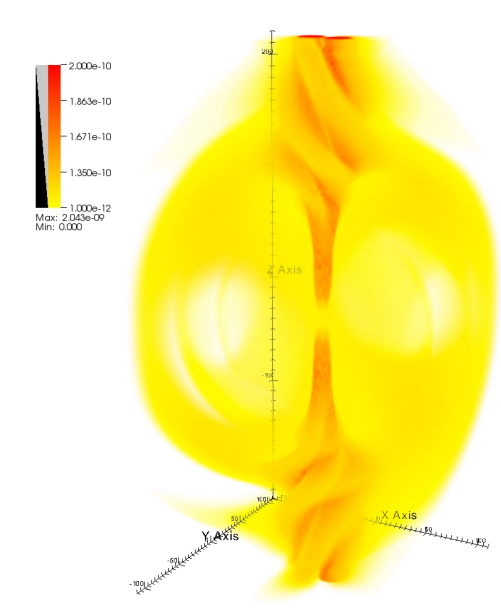
Min: 0.000
Z Axis
X Axis
Y Axis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1.863e-10
1.671e-10
1.350e-10
1.000e-12
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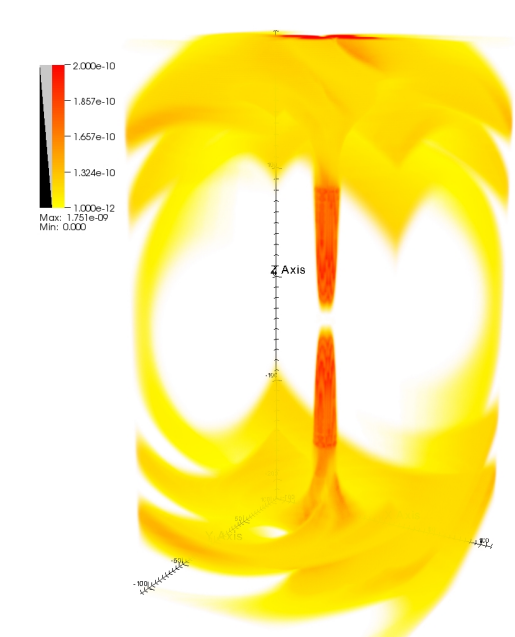
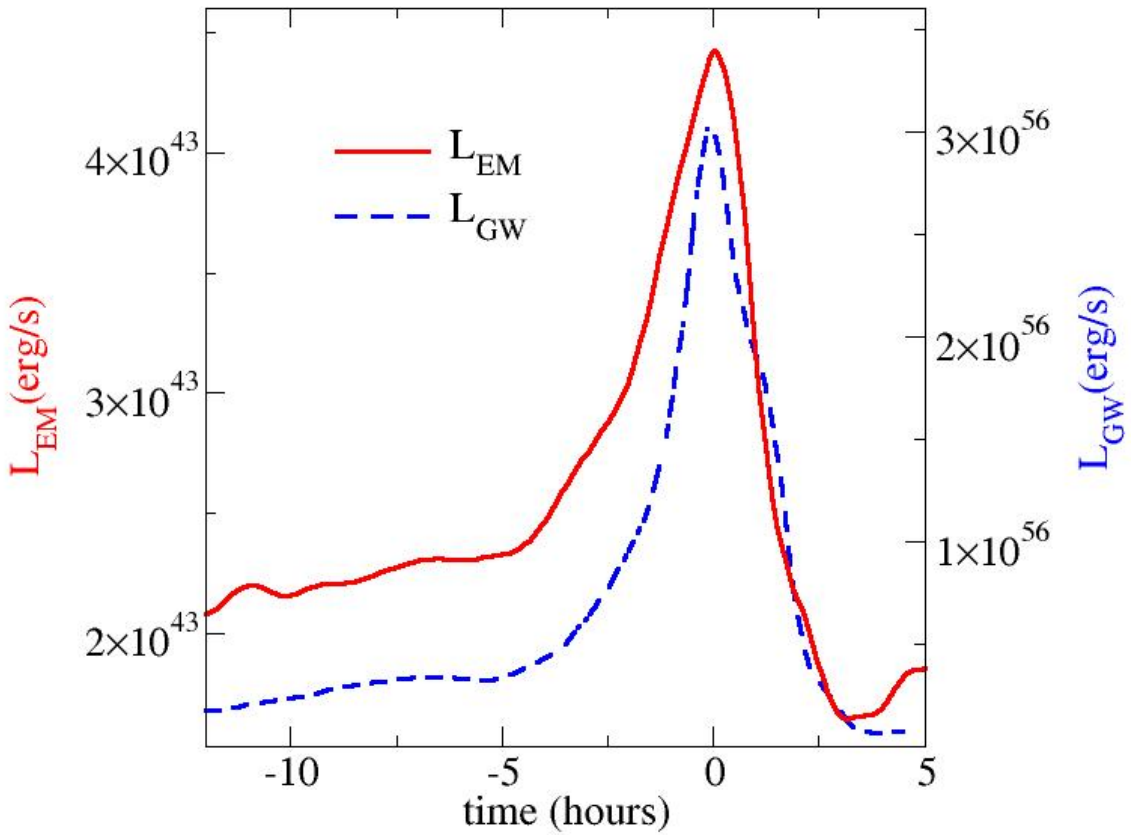
Min: 0.000
Z Axis
X Axis
Y Axis


2.000e-10
1.857e-10
1.657e-10
1.324e-10
1.000e-12
Max: 1.751e-09
Min: 0.000
Z Axis

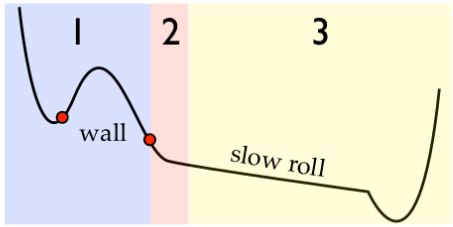
BH-BH with Force Free

- (macroscopic) Poynting flux:
  - Collimated flux for each hole
  - Isometric output peaks at merger
- Electromagnetic luminosity drives radiative processes...*unknown radiative efficiency*
- EM flux mostly **pre-merger** as opposed to GW emission in final few hours

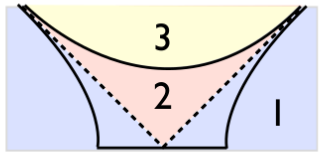


Other Interests

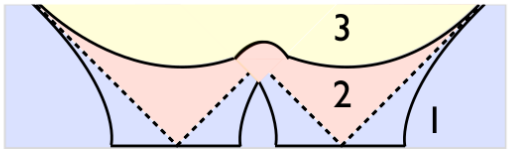
- Cosmology
  - Inflation (eternal, topological, bubble collisions)
- Nonlinear dynamics
  - Topological defects–monopoles, cosmic strings
  - Nonlinear wave equations & boson stars
  - Black Hole Critical Behavior
  - AdS-CFT Correspondence
- High Performance Computing
  - Techniques: AMR, Multigrid, domain decomposition
  - Heterogenous computing (GPGPU, Phi, Fusion, etc) w/ OpenCL and OpenAcc



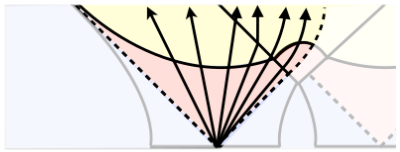
Model



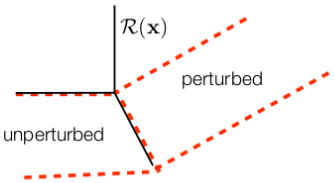
Single Bubble



Collision Simulation



Metric Reconstruction



Cosmological Signatures