ASTROPHYSICS OF COMPACT BINARIES

Surendra Padamata

Break...

Topics of current interest

Gravitational waves - compact binaries

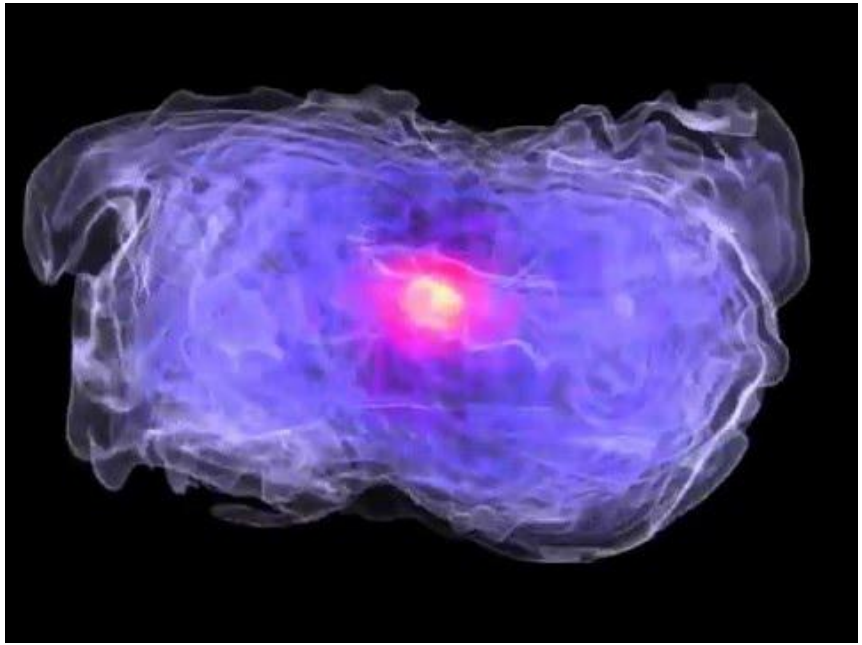
FRB, sGRB, accretion disks and flows, kilonova, TDE

Supernovae

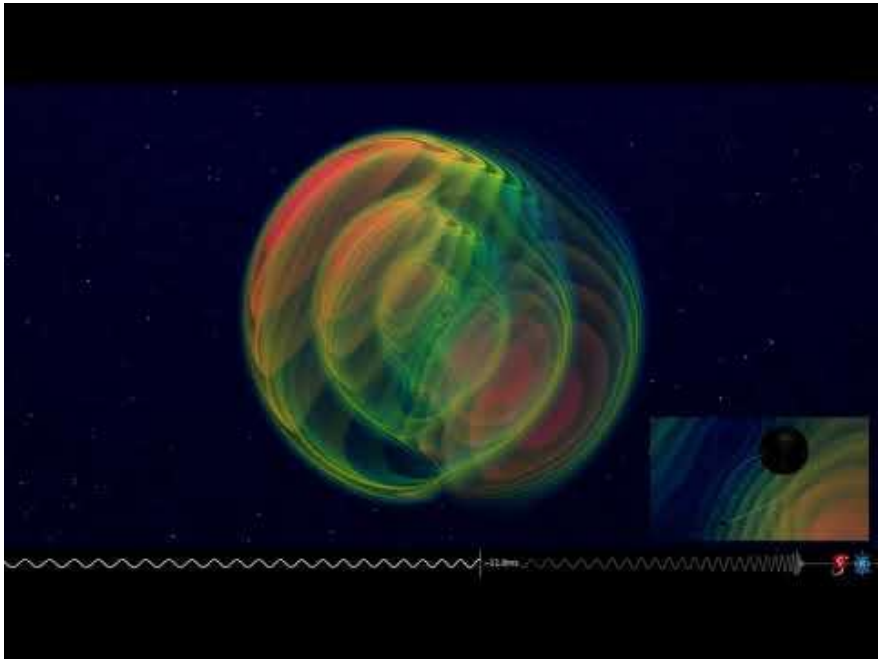
Mathematical relativity and Cosmology

Tests of GR, constraning physics at high densities, verifying models - providing templates and data for observations

Compact mergers

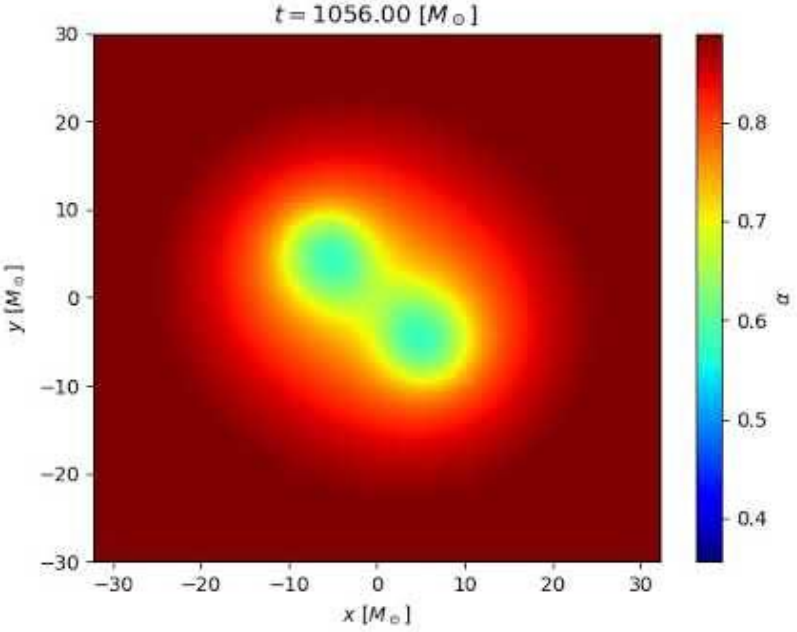


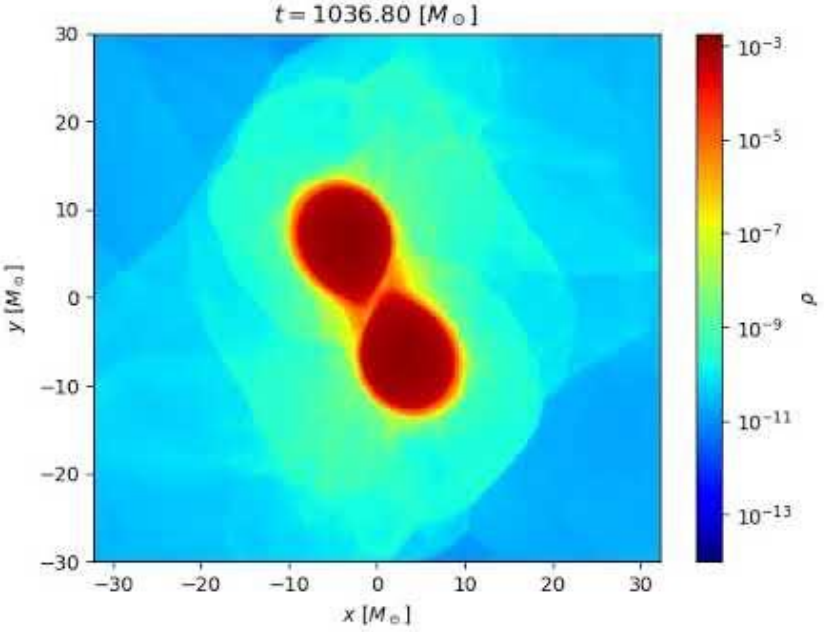
Credits: David Radice et al



Credits: Max Planck Institute for Gravitational Physics and SXS

BBH and BNS merger

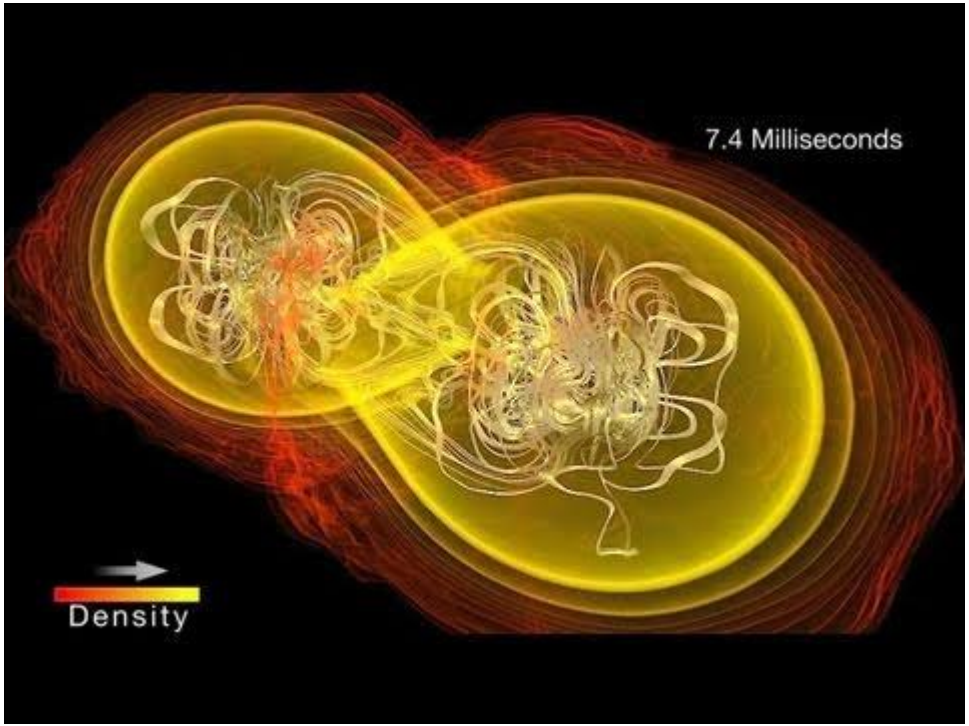




Future directions

- Creating initial data for hybrid binaries like NS-BH, WD-IMBH
- Including eccentricity, spins, magnetic fields
- Resolving turbulence effects and various instabilities
- High precision waveforms
- Adding new microphysics like neutrino absorption and neutrino annihilation
- Alternate theories of gravity
- Better understanding of NS structure(Crust, Pasta, Lattice, elasticity, super fluidity and conductivity, inner core)

sGRB

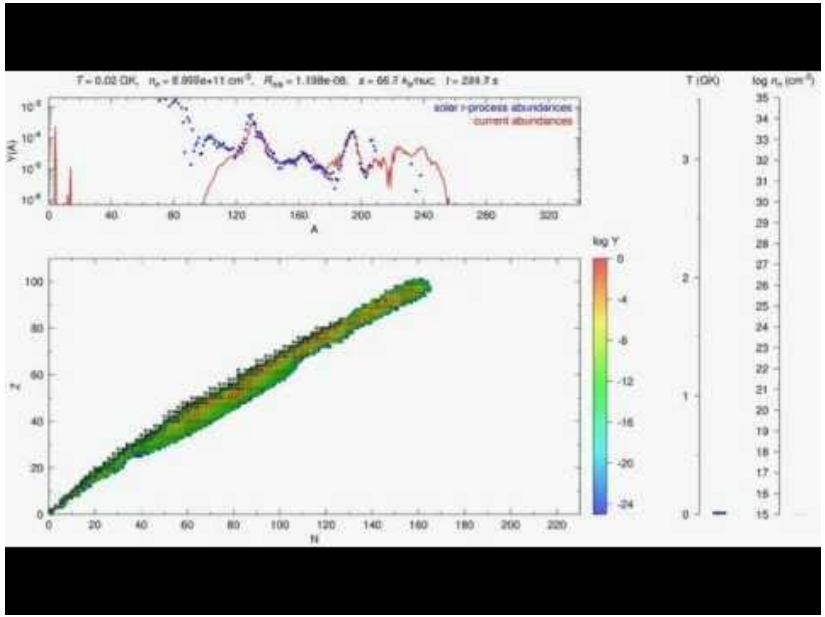


Credits: NASA

Future directions

- Effects on radio afterglow due to jet shock
- Origin of prompt emission- reconnection, shocks
- Progenitors
- Evolution of the jet

Kilonova



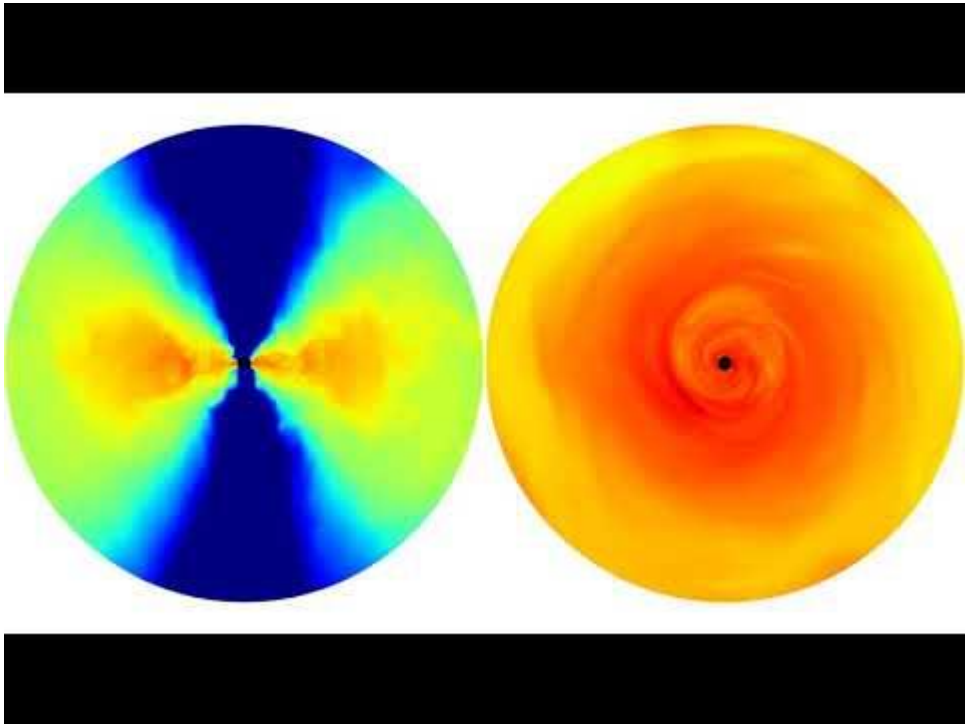
Credits:Joel de Jes´us Mendoza-Temis et al

Credits: ESO/L. Calçada. Music: Johan B. Monell (www.johanmonell.com)

Future directions

- Better modeling of dynamical and wind ejecta
- Inclusion of nuclear burning
- Blue kilonova and Red kilonova origins
- Distribution of masses and velocities of ejecta
- Event rate
- Solar abundance

Accretion disks



Credits: Illinois Physics

Future directions

- Better viscous modeling
- Including new microphysics

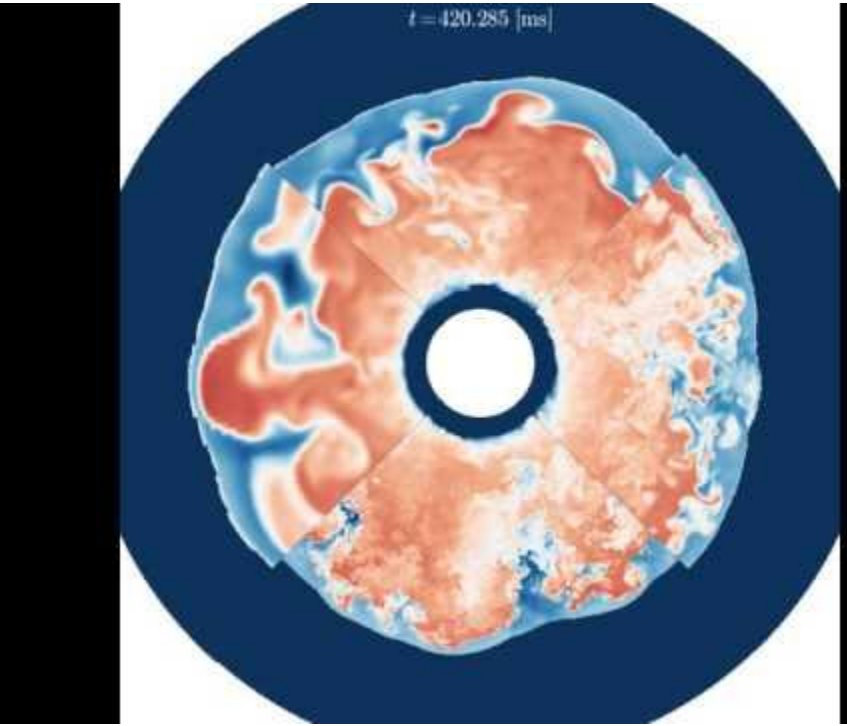
TDE

Credits: NASA Goddard Space Flight Center
NASA/CXC/U. Michigan/J. Miller et al.
NASA/CXC/M. Weiss

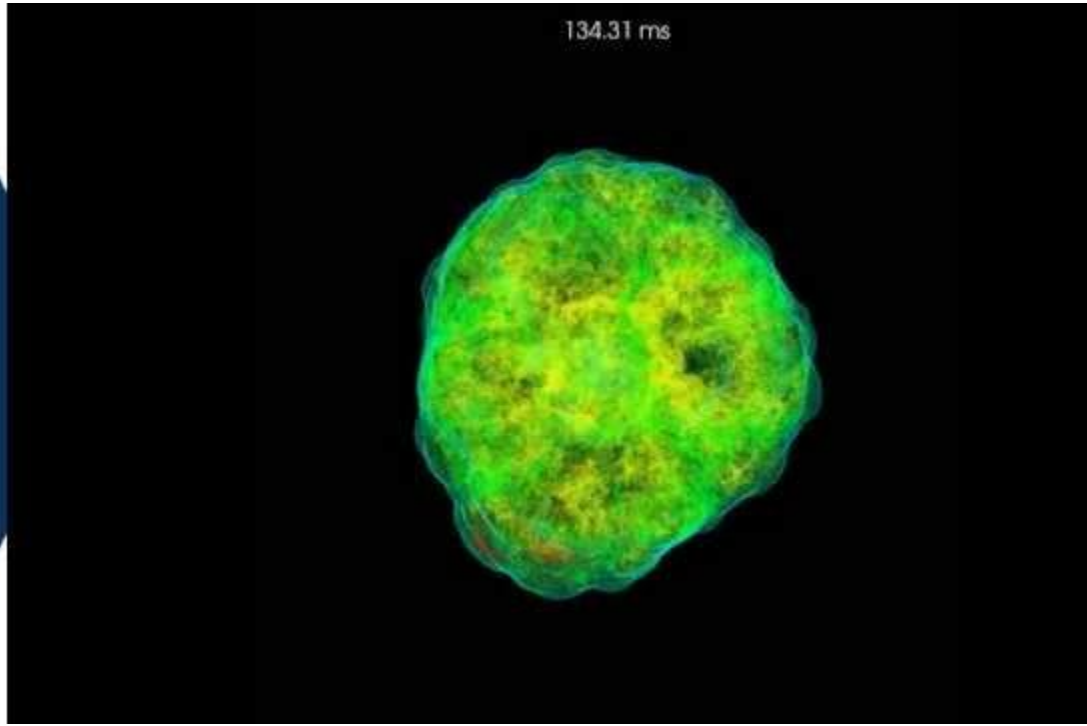
Future directions

- Studying this set up in the case of high mass ratio binaries
- Understanding and modeling multi-messenger emission from such scenarios
- More 3D simulations not just 1D and 2D

Supernovae



Credits: David Radice et al



Credits: SXS Collaboration

Future directions

- More 3D simulations
- Effects of turbulence
- Better understanding the explosion process
- Asymmetric setting

Break...

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Gravitational wave astronomy and astrophysics

- What is it? Why? How?
- Data analysis - template banks, surrogate modeling, detection pipelines
- Population studies - distribution, event rate, recoil
- Tests of GR and alternates
- EOS and final post-merger remnant constraints
- Hubble constant, Dark matter
- Chemical evolution of the observable universe
- Better understanding of various astrophysical processes through multi-messenger observation (localization, EM counterparts, cosmic rays and HE neutrinos)

Resources

Open Astrophysics Bookshelf by Open-Astrophysics-Bookshelf

PHY 604: Computational Methods in Physics and Astrophysics II

Surendra Padamata - Software

https://bitbucket.org/ssp5361/gwa2020/src/master/

Coursera: **The Finite Element Method for Problems in Physics, Introduction to Numerical analysis, Simulation and modeling of natural processes and Computers, Waves, Simulations: A Practical Introduction to Numerical Methods using Python**

Edx: **High Performance Finite Element Modeling Part 1 and 2, Plasma Physics and Relativity and Cosmology**

Skill set

Literature review - arXiv, inspire, google scholar

Numerical methods - FD, FE and FV

Programming language - C++, Python

Visualization - Python, VisIT, YT, ffmpeg

Software development - git

Shell scripting - bash

HPC - Parallelization (eg: MPI, OpenMP) - **XSEDE schools**

Tips

Maintain a github/bitbucket page

Explore open source software and their structures

Develop your own codes implementing new methods to old problems

Create reports - **LaTex**

Explore and expand - **arXiv**, **Inspire**

Collect all documents and structure them - Zotero

Twitter, magazines like **Quanta**, **Nature**, **Science**, **Symmetry**

Special mention: astrobites !!!

Books and reviews

NR and BBH - ICTS School-HP

BNS mergers - ICTS School-IH

CCSNe - Recent overview

sGRB - ICTS school-FG

Kilonova - ICTS school-MT

Accretion flows - Intro, NDAF

Numerical methods - Leveque FV, FD and CL

Theory of PDEs - Lawrence.C.Evans

C++ - Intro

FRB - collection

TDE - Recent overview

List of universities

- Graduate schools abroad and in India for GWAVE astrophysics
- MSU, SBU, UW, UoArizona, UCB, ANU, UChicago, UTorronto, UoJena, UoTrento, MPIs, UoMelboune, UoTokyo, Kyoto, UoSouthampton, UoHamburg, UoBonn

Thank you for your attention!

Q&A