

Numerical techniques for modeling relativistic hydrodynamics in Astrophysics and Cosmology

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Course content:

C1: - Basic properties of fluids and plasmas in astrophysics

- ❖ Ideal versus dissipative fluids
- ❖ Euler and the Navier-Stokes equations
- ❖ Compressible, weakly compressible and incompressible fluid flows
- ❖ Magnetohydrodynamics

C2: Numerical methods in hydrodynamics

- ❖ The equations in the finite space
- ❖ Conditionally versus unconditionally stable numerical schemes
Explicit & implicit formulation
- ❖ Preconditioning techniques and defect-correction iteration procedure

C3: Introduction to programming and computer-solving simple equations

C4: Introduction to General Relativity & Relativistic Cosmology

- ❖ **A brief** derivation of the relativistic & general relativistic Euler and Navier-Stokes equations
- ❖ Dynamics of the expanding universe
 - Basic concepts in modern cosmology:

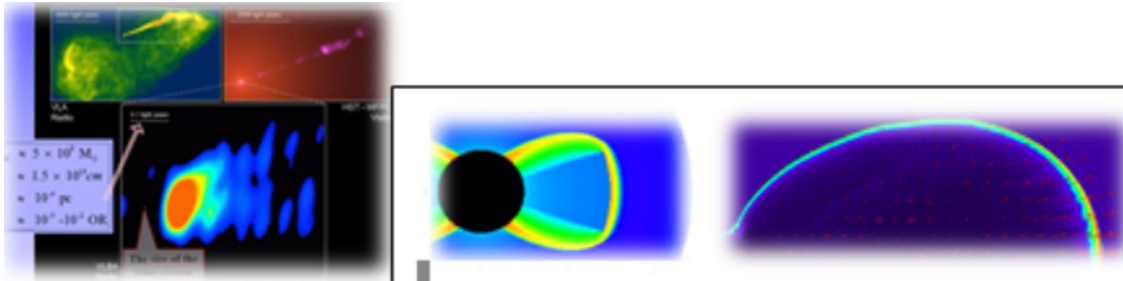
Black holes, dark matter, dark energy, inflation

C5: Numerical aspects of relativistic Cosmology

C6: Projects:

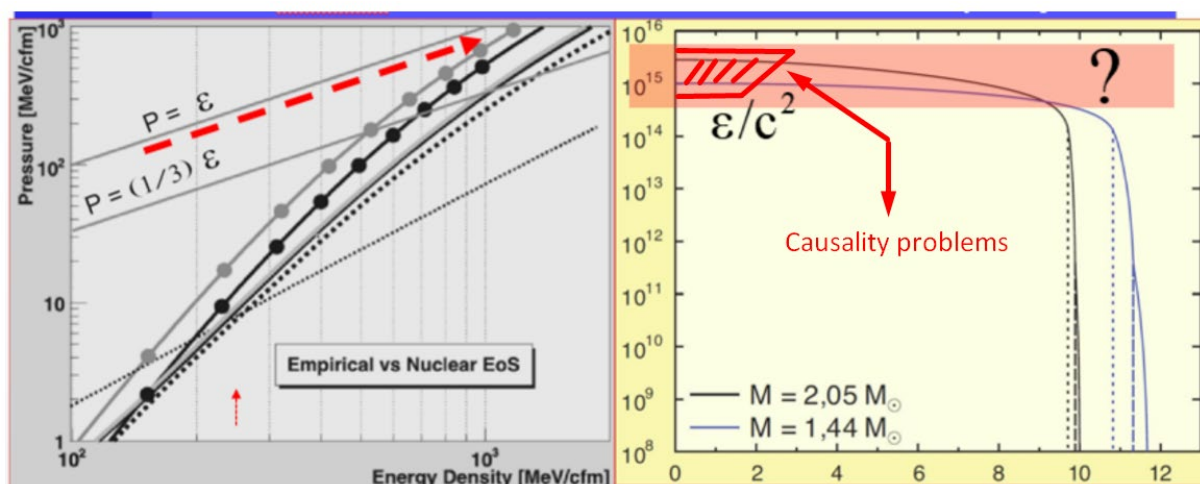
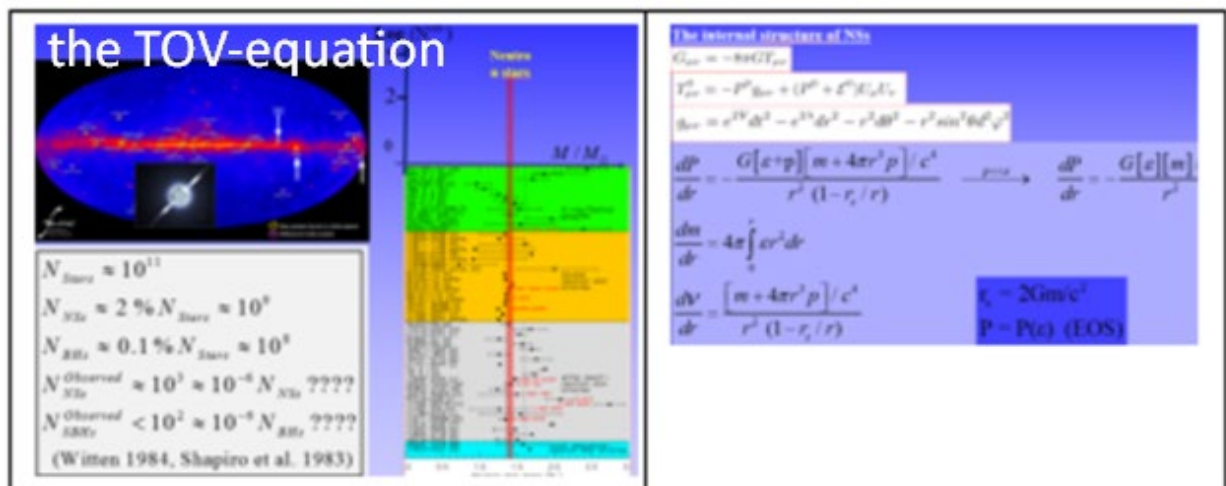
Numerical methods, programming and computational techniques

I. The propagation of ultra-relativistic shock fronts (1D)



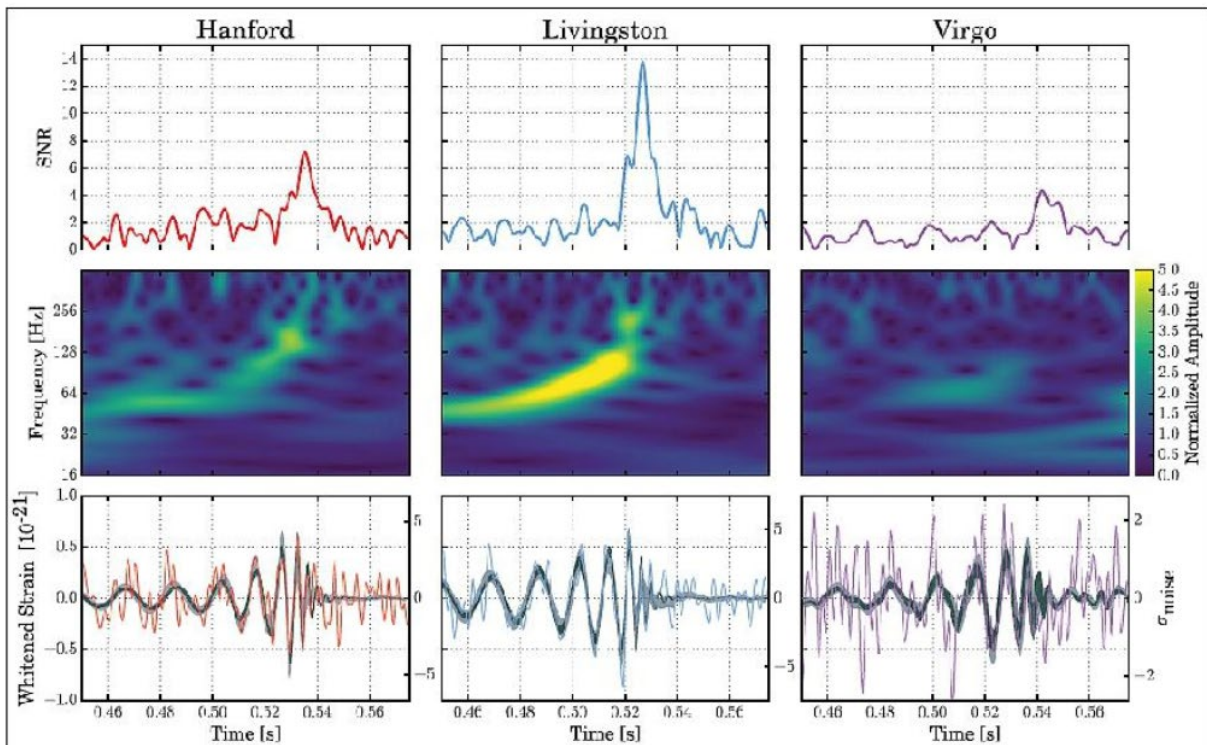
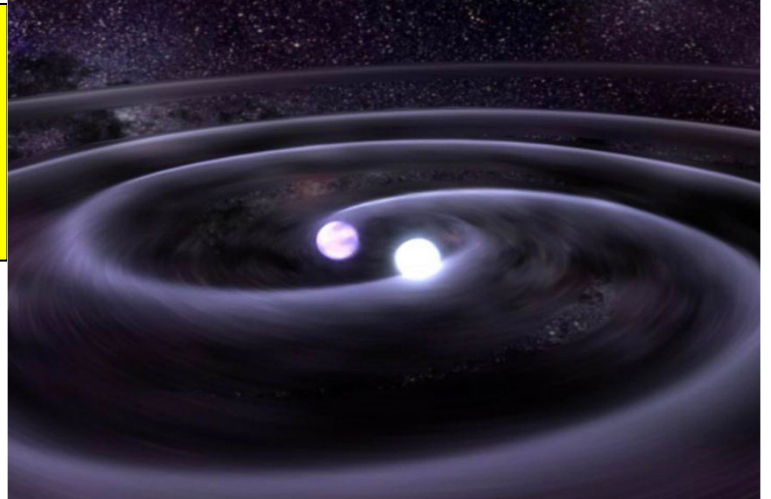
II. Studying the internal structure of neutron stars

➤ Exploring the internal structure of neutron stars by solving



Project-3: The story of the neutron star merger in

GW170817



Addition projects:

**I. Hadronization of the big bang's progenitor:
Numerical simulation**

II. Theory:

- a. Glitch phenomena in pulsars & Superfluidity
- b. GR derivation of the UNIMOUN model

Literature:

1. Hirsch,C., Numerical Computation of Internal and External Flows. Vol. I and II.
John Wiley & Sons, Chichester, 1990
2. Caminzind, M., "Compact Objects in Astrophysics", Springer-Verlag, 2007
3. Hobson et al., "General Relativity"
4. Hujeirat,A.A.; A collection of scientific articles & reports

❖ **Lecture notes are downloadable weekly from:**



(<http://www1.iwr.uni-heidelberg.de/groups/compastro/home/>)

❖ **Exercises should be answered and submitted timely,
namely: before the start of the subsequent lecture**