Title: Lecture - Strong Gravity, PHYS 777

Speakers: William East

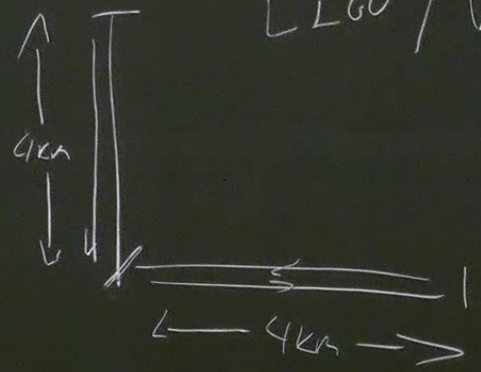
Collection/Series: Strong Gravity (Elective), PHYS 777, February 24 - March 28, 2025

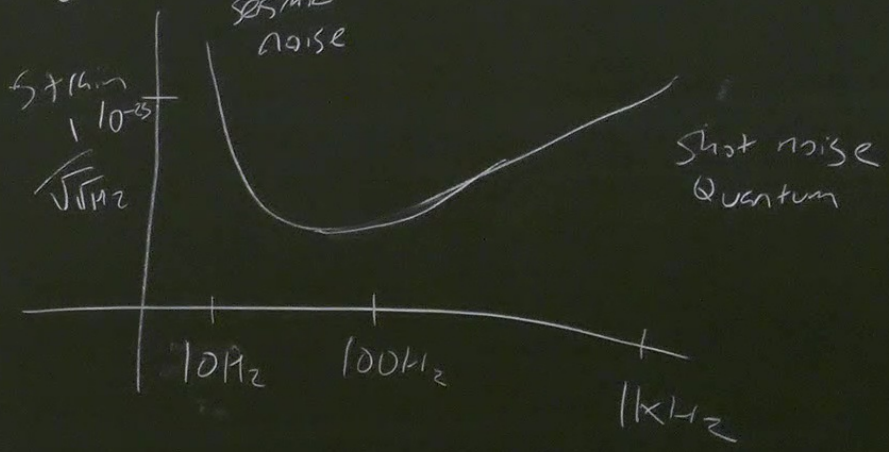
Subject: Strong Gravity

Date: March 28, 2025 - 11:30 AM

URL: https://pirsa.org/25030054

LIGO / Virgo / Kagra

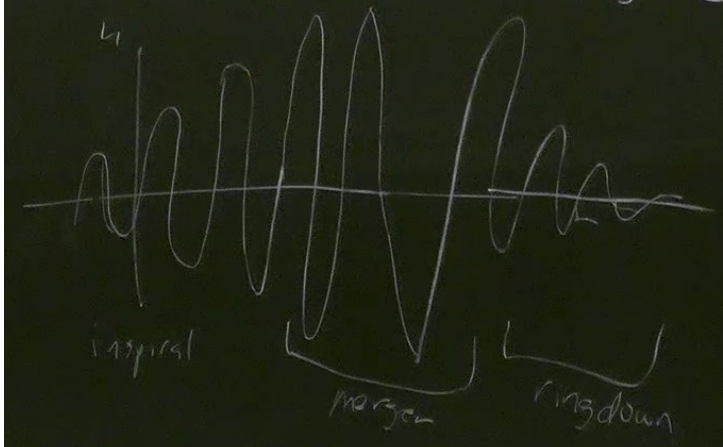


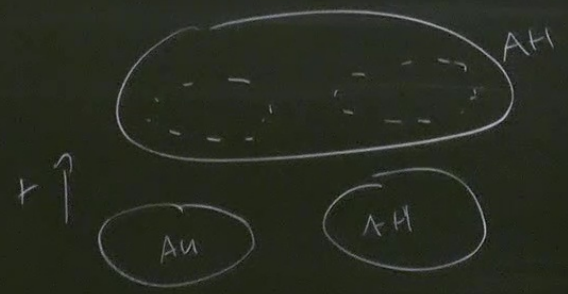


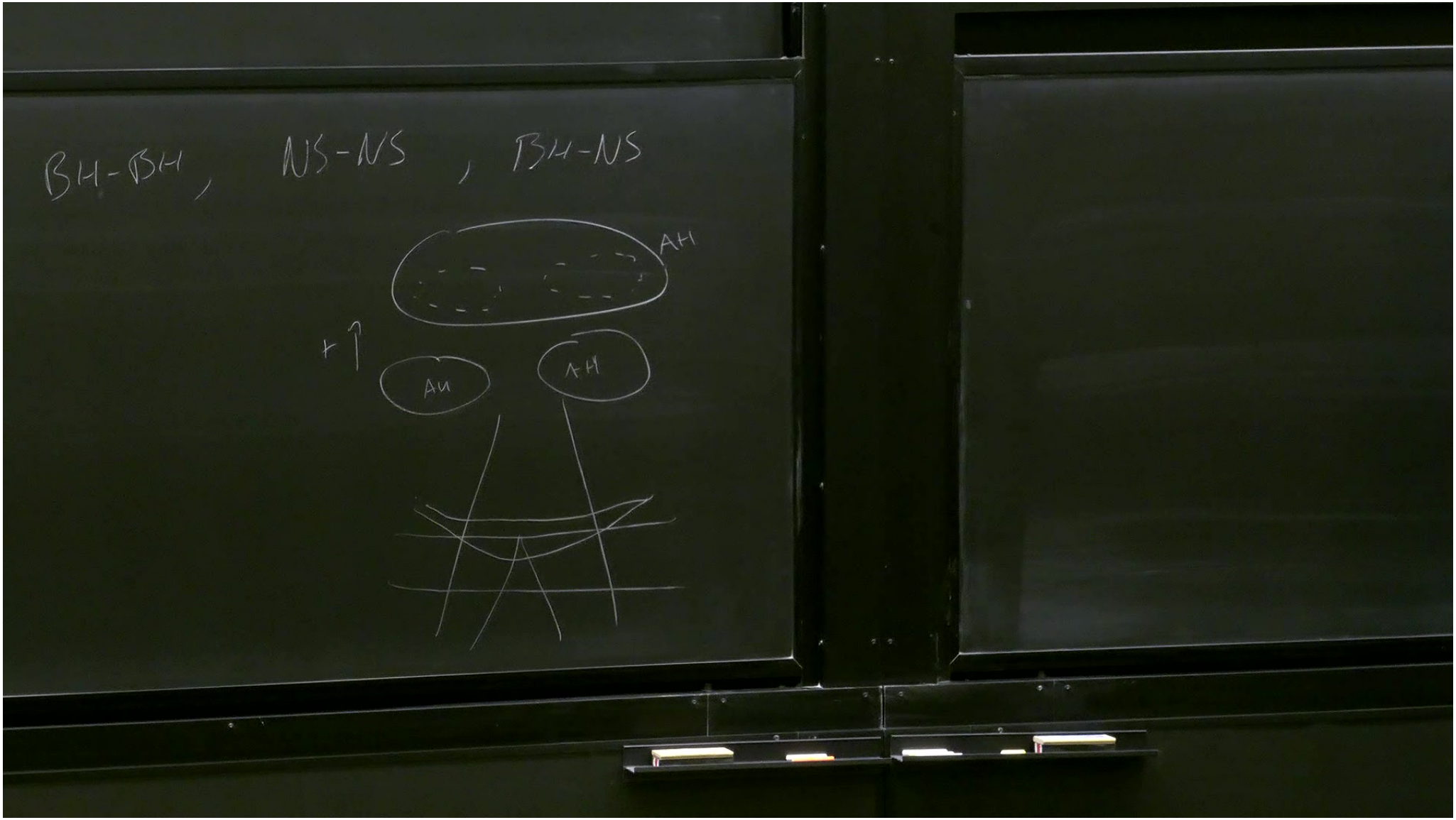
Compact Object Mergers

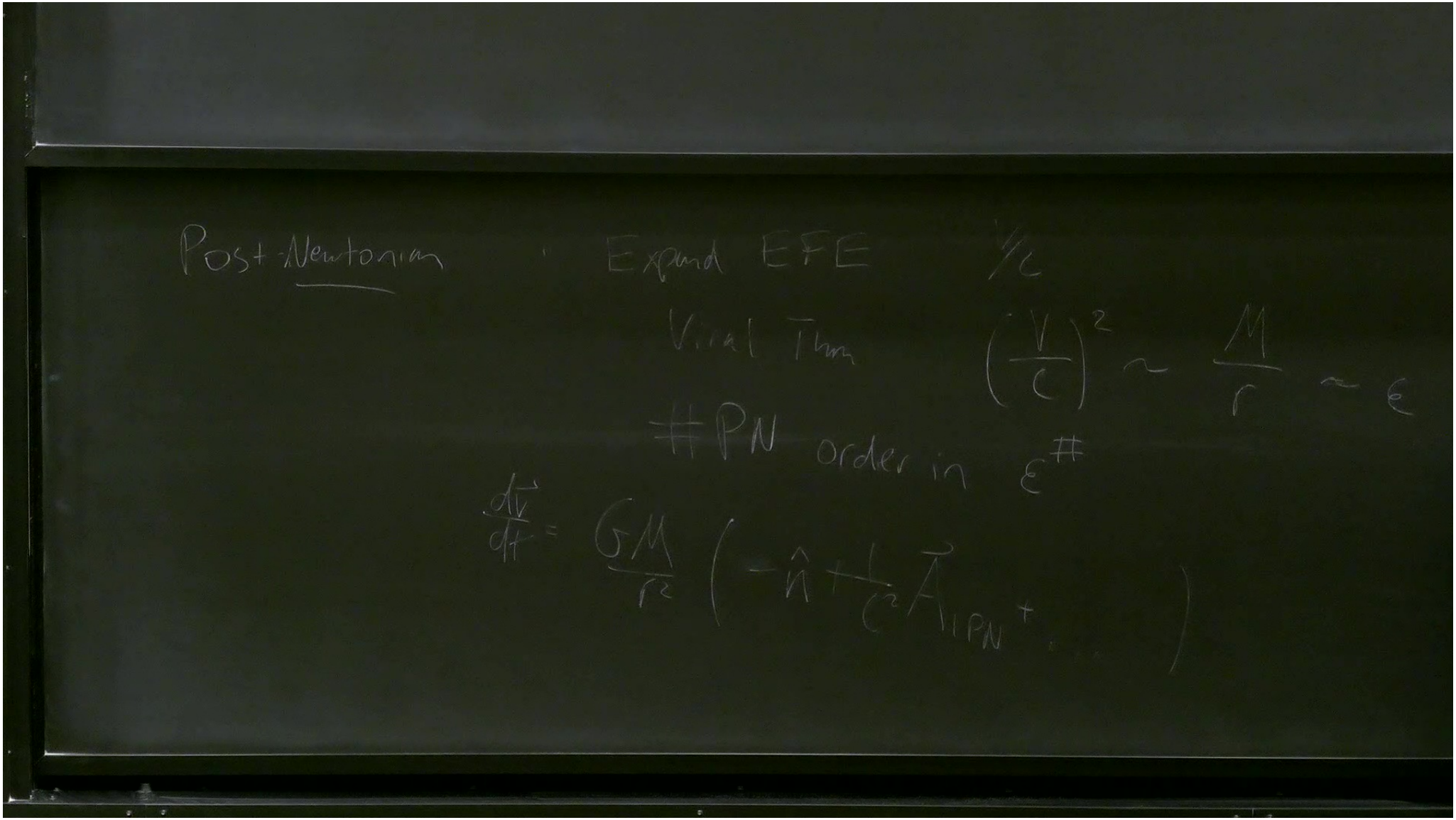
BH-BH, NS-NS, BH-NS

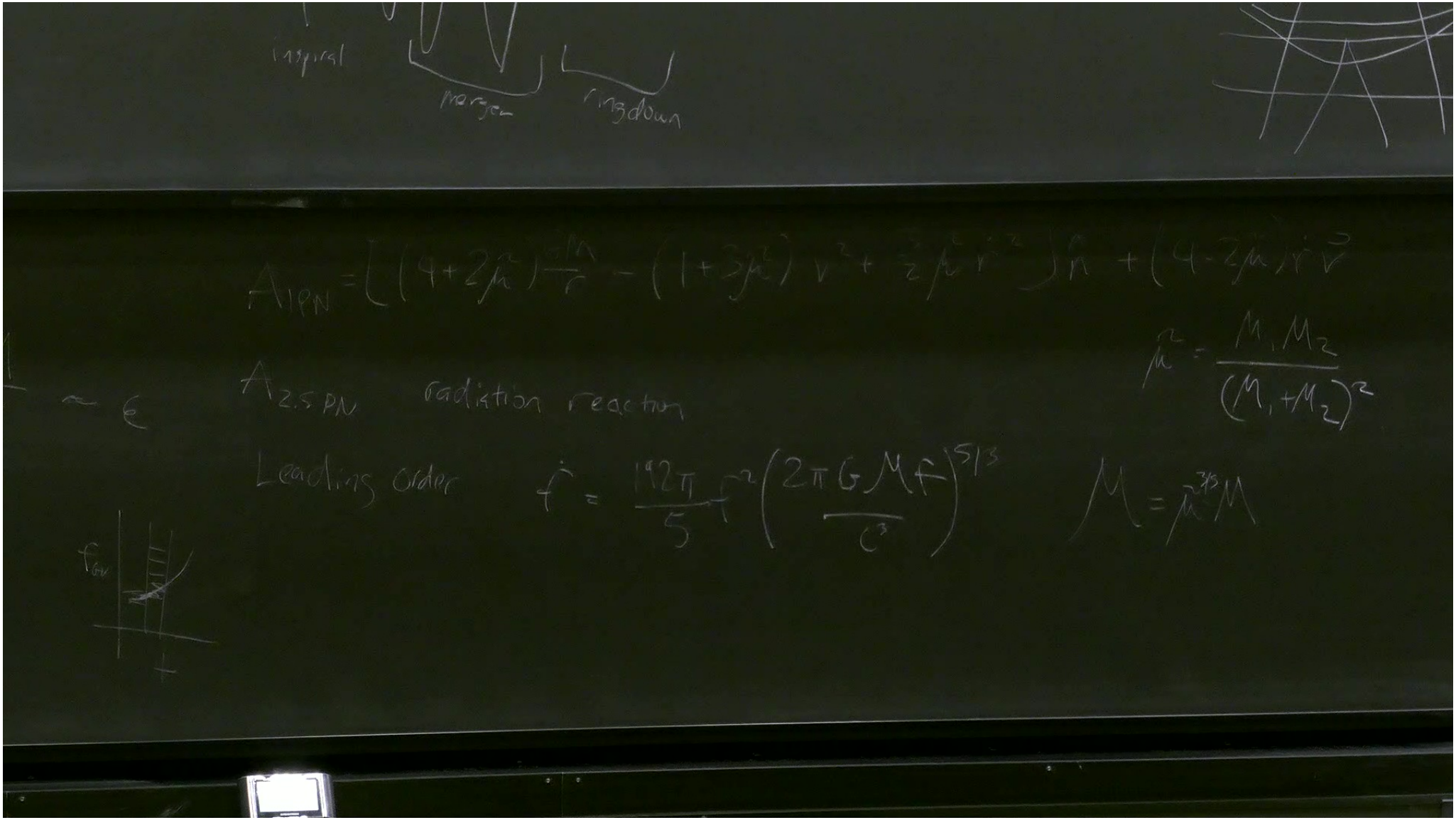
Vacuum EFE $R_{\mu\nu} = 0$

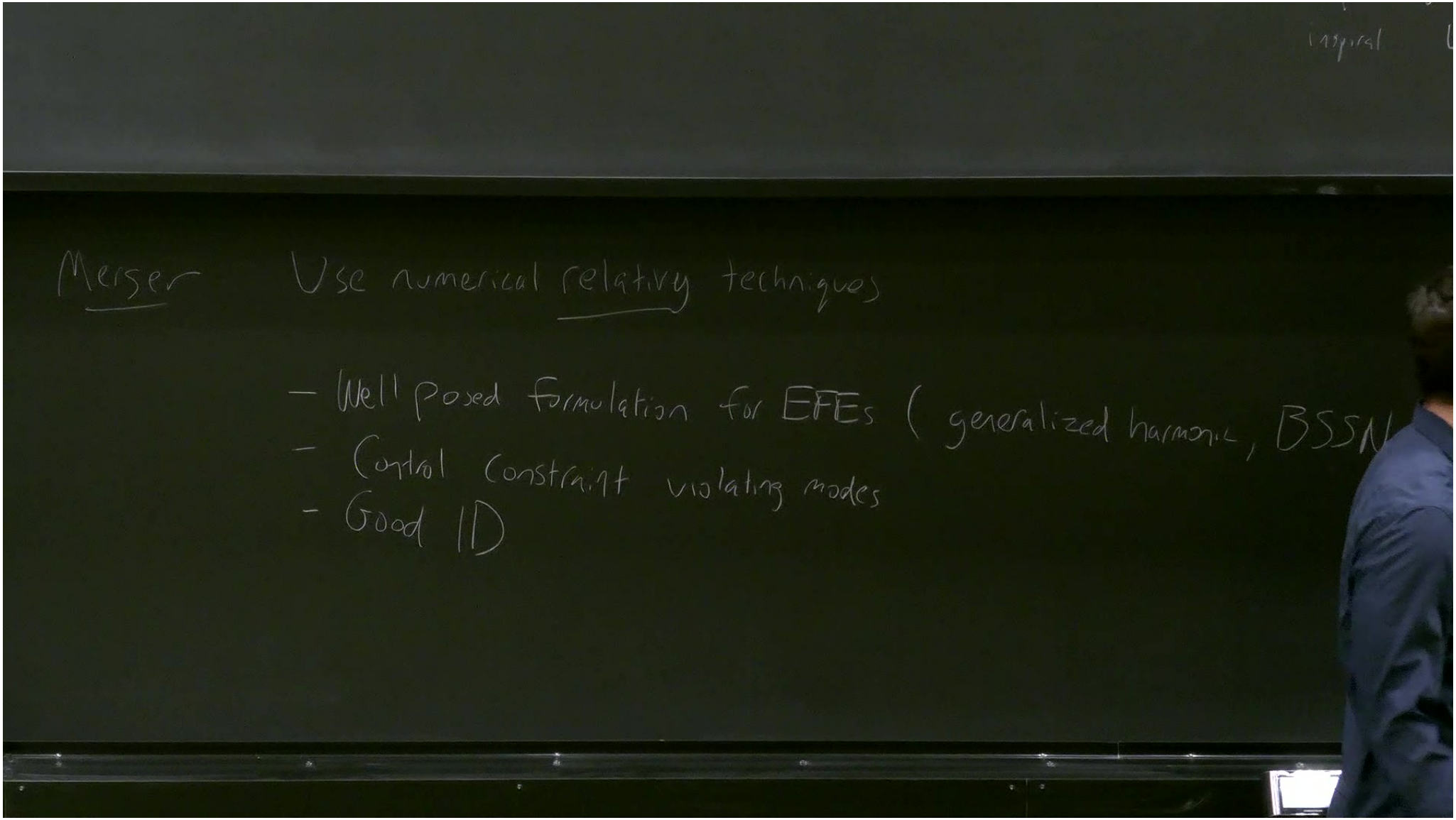


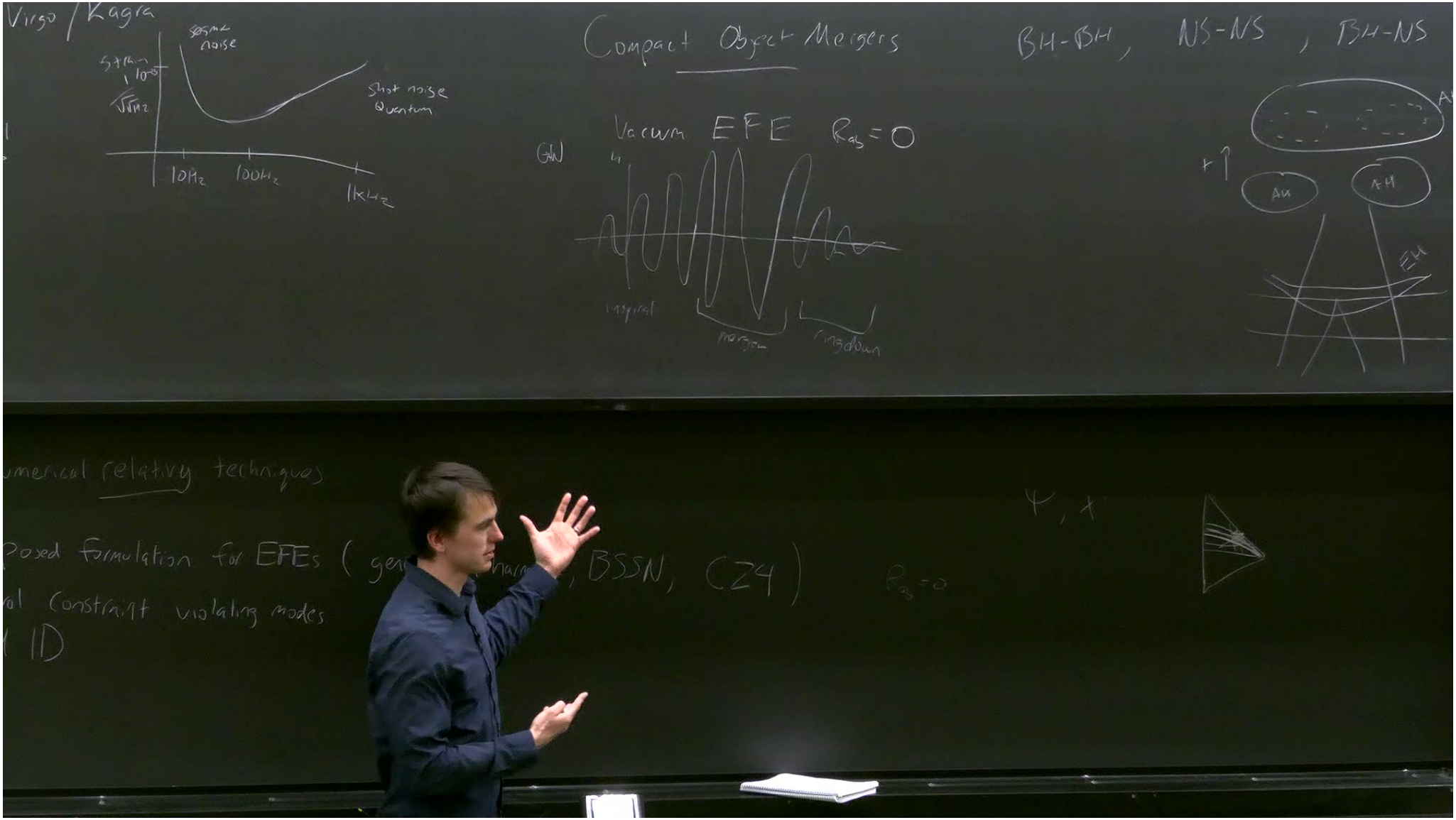


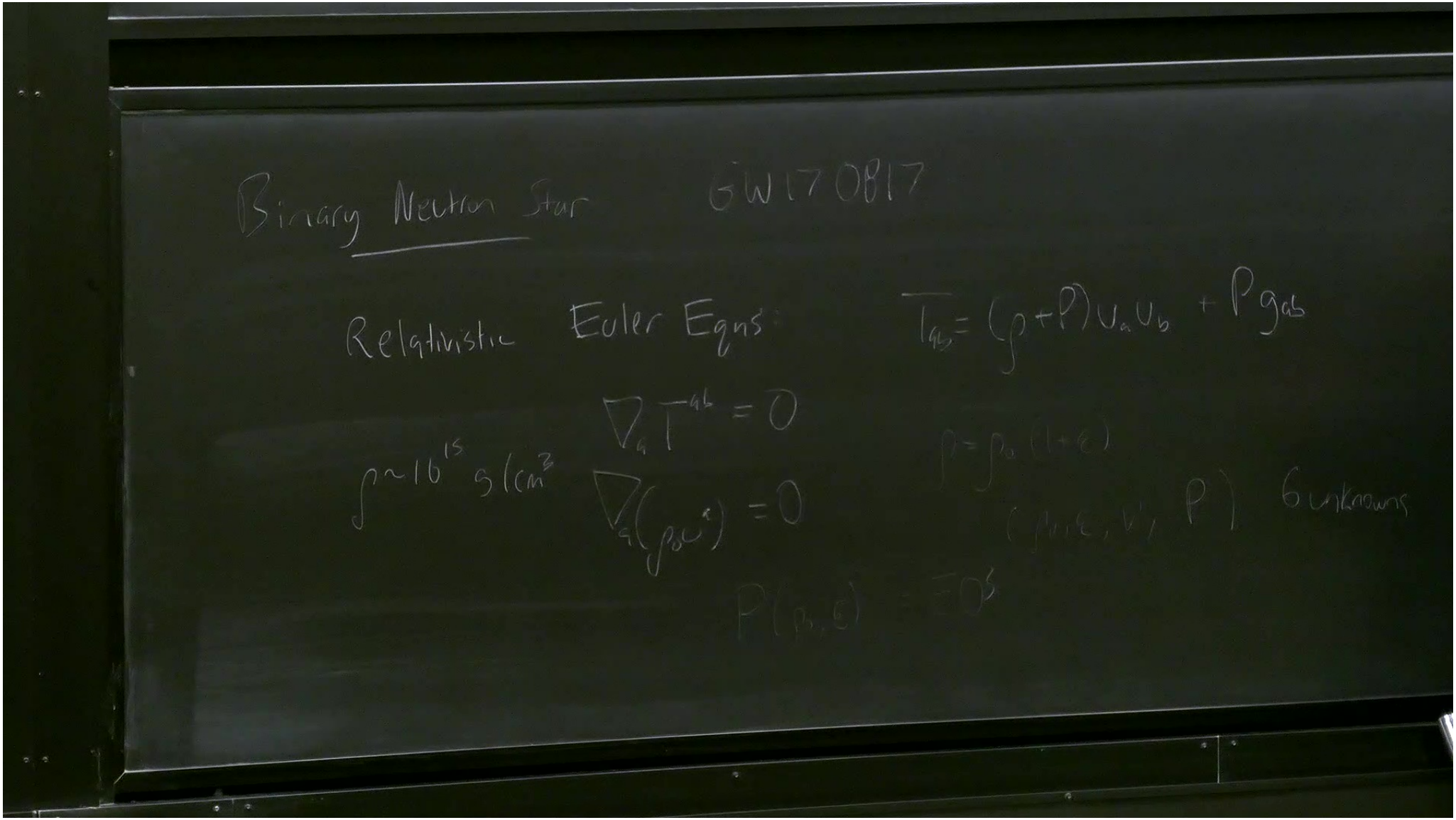

BH-BH, NS-NS, BH-NS
AH
AH
AH


Post-Newtonian
Expand EFE
1/c
Virial Thm
$\left(\frac{v}{c}\right)^2 \sim \frac{M}{r} \sim \epsilon$
PN order in $\epsilon^{\#}$
$\frac{d\vec{v}}{dt} = \frac{GM}{r^2}\left(-\hat{n} + \frac{1}{c^2}\vec{A}_{1PN} + \ldots\right)$


inspiral
merger
ringdown
$A_{1PN} = \left[(4+2\dots)\frac{M}{r} - (1+3\dots)v^2 + \dots \right] \hat{n} + (4-2\dots) r\dot{r}\vec{v}$
$\mu = \frac{M_1 M_2}{(M_1+M_2)^2}$
$A_{2.5\,PN}$ radiation reaction
Leading order $\dot{f} = \frac{192\pi}{5} f^2 \left(\frac{2\pi G M f}{c^3} \right)^{5/3}$
$M = \mu^{3/5} M$
f_{GW}


Merger
Use numerical relativity techniques
- Well posed formulation for EFEs (generalized harmonic, BSSN
- Control Constraint violating modes
- Good ID


Virgo / Kagra
seismic noise
shot noise
Quantum
10Hz
100Hz
1kHz
Compact Object Mergers
BH-BH, NS-NS, BH-NS
Vacuum EFE
GW
inspiral
merger
ringdown
AH
EM
relativy techniques
BSSN, CZ4)


Binary Neutron Star
GW170817
Relativistic Euler Eqns:
$T_{ab} = (\rho + P) u_a u_b + P g_{ab}$
$\nabla_a T^{ab} = 0$
$\rho \sim 10^{15}$ g/cm^3
$\nabla_a (\rho u^a) = 0$
$P = \rho_0 (1 + \epsilon)$
(ρ, ε, v, P) 6 unknowns
$P(\rho, \epsilon)$

Leading order effect

Phase $\Psi(f) = \frac{3}{128\eta}(\pi M f)^{-5/3}\left[1 + \alpha_{PN1}\, x^{1} + \dots + (\alpha_{SND} + \alpha_{tide})\, x^{5} + \dots\right.$

$\alpha_{tide} = -24\left[\left(1 + 12\frac{m_2}{m_1}\right)\frac{m_1^5}{M^5}\Lambda_1 + 1 \leftrightarrow 2\right]$

$\Lambda_1 = \frac{2}{3} k_2 \left(\frac{R_1}{m_1}\right)^5$

$Q_{ab} = -\Lambda M^5 \mathcal{E}_{ab}$

Q_{ab}: quadrupole moment; $\mathcal{E}_{ab}$: tidal moment