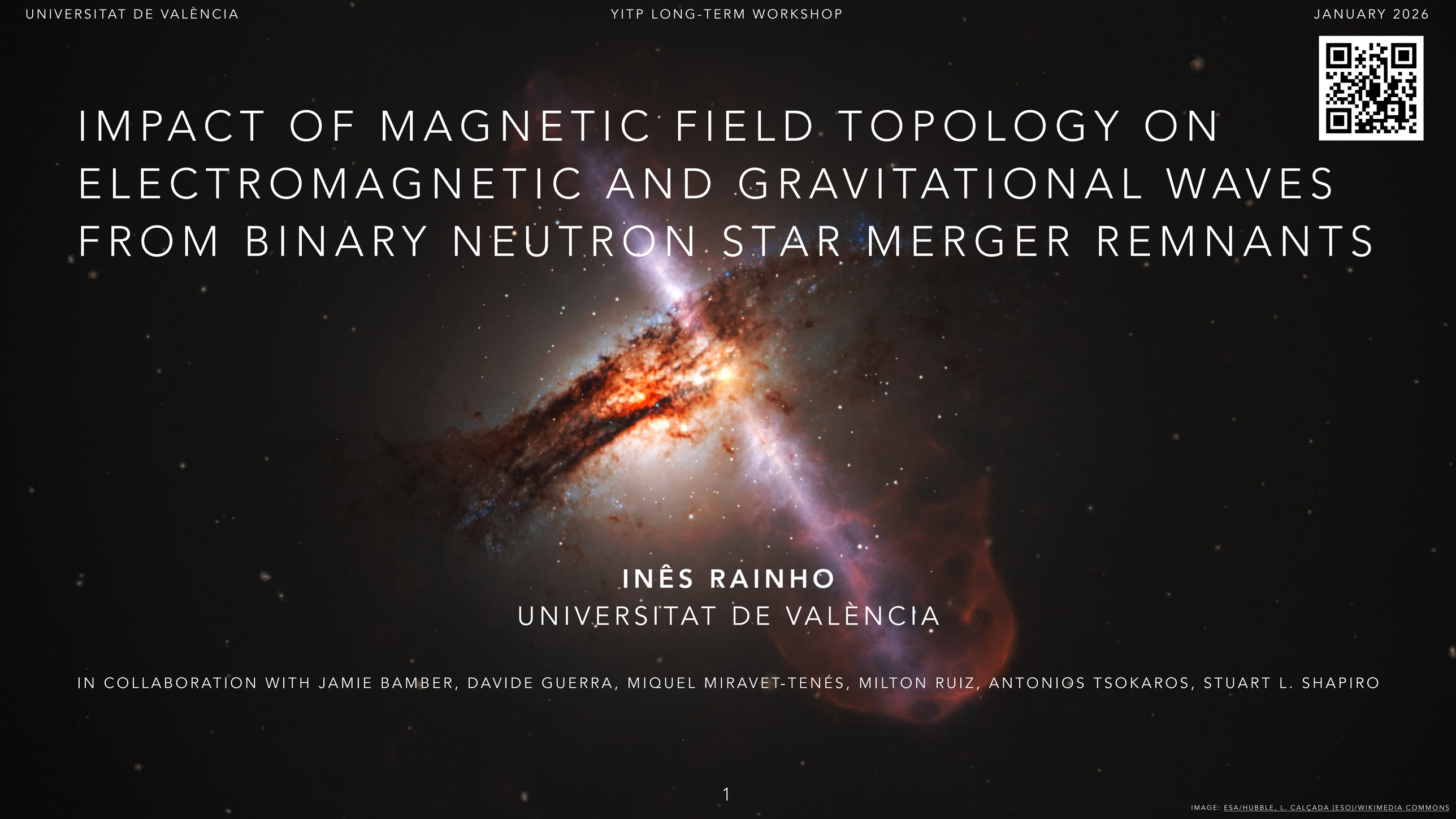
IMPACT OF MAGNETIC FIELD TOPOLOGY ON ELECTROMAGNETIC AND GRAVITATIONAL WAVES FROM BINARY NEUTRON STAR MERGER REMNANTS



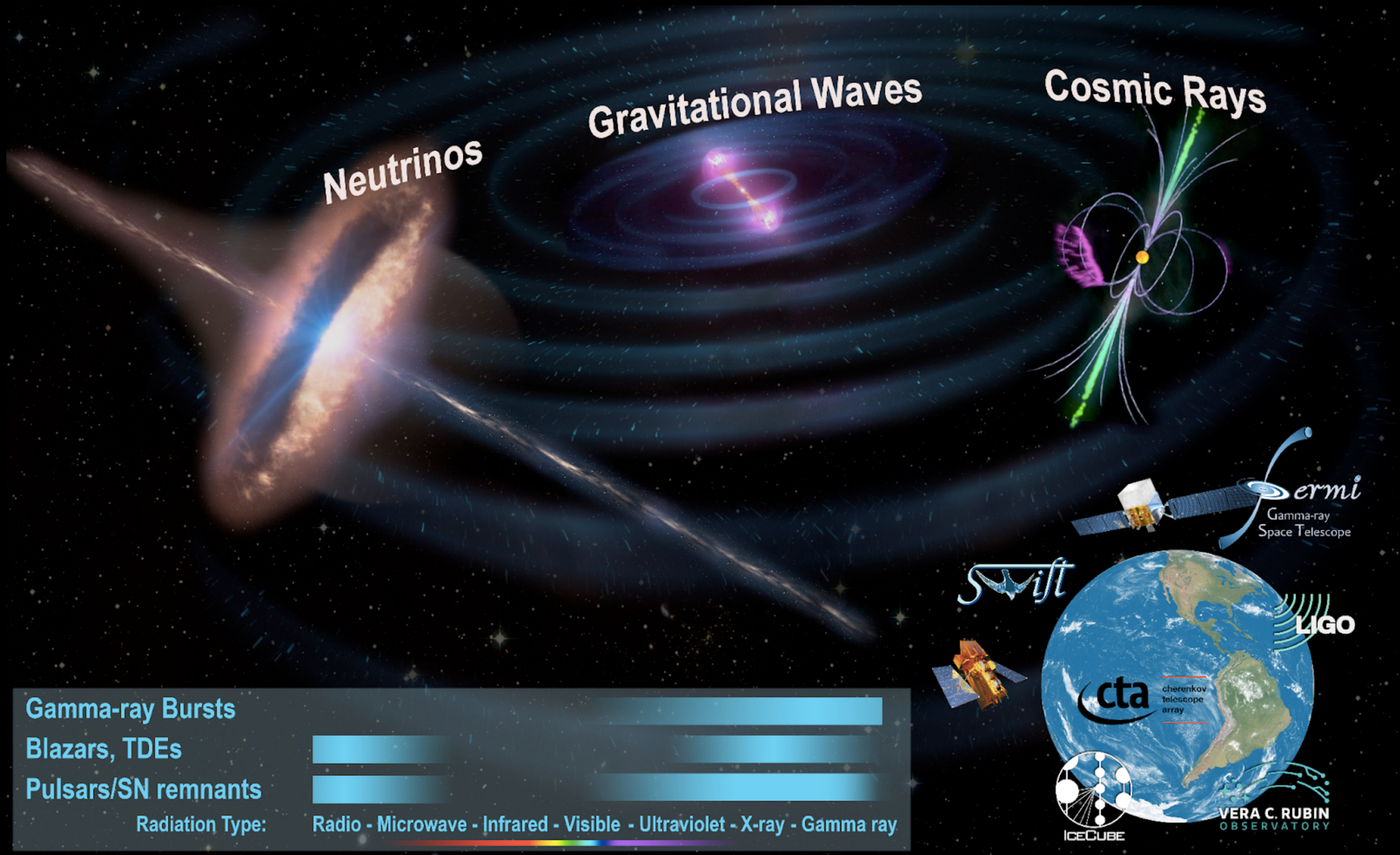
INÊS RAINHO
UNIVERSITAT DE VALÈNCIA

IN COLLABORATION WITH JAMIE BAMBER, DAVIDE GUERRA, MIQUEL MIRAVET-TENÉS, MILTON RUIZ, ANTONIOS TSOKAROS, STUART L. SHAPIRO

IMAGE: ESA/HUBBLE, L. CALÇADA (ESO)/WIKIMEDIA COMMONS

OBSERVING THE UNIVERSE

GRAVITATIONAL AND ELECTROMAGNETIC SIGNALS

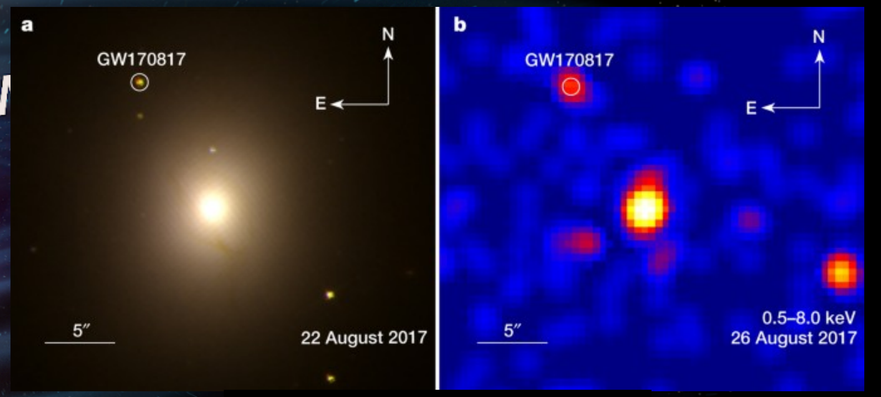


R.M. Sambruna et al. 2022

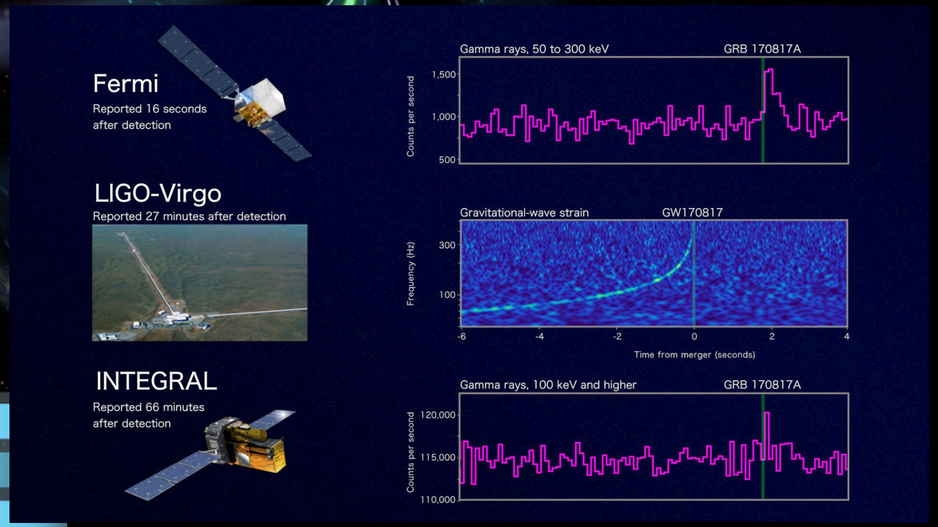
OBSERVING THE UNIVERSE

GRAVITATIONAL AND ELECTROMAGNETIC SIGNALS

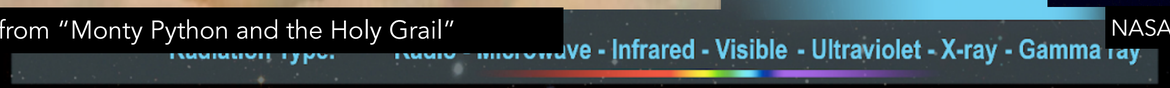
Adapted from "Monty Python and the Holy Grail"



Troja E. *et al.*, Nature **551**, 71-74 (2017)



NASA's Goddard Space Flight Center, Caltech/MIT/LIGO Lab and ESA



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NEUTRON STARS' MAGNETIC FIELDS

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- Typically, **purely poloidal** fields are considered

  Other topologies explored recently [Bamber et al (2024), Gutiérrez et al (2015), Cook et al (2015)]

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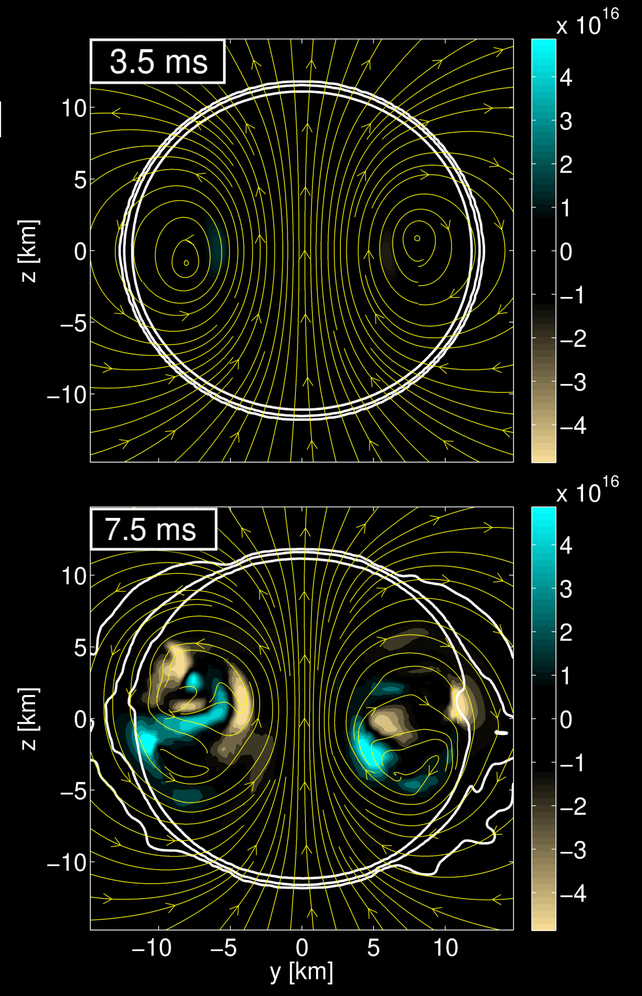

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NICER observations J0030+0451

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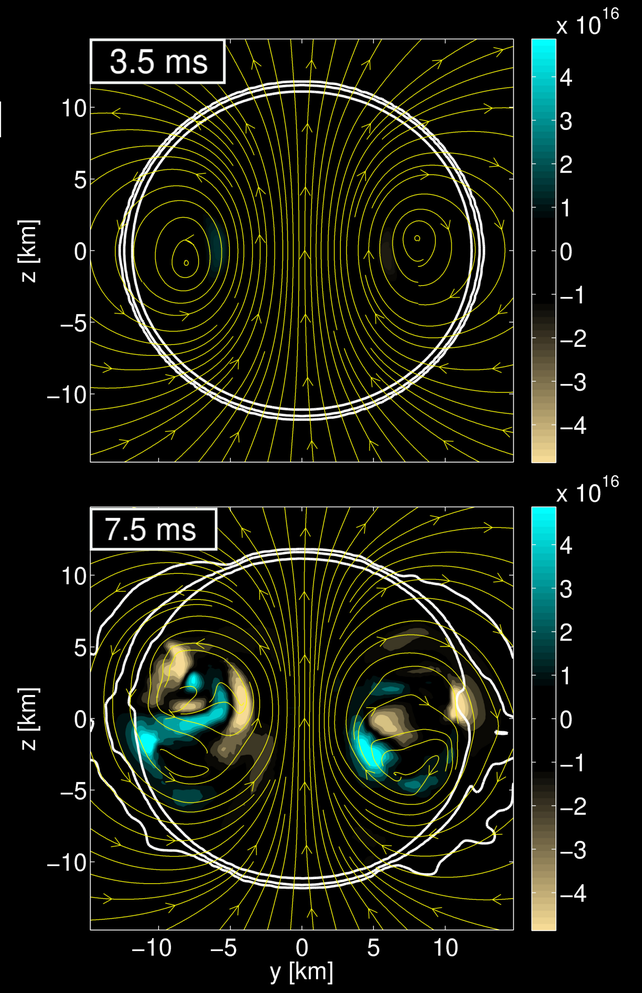

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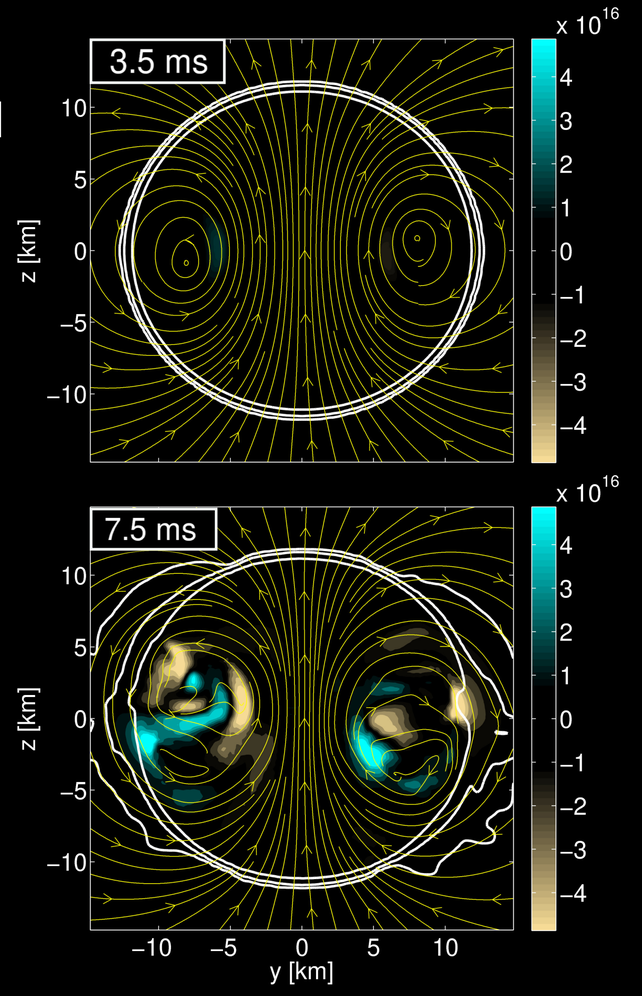

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- 2/3 hot spots only in the southern hemisphere

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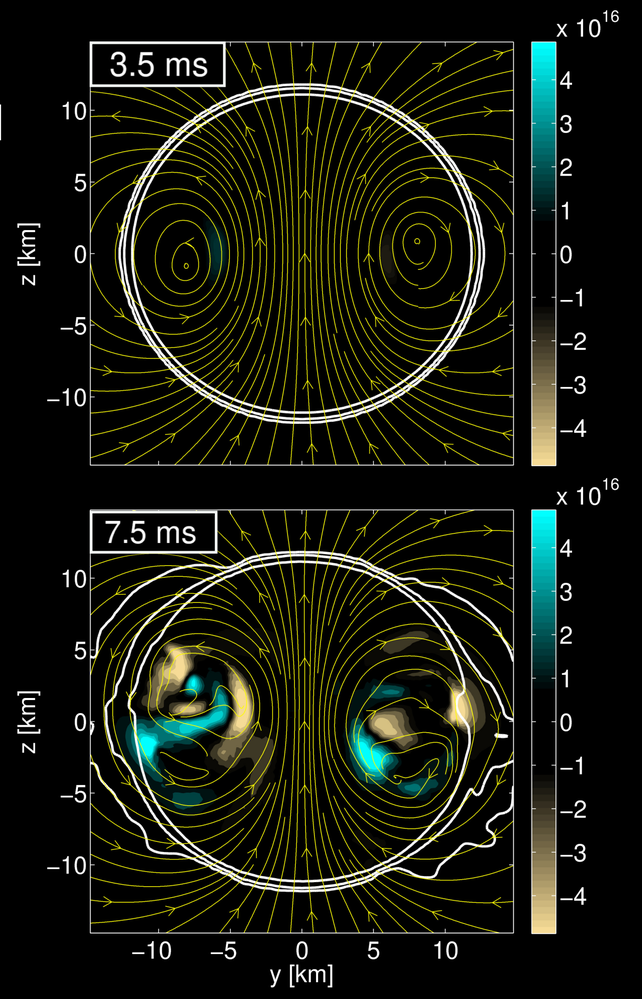

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- 2/3 hot spots only in the southern hemisphere

  [Miller+(2019), Riley+(2019), Dittmann+(2024)]

  $\Longrightarrow$ non-**dipolar** magnetic field!

MAGNETIC FIELD MODELS

More general scenario with exterior dipole

$$\mathbf{A} = a_T \mathbf{A_T}[r < R_{\mathrm{NS}}] + (1 - a_T)\mathbf{A_P} \qquad [x] = \begin{cases} 1, & \text{if } x \text{ is true} \\ 0, & \text{otherwise} \end{cases}$$

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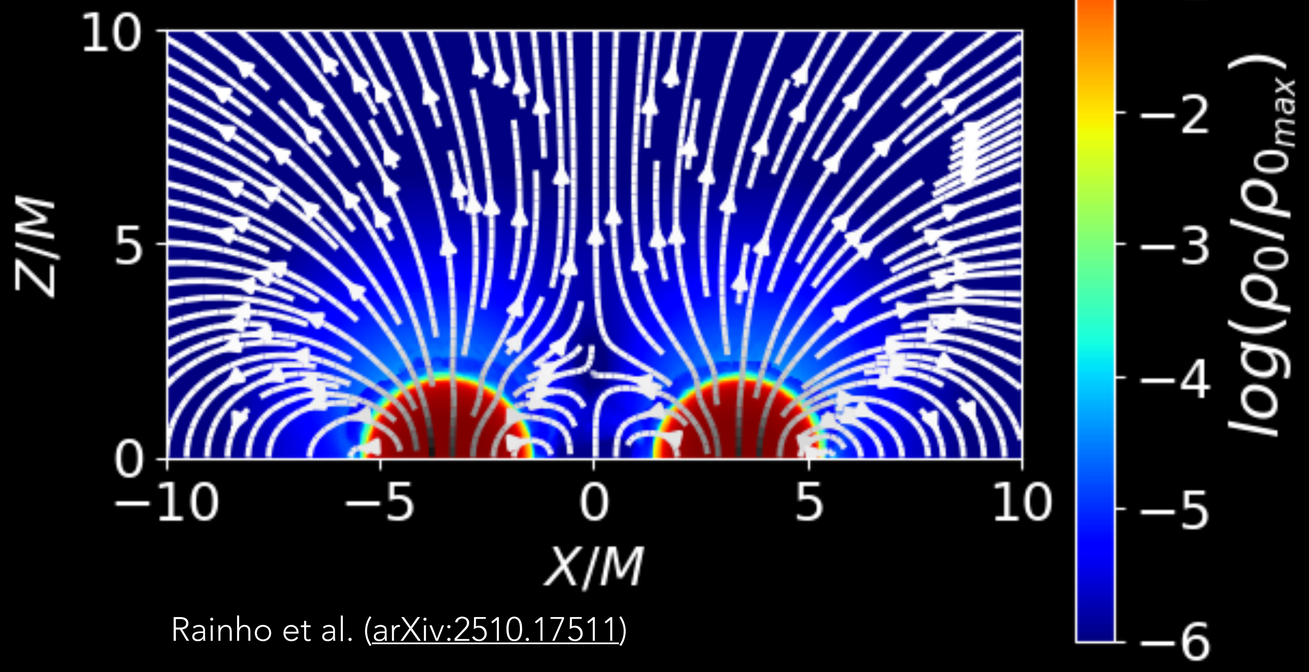

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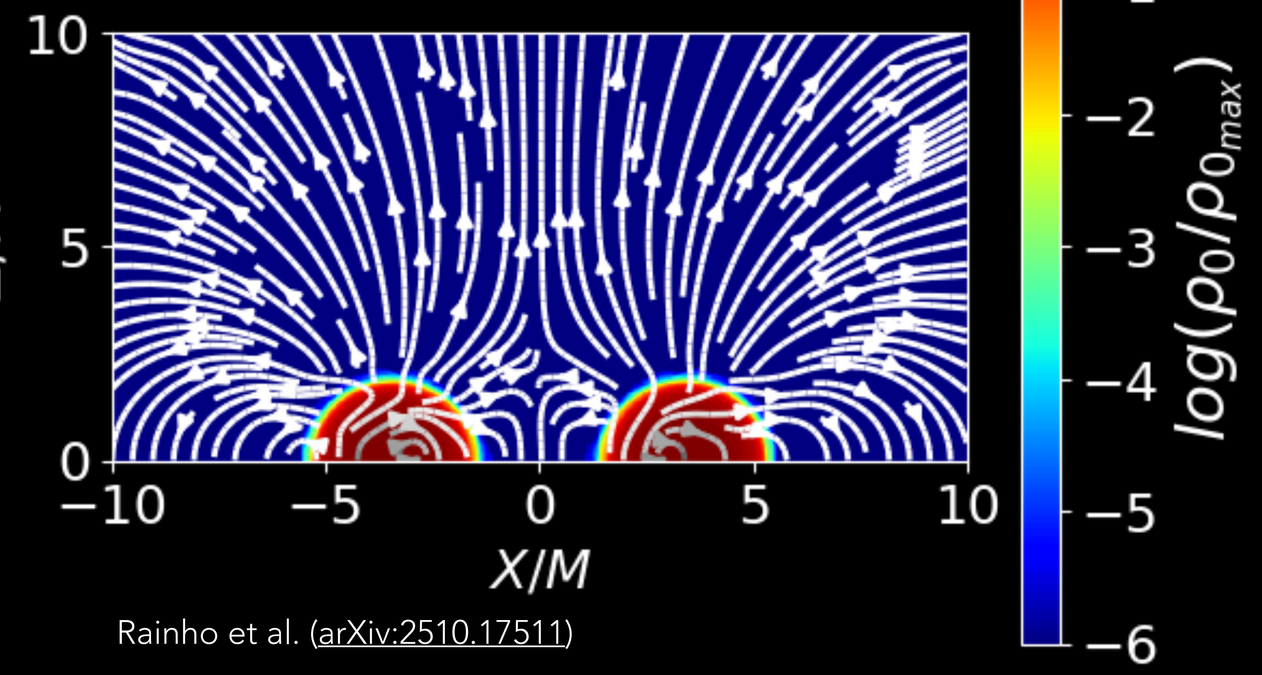

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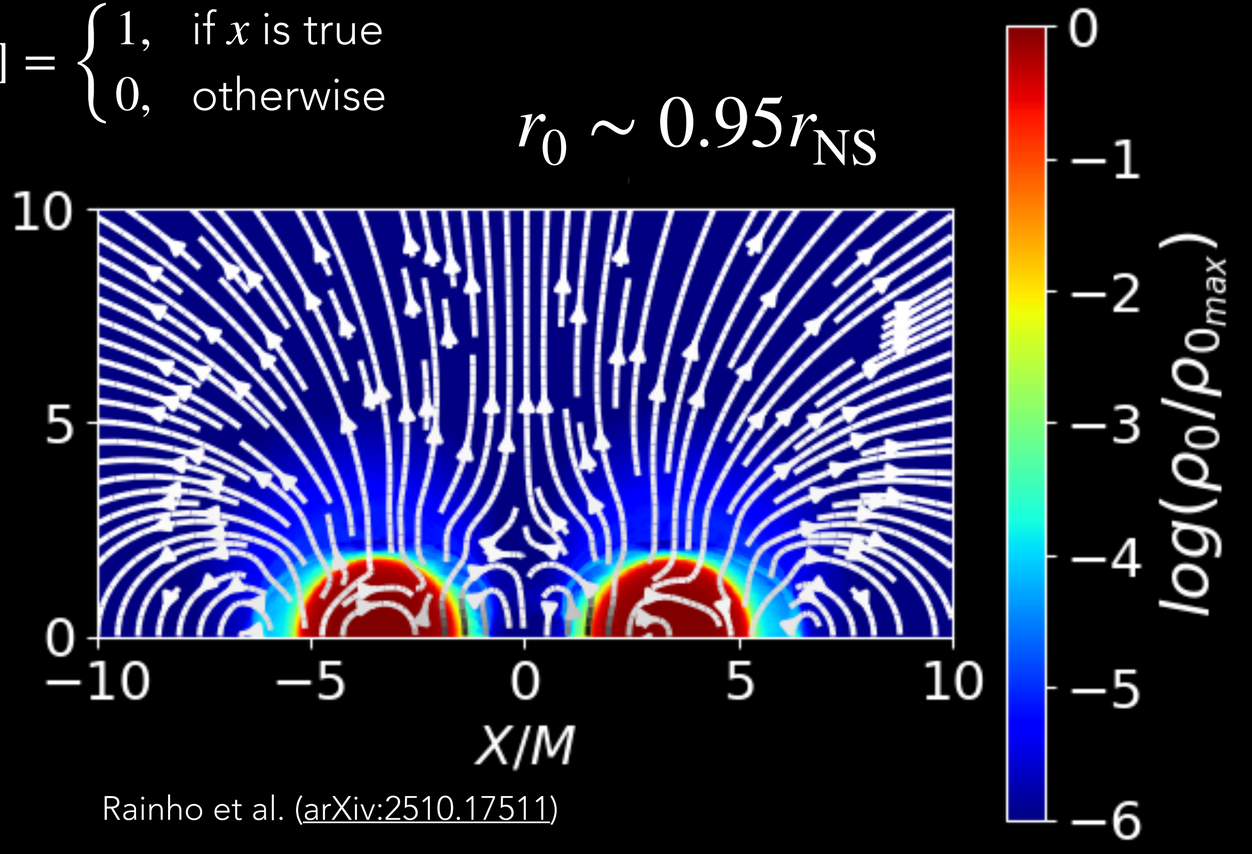

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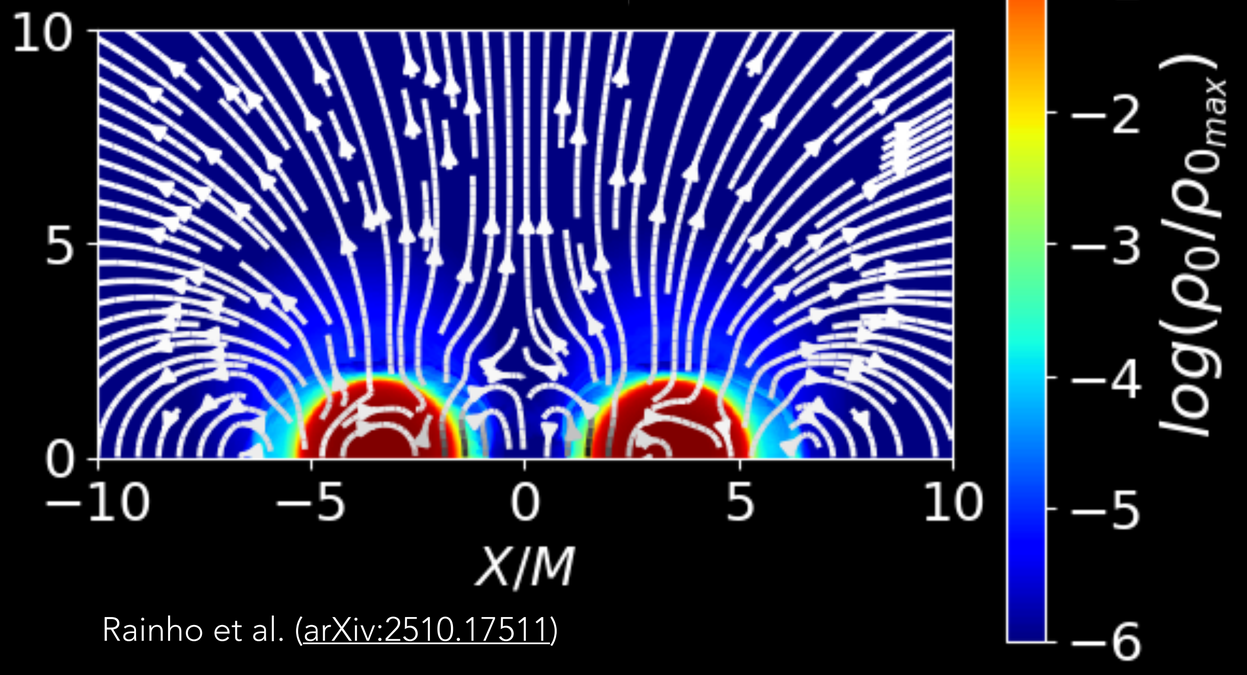
$0.5 r_{\rm NS}$

$r_0 \sim 0.95 r_{\rm NS}$



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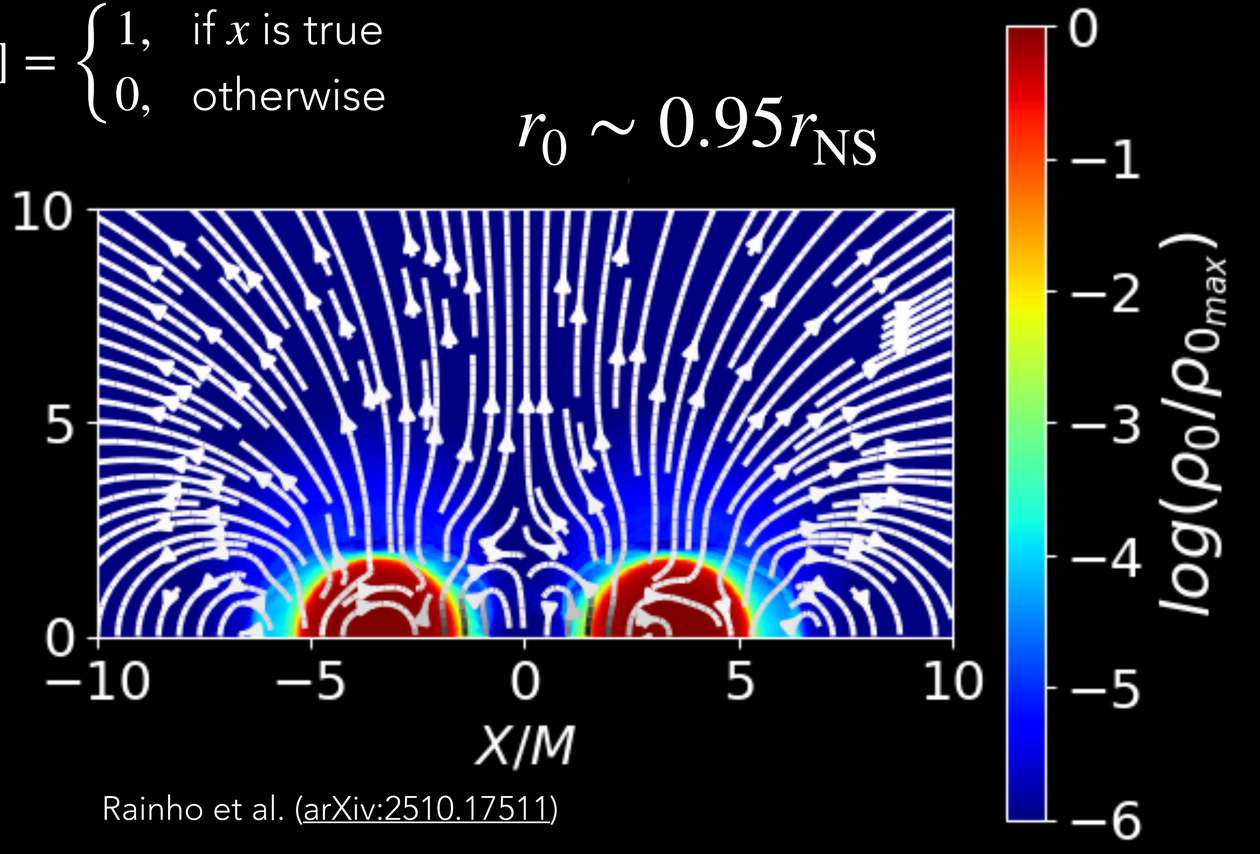

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MAGNETIC FIELD MODELS

TO COMPARE THE DIFFERENT CONFIGURATIONS, SET

$$\beta^{-1} \equiv \frac{P_{\rm mag}}{P_{\rm gas}} = 0.003125$$

More general scenario with exterior dipole

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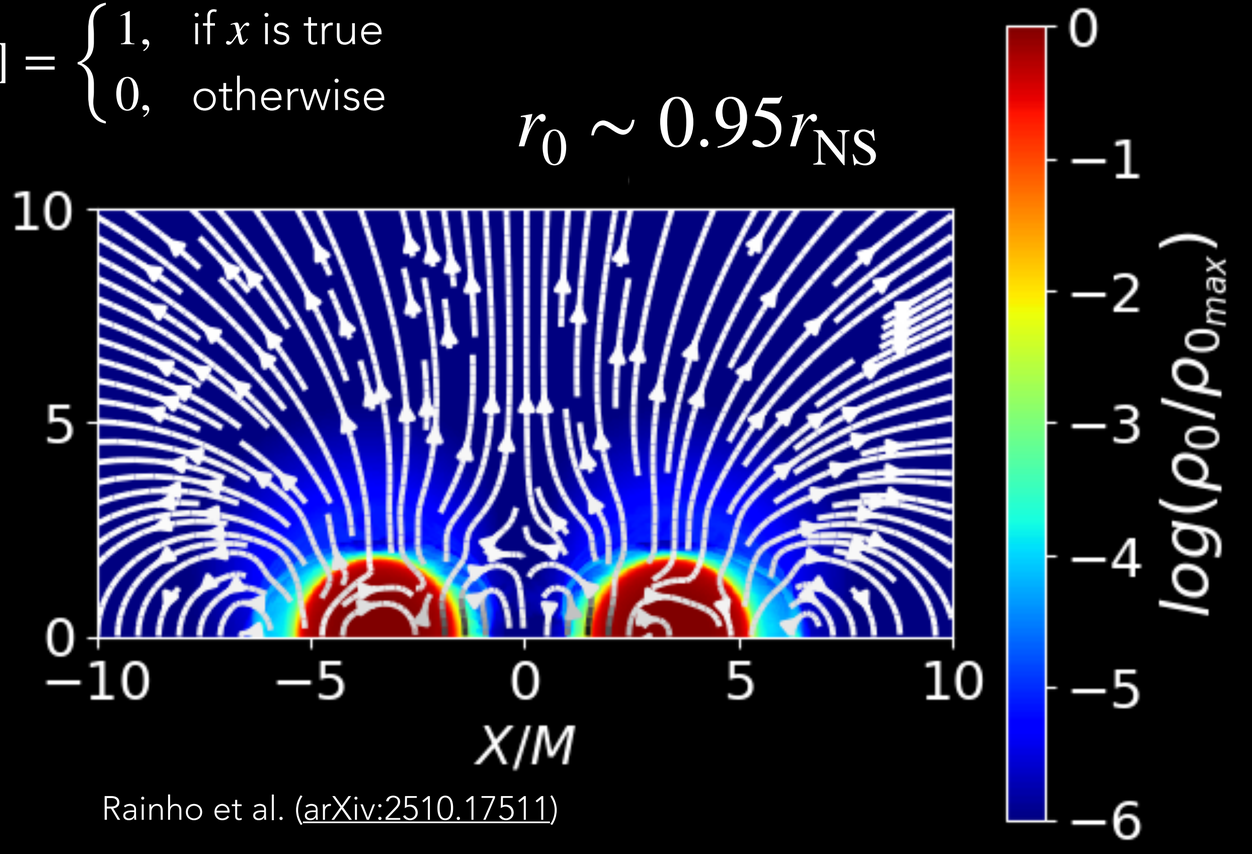

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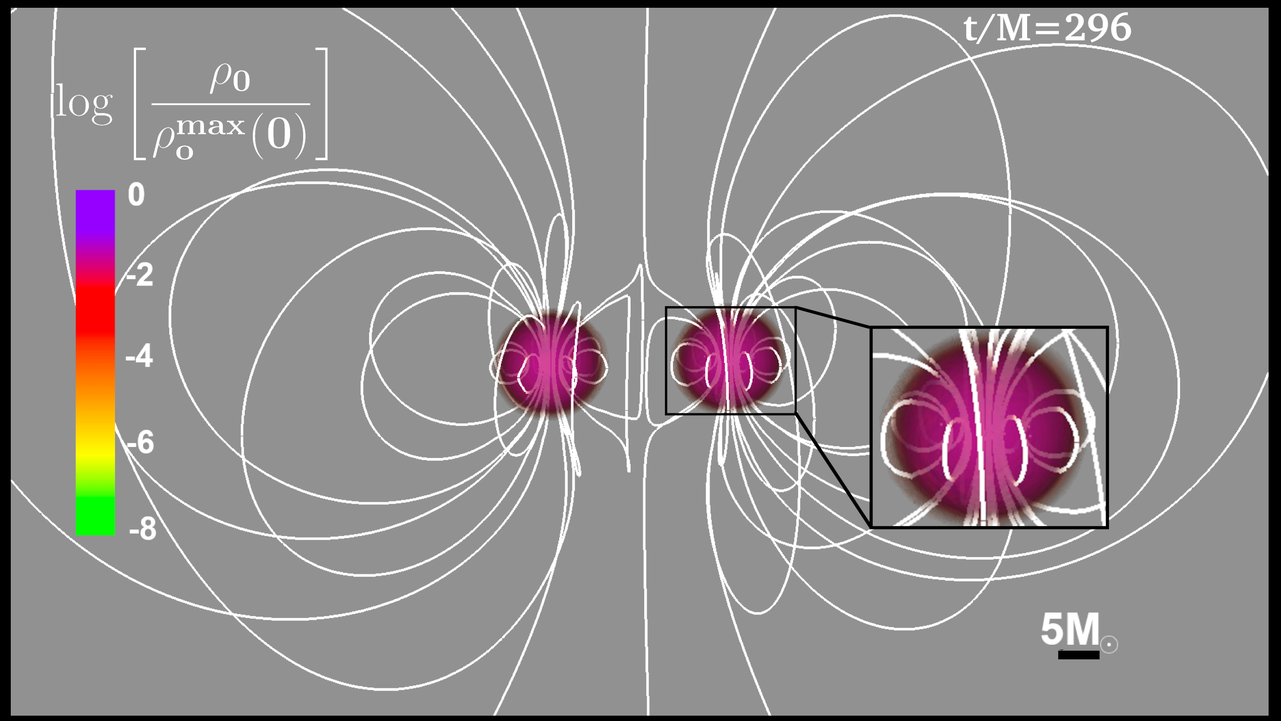
NUMERICAL SETUP FOR GRMHD SIMULATIONS



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NUMERICAL SETUP FOR GRMHD SIMULATIONS

- Initial data from **PCOCAL**
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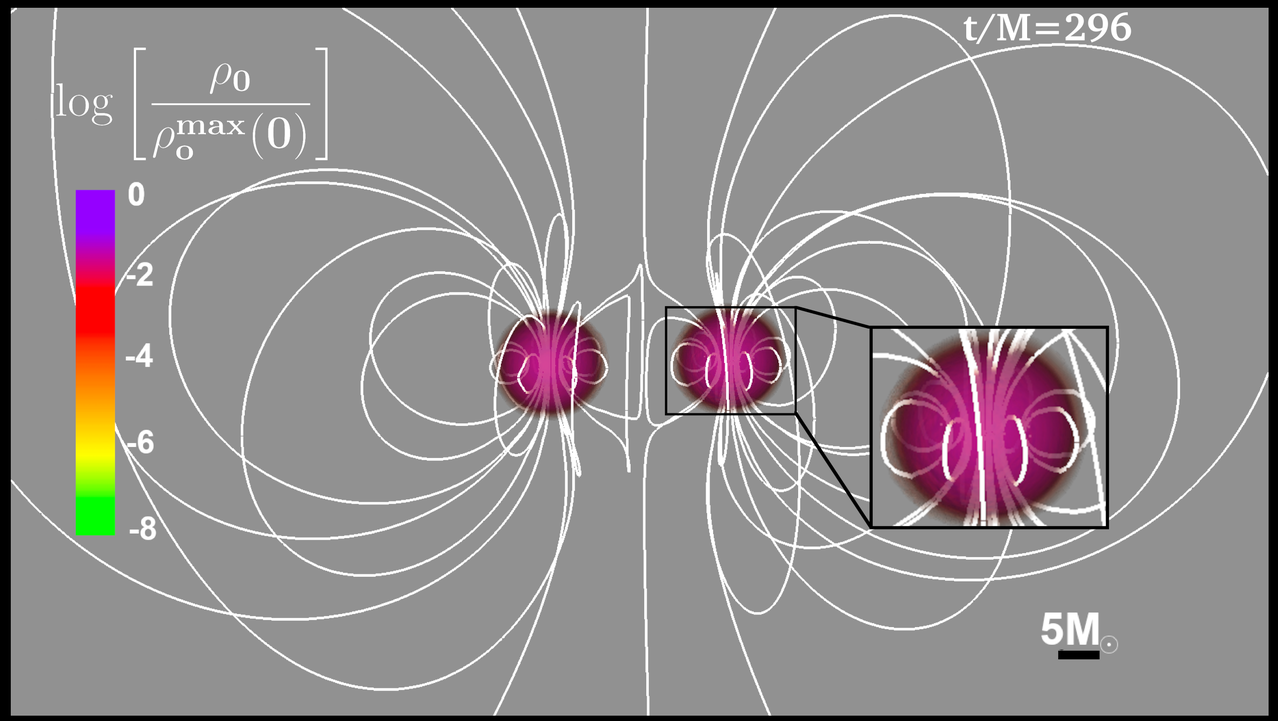

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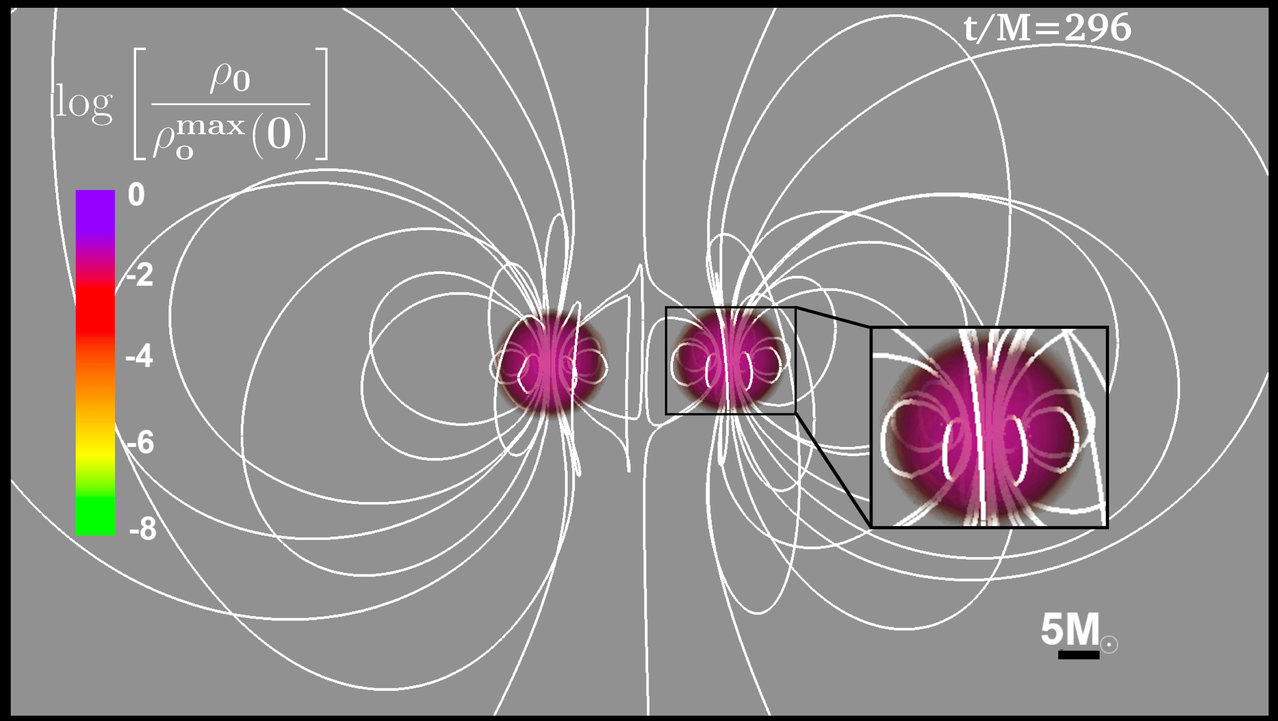
NUMERICAL SETUP FOR GRMHD SIMULATIONS

- Initial data from **PCOCAL**
  - **EOS**: SLy and WFF1
  - **Illinois GRMHD** code
    - BSSN formulation + puncture gauge conditions
    - Ideal MHD



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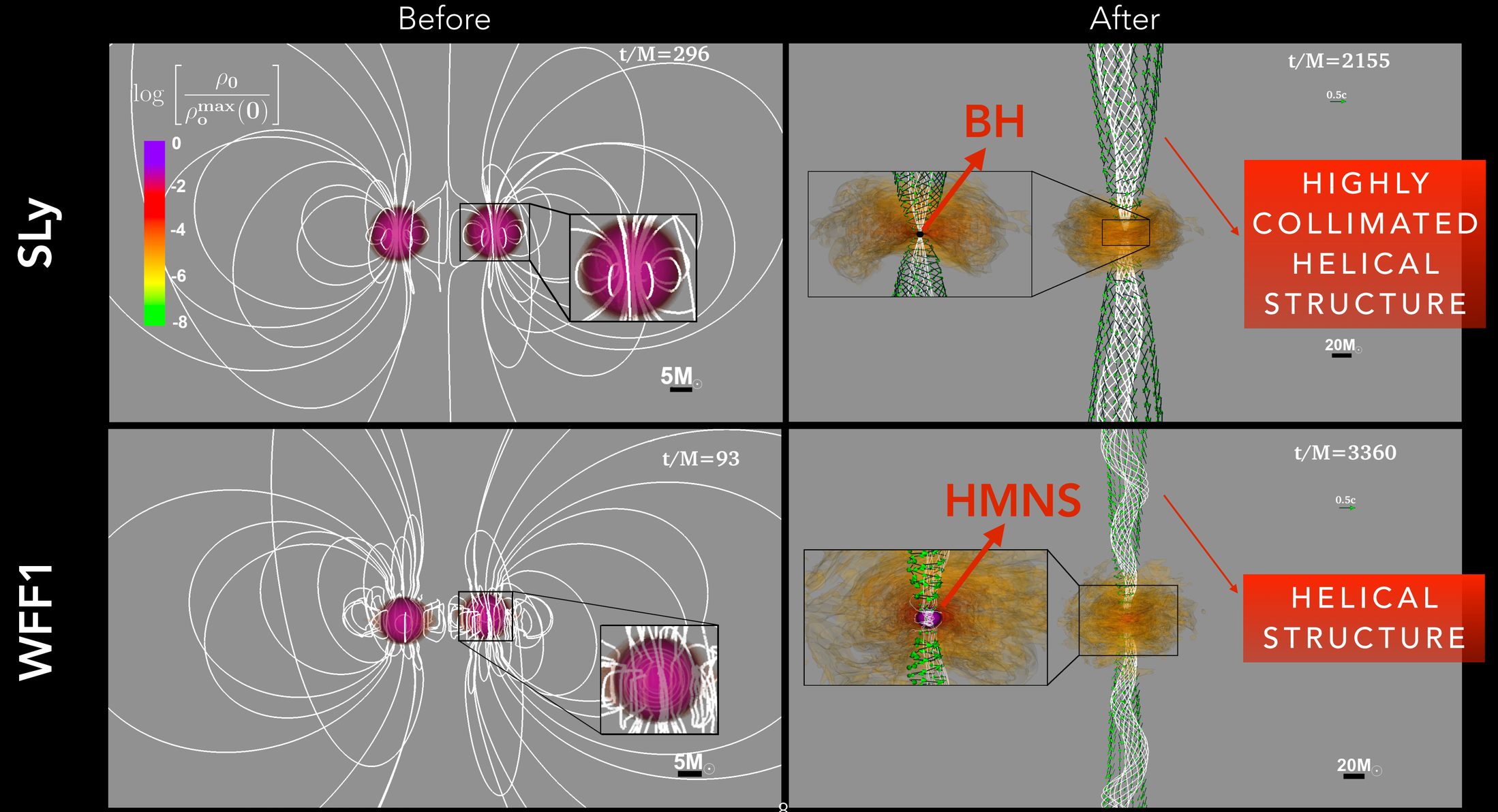
ELECTROMAGNETIC SIGNALS: INCIPIENT JET



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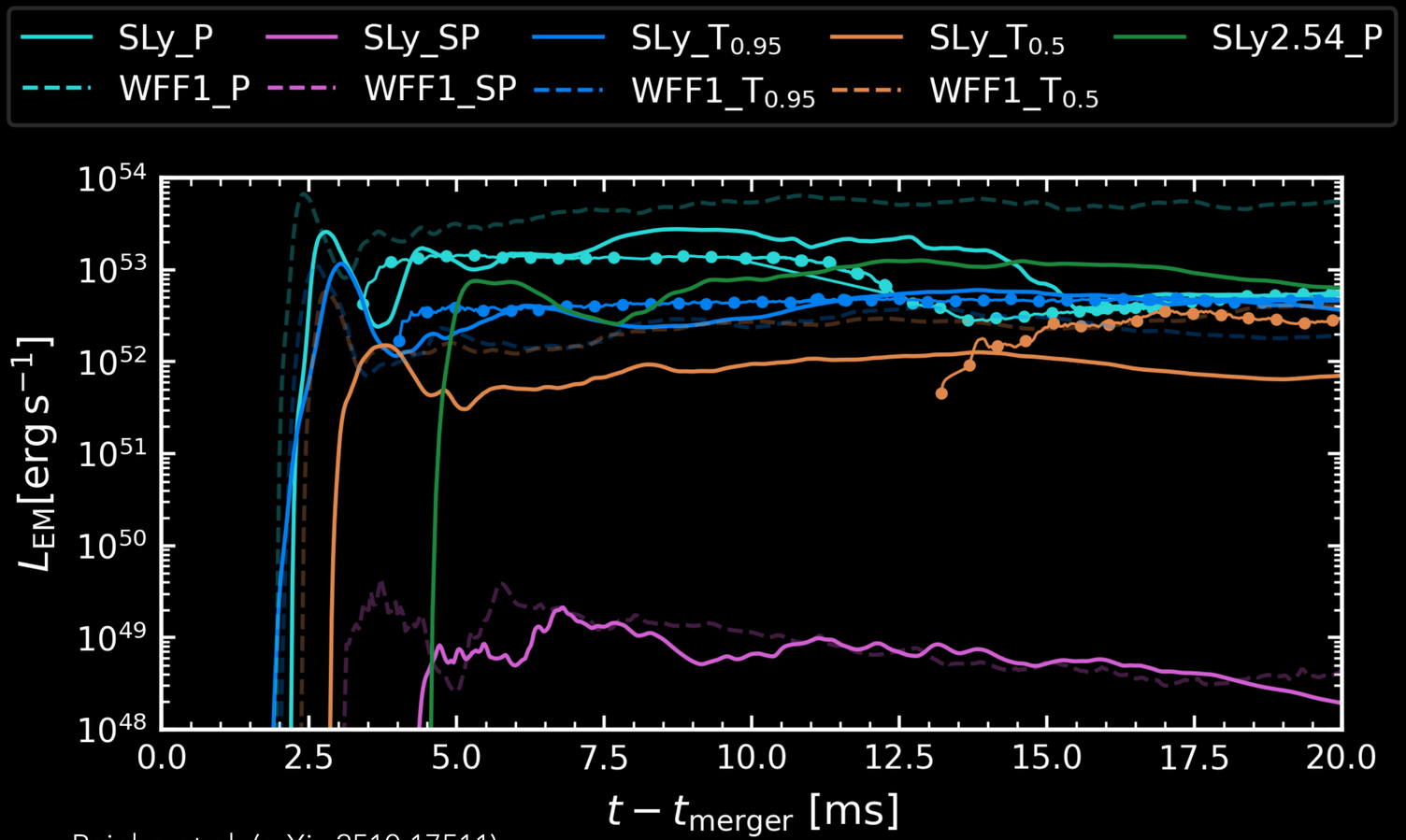
ELECTROMAGNETIC LUMINOSITY

- $L_{\gamma,\mathrm{iso}} \sim 10^{51} - 10^{54} \mathrm{erg\,s^{-1}}$
- BZ luminosity consistent with SLy_P and SLy_$T_{0.95}$ ~15 ms after merger



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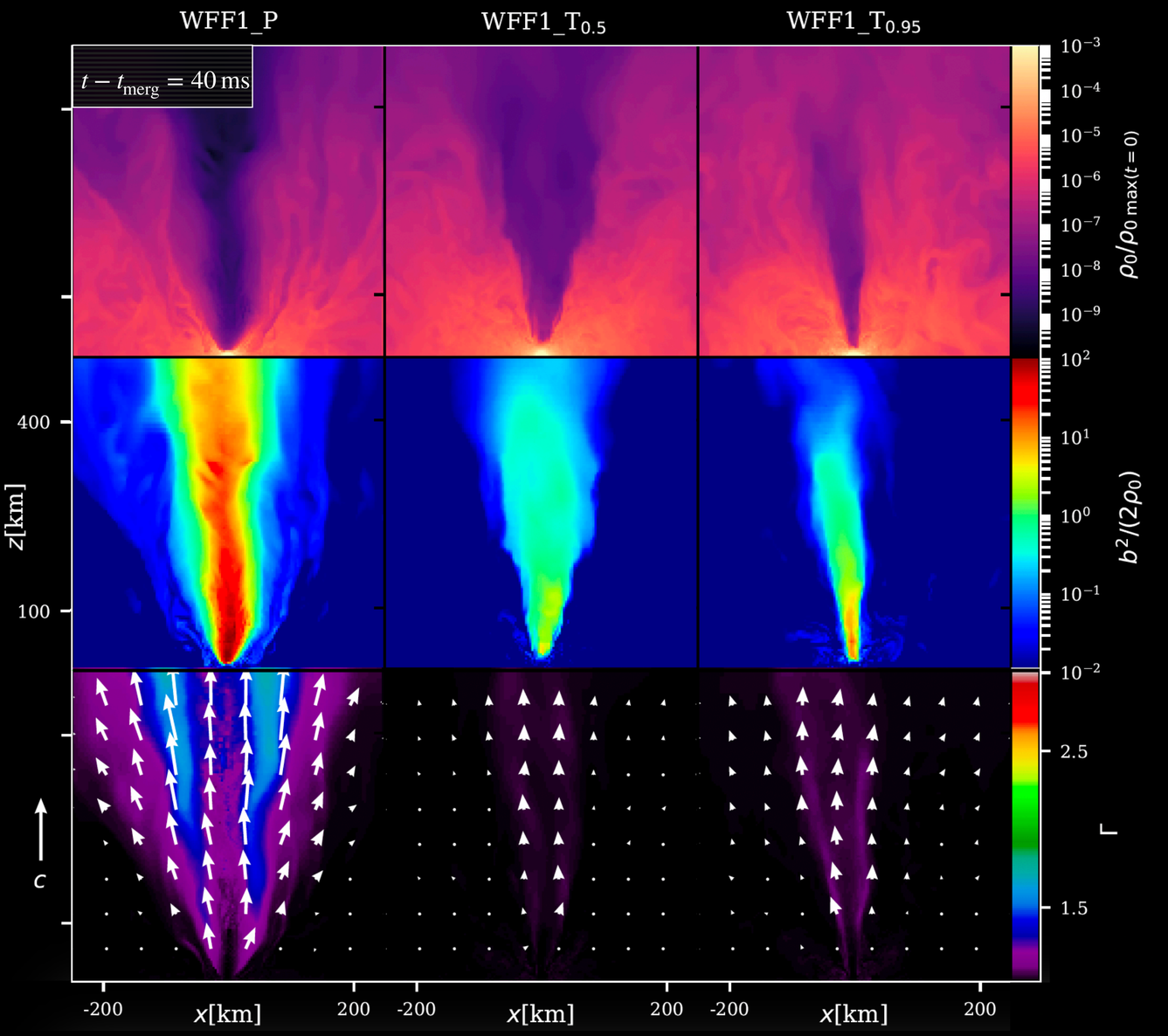
EM SIGNALS: CONSISTENT WITH SHORT GRB

- Extended initial poloidal component → cleaner/wider funnel
- Largest Lorentz factor for pulsar-like configuration
- $M_{\rm ejecta}(\rm P) > M_{\rm ejecta}(T_{0.5}) > M_{\rm ejecta}(T_{0.95})$



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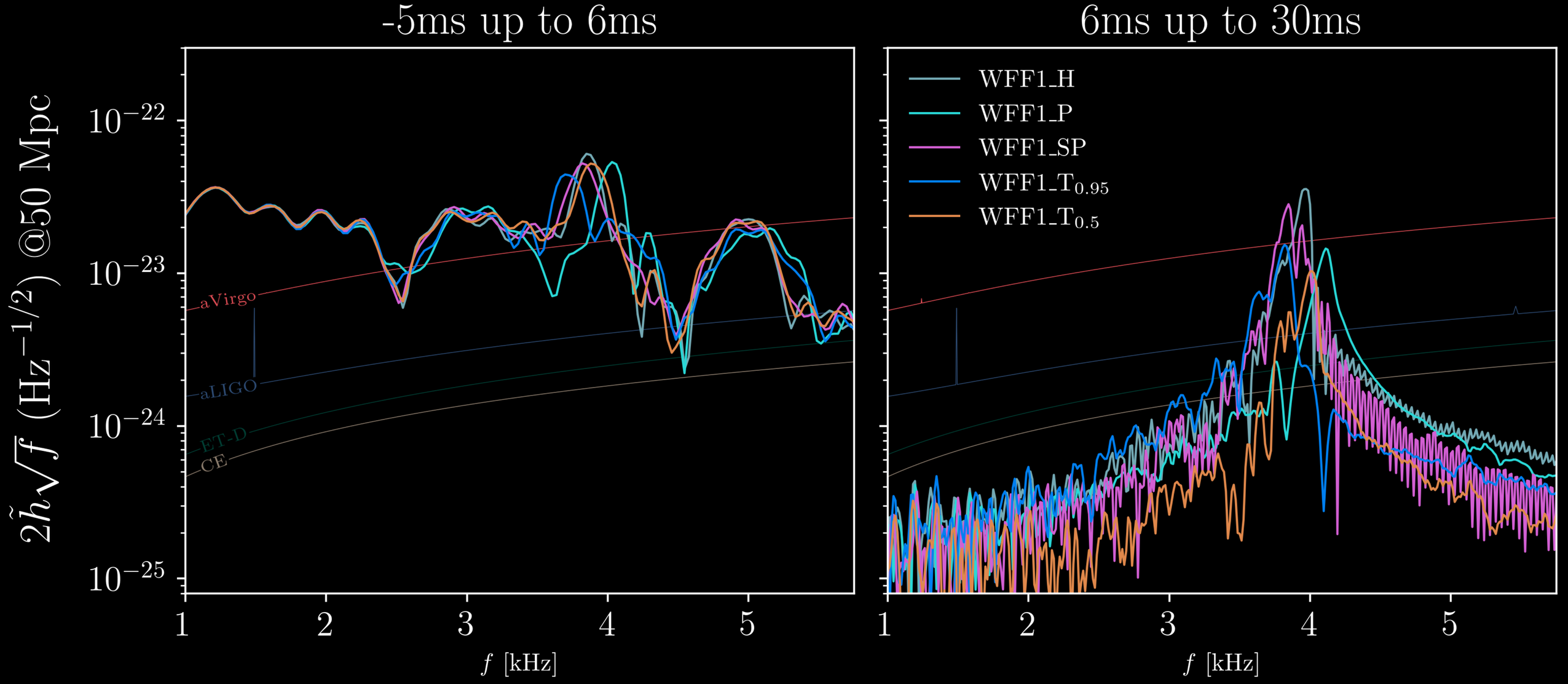
GWS: FREQUENCY SHIFT



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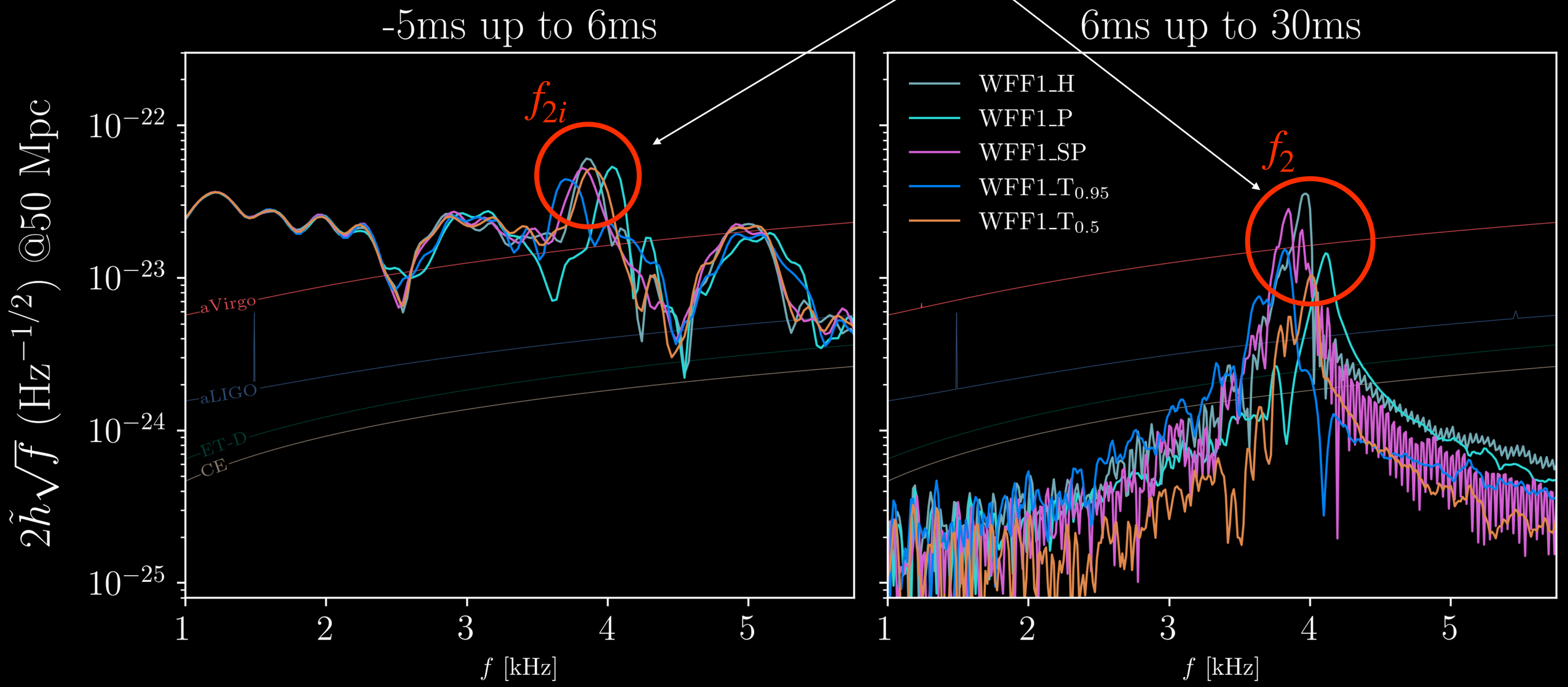
GWS: FREQUENCY SHIFT

SHIFT IN THE PEAK FREQUENCY!



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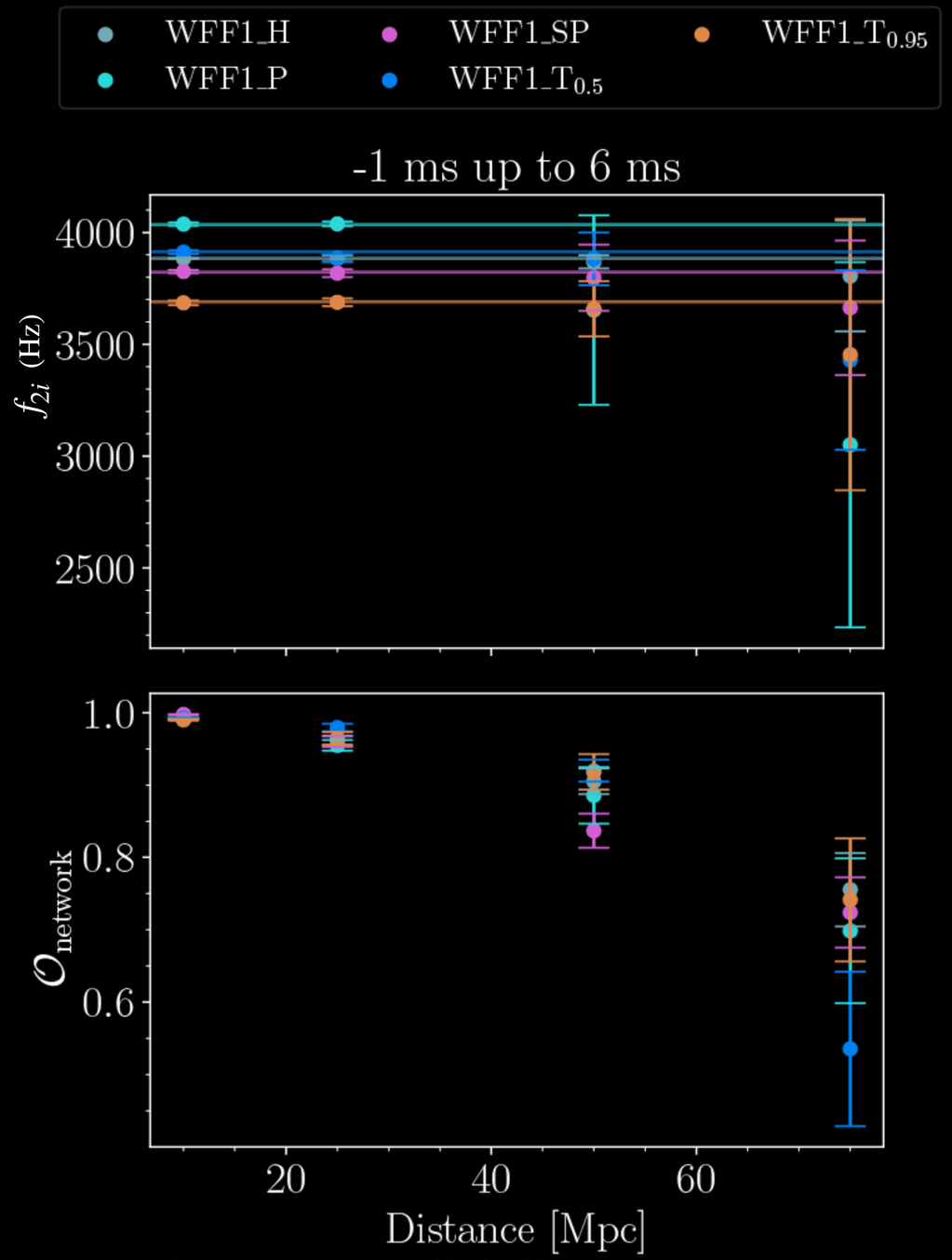
GWS: DETECTABILITY OF THE SHIFT

- *BayesWave* algorithm [N. J. Cornish and T. B. Littenberg, 2015]
- Third-generation detector Einstein Telescope
- Optimal sky location and inclination
- Distinguishable up to $\sim 50\,\mathrm{Mpc}$



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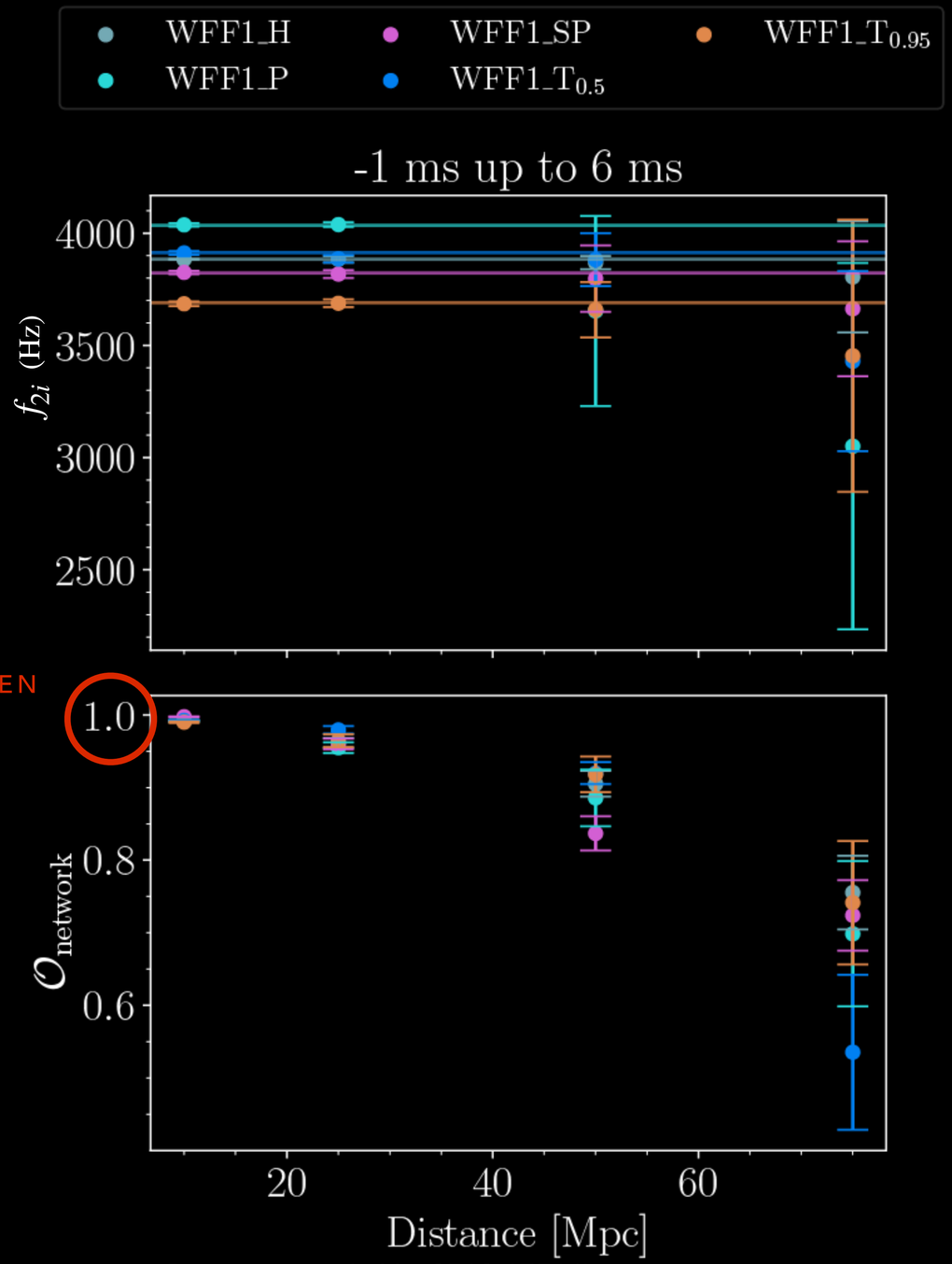

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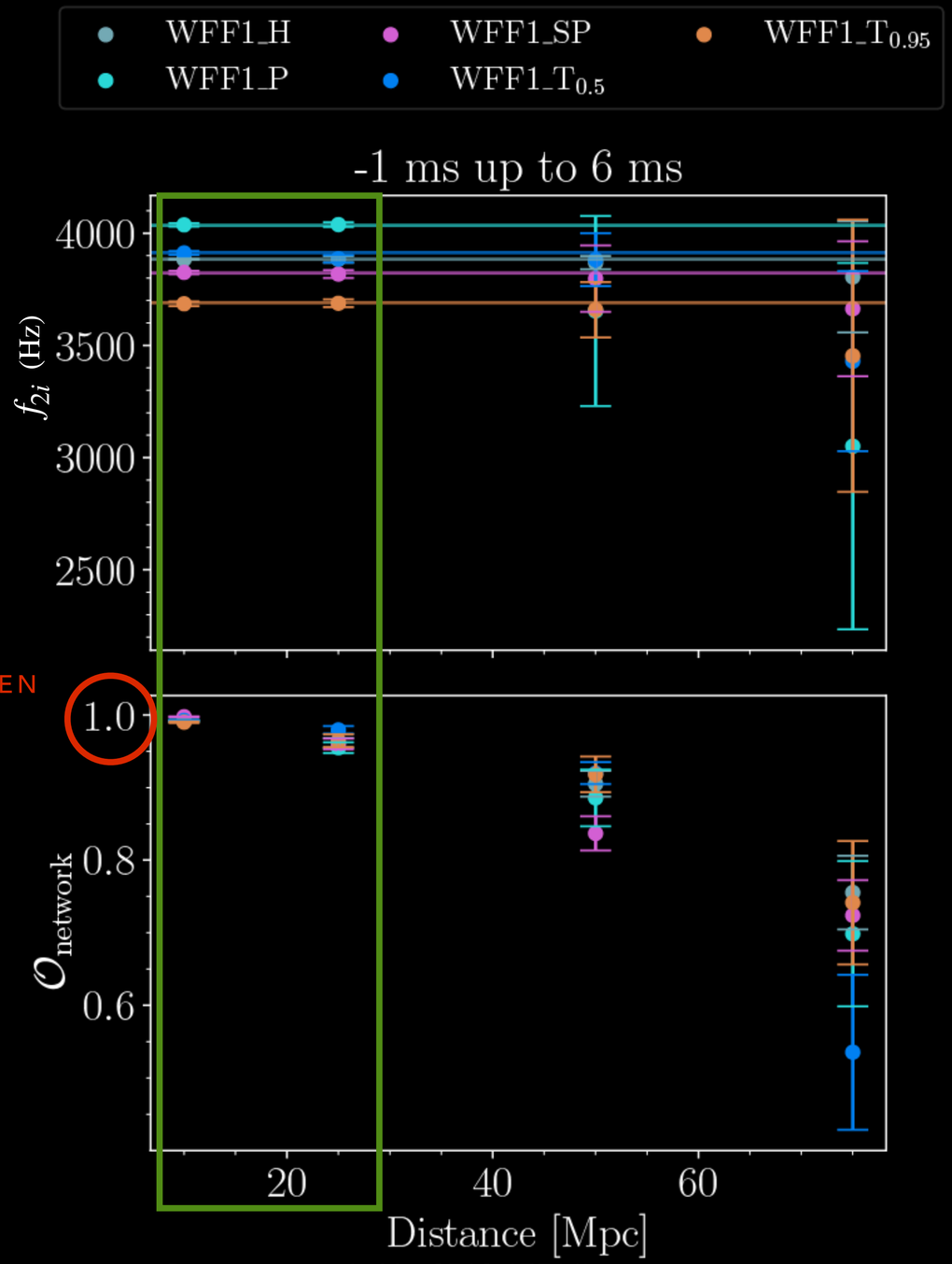

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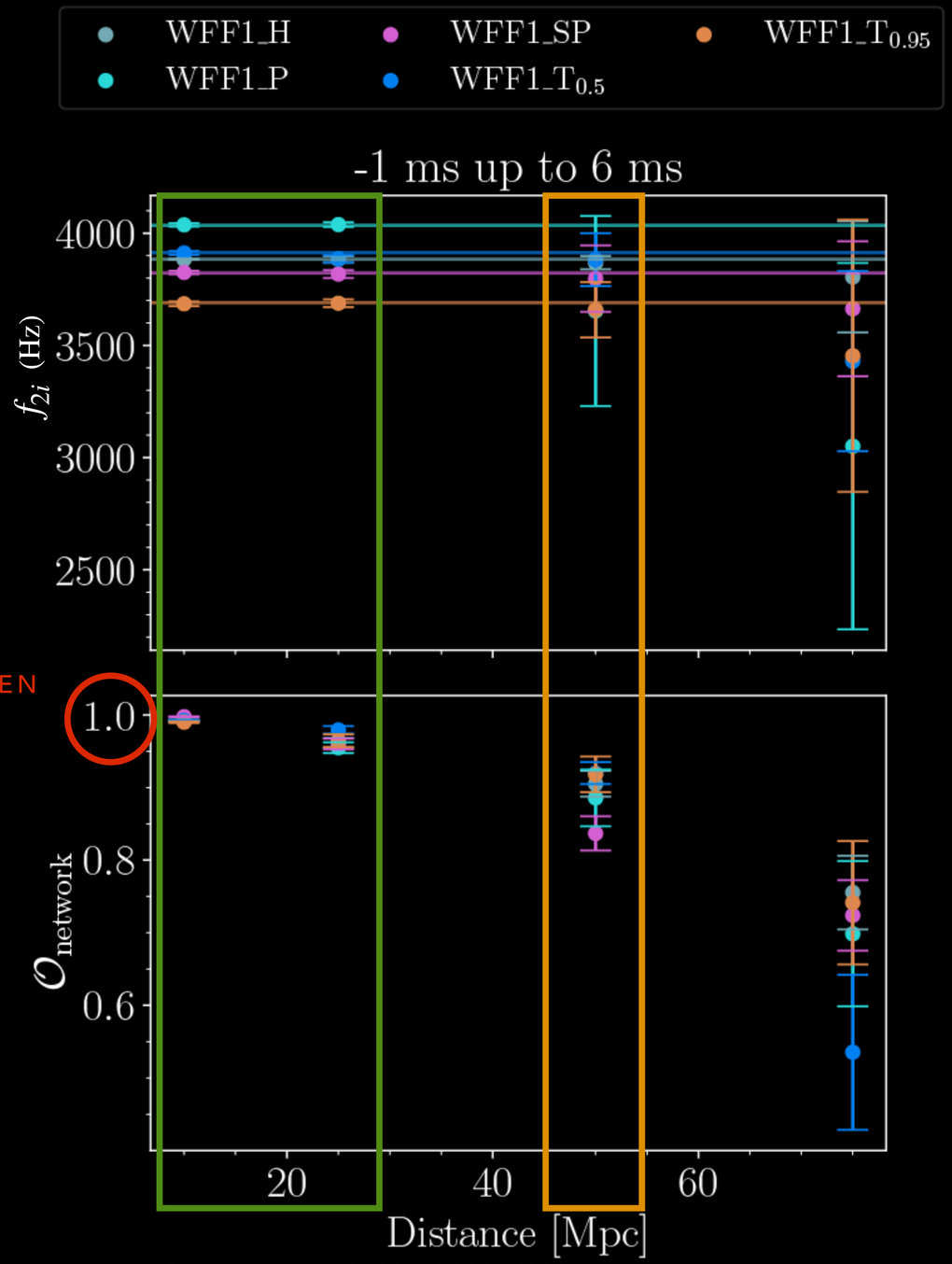

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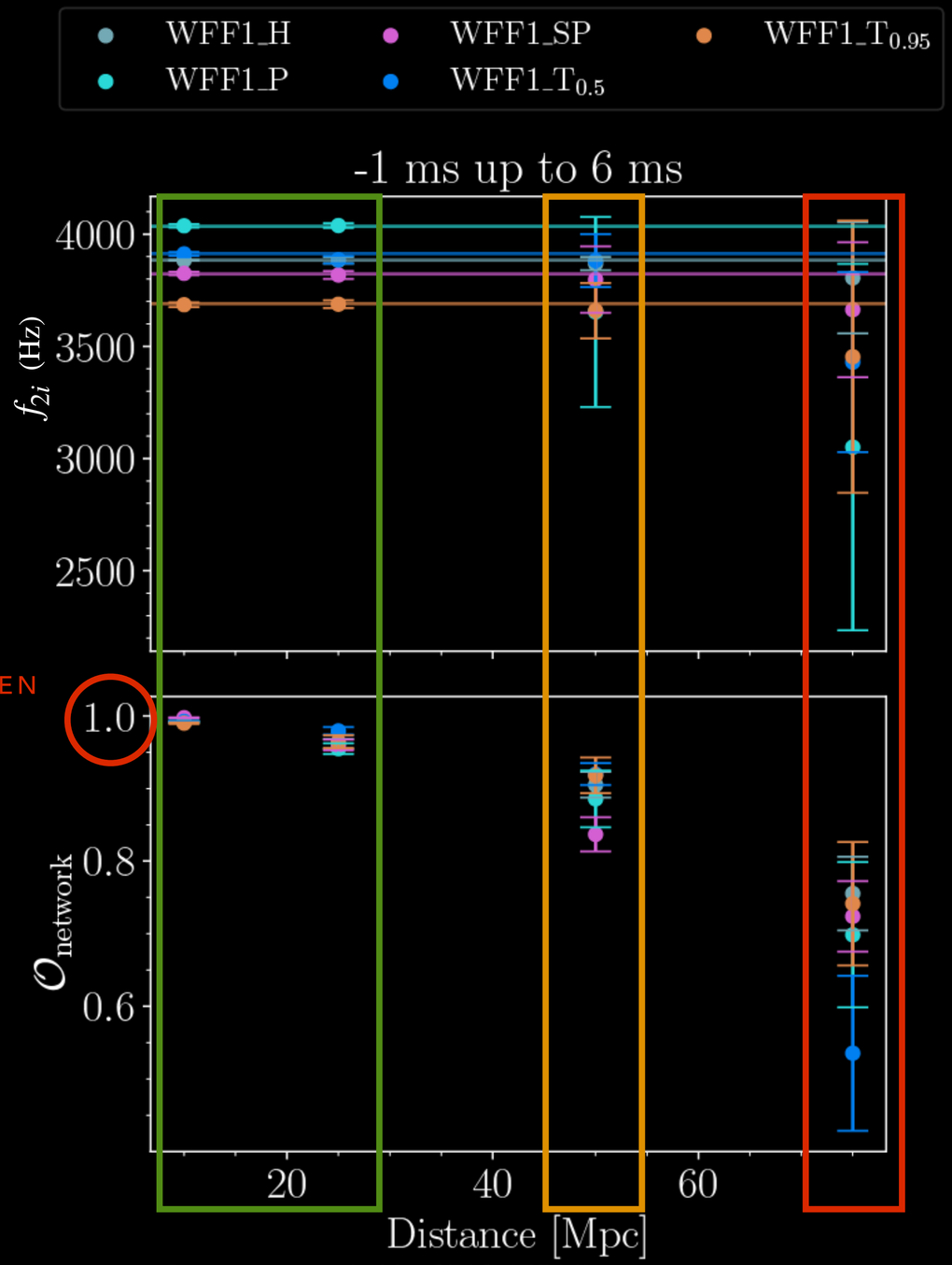

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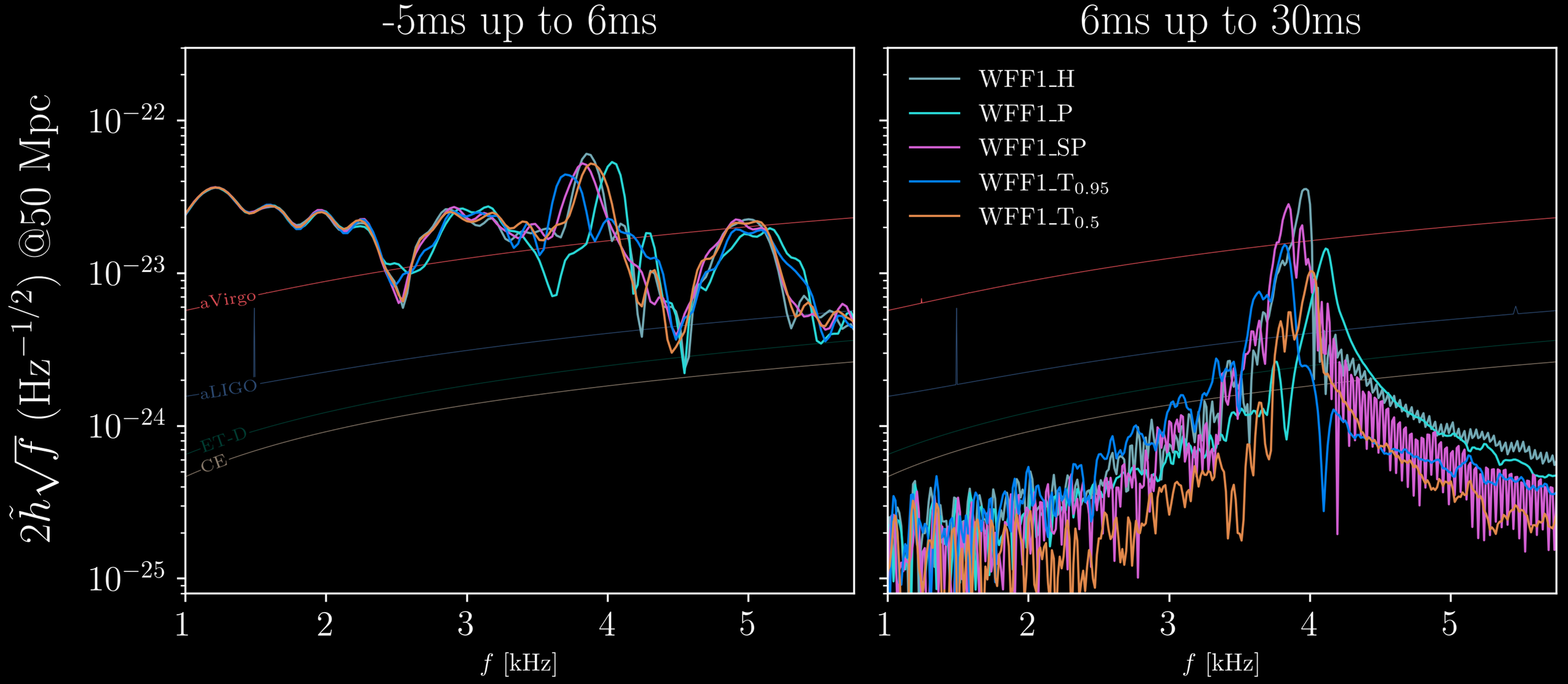

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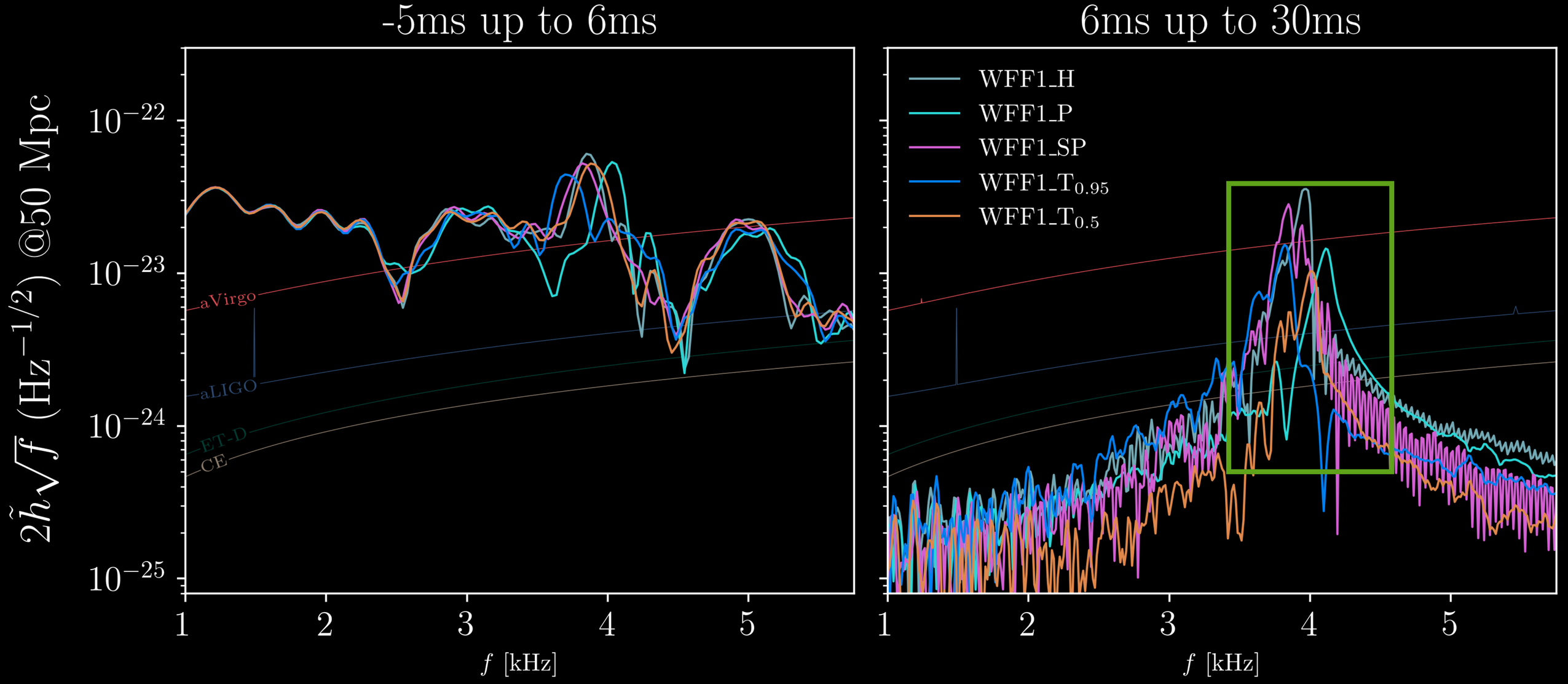

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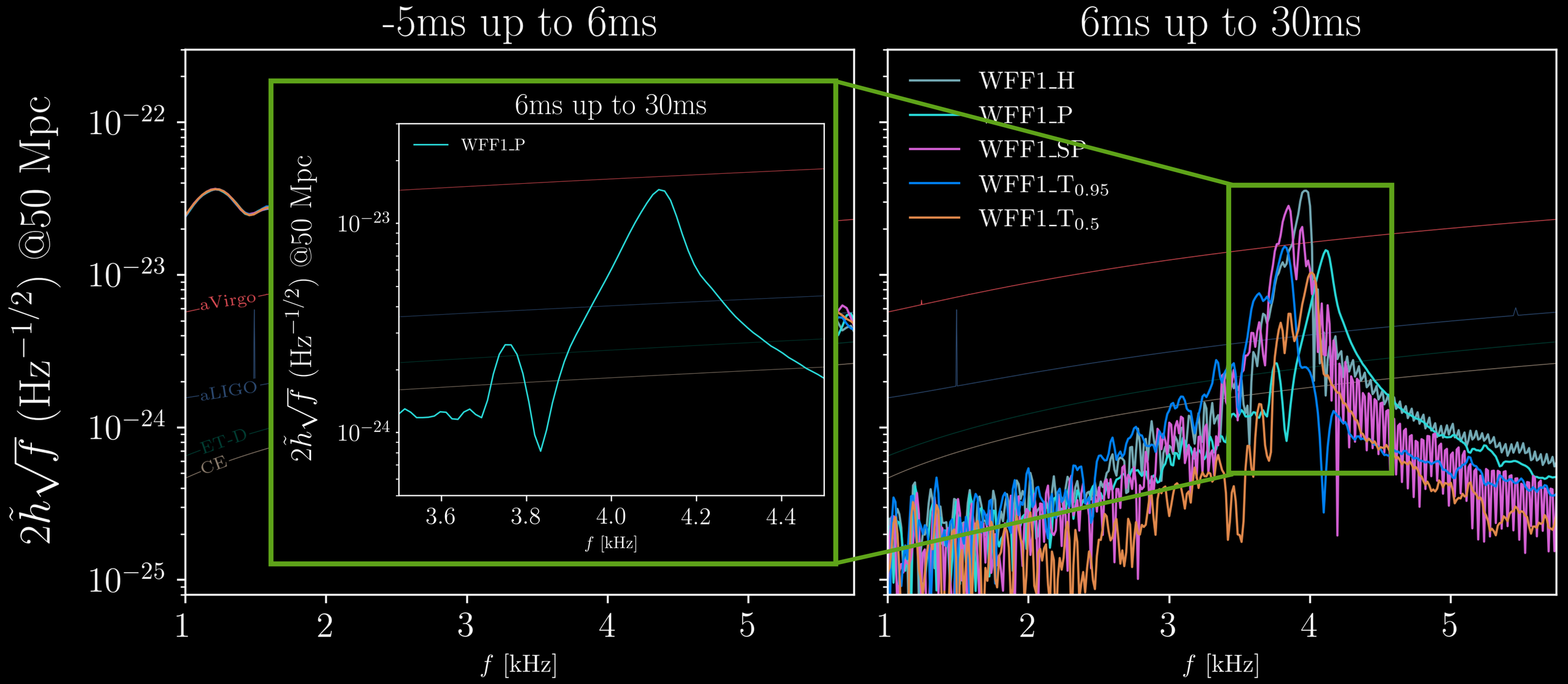

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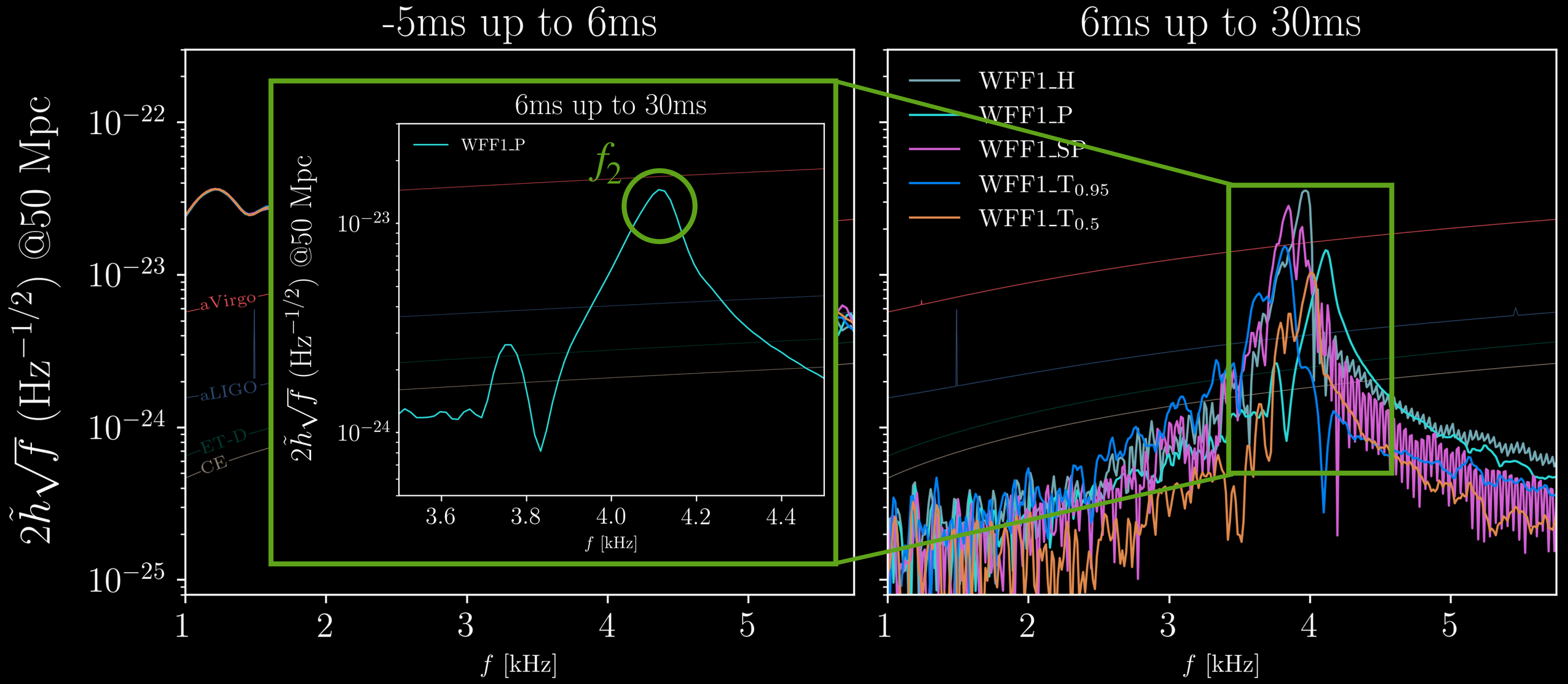

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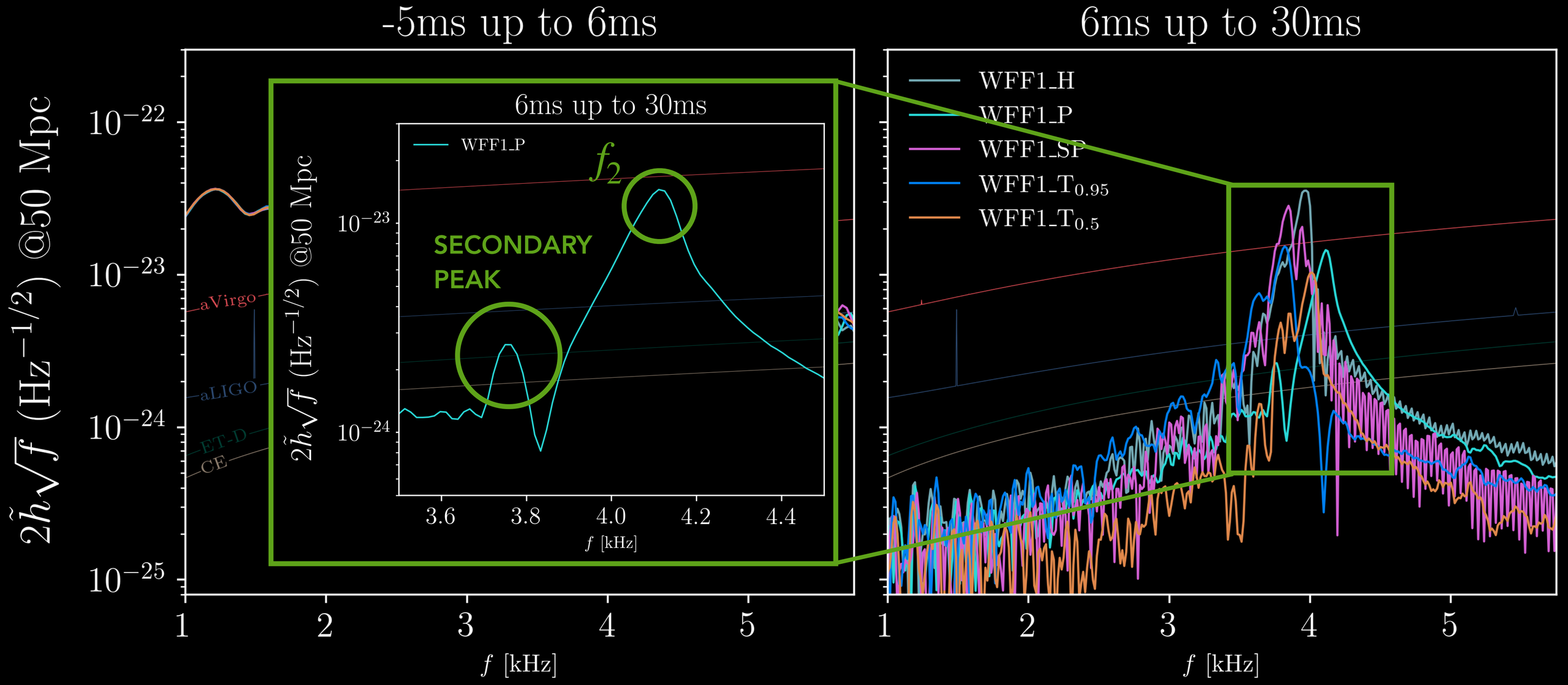

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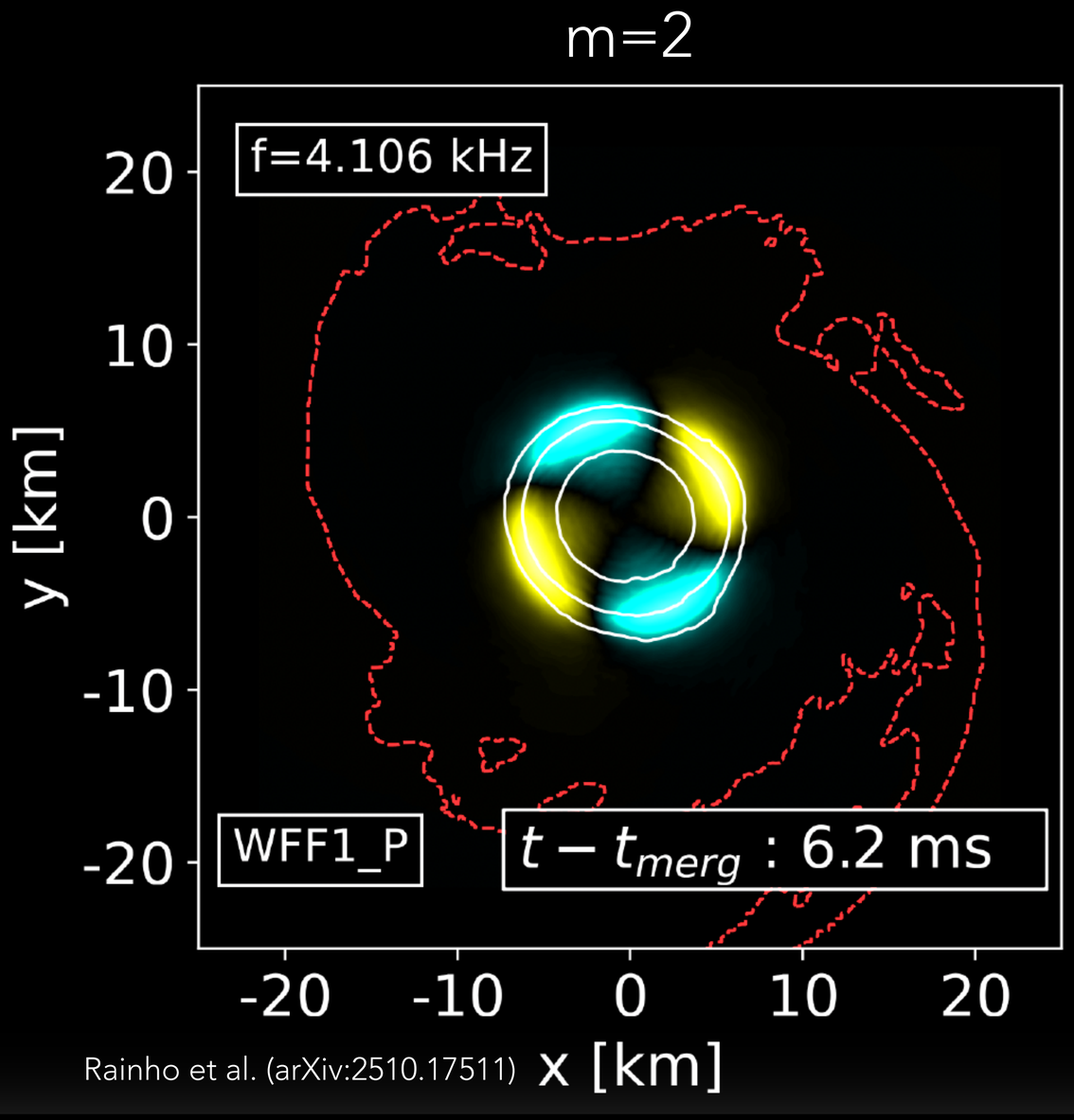
GWS: DENSITY EIGENFUNCTIONS



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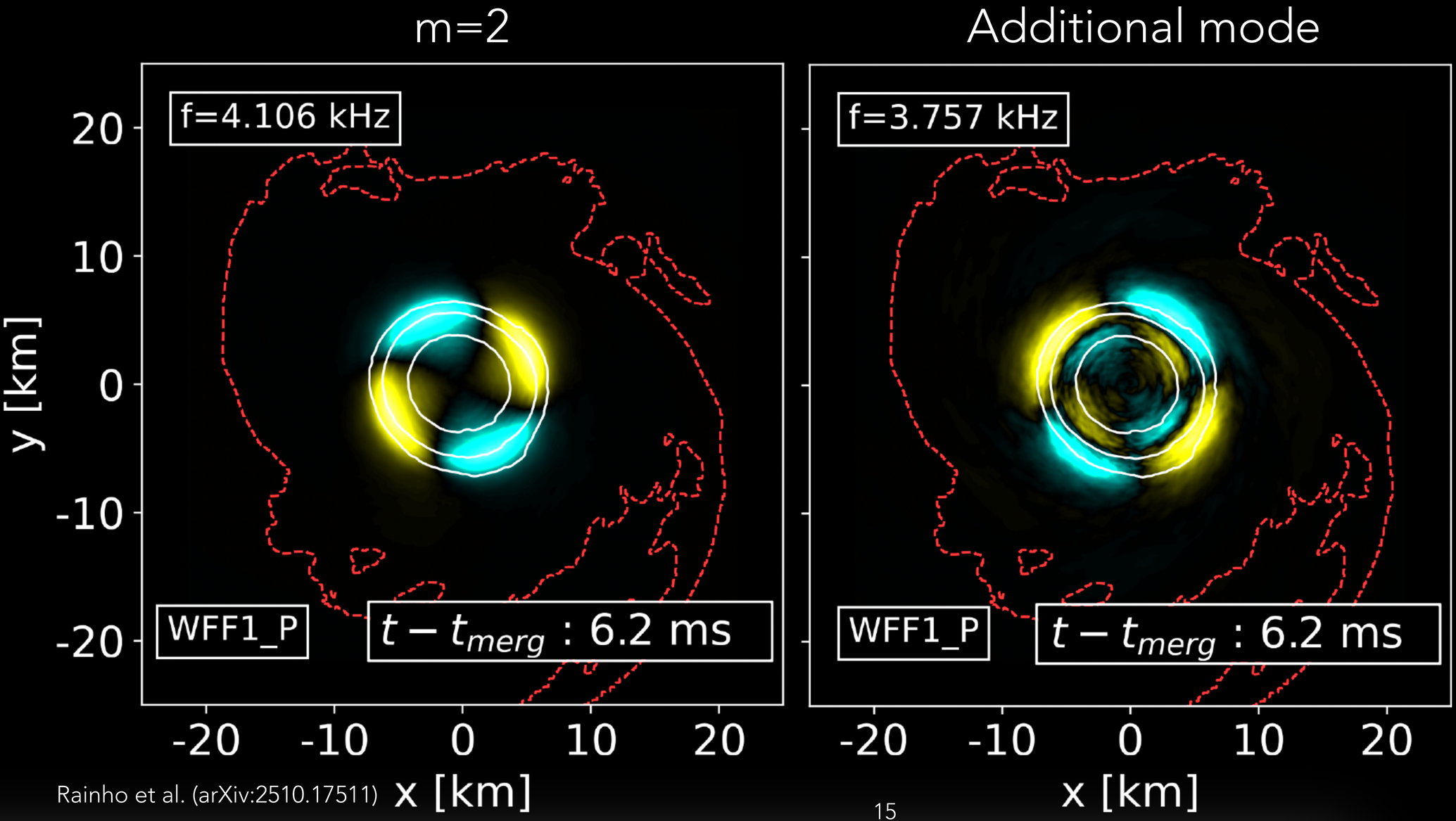

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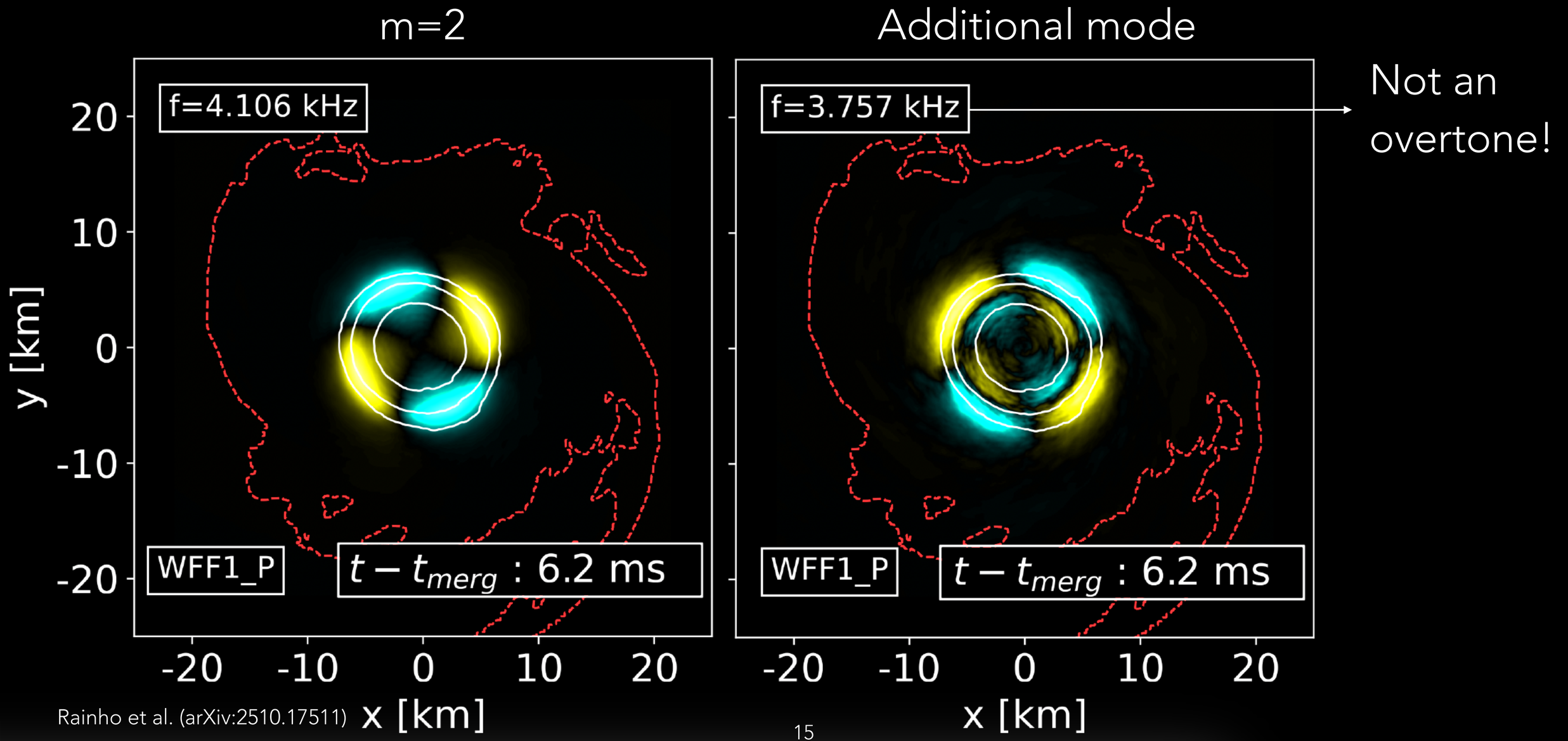

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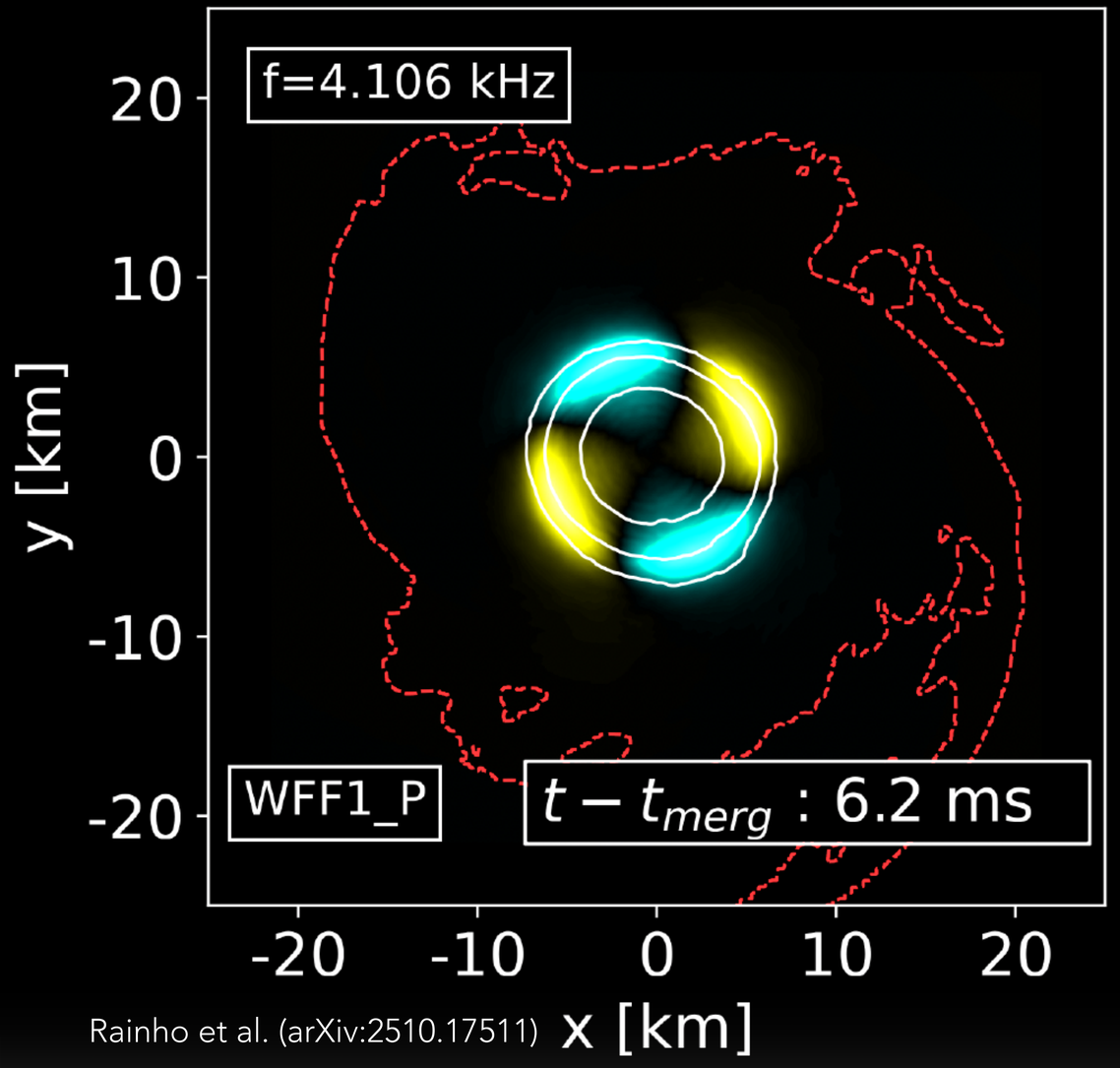
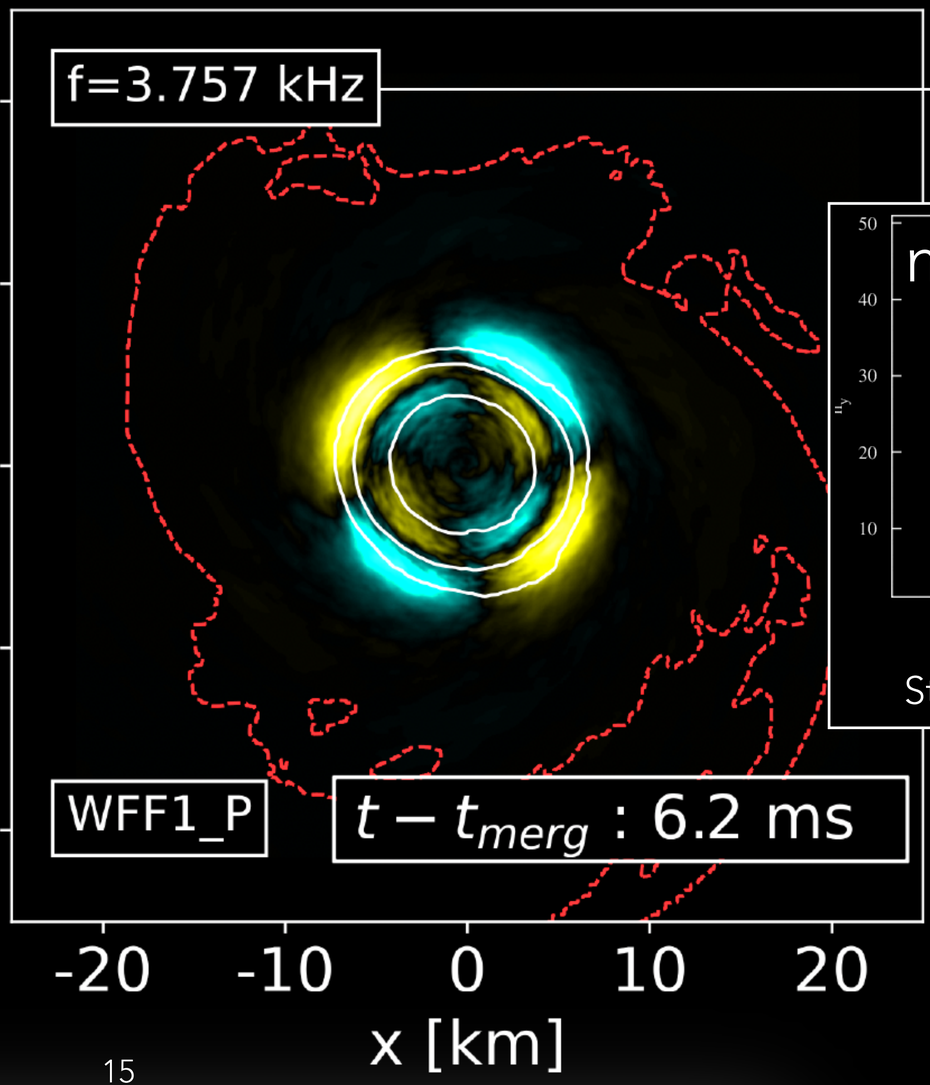
GWS: DENSITY EIGENFUNCTIONS

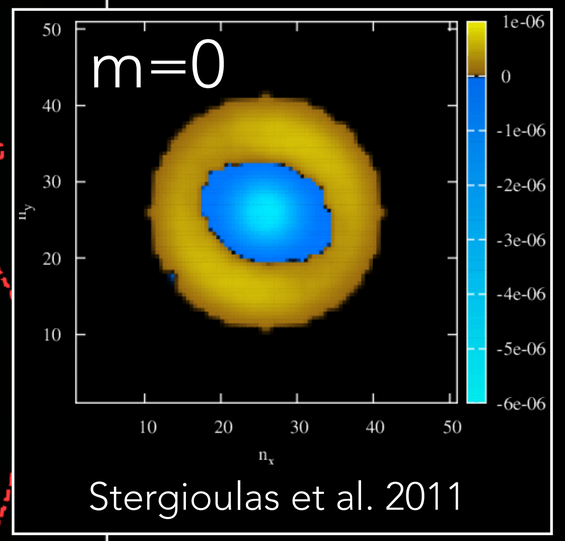
m=2

Additional mode





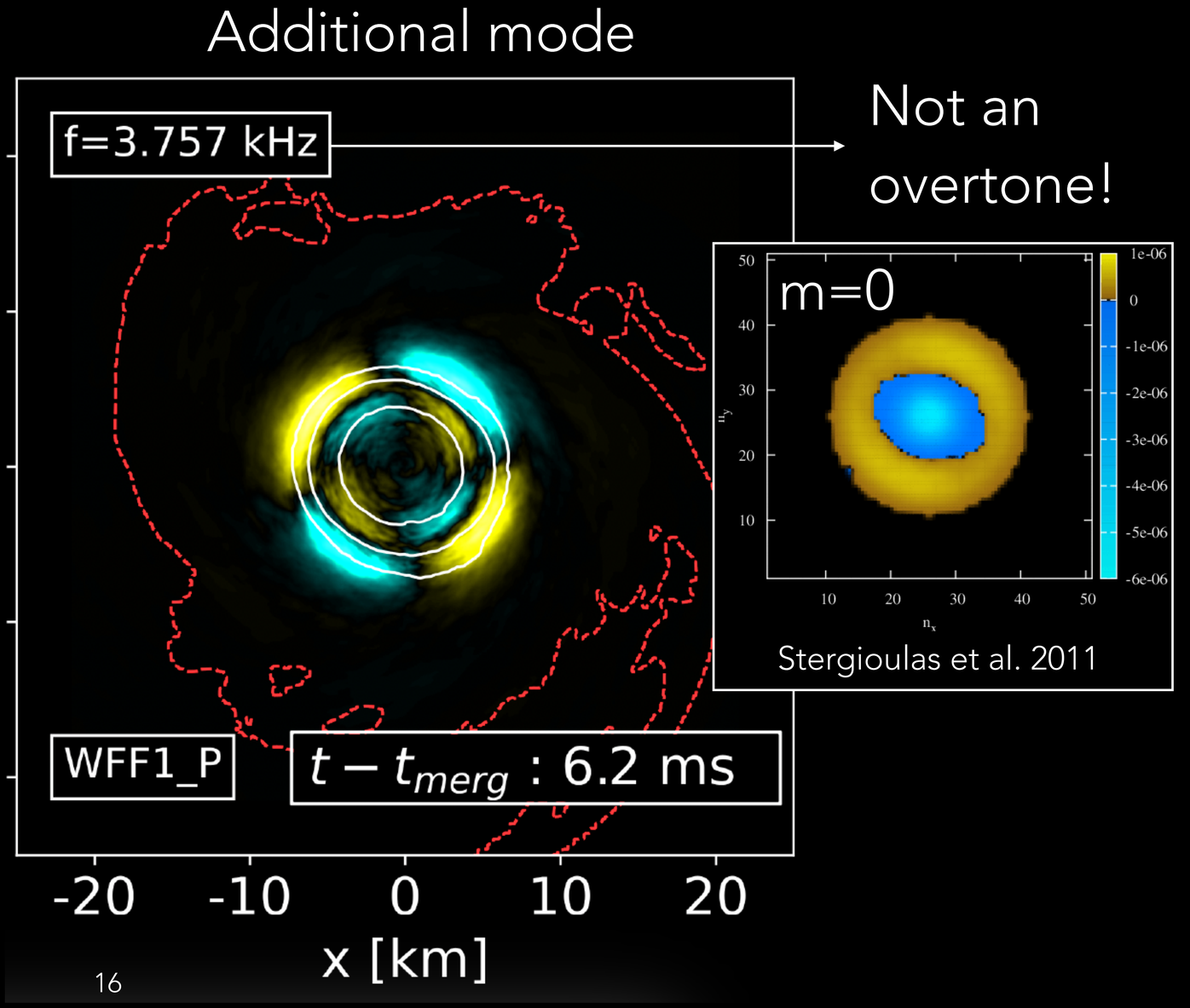
Not an overtone!



Rainho et al. (arXiv:2510.17511)

GWS: DENSITY EIGENFUNCTIONS

- The additional mode observed is a **non-linear coupling** of the **m=0 and m=2** modes



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ありがとうございます！

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