


REFINING HUBBLE CONSTANT WITH SUBDOMINANT GW-MODES

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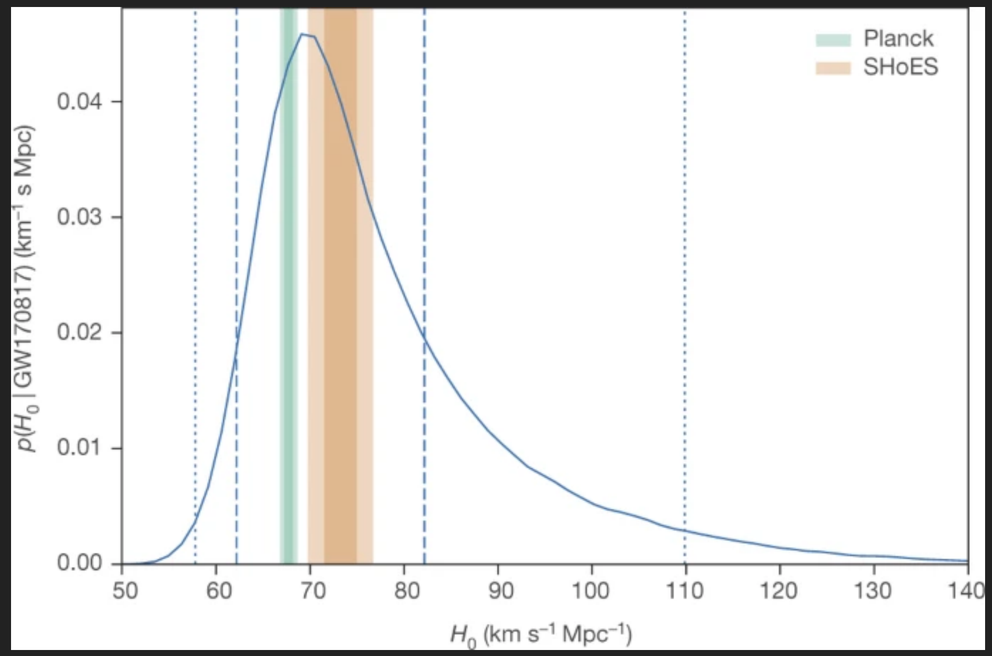
TIM DIETRICH AND PAUL D. LASKY

(APJL 912 L10 (2021))

FIRST BINARY NEUTRON MERGER

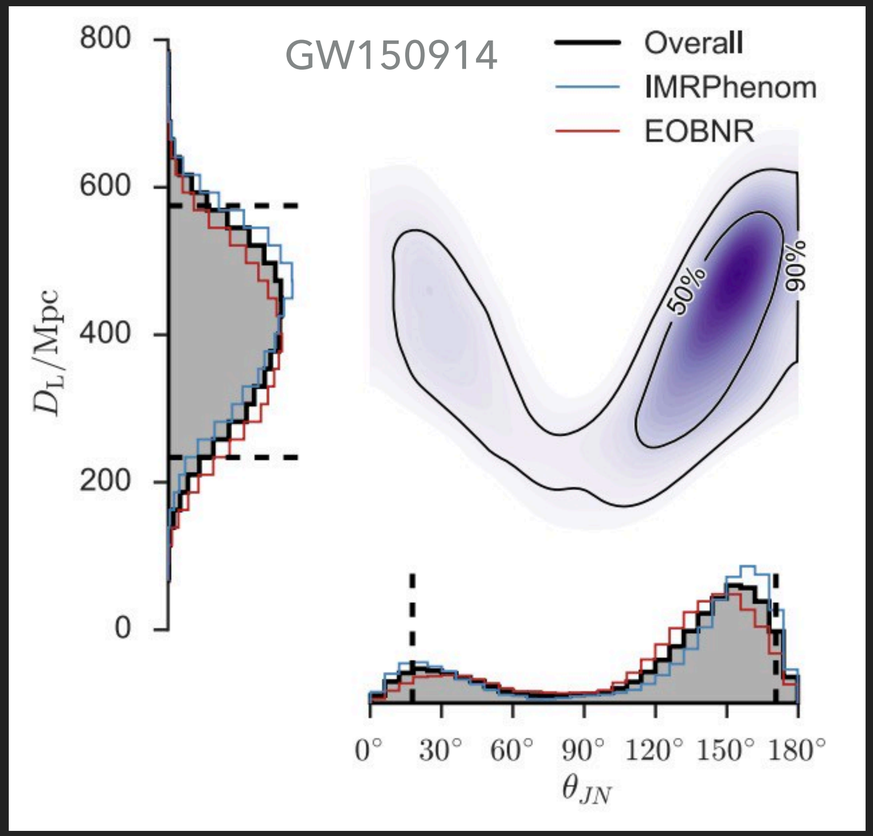
- GW170817
- Electromagnetic counterpart
- Multi-messenger Astronomy
  - Hubble constant:
    - New GW estimate: 70 km/s/Mpc (15%)
    - Planck, 2018: 67.4 km/s/Mpc (<1%)



B P Abbott et al. (2017)

FIRST BINARY NEUTRON MERGER

- GW170817
- Electromagnetic counterpart
- Multi-messenger Astronomy
  - Hubble constant:
    - New GW estimate: 70 km/s/Mpc (16%)
    - Limitation
      - 1) Loudness
      - 2) Degeneracy (d_L and ι (θ_{JN}))
    - Planck, 2018: 67.4 km/s/Mpc (1%)

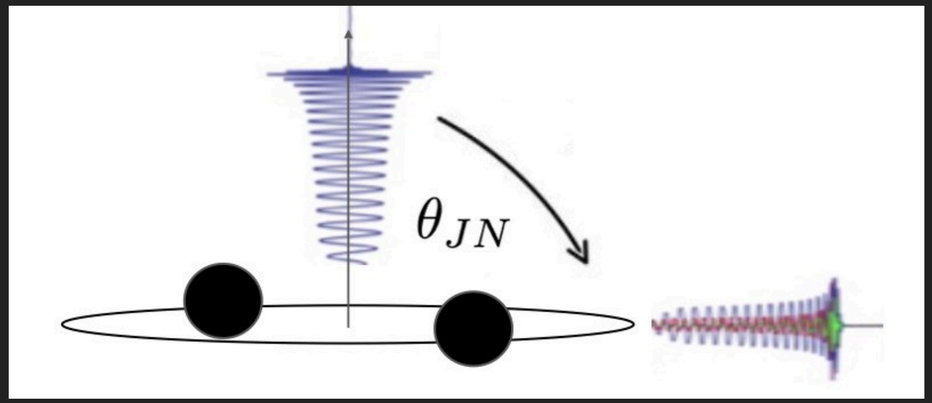


LIGO+Virgo (2016)

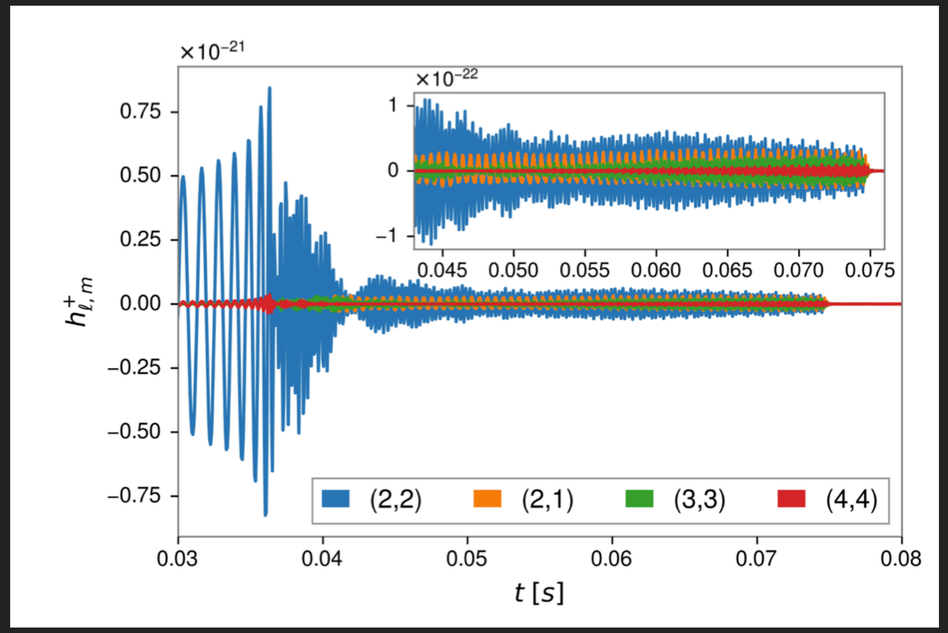
SUBDOMINANT MODES IN GRAVITATIONAL WAVES

$$h_+ - ih_\times = \frac{1}{d_\mathrm{L}} \sum_{\ell \geq 2} \sum_{m=-\ell}^{m=\ell} Y^{-2}_{\ell,m}(\iota, \psi)\, h_{\ell,m}(\Xi)$$

- Emission dominated by (2,2) mode
- Else, it's subdominant (higher mode)
- Important → massive and asymmetric
- BNS: Weak inspiral, short merger



Someone (year)



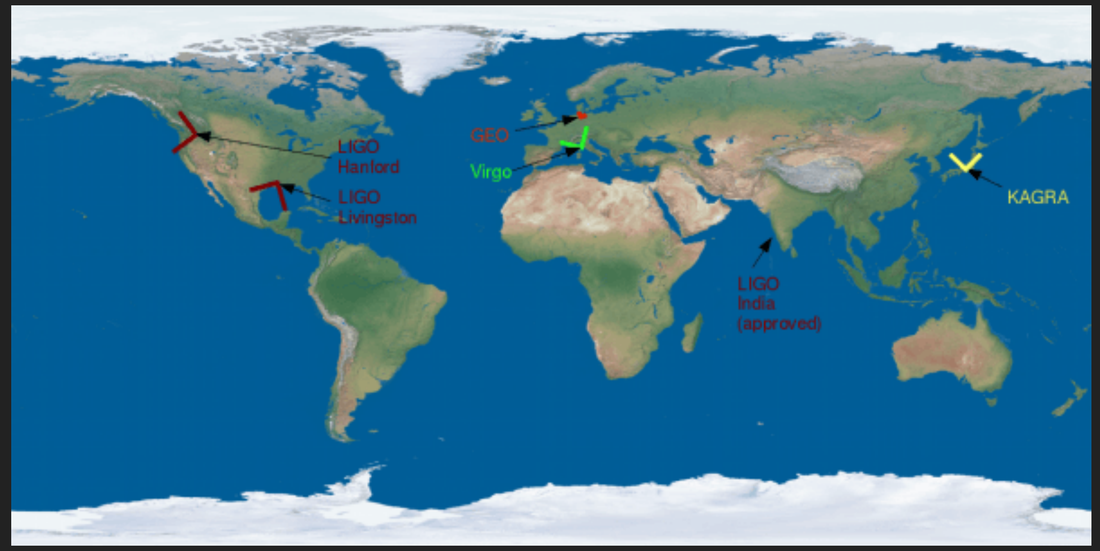
Bustillo *et al.* (2021)

INJECTION

- IMRPhenomHM, at 40 Mpc
- Mass ratio: q = 1 and q = 1.5
- Inclination: Face On and Edge On
- Spins: s = 0, s = 0.3, s = -0.3

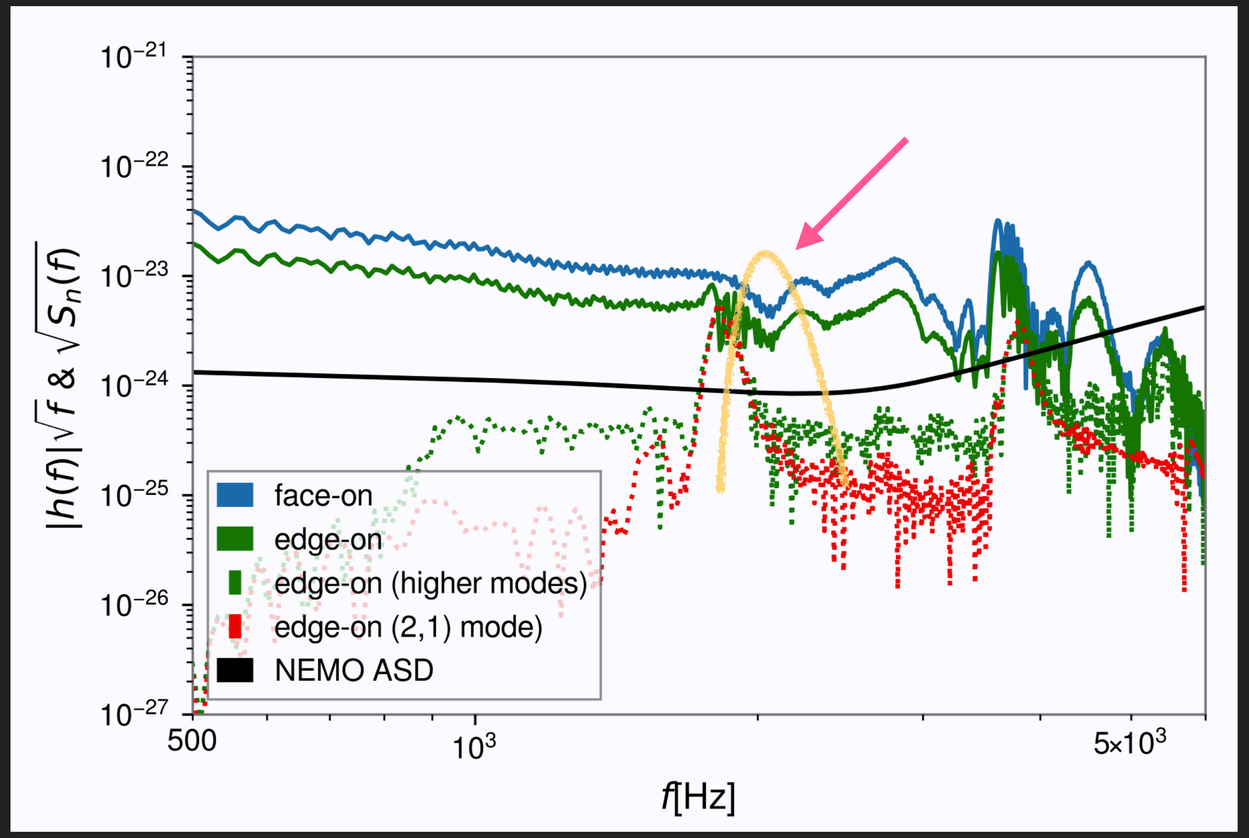
DETECTORS

- Hanford and Livingston (HL)
- Handford and Virgo (HV)
- Hanford, Livingston and Virgo (HLV)
- Equipped with NEMO PSD

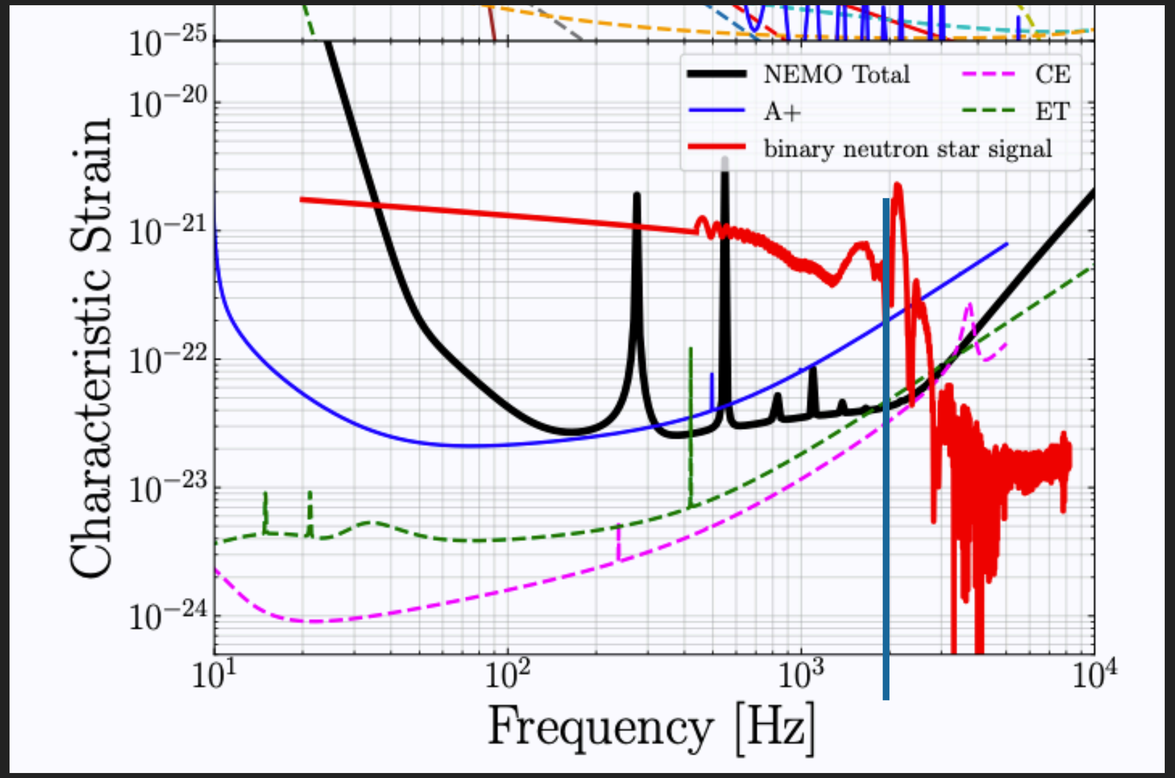


From: http://public.virgo-gw.eu/a-worldwide-network/
The Virgo Collaboration/LAPP and Tom Patterson
(www.shadedrelief.com)

NEMO

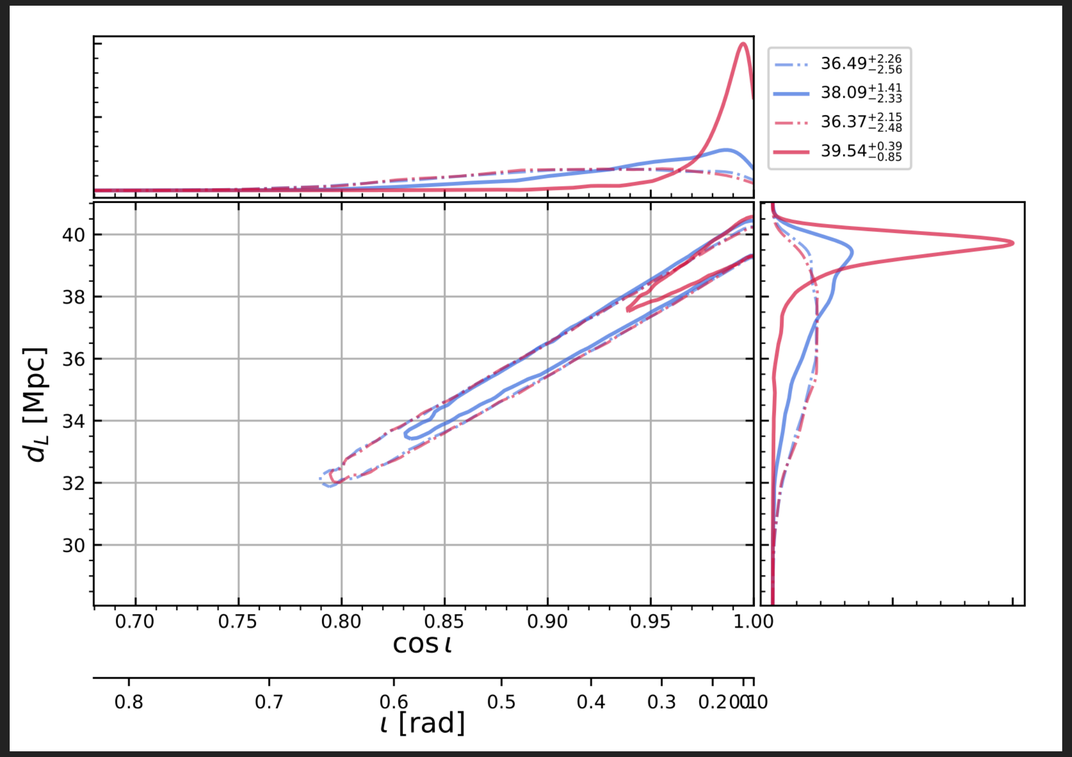


Bustillo *et al.* (2021)

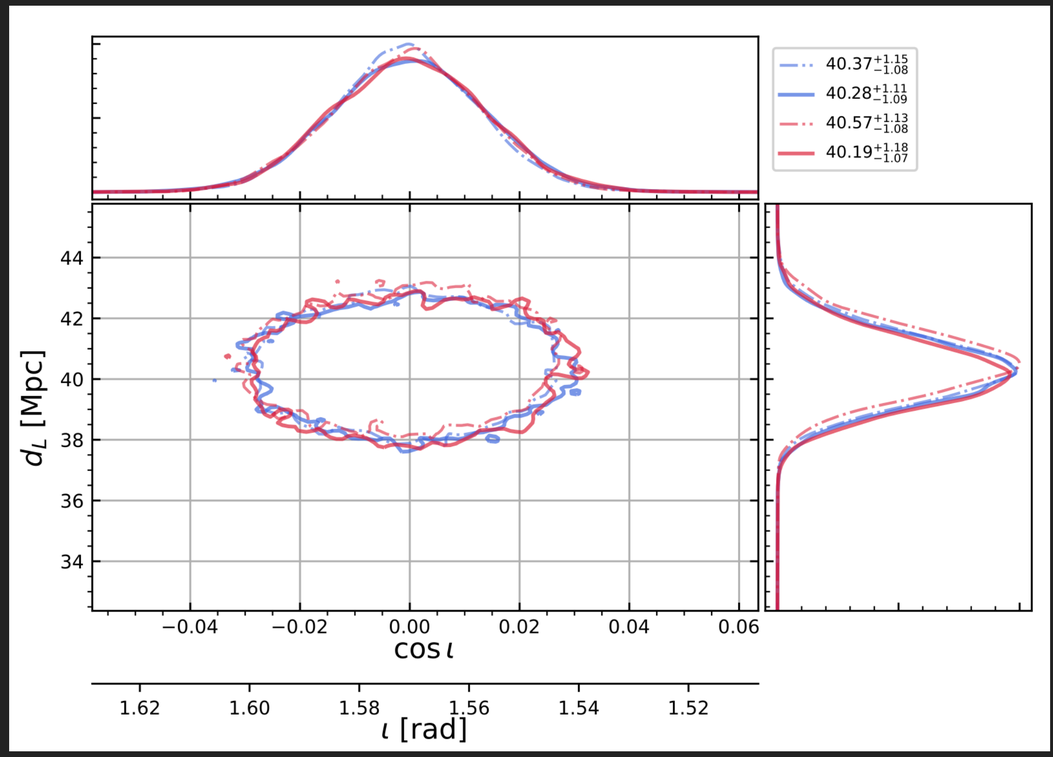


Ackley, K. et al. (2020)

FACE-ON



EDGE-ON



q = 1 (equal), no HM | q = 1 (equal), with HM | q = 1.5 (unequal), no HM | q = 1.5 (unequal), with HM

Leong+ (In preparation)

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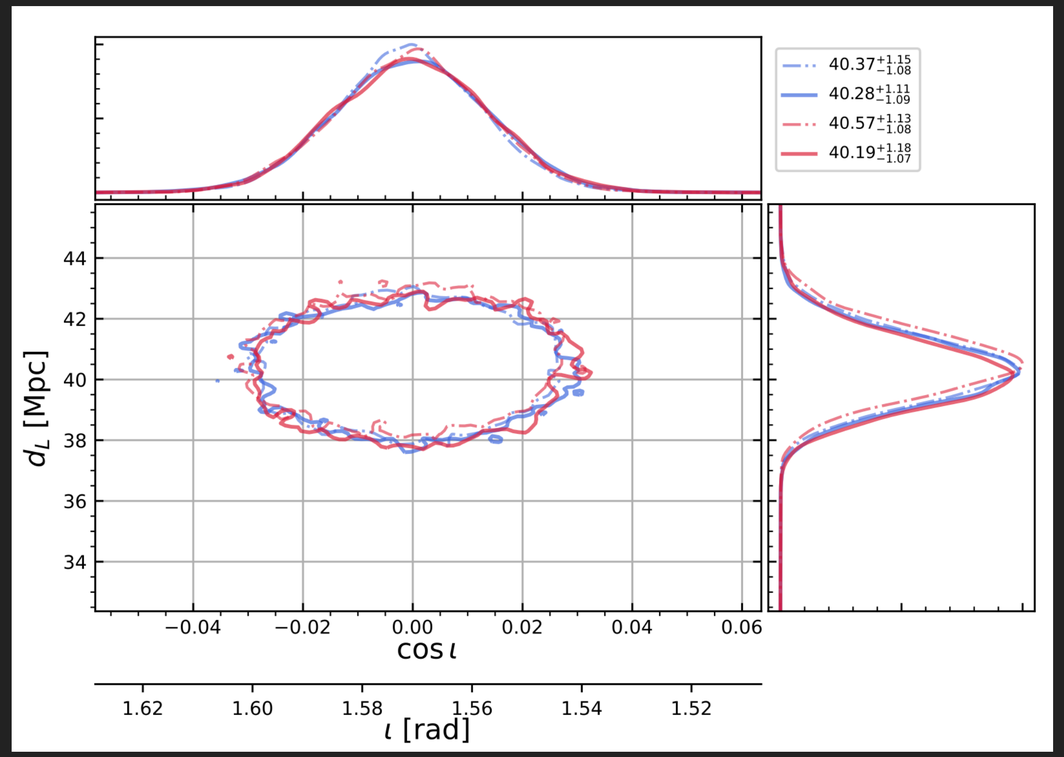

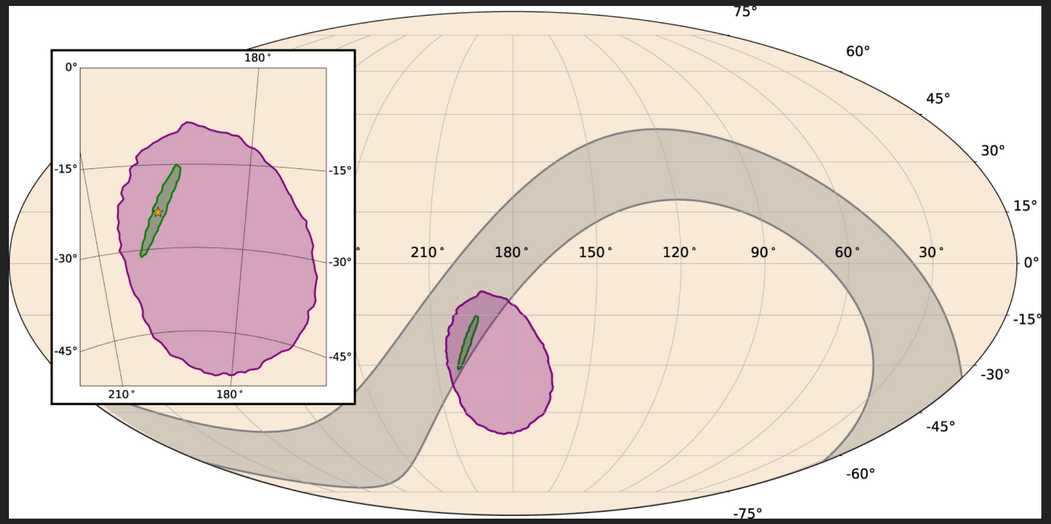

B. P. Abbott *et al* (2017)

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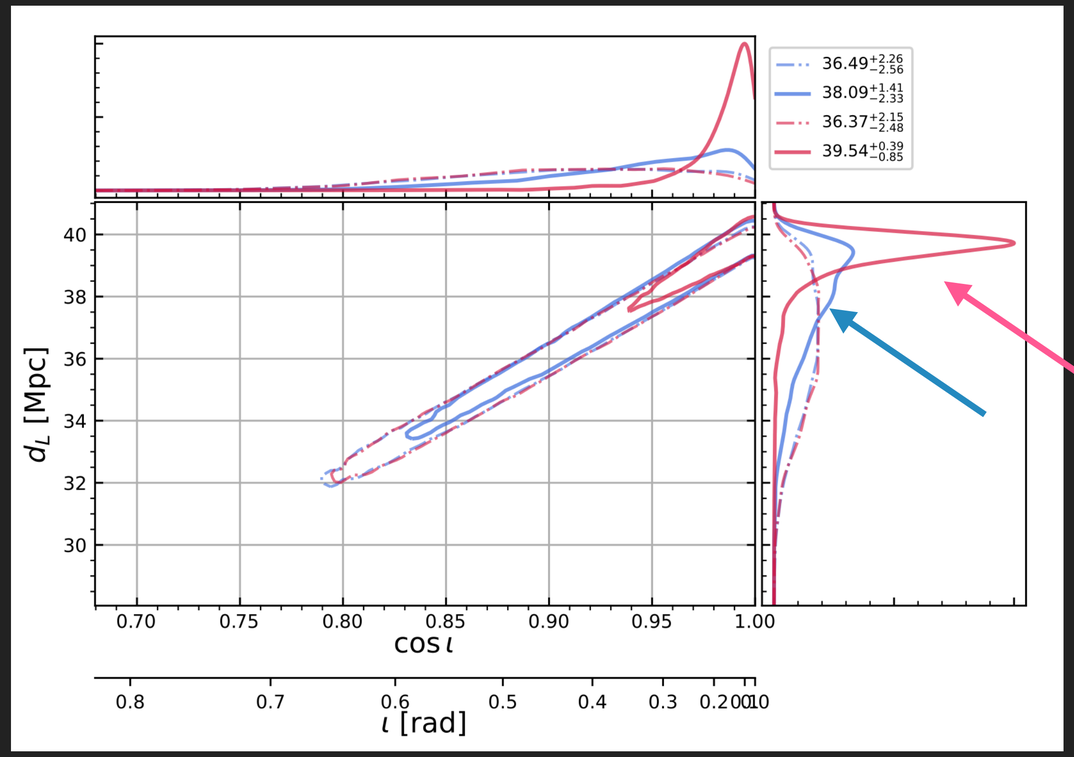

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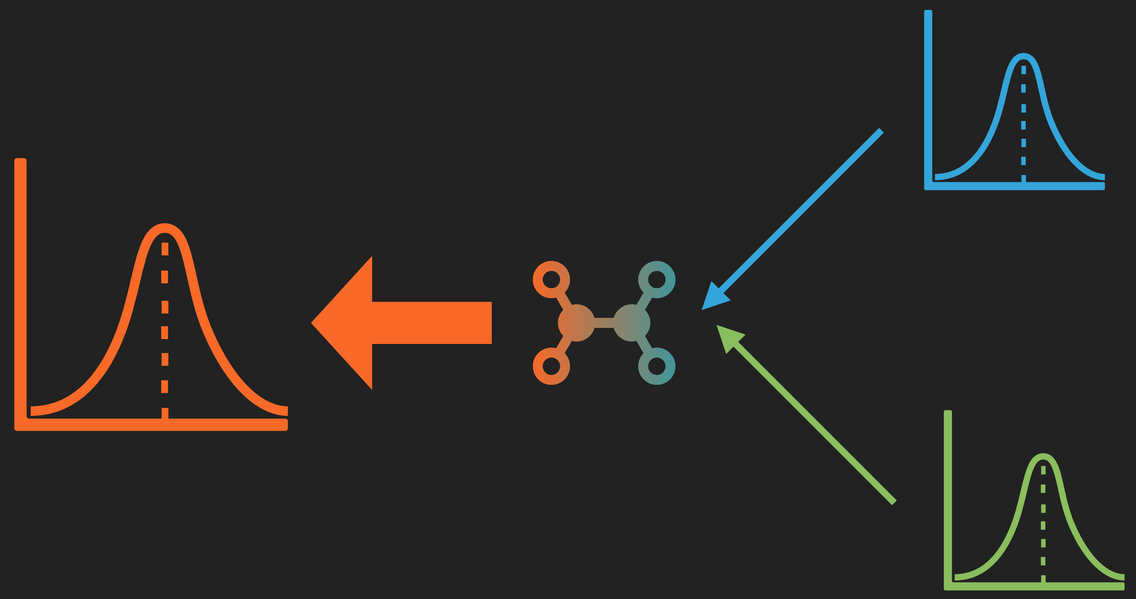
HUBBLE CONSTANT



$$H_0 = \frac{cz}{D_L}$$

HUBBLE CONSTANT

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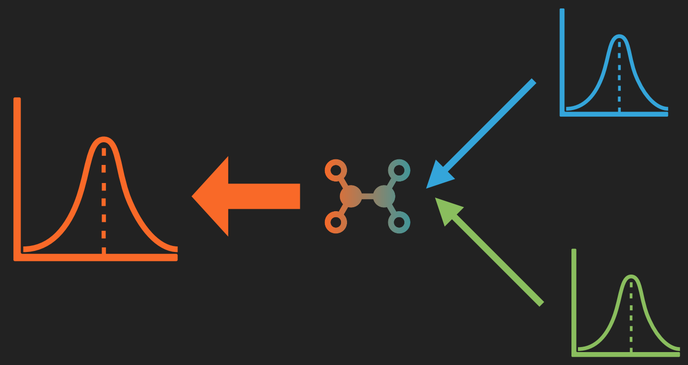

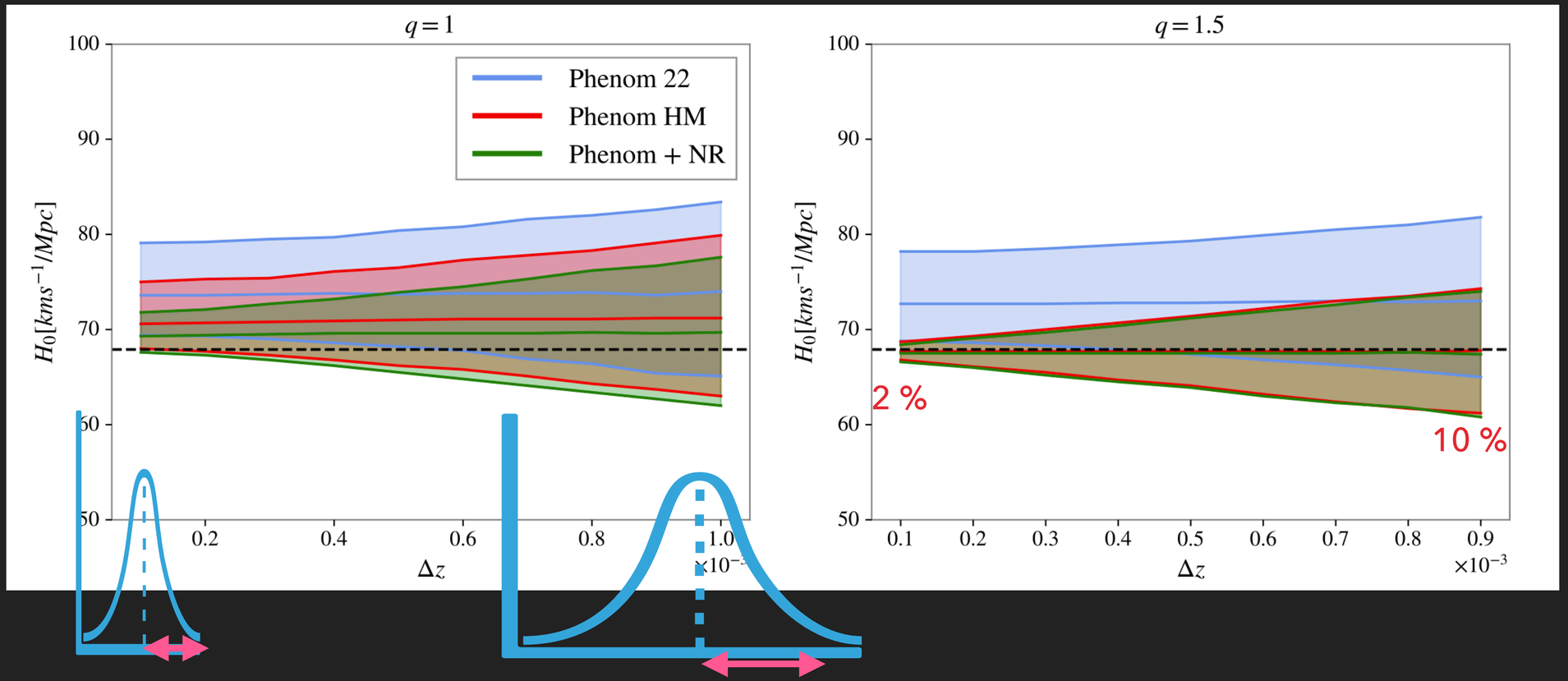

TO SUM UP…

- Distance measurement fundamentally limited by distance - inclination degeneracy
- Higher modes breaks this degeneracy for binary black hole system
- Future detectors : break the degeneracy for low mass system
- Hubble Constant
  - Current redshift measurement improves accuracy by 25%
  - Improve redshift measurement: higher mode enable percent level measurement of the Hubble Constant
- Open the door to study and check of the anisotropy of the Hubble parameter 🤔

REFERENCE

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- B. P. Abbott *et al.* ApJL 848 L13 (2017)
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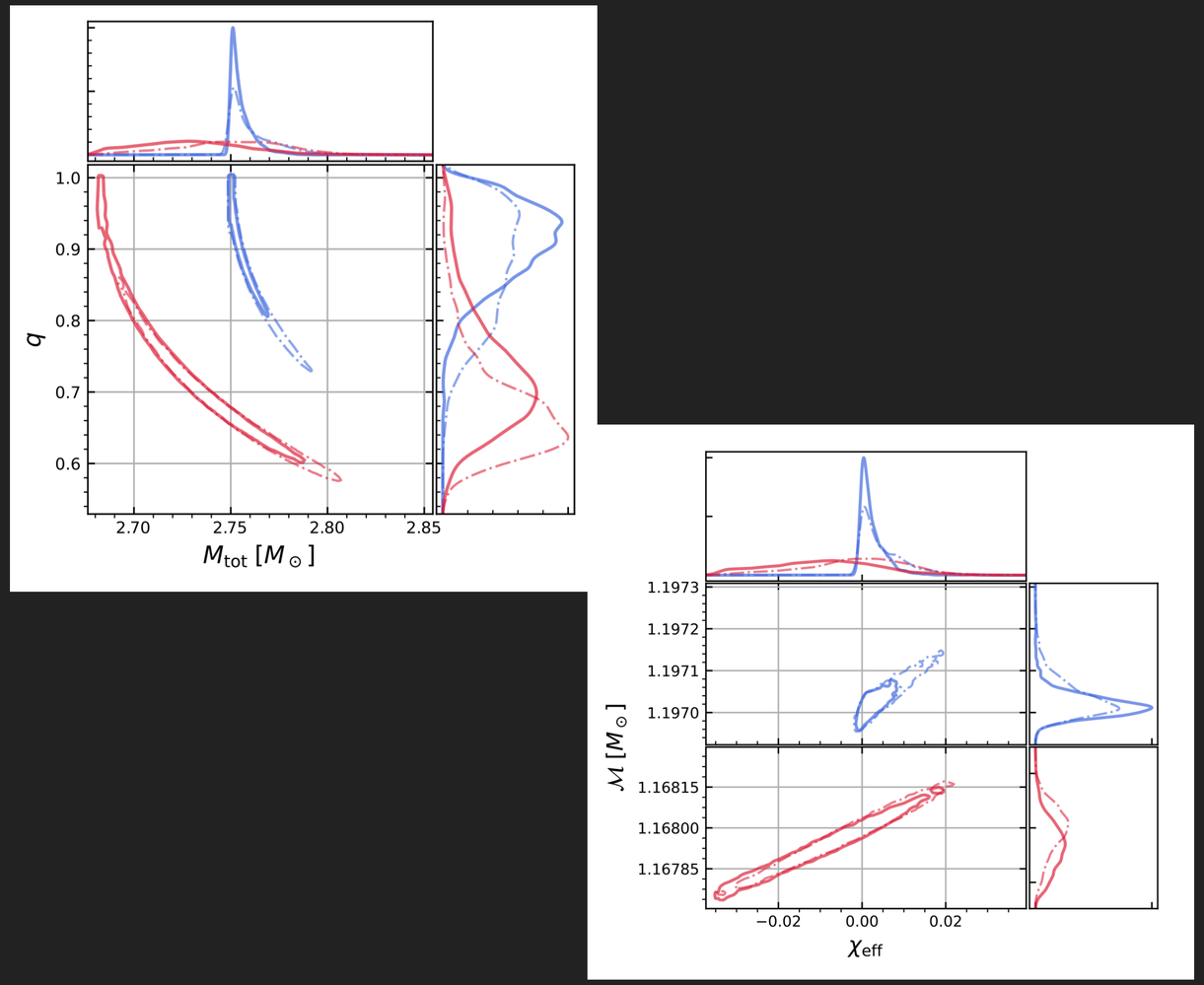
- David Radice, Sebastiano Bernuzzi, and Christian D. Ott. Phys. Rev. D 94, 064011 (2016)
  doi: 10.1103/PhysRevD.94.064011

TOTAL MASS V.S. MASS RATIO

FACE-ON



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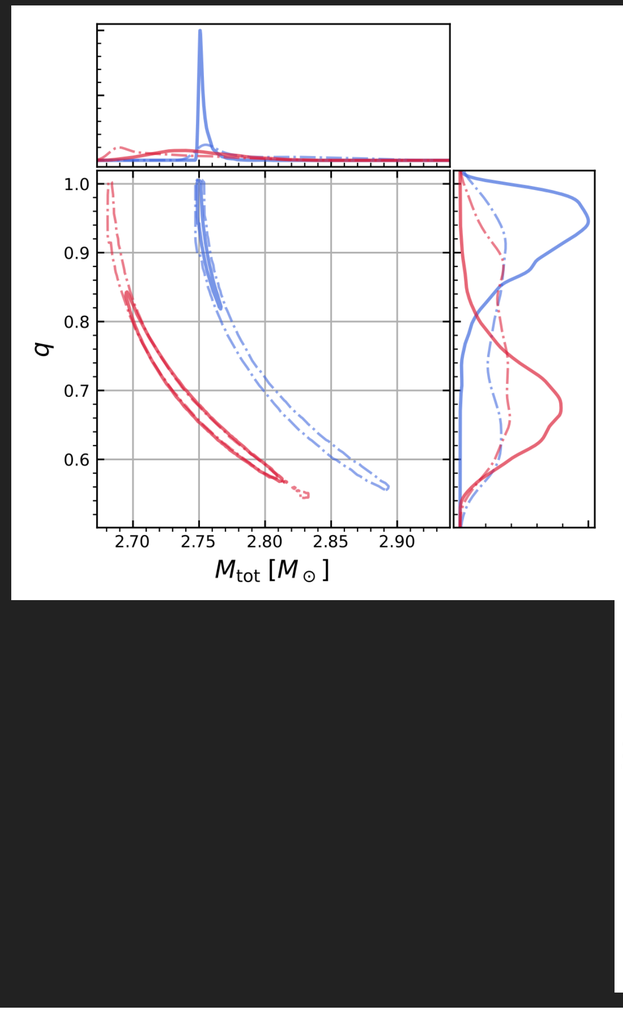

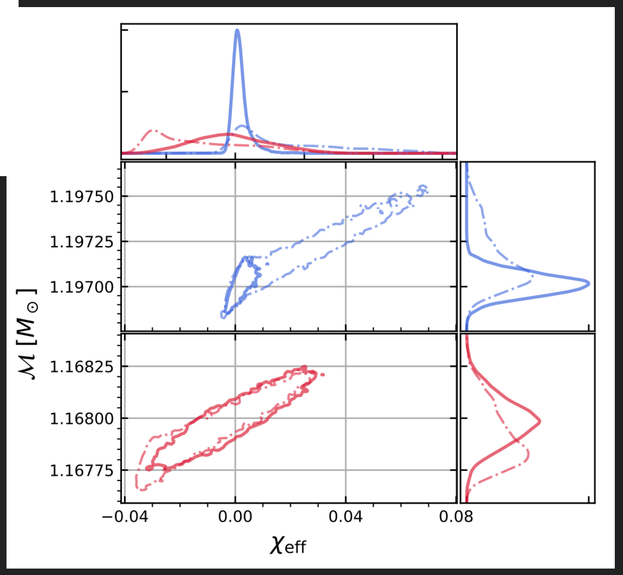

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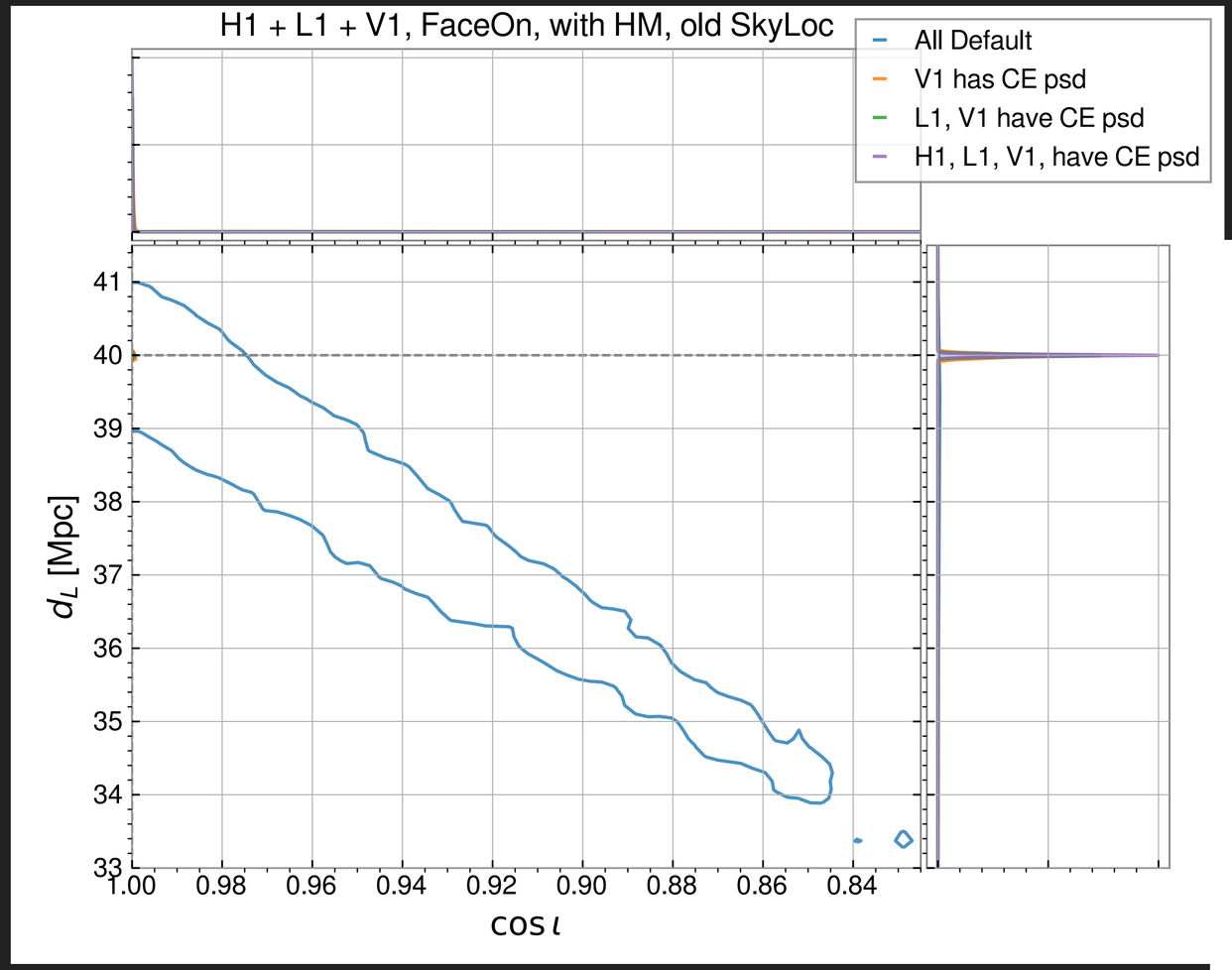
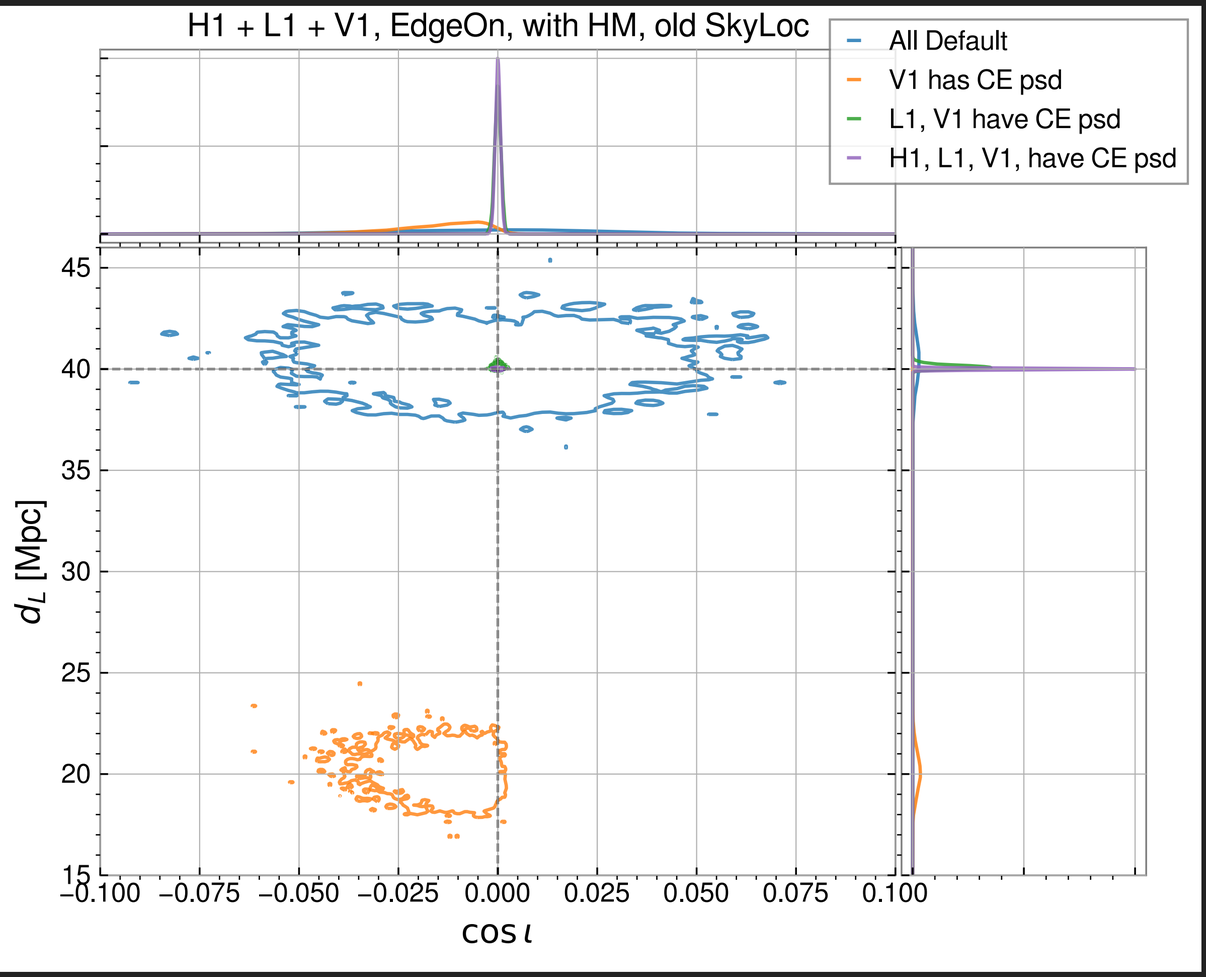
POWER OF 3RD GENERATION





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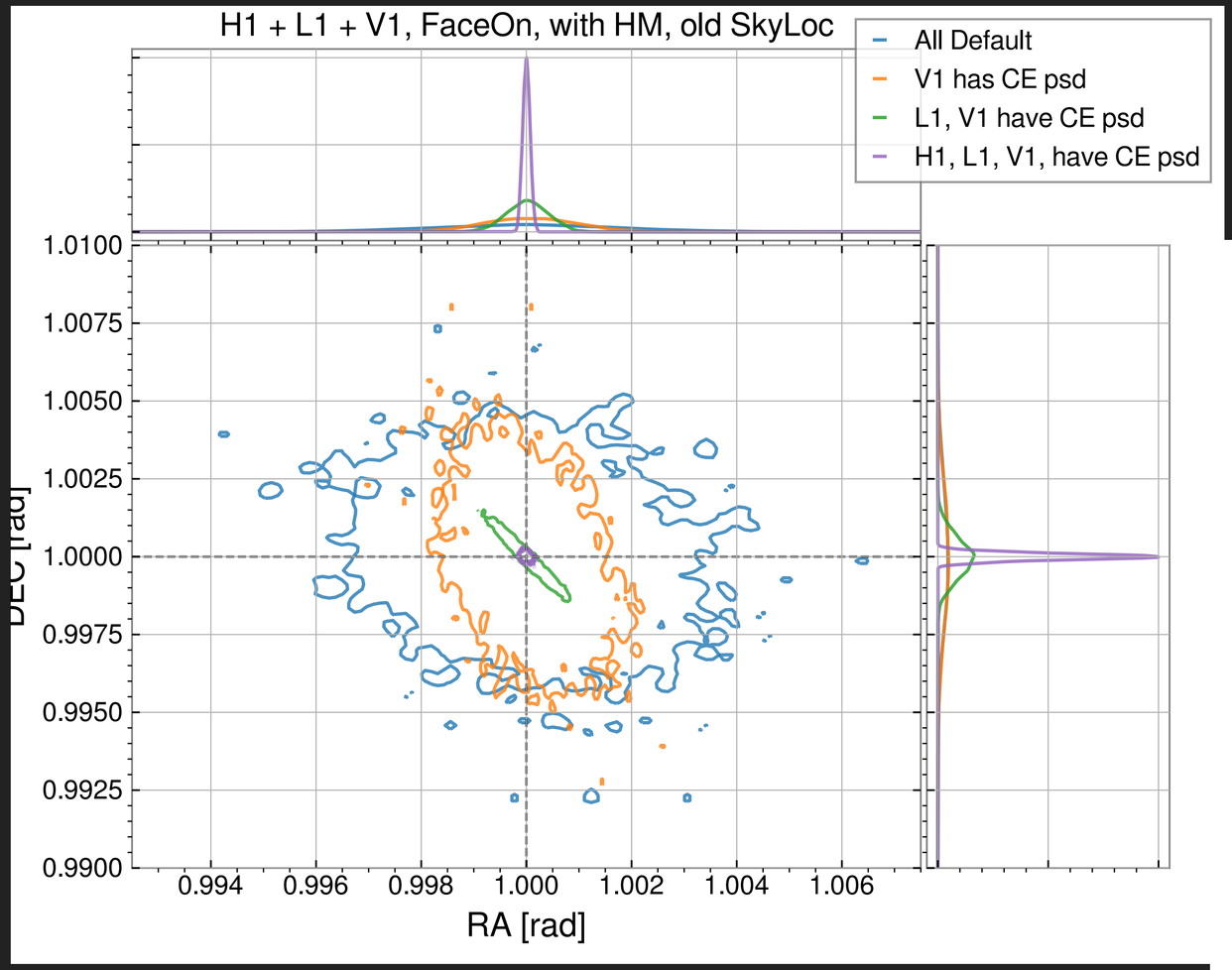
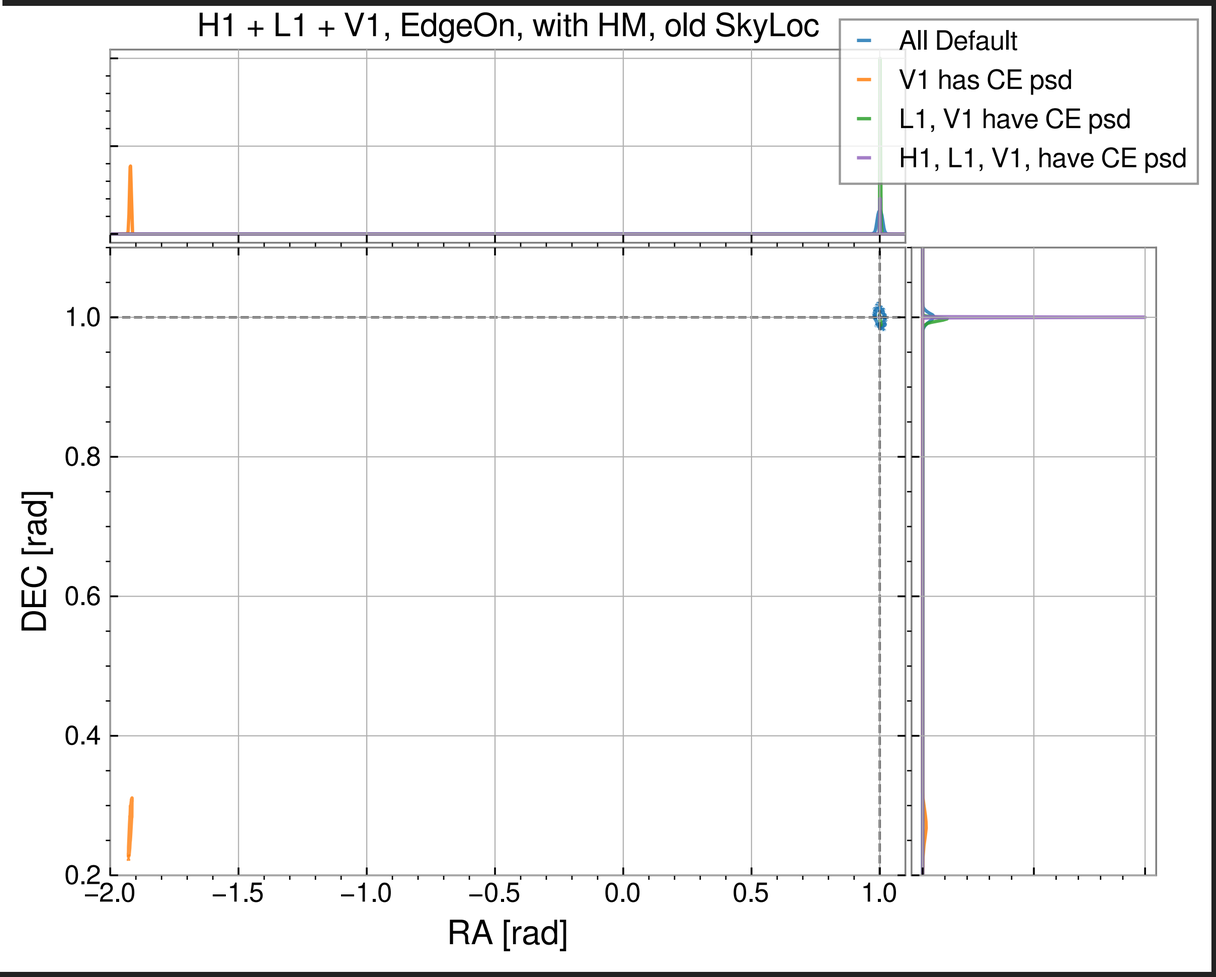
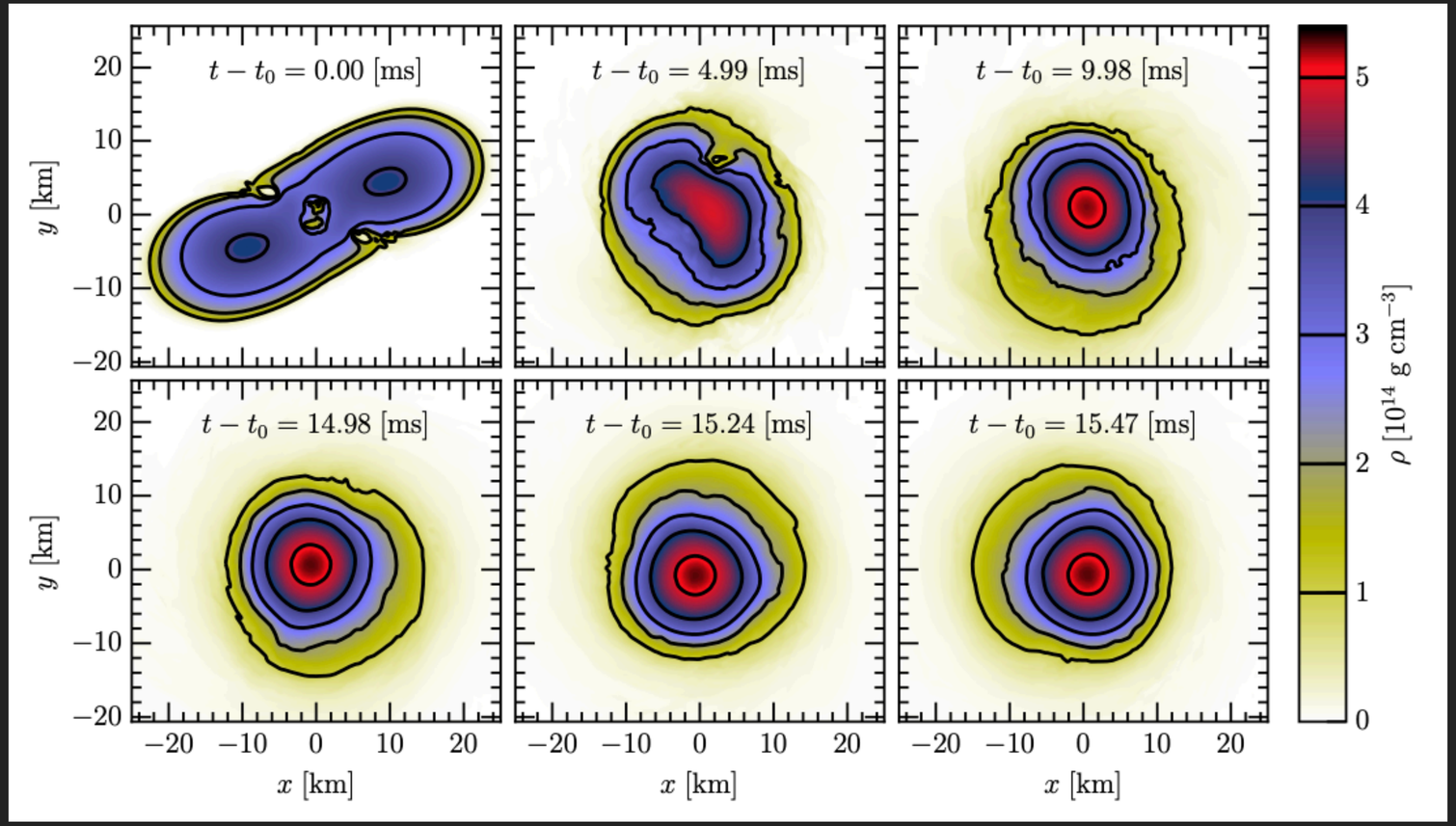




ONE ARM INSTABILITY



David Radice+ (2016)