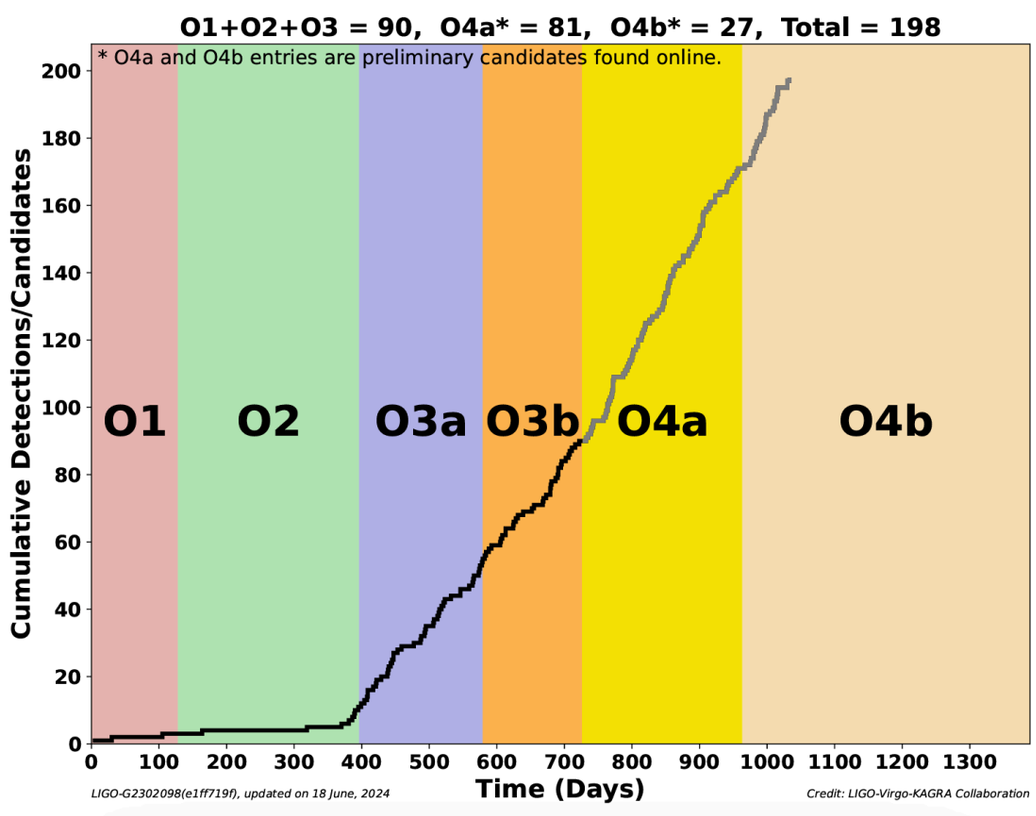
Matter-Dominated Gravitation Wave Sources

Alexey Bobrick

2024

Key Points

- **GW dHz astronomy will make history**
- **Largest number of science cases**
- **Transient sky**
- **Research needed**



Credit: NASA

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Seeing with GWs

- **New eyes for astronomy**
- **Unseen objects, e.g. BBHs** Abbot+16
- **Hidden regions, e.g. DNSs** Abbot+17
- **Unique signal profile**
- **All directions** Evans+23
- **ET, CE will see all BBH mergers** Branchesi+23

GW: $$h_{\rm GW} \propto \frac{1}{d} \longrightarrow N_{\rm objects} \propto d^3 \propto h_{\rm GW}^{-3}$$

EM: $$F_{\rm EM} \propto \frac{1}{d^2} \longrightarrow N_{\rm objects} \propto d^3 \propto F_{\rm EM}^{-3/2}$$

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dHz Band: Interesting binaries

- **Binaries about to do something interesting:**

LIGO: $$\tau_{\rm GW} \propto 2.9\,{\rm sec}\left(\frac{M_{\rm chirp}}{M_\odot}\right)^{-5/3}\left(\frac{f_{\rm GW}}{100\,{\rm Hz}}\right)^{-8/3}$$

LGWA: $$\tau_{\rm GW} \propto 9.3\,{\rm yr}\left(\frac{M_{\rm chirp}}{M_\odot}\right)^{-5/3}\left(\frac{f_{\rm GW}}{0.1\,{\rm Hz}}\right)^{-8/3}$$

LISA: $$\tau_{\rm GW} \propto 2.0\,{\rm Myr}\left(\frac{M_{\rm chirp}}{M_\odot}\right)^{-5/3}\left(\frac{f_{\rm GW}}{0.001\,{\rm Hz}}\right)^{-8/3}$$

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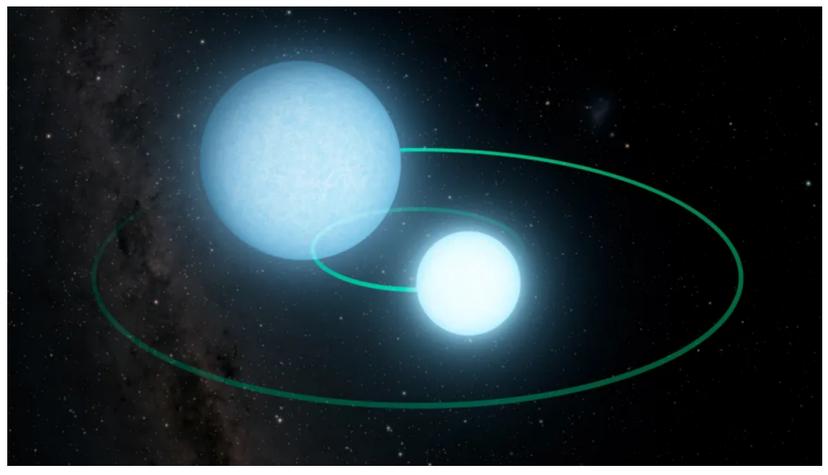
Double White Dwarfs

- Detached population extragalactic
- Detection horizon 30-100Mpc
- About 100DWDs, few Galactic
- Interaction phase short AB+17
- Formation of interacting DWDs

Ajith+24



Credit: Caltech/IPAC

$$\tau_{\rm GW} \propto 9.3\,{\rm yr}\left(\frac{M_{\rm chirp}}{M_\odot}\right)^{-5/3}\left(\frac{f_{\rm GW}}{0.1\,{\rm Hz}}\right)^{-8/3}$$

$$\frac{\tau_{\rm GW,LGWA}}{\tau_{\rm GW,LISA}} \propto \frac{N_{\rm DWD,LGWA}}{N_{\rm DWD,LISA}} \propto \left(\frac{f_{\rm GW,LGWA}}{f_{\rm GW,LISA}}\right)^{-8/3} \approx 5\cdot 10^{-6} \approx \frac{\rm several}{10^6}$$

Talk by J.Morán-Fraile today

Talks by S.Toonen, T.Kupfer today

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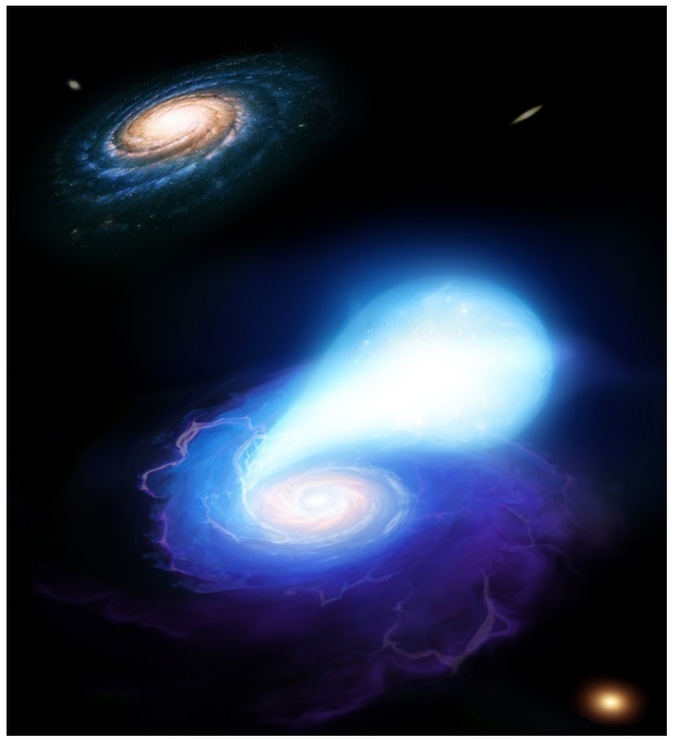
WD-NS Binaries

- About 10x fewer than DWDs Toonen+19
- All extragalactic, 10 systems
- Short-lived XRBs AB+17
- May witness formation of ULXs
- LGWA may identify transients



Credit: M.Garlick

Talk by J.Morán-Fraile today

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dHz Band: Shocks

- Shocks
- GW memory
  - Changes in v, a, phi, … - permanent changes in the metric tensor

LIGO: $L_{\rm acc} \propto 100\,{\rm km} \left(\frac{v}{10000\,{\rm km/s}}\right) \left(\frac{f}{100\,{\rm Hz}}\right)^{-1}$

LGWA: $L_{\rm acc} \propto 0.14\,R_\odot \left(\frac{v}{10000\,{\rm km/s}}\right) \left(\frac{f}{0.1\,{\rm Hz}}\right)^{-1}$

LISA: $L_{\rm acc} \propto 14\,R_\odot \left(\frac{v}{10000\,{\rm km/s}}\right) \left(\frac{f}{0.001\,{\rm Hz}}\right)^{-1}$

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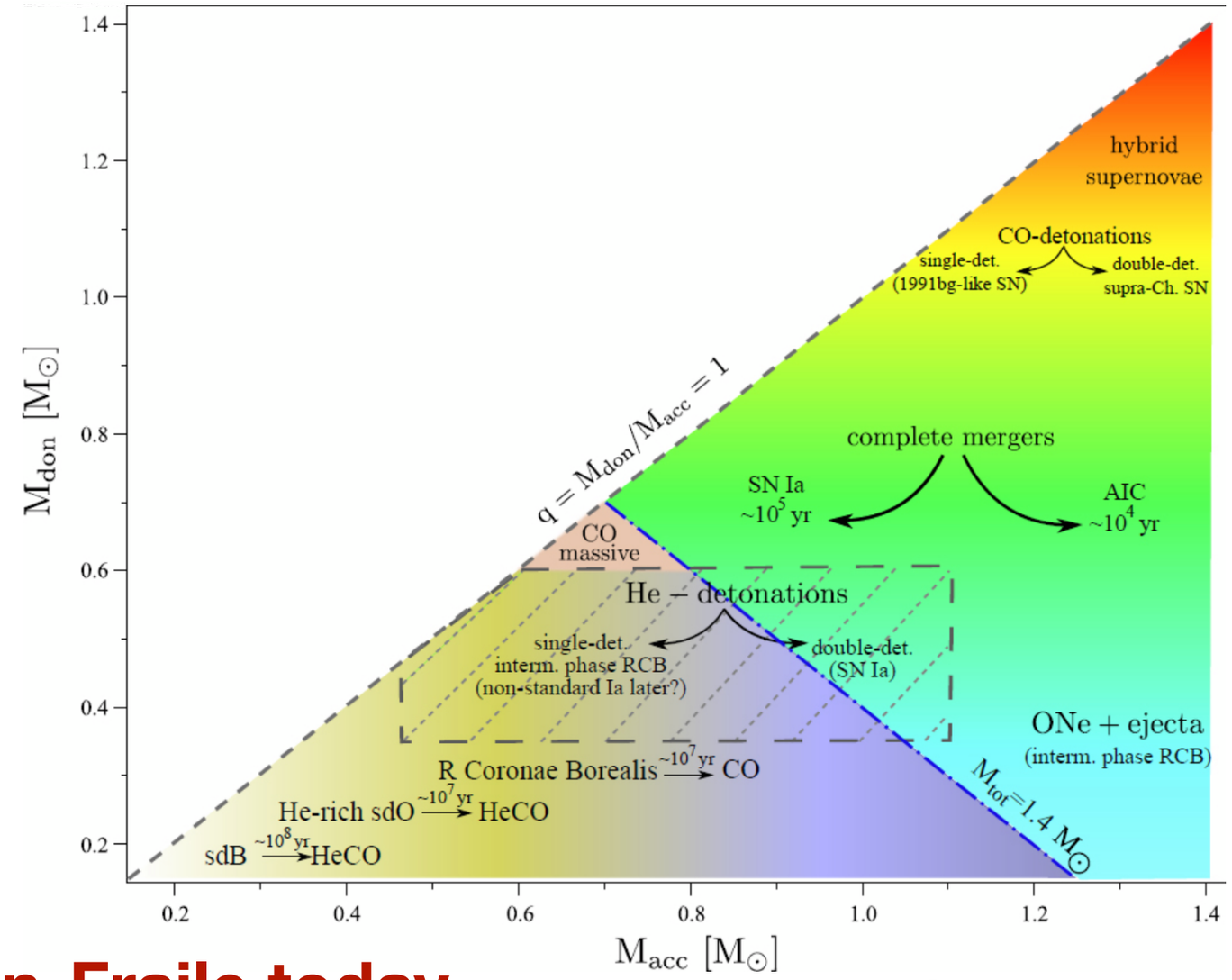
DWD Explosions



Talk by J.Morán-Fraile today

Credit: Dan+14

- **Supernovae Type Ia**
- **Details of detonations**
- **Other transients**

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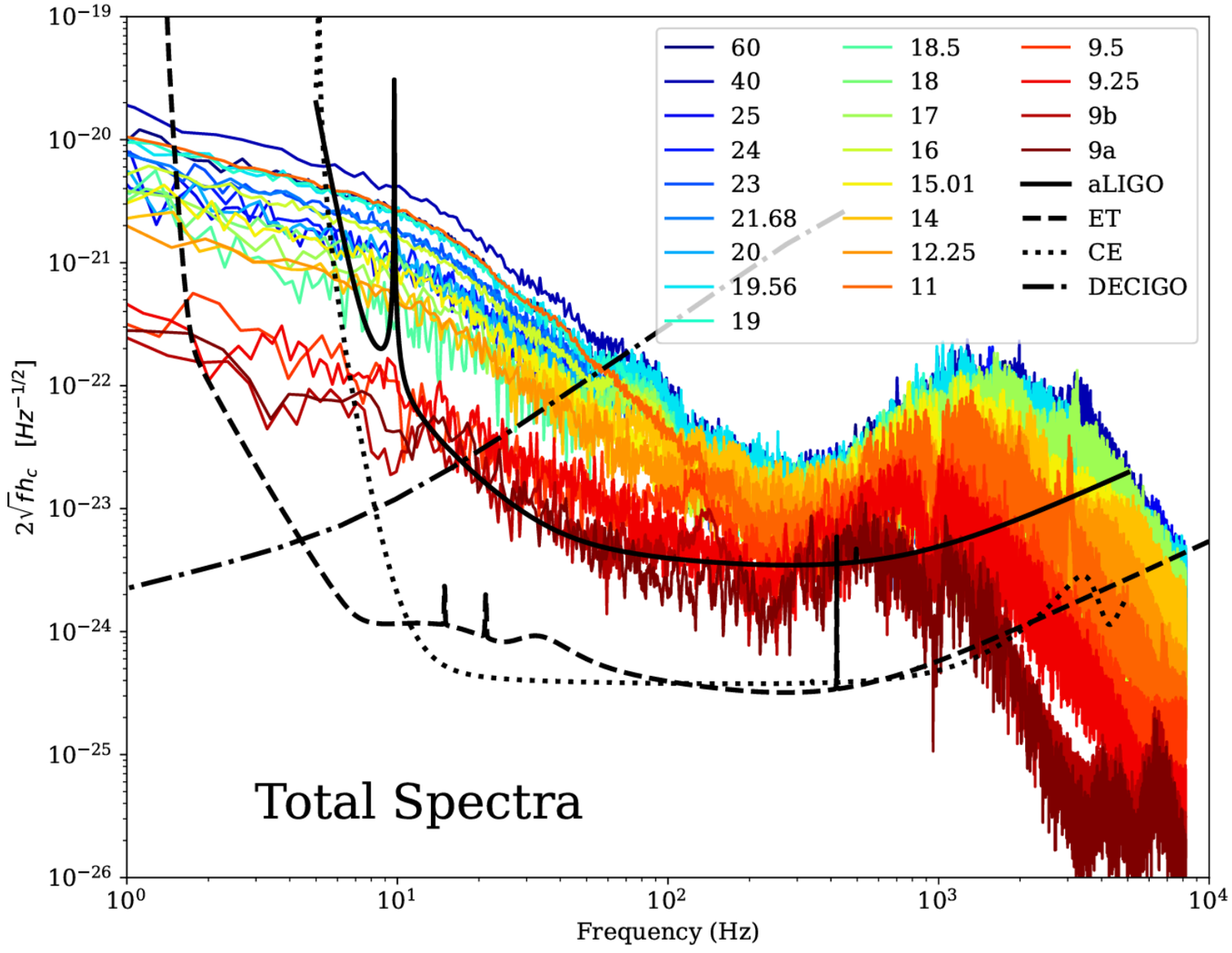
Core-Collapse SNe



@10kpc

Credit: Choi+24

- **Informative, multimessenger**

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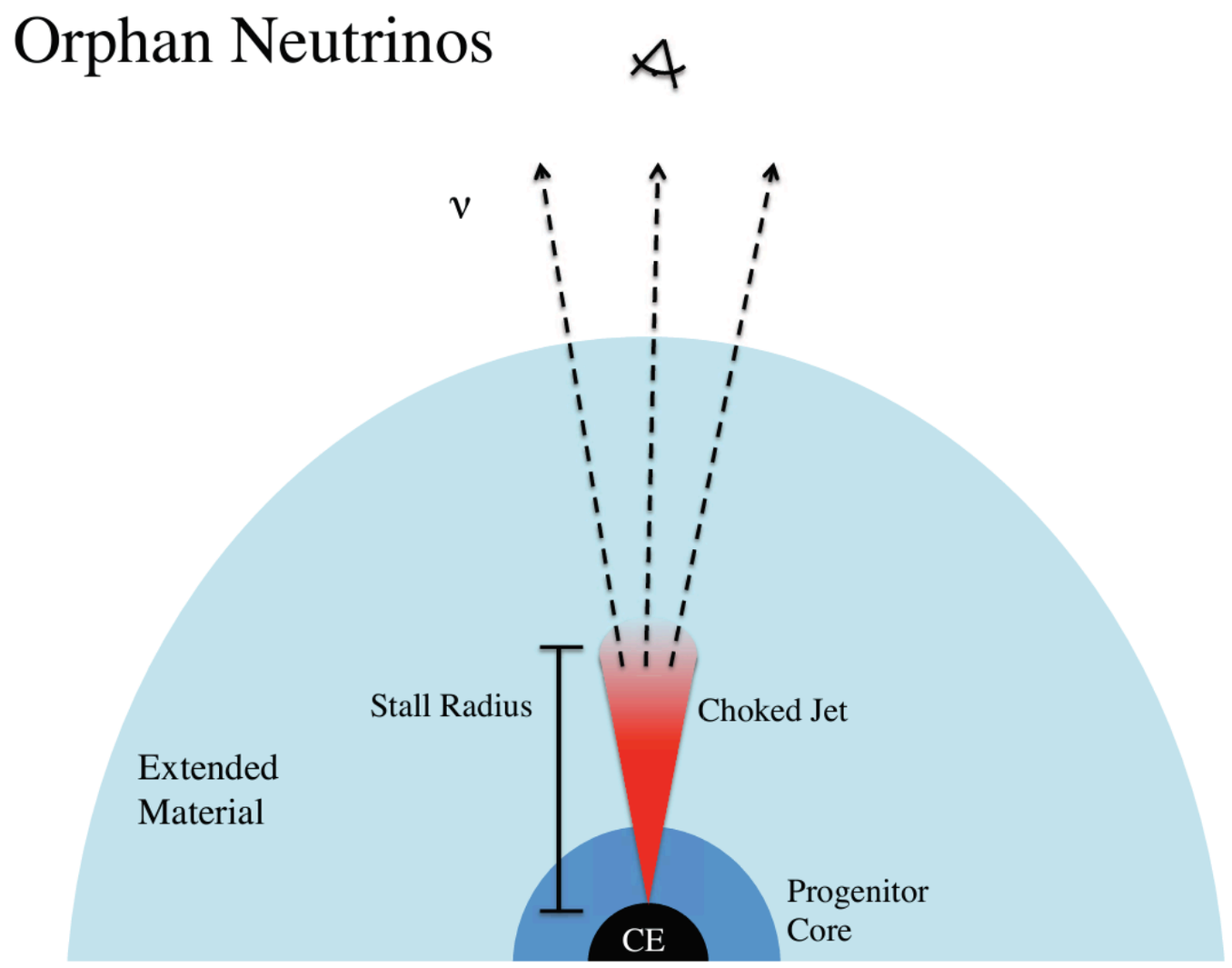
(Choked) Gamma-Ray Bursts



Credit: Senno+16

- **Local Universe, may be hidden**

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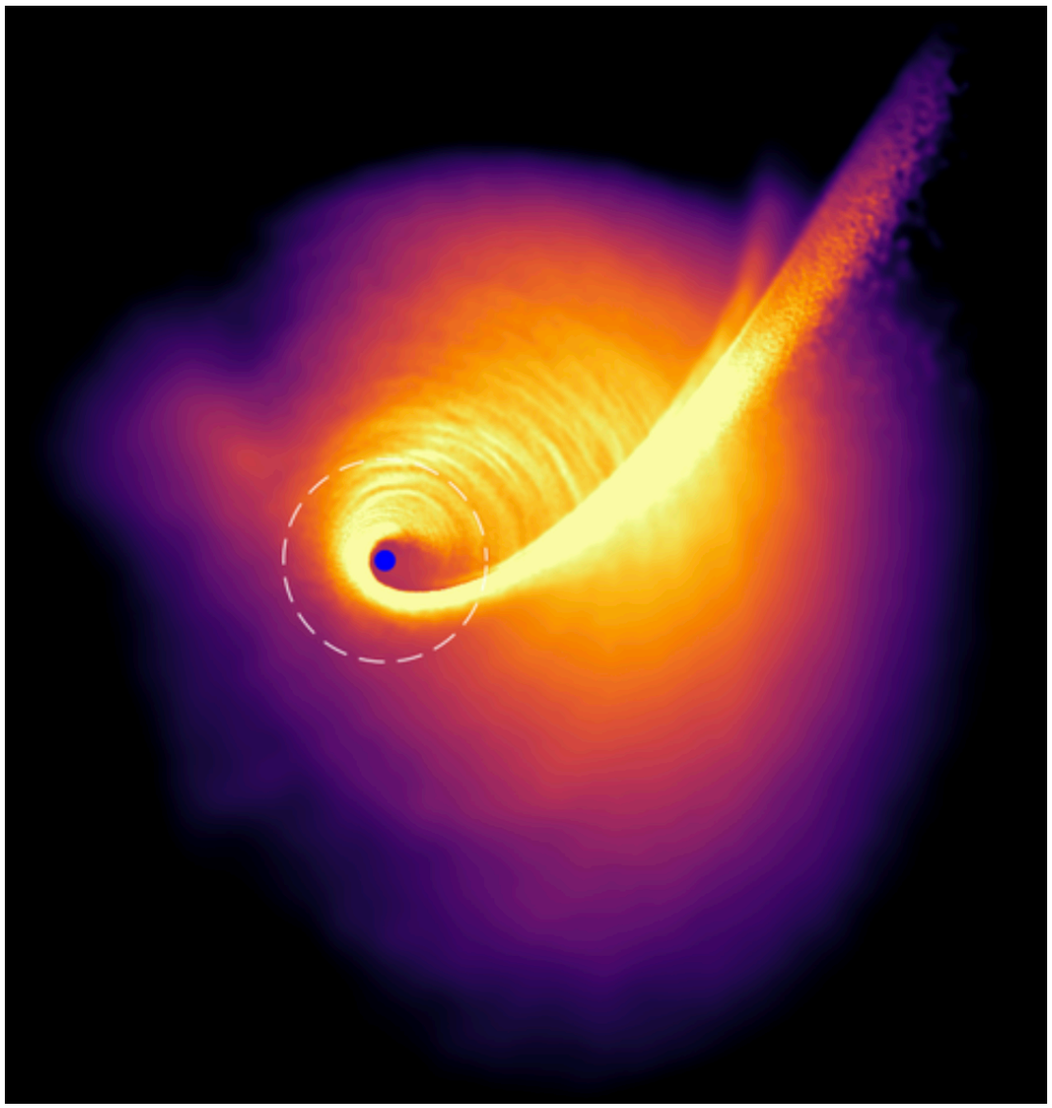
Tidal Disruption Events



Credit: Jankovič+23

- Local Universe, low-mass MBHs

Talk by Elisabeth Kepler today

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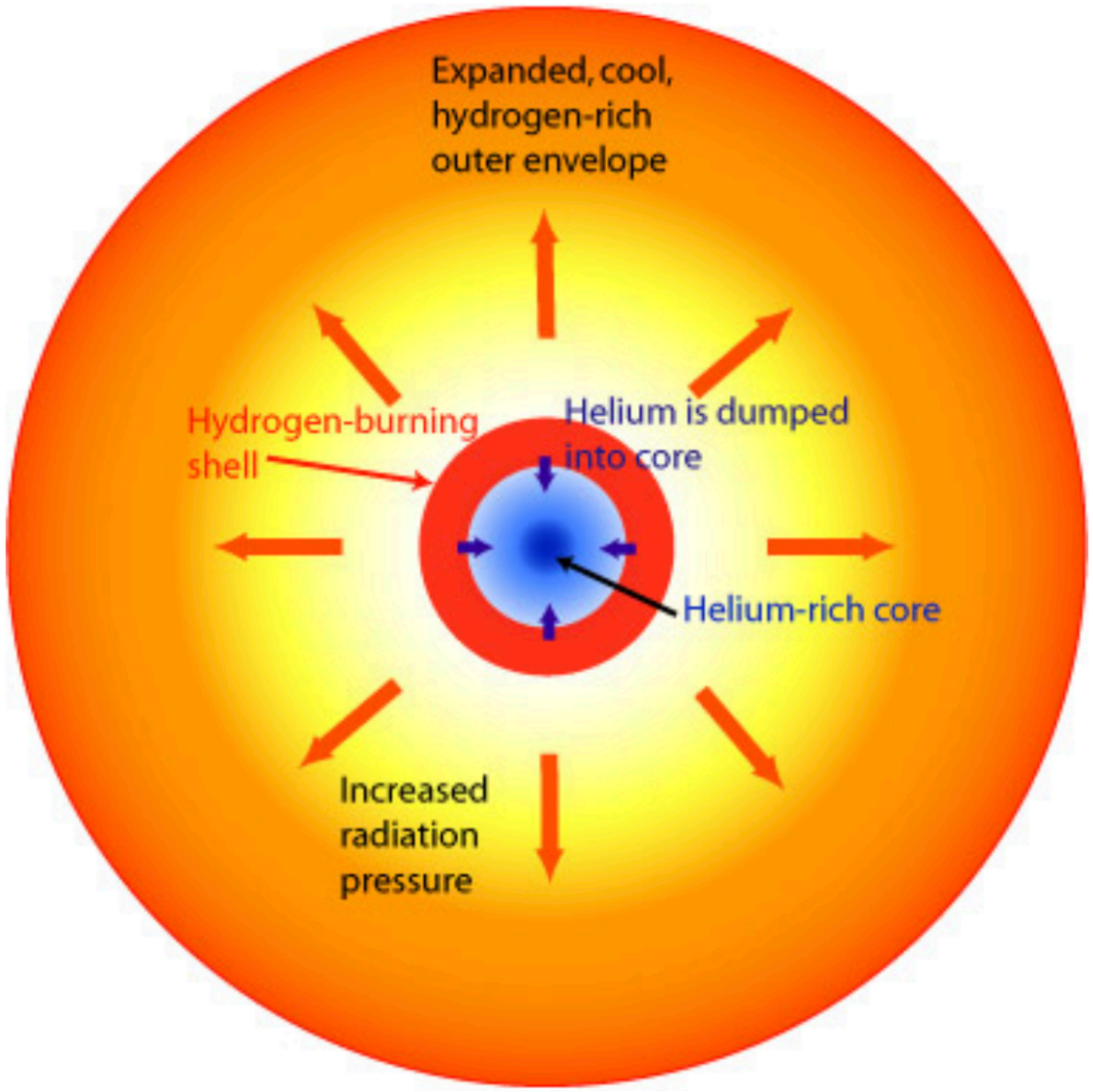
He Flashes



Credit: CSIRO

- Asymmetric ignition
- < 1min timescale Paxton+11
- 1 per decade Ajith+24

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The dHz Band

$$f_{\rm GW} \propto 4 \cdot 10^{-5}\,{\rm Hz}\sqrt{\frac{\langle \rho_{\rm matter} \rangle}{{\rm g/cm^3}}}$$

LIGO: $\langle \rho_{\rm matter,LIGO} \rangle \approx 10^{13}\,{\rm g/cm^3}$

LGWA: $\langle \rho_{\rm matter,LGWA} \rangle \approx 10^{7}\,{\rm g/cm^3}$

LISA: $\langle \rho_{\rm matter,LISA} \rangle \approx 10^{3}\,{\rm g/cm^3}$

- **Other types of sources:**
  - **Stellar cores?**
  - **Accretion discs?**
  - **Stellar jets?**

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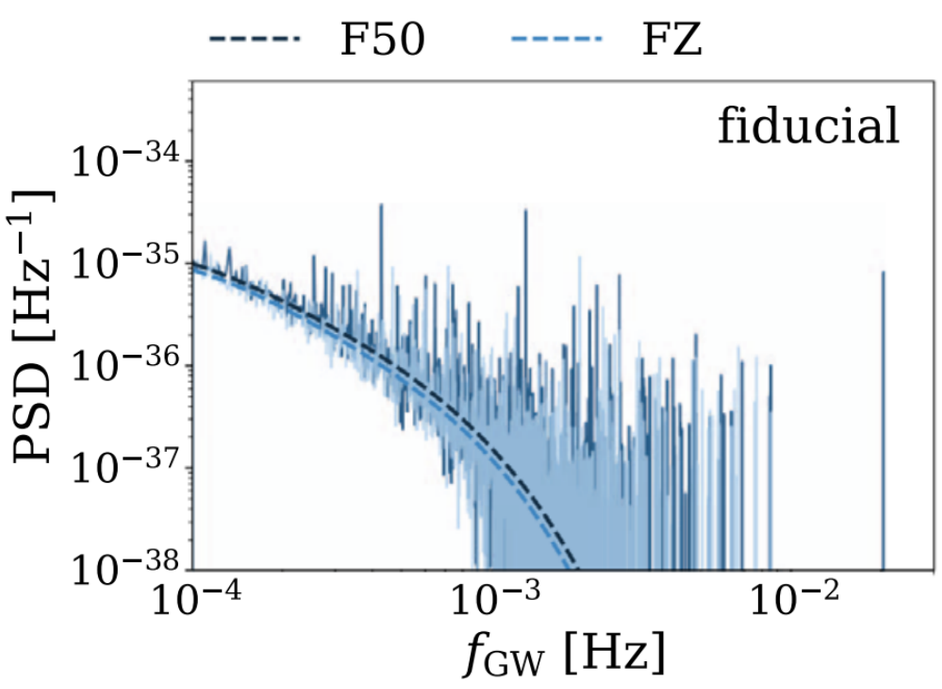
Combined Signal

- **Dominated by extragalactic binaries (BBHs, DWDs, WDNSs)**
- **Few very bright sources**
- **Diverse burst signals expected**
- **Importance of EM**

LISA example:



Credit: ESO

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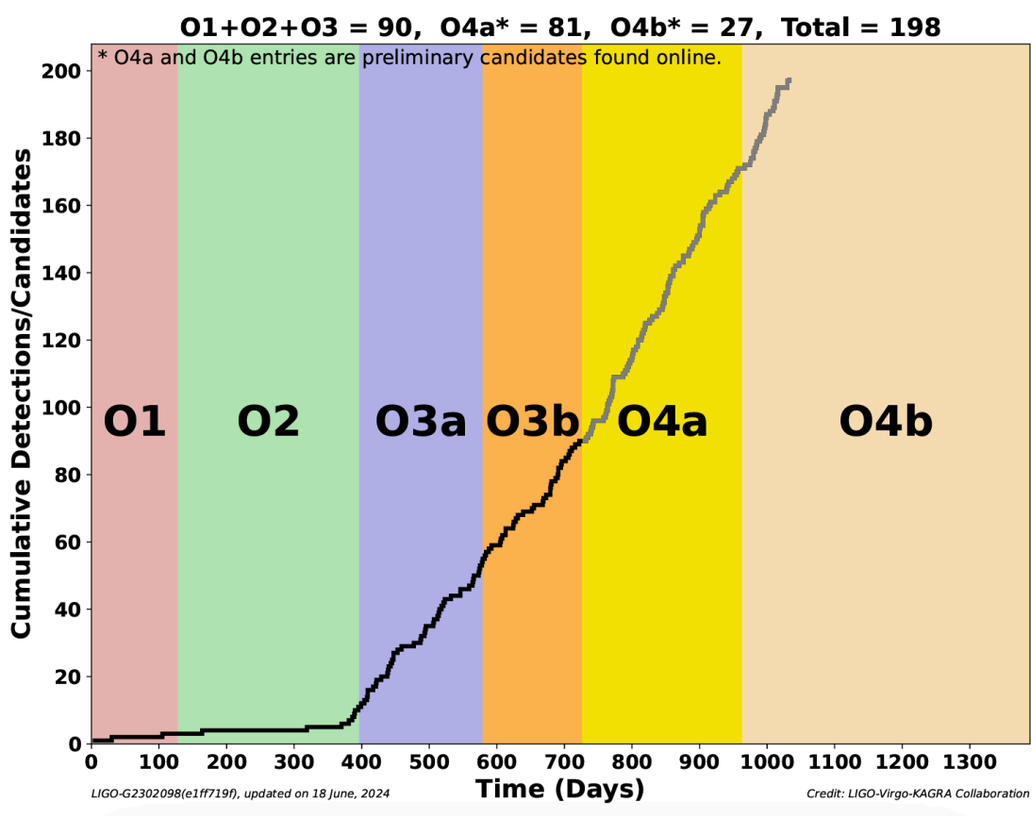

Credit: NASA

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Possible Discussion Points

- **Science value relative to kHz/mHz GWs**
- **Need to identify dominant signals**
- **Landscape is new - new discoveries possible**
- **Possible that 90s-00s science could not appreciate dHz astronomy**
- **Synergies with neutrino astronomy**
- **Synergies with EM**
- **Many of the white paper topics may be developed into separate papers**
- **Science with Soundcheck**
- **Other science cases**

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