Figure of Merit and Detector Design

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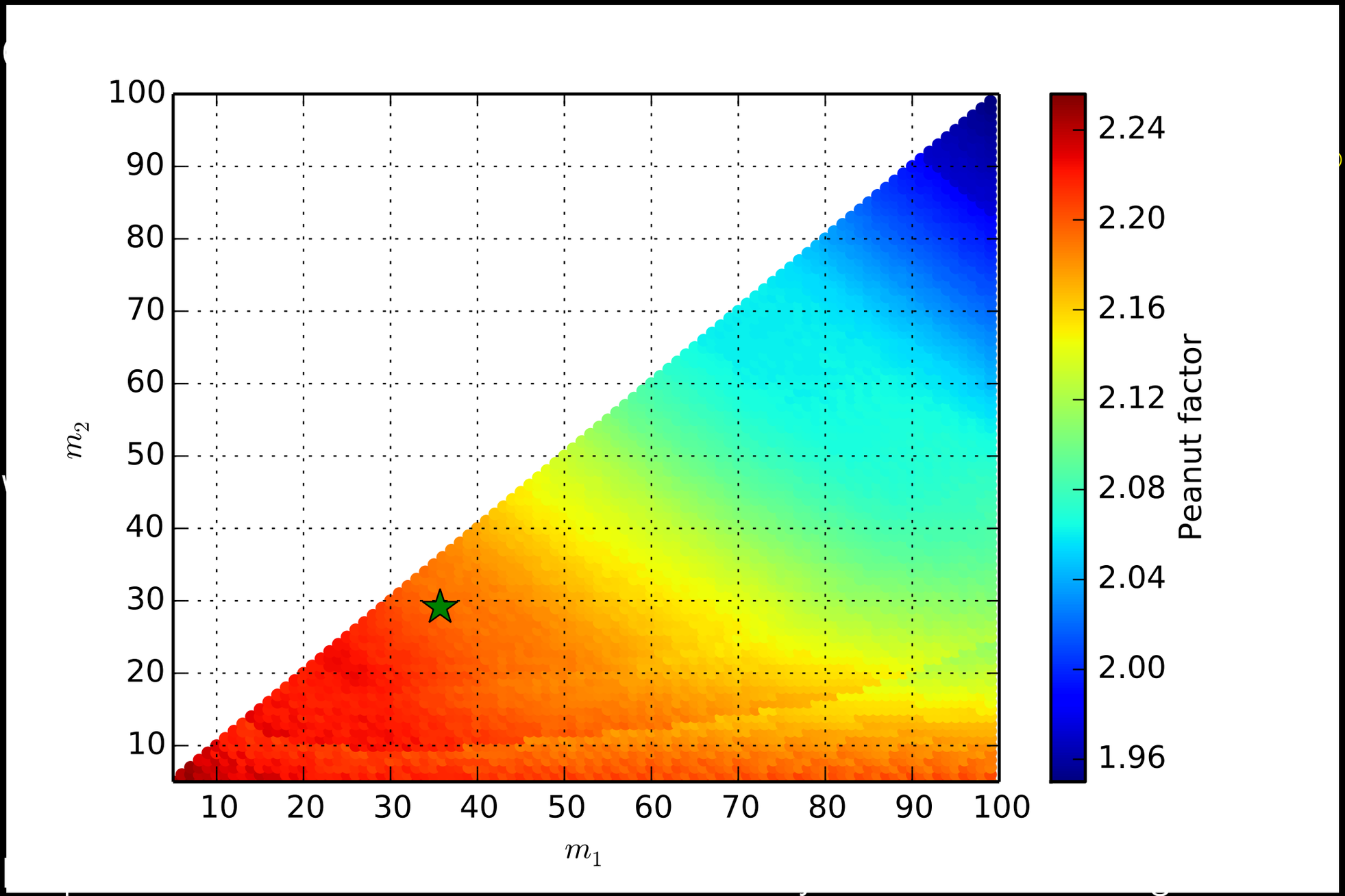
Different distance measures

- Canonical distance measures:
  - **Horizon**: The maximum distance a detector can detect an 1.4-1.4 $M_{\odot}$ binary merger with optimum alignment at signal-to-noise of 8.
  - **Range**: Cube root of 3π/4 x (average detectable volume)
    - **Range** x 2.26 = **Horizon**
- Why do we need different distance measures?
  - **Cosmological effects**: time dilation, cosmological volume
  - **Source evolution**
  - **Different sources**
- Proposed distance measures are divided by the audience/usage

Different distance measures



Holz & Chen LIGO DCC-P1600071

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Detector performance

- **Horizon**: The farthest luminosity distance the given source could ever be detected above threshold (i.e., at optimal sky location and binary inclination/orientation).

- **Response distance, R_x** : The luminosity distance at which (100-x)% of the sources would be detected, for sources placed isotropically on the sky with random inclinations/orientations, *but with all sources placed at exactly this distance.*

Rates-ers

- **Redshifted volume**: The spacetime volume surveyed per unit detector time.

- **Range**: Cube root of 3π/4 x (**Redshifted volume**)

Astronomers (EM counterpart followers) / Cosmologists

- **Reach**: The luminosity distance within which x% of the total sample of detections would be detected.

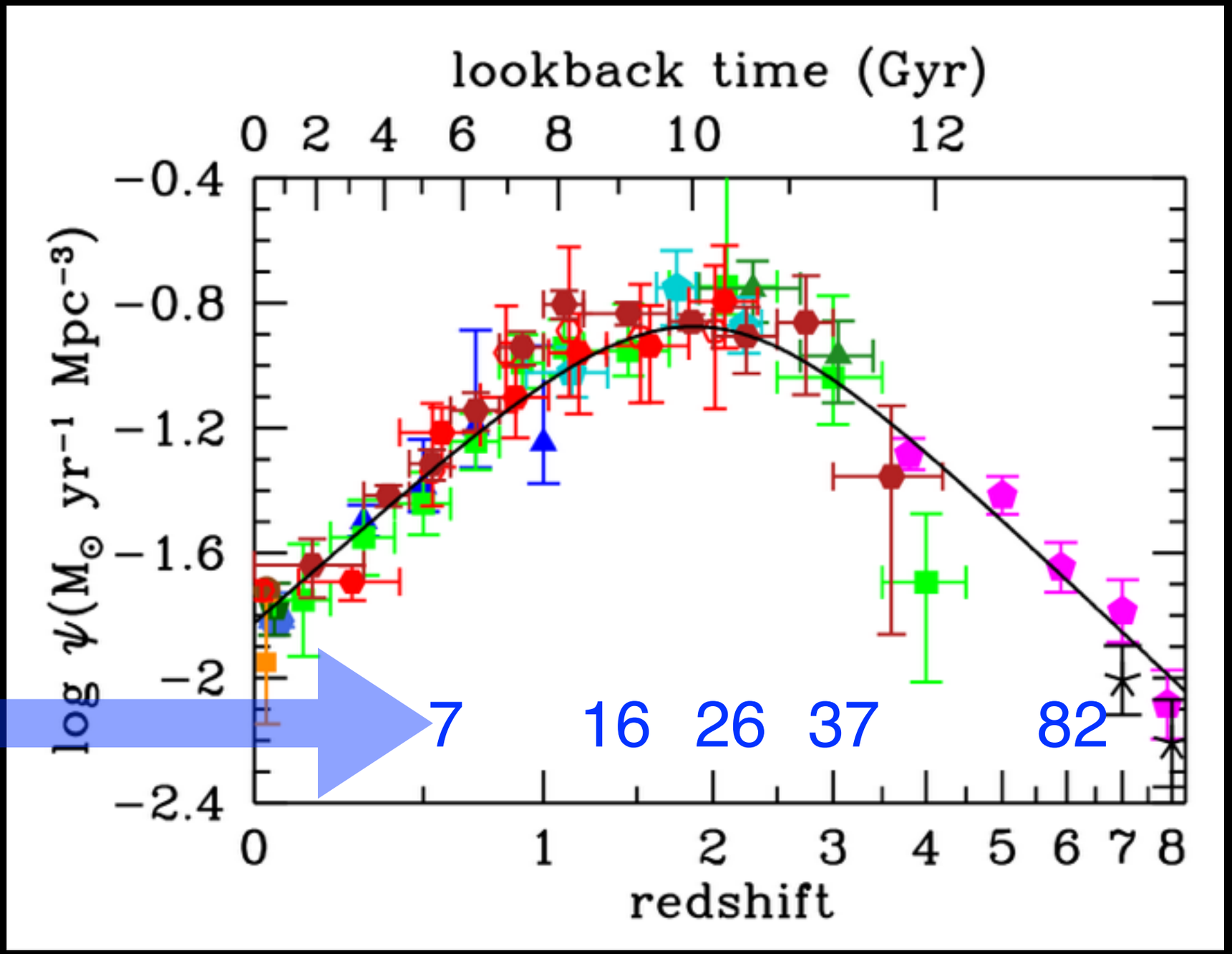
- **Reach with evolution**: Same as the **Reach**. We now scale the source frame rate density by the star formation rate. This is a very rough approximation to the effect of rate evolution on the detected sample.

- **Average Reach**: The average luminosity distance of the detected sample.

- **Average Reach with evolution**: Same as above.

Star Formation History (as approx. to the evolution history)

Luminosity distance (Gpc)



Madau & Dickinson (2014)

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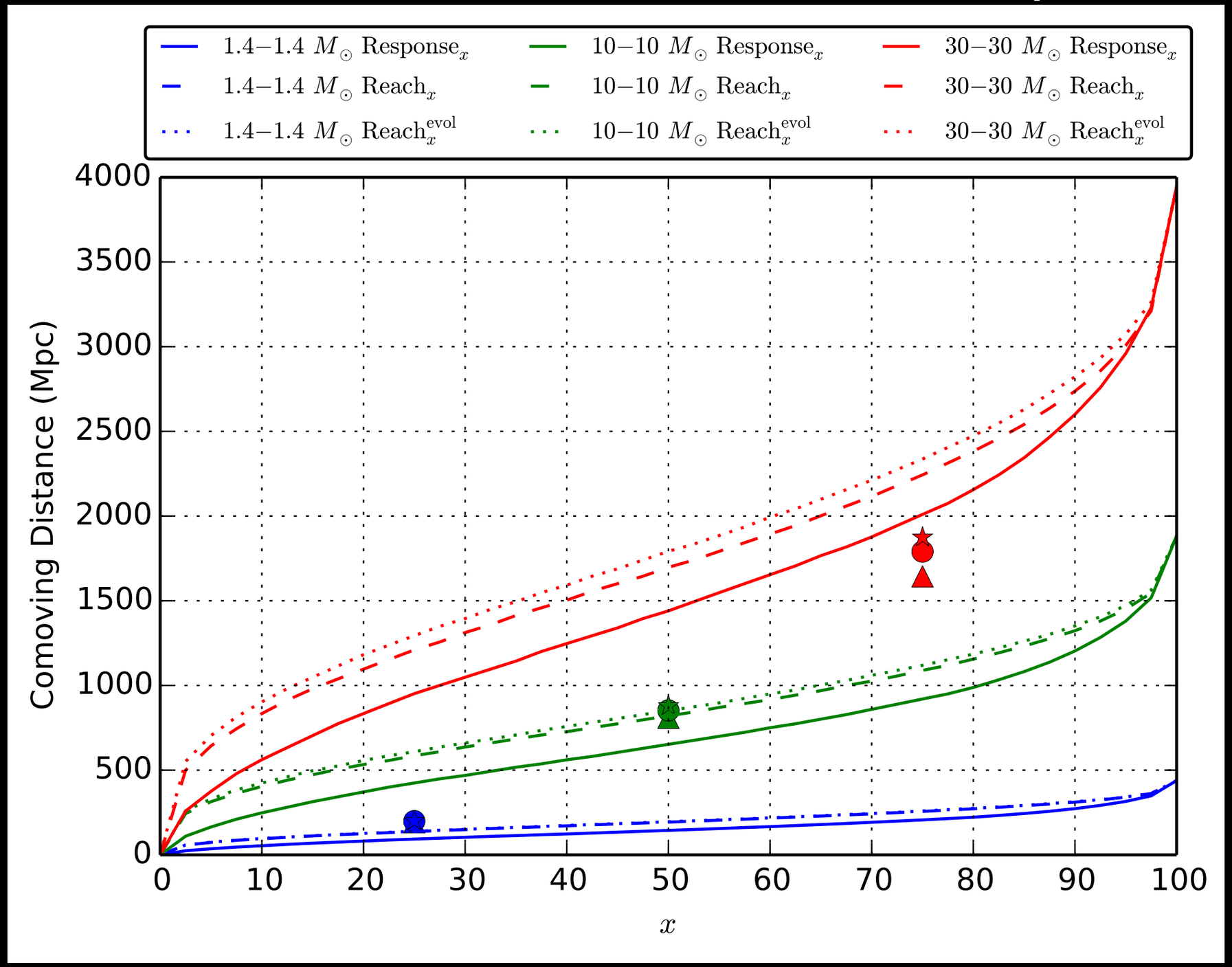
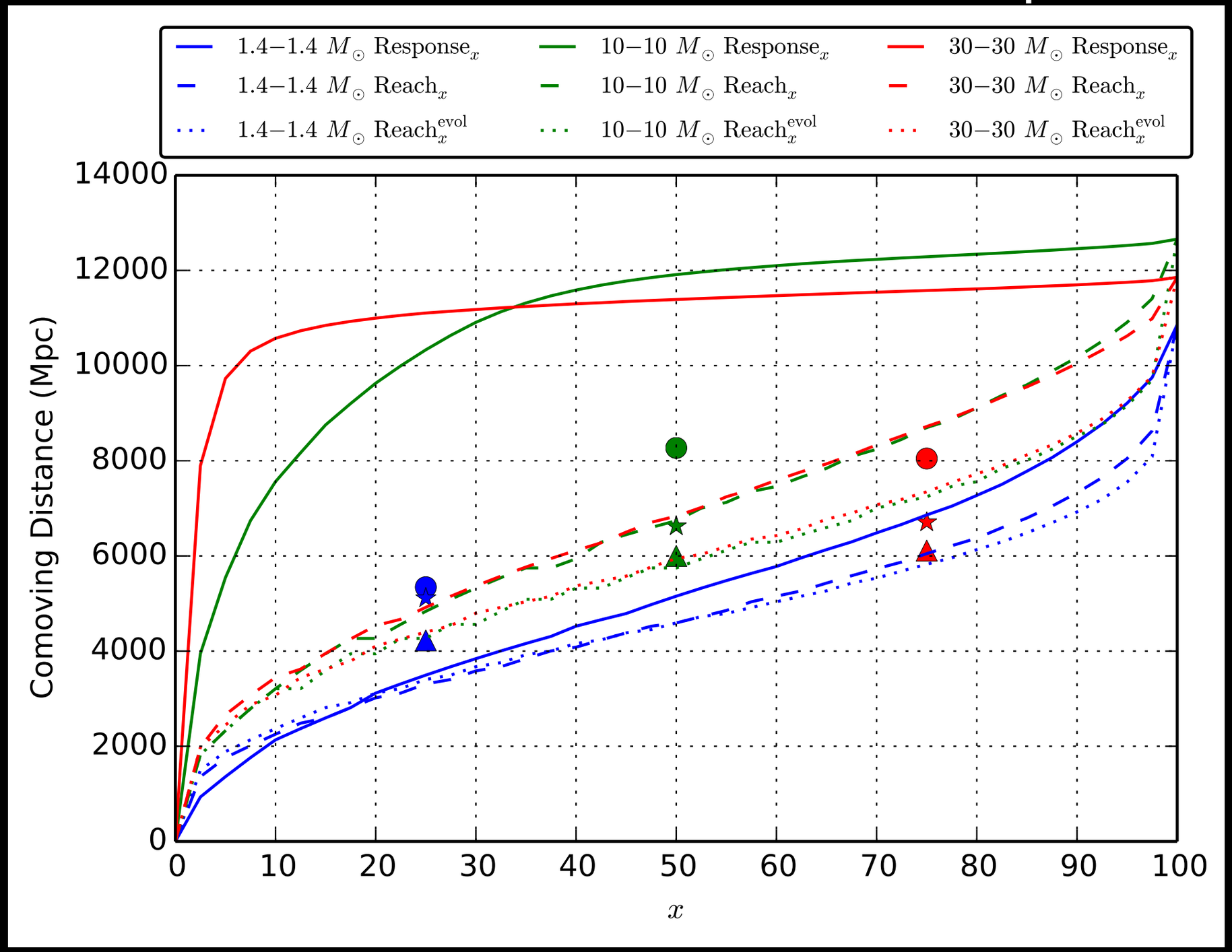
2G distance measure comparison



Triangle-**Range**, Circle-**Average Reach**,
Star-**Average Reach with evolution**

3G distance measure comparison



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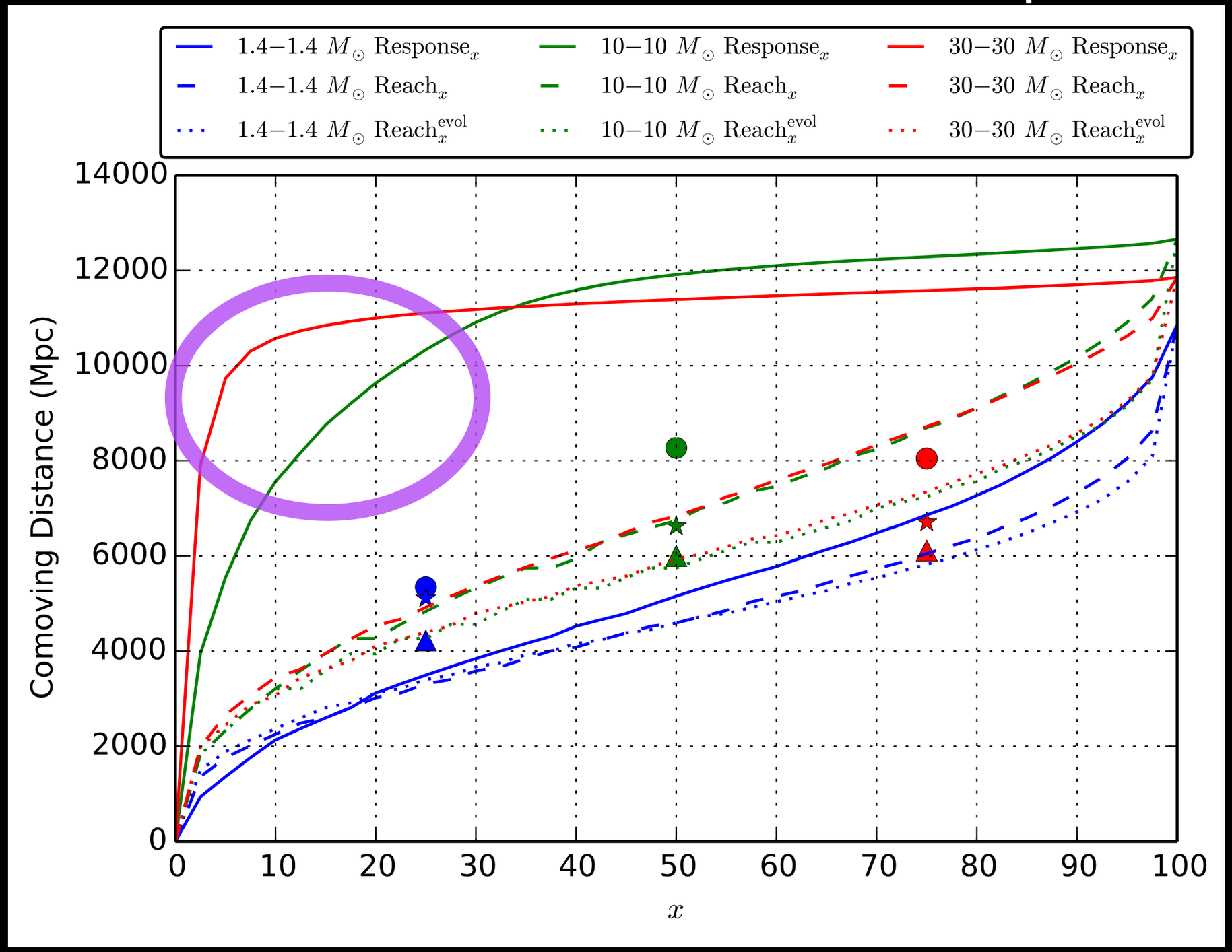

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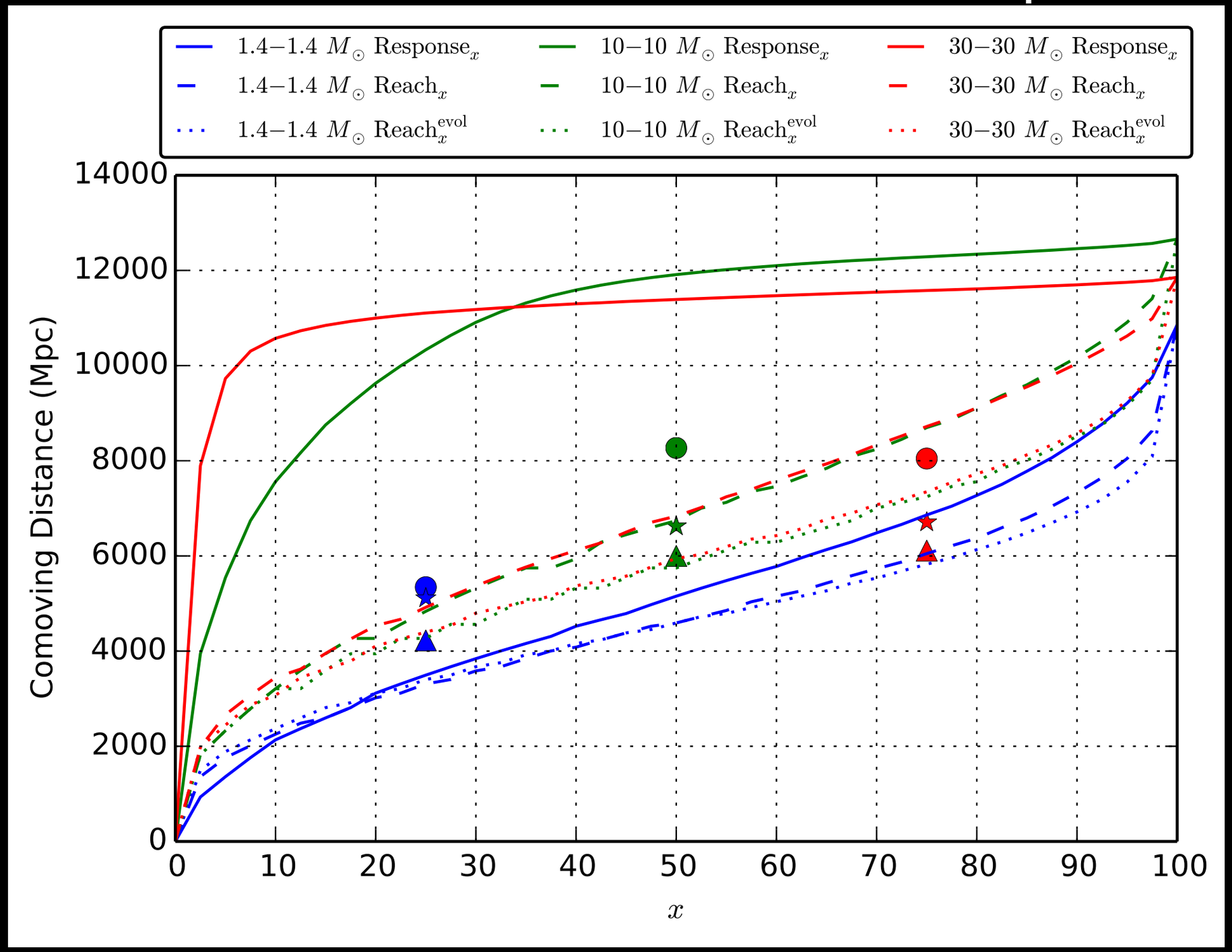

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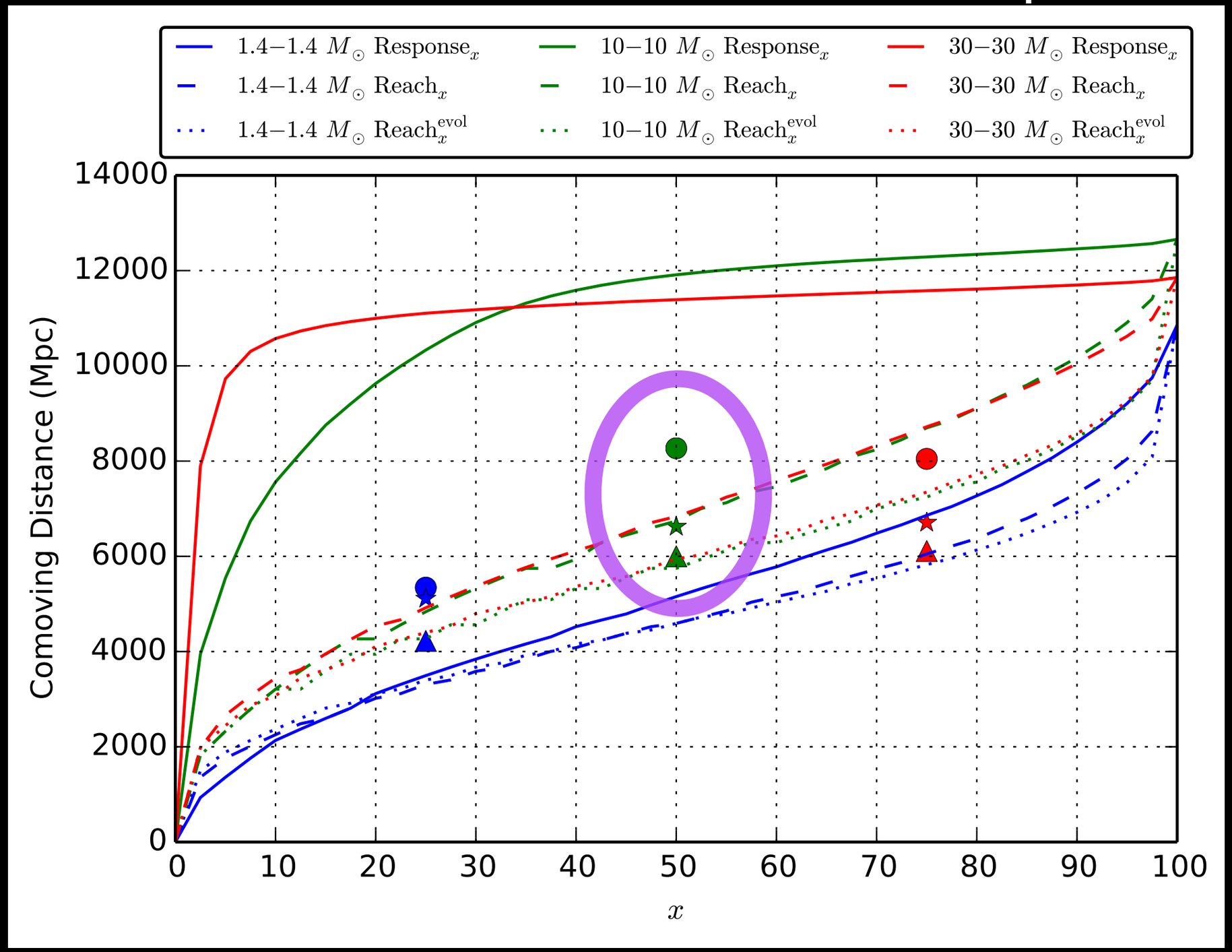

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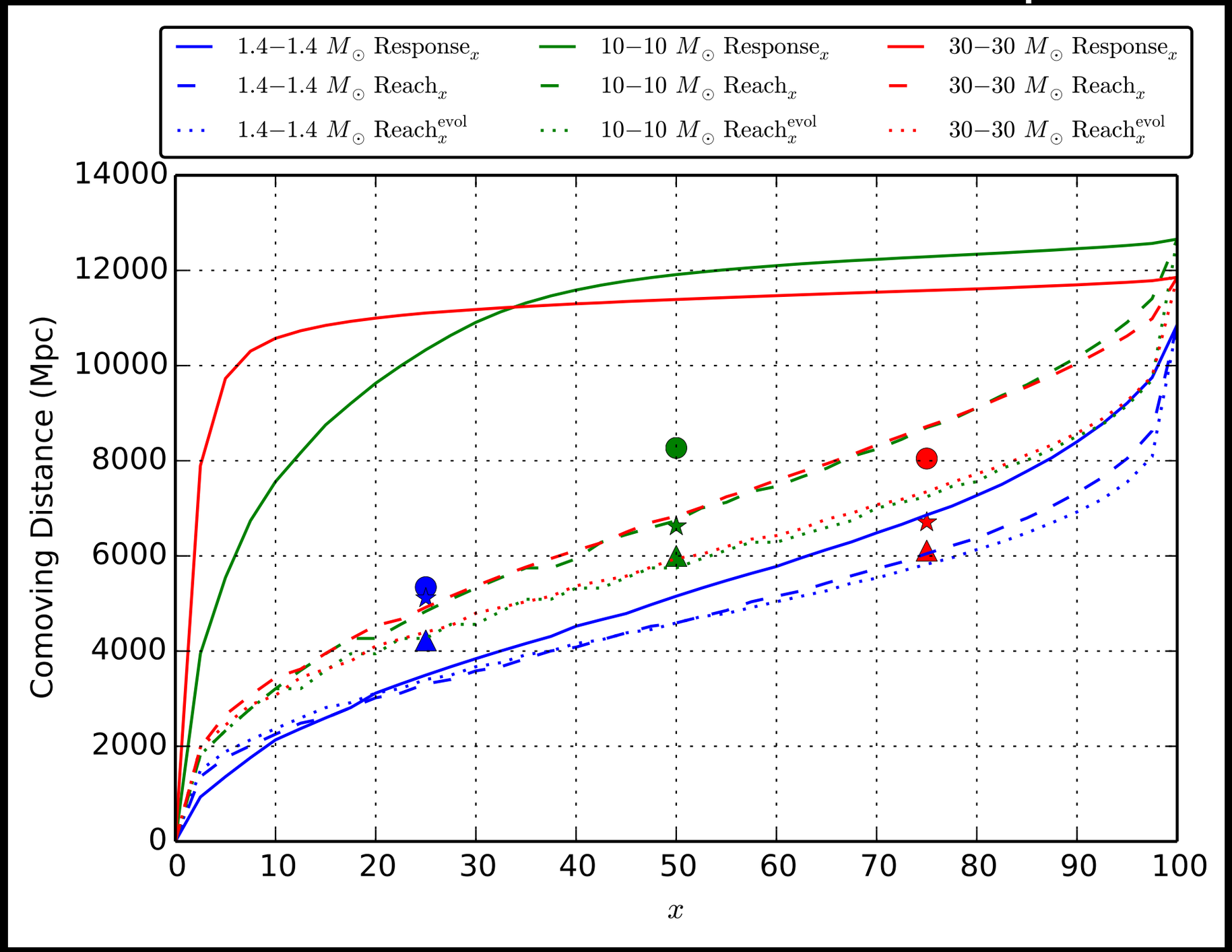

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Single Detector

*__Binary neutron star merger__ rate density=1E3 Gpc^{-3} yr^{-1}

*__30-30 M⊙ binary black hole merger__ rate density=2E1 Gpc^{-3} yr^{-1}

	Redshifted Volume (Gpc^3)	Response 90 (Gpc)	Reach 90 (Gpc)	Reach 90, evol.(Gpc)
A+	0.2 / 77	0.6 / 11	0.7 / 11	0.7 / 11
Voyager	1.8 / 288	1.4 / 41	1.6 / 27	1.6 / 26
ET_D	41 / 821	7 / 500	8 / 112	8 / 56
CE	316 / 957	57 / 389	37 / 131	31 / 63

SNR threshold of 8

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Network (using CE noise curve)

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HL	54 / 567	8 / 374	9 / 66	9 / 42
HLV	85 / 718	11 / 397	10 / 86	11 / 48
HLVJI	145 / 840	16 / 425	14 / 117	14 / 55

SNR threshold of 12

Figure of merit for different science cases

- High SNR threshold: for golden events
- Keep updating the source evolution models
- Isotropy of sources: cosmic 3D structure?
- Burst range
- EM models driven: cost function of next generation telescopes
- And more…

Summary

- We need different distance measures for 2G/3G.
- Different distance measures corresponding to different science cases will help evaluating/ comparing different detector configurations.