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Astrophysical Interpretation of Gravitational Wave Burst Searches

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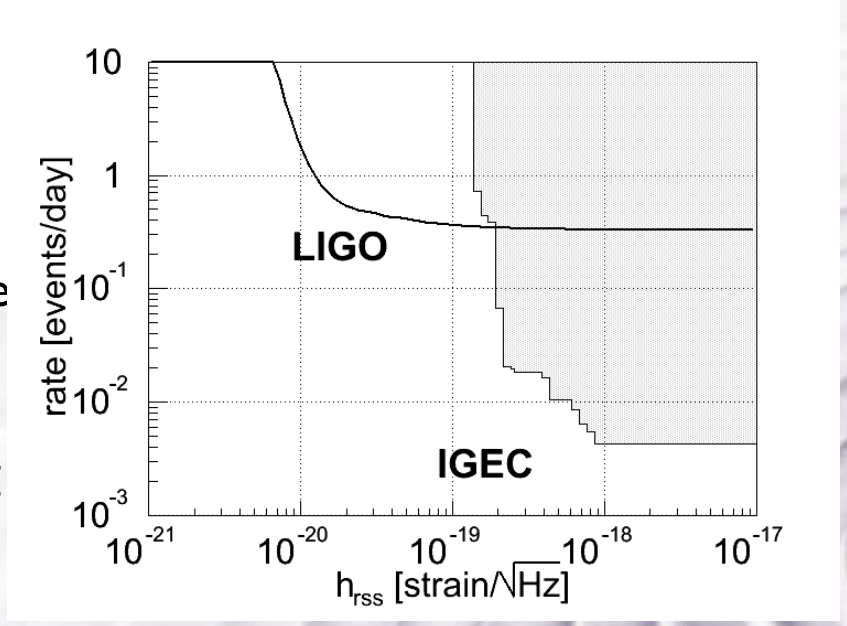
How do we report burst search results?

- Detector-centric "Rate vs. Strength"
  - Rate? Event rate *in/at detector*
  - Strength? Measure of wave amplitude *in/at detector*
- About sources?
  - "Strength" reveals nothing about, e.g., absolute luminosity
- About populations?
  - "Rate" reveals nothing about intrinsic source rate, which depends on source distribution in space and source energy radiated



How can we report astrophysically meaningful results?

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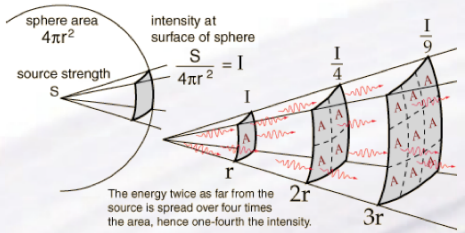
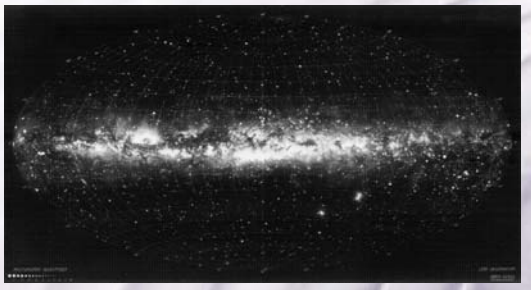
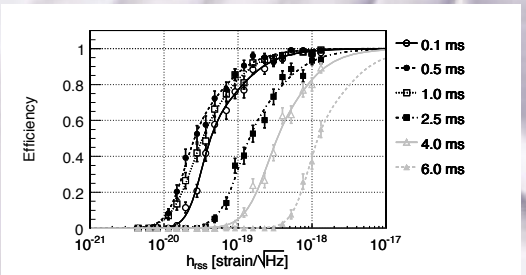
From Detector to Source

- Wave "strength" at detector depends on
  - Intrinsic energy radiated in each polarization, source distance, beam pattern and orientation relative to detector
- Event "rate" at detector depends on
  - Source rate in population, detection efficiency as function of wave "strength"







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Astrophysical Rate vs. Strength

- *Astrophysical Rate:* Event rate *in population*
- *Astrophysical "Strength":* Astrophysically meaningful amplitude parameter (e.g., radiated energy)
- Rate v. strength bound: $R(E) = \dfrac{k}{T_{\rm obs}\epsilon(E)}$
  - Constant k set by number of observed events (0.15 for no observed events)
  - $\epsilon(E)$ is *efficiency in population*

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Efficiency in Population

- Efficiency: observed/total
- Observed:
  - Integral of source rate distribution (location, orientation, luminosity) over detection efficiency, observation schedule
- Total:
  - Integral of source rate distribution over observation schedule

$$N_{\rm astro}(\dot\rho, P, \Pi) = \int d^3x \frac{d^2\Theta}{4\pi}\frac{d\psi}{2\pi}\,[dE\,P(E)]\,[dt\,\Pi(t)]$$
$$\dot\rho(\vec{x})\epsilon_{\rm det}(h(\vec{x}|E,\Theta,\psi,t) : D(t))$$

$$N_{\rm total} = \int [dt\,\Pi(t)]\left[d^3x\,\dot\rho(\vec{x})\right]$$

$N_{\rm astro}$ Expected number of observed sources
$N_{\rm total}$ Total number of sources
$h(x)$ gw at detector from source at x
$P(E)$ fraction of sources that radiate energy E ("luminosity function")
$\pi(t)$ Observation schedule (1 if observing at time t, 0 otherwise)
$\dot\rho(\vec{x})$ source rate density at x
$D(t)$ detector projection tensor
$\epsilon_{\rm det}$ efficiency to detection to projected wave

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Example

- Source population
  - Assume sources trace old stellar population
  - Galactic model with thin disk, thick disk, bulge, bar and halo characteristic of observed white dwarf population
- Source model
  - Impulsive event involving stellar mass compact object (e.g., supernovae, aic, etc); axisymmetric source & standard candle amplitude
  - Flat spectral density to 1KHz, 10ms duration
- Detector, etc.
  - Four detectors at locations of Virgo, LIGO H1, H2 (2Km), L1
  - Efficiency: Sharp sigmoid with 50% efficiency at ~10^{-20} $Hz^{-1/2}$ for H1, L1, Virgo, ~$2x10^{-20}$ $Hz^{-1/2}$ for H2
  - Observation Schedule: 100%

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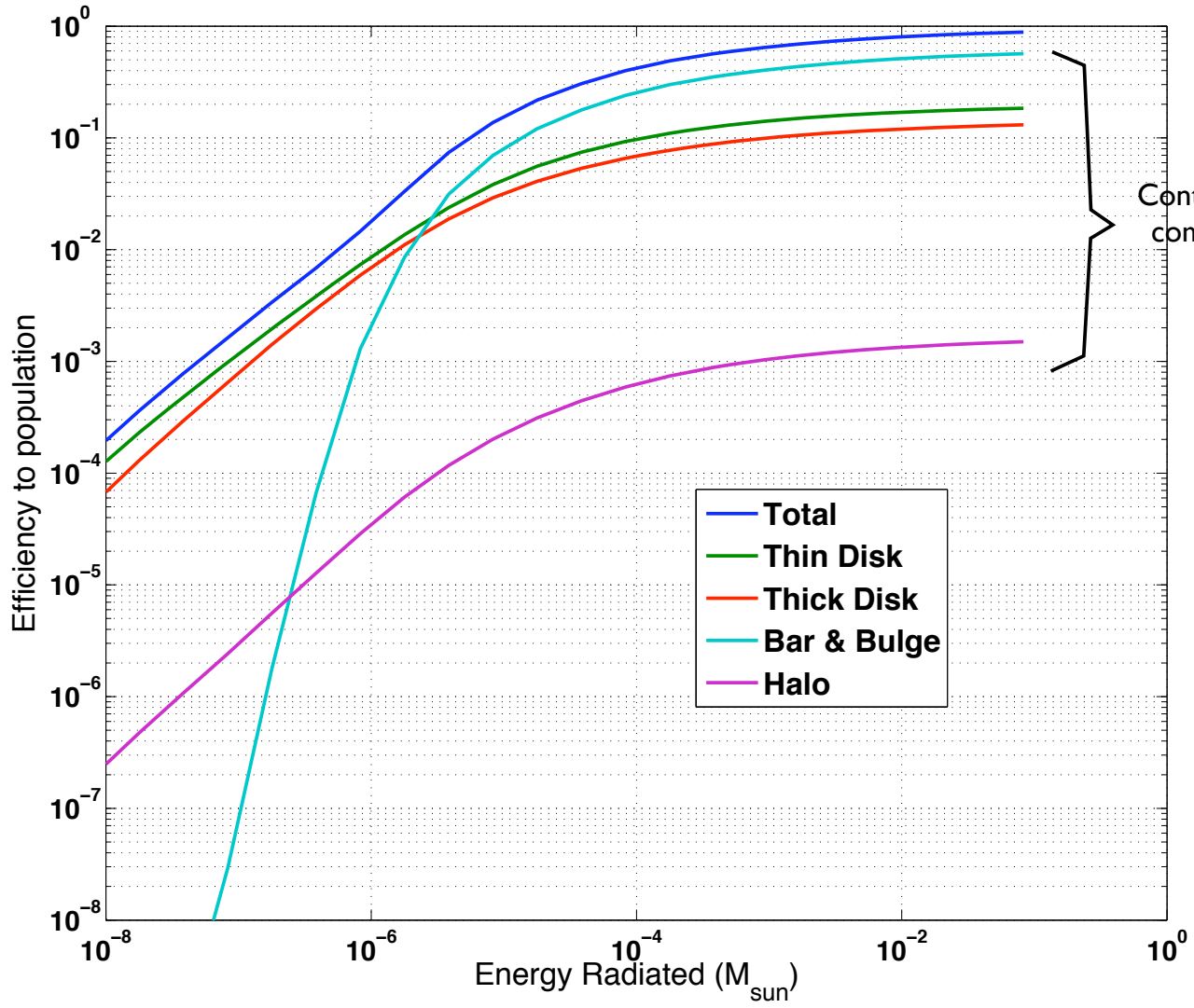

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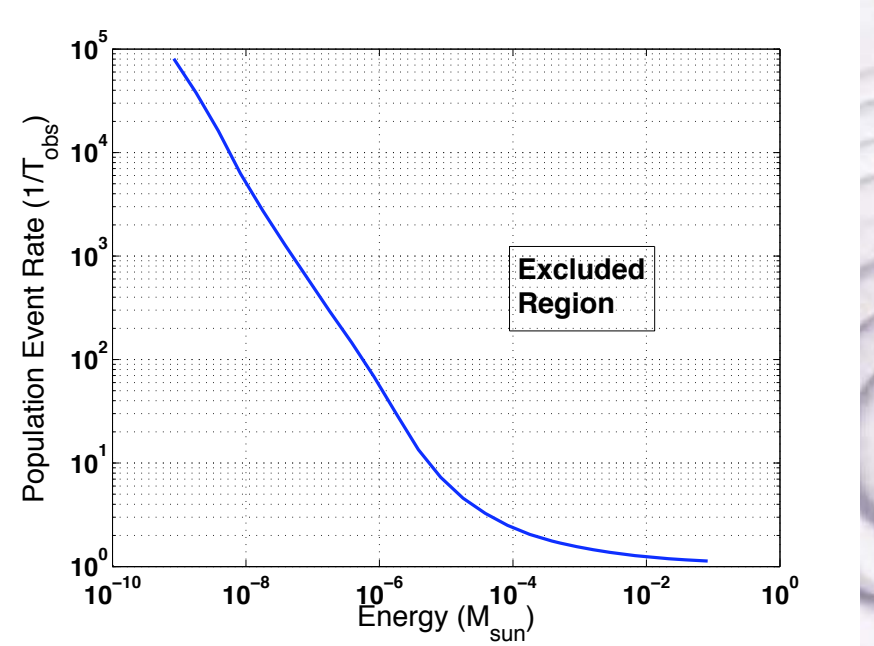
Astrophysical Rate vs. Strength

- *Astrophysical Rate:* Event rate in population
- *Astrophysical Strength:* Intrinsic energy radiated



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Conclusions & Recommendations

- Current gravitational wave burst searches can be interpreted astrophysically
- Additional information on observation schedule can increase power of analysis
  - What is observation schedule?
  - What is time-dependent detector efficiency?
  - When were candidate burst events observed?
- Publish intrinsic efficiency, observation schedule information
  - Allow astronomers to draw their own conclusions!