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Astrophysical Interpretation of Gravitational Wave Burst Searches

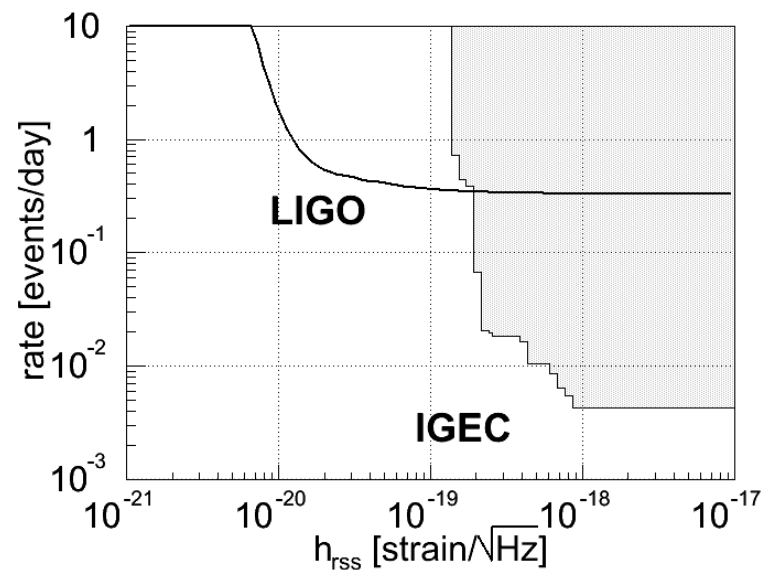
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How do we report burst search results?

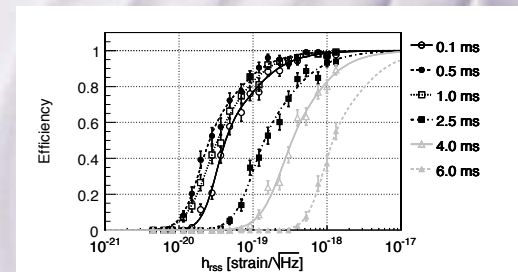
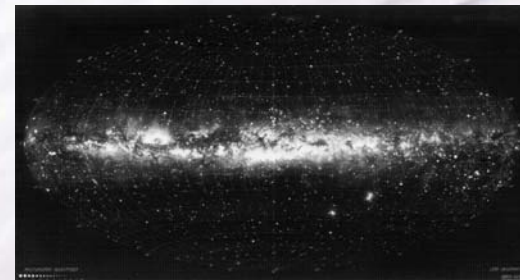
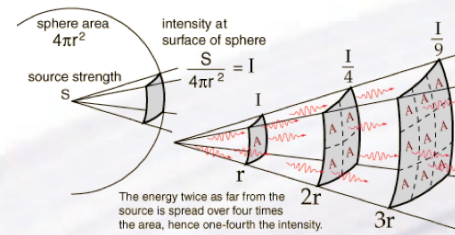
- Detector-centric “Rate vs. Strength”
 - Rate? Event rate *in/at detector*
 - Strength? Measure of wave amplitude *in/at detector*
- About sources?
 - “Strength” reveals nothing about, e.g., absolute luminosity
- About populations?
 - “Rate” reveals nothing about intrinsic source rate, which depends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



How can we report astrophysically meaningful results?

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”





Astrophysical Rate vs. Strength

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



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

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

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

N_{astro} Expected number of observed sources

N_{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

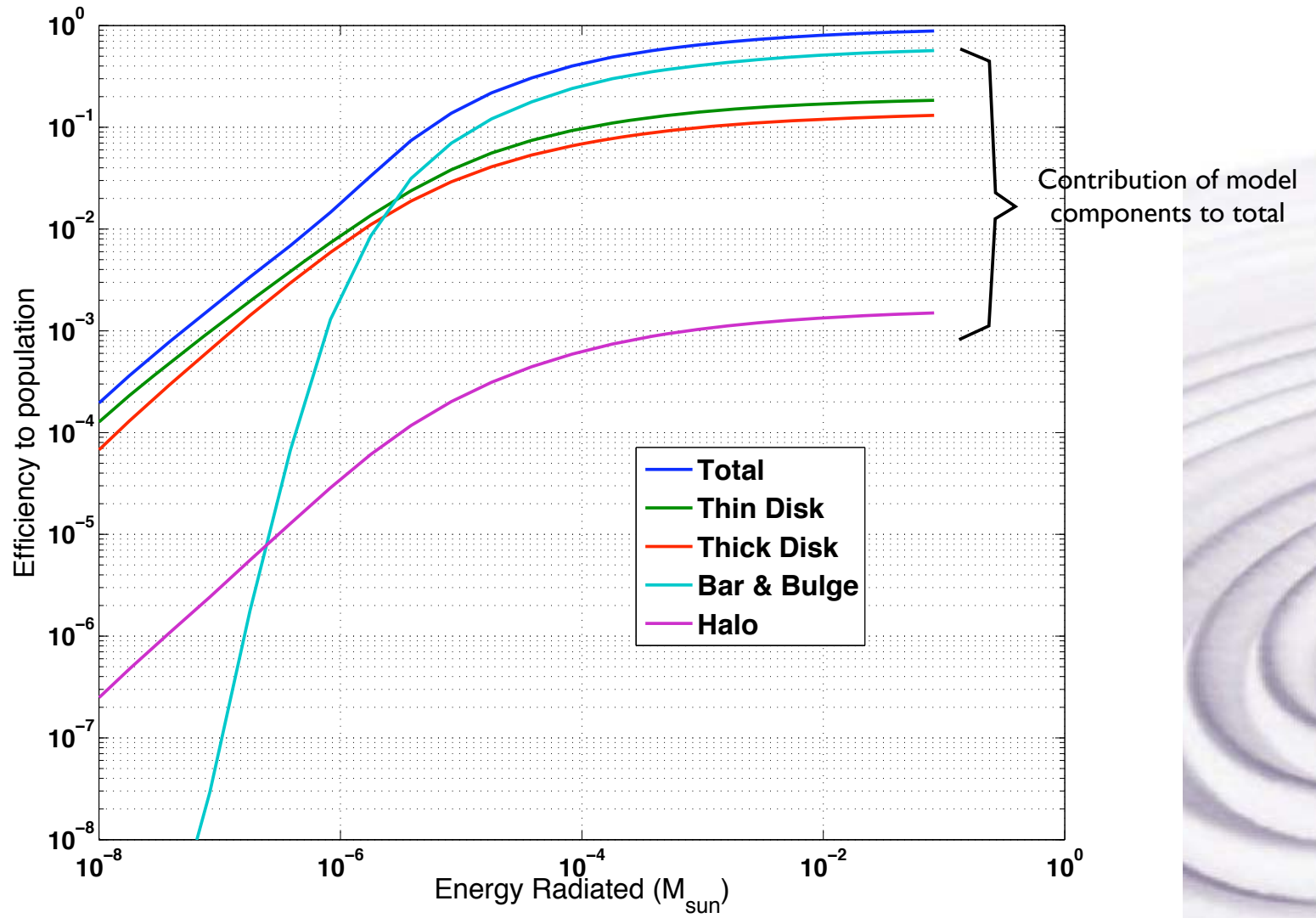
$D(t)$ detector projection tensor

ϵ_{det} efficiency to detection to projected wave



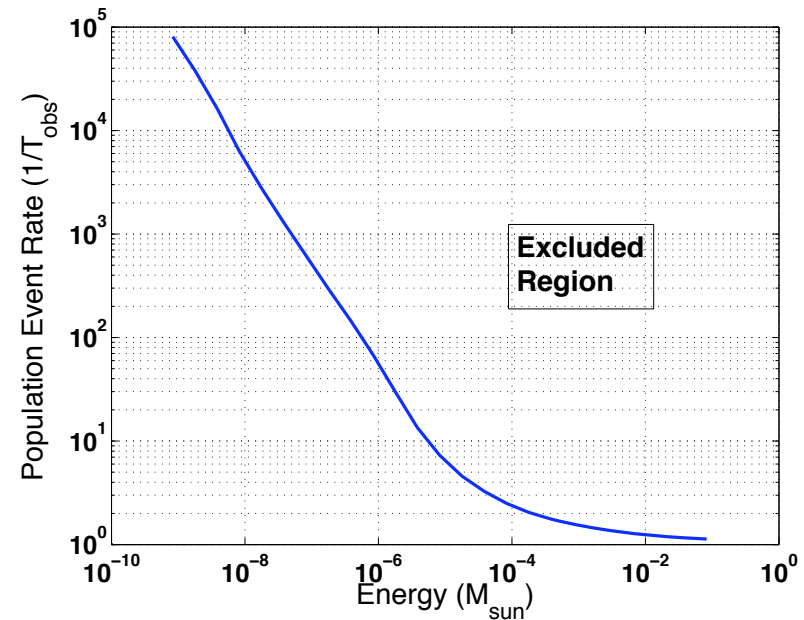
Example

- 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 $\sim 10^{-20} \text{ Hz}^{-1/2}$ for H1, L1, Virgo, $\sim 2 \times 10^{-20} \text{ Hz}^{-1/2}$ for H2
 - Observation Schedule: 100%



Astrophysical Rate vs. Strength

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



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!