Optical Supernovae GW Search: Some thoughts on data analysis nuts and bolts

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Caltech SN Workshop
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A Search for CCSNe in the Nearby Universe

Optically-triggered search for GW from CCSNe $<\sim 25$ Mpc
Detection statement and first SN model upper limits

Motivation:
- Attempt to constrain extreme SN models
- Prepare for Betelgeuse
- Prepare for aLIGO
- Prepare for a neutrino+optical triggered search

Optimize search for theoretical predictions…
- frequency, duration, and modeled waveforms
... but remembering the unknown unknowns
My workshop goals

**Come away with a plan**
- Identify challenges
- Deal out initial tasks
- ExtTrig telecon

What models do we expect to limit in S5/S6? aLIGO? ET?

**Decide which GW waveforms to include in the search**

Begin to think about future searches
Mostly I have DA questions, not DA answers

- What target GW waveforms should we use? (connects theory and DA)
- How do our upper limits depend on signal region size?
- How to handle GW data gaps in the signal region?
- How to handle changing detector networks over the signal region?
- How to handle data quality effectively?
- Can we devise an effective sky location veto to improve sensitivity?
- Can glitch suppression be effectively folded into the detection statistic?
- Optimize clustering on the time-frequency plane
- Can we modify and use an existing pipeline?
- How much better can we do than the all-sky all-time search?
- Will models be constrained by closest SN(e), or can we fold them together?
Do we agree on the following DA approach?

Excess power type externally triggered “burst” search
1… N detectors $\rightarrow$ Time-frequency tilings $\rightarrow$ clustering
e.g. X-Pipeline, Flare, Coherent Waveburst, Omega

Choose appropriate signal region and background region

Search for significant analysis events in signal region
use background region to estimate false alarm rate

Set model-dependent loudest event upper limits
use target waveform simulations injected into detector noise
Rejecting glitches

Larger signal region $\rightarrow$ larger probability of getting a big glitch

Big glitches make for worse upper limits

Data quality will be critical, as in the all-sky all-time searches

Also, the DA pipeline must work hard to reject glitches
  old technology: null stream, amplitude consistency (H2 helps)
  sky location veto
  measure glitchiness at each frequency; include in detection statistic
A changing GW detector network

GW detectors coming up and down

Antenna factors change with Earth’s rotation

This is new for extrig searches, old for all-time searches

How to present upper limit results?

Gregg Harry 2007
Excess power + clustering

Several of the SNGW waveforms have gaps
2D clustering with “gap jumping” capabilities

Murphy, Ott, & Burrows 2009
GW emission from convection/SASI/turbulence
Multiple triggers, one upper limit?

Several SNe, at different distances

Signal regions will have missing data

Can we make a compelling combined statement?
Could it improve constraints?
Table 1: List of optically discovered core-collapse SNe discovered within ~25 Mpc from Earth with potential explosion dates between Nov 4, 2005 and Feb 5, 2010. Given are the SN name, the name of the host galaxy, the date of discovery, the core-collapse SN spectral subtype (see, e.g., [1]), and the approximate distance. Note that the date of astronomical discovery always postdates the actual explosion.

<table>
<thead>
<tr>
<th>SN</th>
<th>Host Galaxy</th>
<th>Date</th>
<th>Type</th>
<th>Distance</th>
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<tr>
<td>2010K</td>
<td>SDSS J120246.67+022405.0</td>
<td>20100108 [6]</td>
<td>IIP</td>
<td>?</td>
</tr>
<tr>
<td>2009js</td>
<td>NGC 918</td>
<td>20091011 [14]</td>
<td>II</td>
<td>~ 17 [8]</td>
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<tr>
<td>2009hd</td>
<td>NGC 3627</td>
<td>20090702 [16]</td>
<td>II</td>
<td>~ 10.6 [17]</td>
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<tr>
<td>2009dq</td>
<td>IC 2554</td>
<td>20090424 [18]</td>
<td>IIb</td>
<td>~ 16.7/25.6 (?) [4, 19]</td>
</tr>
<tr>
<td>2009bw</td>
<td>UGC 2890</td>
<td>20090327 [20]</td>
<td>II</td>
<td>~ 14.7 [NED]</td>
</tr>
<tr>
<td>2009gj</td>
<td>NGC 134</td>
<td>20090520 [22]</td>
<td>IIb</td>
<td>~ 17/20 (?) [4, 8, 19]</td>
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<tr>
<td>2009at</td>
<td>NGC 5301</td>
<td>20090311 [23]</td>
<td>II</td>
<td>~ 27.7 [4]</td>
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<td>2008iz</td>
<td>NGC 3034</td>
<td>20090403 [26]</td>
<td>II</td>
<td>~ 3.89 [27]</td>
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<tr>
<td>2008ij</td>
<td>NGC 6643</td>
<td>20081219 [28]</td>
<td>II</td>
<td>~ 25.5/23.0 [4, 8]</td>
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<tr>
<td>2008fb</td>
<td>UGC 2813</td>
<td>20080824 [29]</td>
<td>II</td>
<td>~ 22.9 [4]</td>
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<tr>
<td>2008eh</td>
<td>UGC 2997</td>
<td>20080727 [30]</td>
<td>(Ia?)</td>
<td>~ 20 [NED]</td>
</tr>
<tr>
<td>2008bo</td>
<td>NGC 6643</td>
<td>20080821 [31]</td>
<td>Ib</td>
<td>~ 25.5/24.6/23 [4, 8]</td>
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<tr>
<td>2007sv</td>
<td>UGC 5979</td>
<td>20071220 [33]</td>
<td>(II?)</td>
<td>~ 20.6 [4]</td>
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<td>2007od</td>
<td>UGC 12846</td>
<td>20070102 [34]</td>
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<td>~ 24.1 [4]</td>
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<td>NGC 1058</td>
<td>20070815 [36]</td>
<td>Ib/c</td>
<td>~ 9.9 [37]</td>
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<td>II</td>
<td>~ 24 [NED]</td>
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<td>2006jc*</td>
<td>UGC 4905</td>
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<td>2006fp</td>
<td>UGC 12182</td>
<td>20060917 [42]</td>
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<td>~ 19 [NED]</td>
</tr>
</tbody>
</table>

* Unusually luminous/energetic explosion, possibly driven by a rapidly spinning protomagnetar or similar 'engine'.

Short term goals

Find out who wants to do what; momentum in ExtTrig telecons

Get some initial target SNGW waveforms to put into noise

Create pipeline prototypes & begin quantifying with waveforms:
  play with glitch-rejecting detection statistics
  play with sky location veto
  optimize clustering for target GW waveforms

Determine SNe set for S5/S6; signal regions
  Katherine Kauffman SURF 2010 (mentors: Christian Ott, PK)
Medium term goals

Settle on a SN search strategy

Methods paper(s) addressing new problems
Should allow for a short results paper
Future searches: 2nd, 3rd generation detectors

Improved optical observations $\rightarrow$ tighter signal regions?

Adding neutrinos to the mix

Planning for a detection
  Collaborations
  Extracting science

Limiting additional models with better detectors