Results from all-sky search for GW Bursts with first generation interferometric detectors

Thursday, June 7, 2012

- F. Salemi, AEI Hannover
  - On behalf of the LIGO Scientific Collaboration and Virgo Collaboration

Overview on all-sky searches

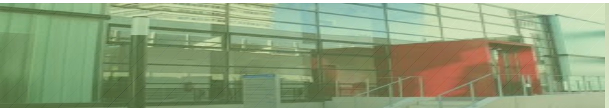
- This talk presents the results from the all-sky burst search on the latest LIGO-Virgo runs (S5-VSR1 and S6-VSR2/3)[1,2,3,4]
- Overall sensitivity is comparable between the 2 data sets
- All-sky (all-time) burst search = no assumptions on incoming direction and time of arrival; minimal assumptions on the signal waveform => robust "all-purpose" untriggered search for fast transients
  - Search for transients of duration $\leq$1 s over the frequency band 64-5000 Hz
- Search pipeline: cWB [5], a coherent algorithm based on constrained network likelihood
- **No candidate events**
- **Upper limits** on the rate of GW bursts by combining all searches on the 1G LIGO-Virgo detectors

Observational time

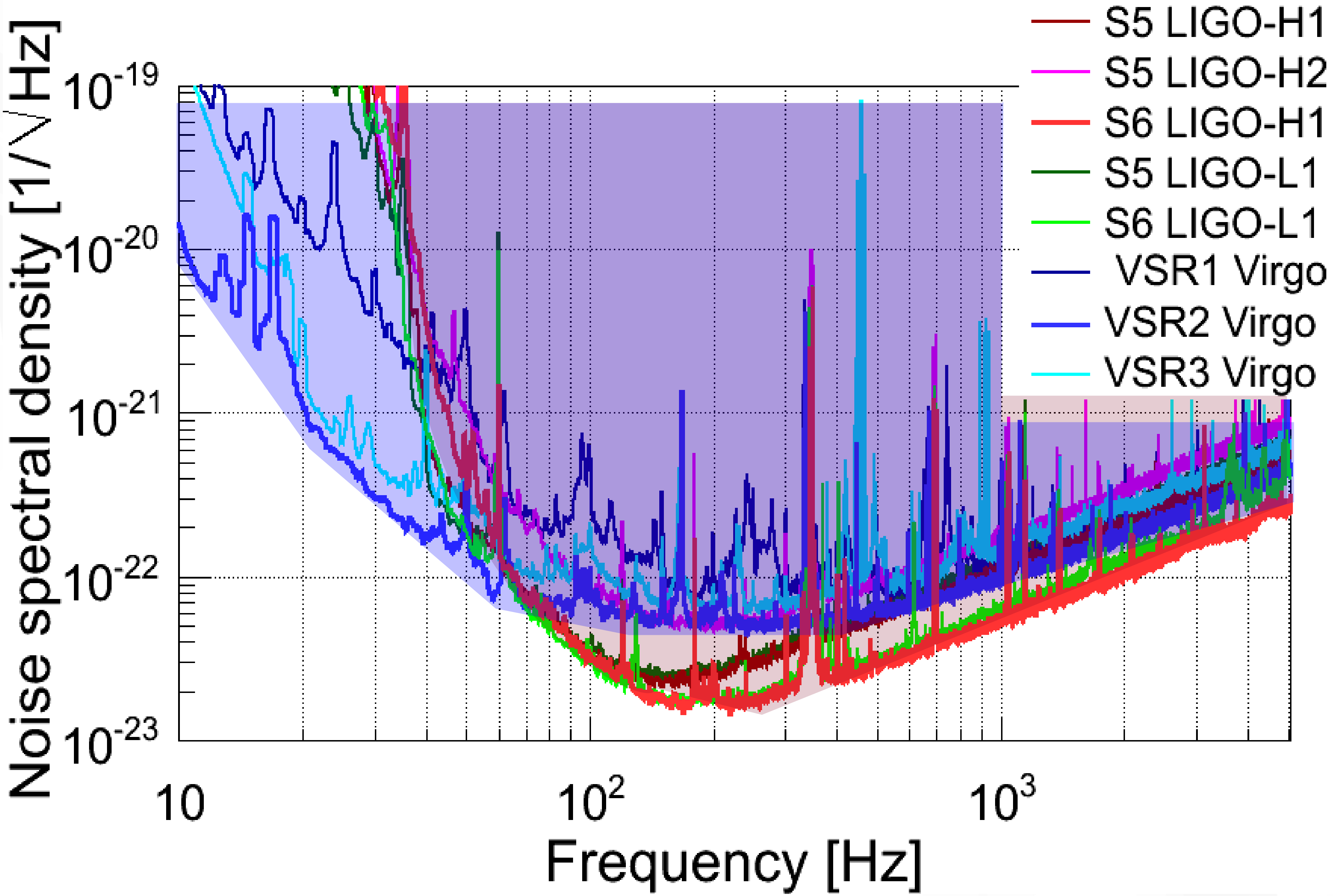
	H1H2L1V1	H1H2L1	H1H2	TOT [days]
S5-VSR1	68	284	104	**429**

	H1L1V1	H1L1	H1V1	L1V1	TOT [days]
S6-VSR2/3	52	85	41	29	**207**

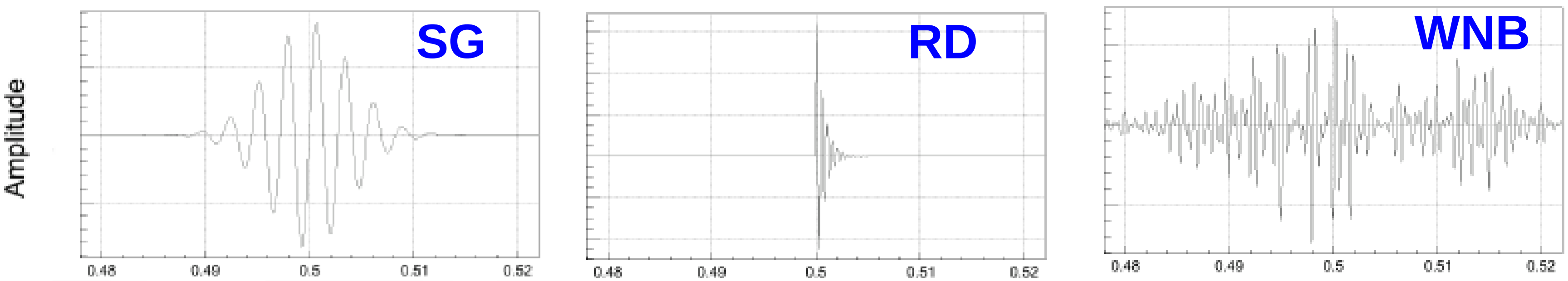
- S5(Nov. 2005 – Oct. 2007) + VSR1(May 2007 – Oct. 2007)
- S6(Jul. 2009 – Oct. 2010) + VSR2(Jul. 2009 – Jan. 2010)+ VSR3(Aug. 2010 – Oct. 2010)
- 4 ifos in S5-VSR1 (H1, H2, L1 and V1) => 3 ifos in S6-VSR2/3
  - H2 decommissioned
- Roughly 2 years of accumulated observational time (after some data quality + omitting network configurations with negligible live time)



Network Sensitivity

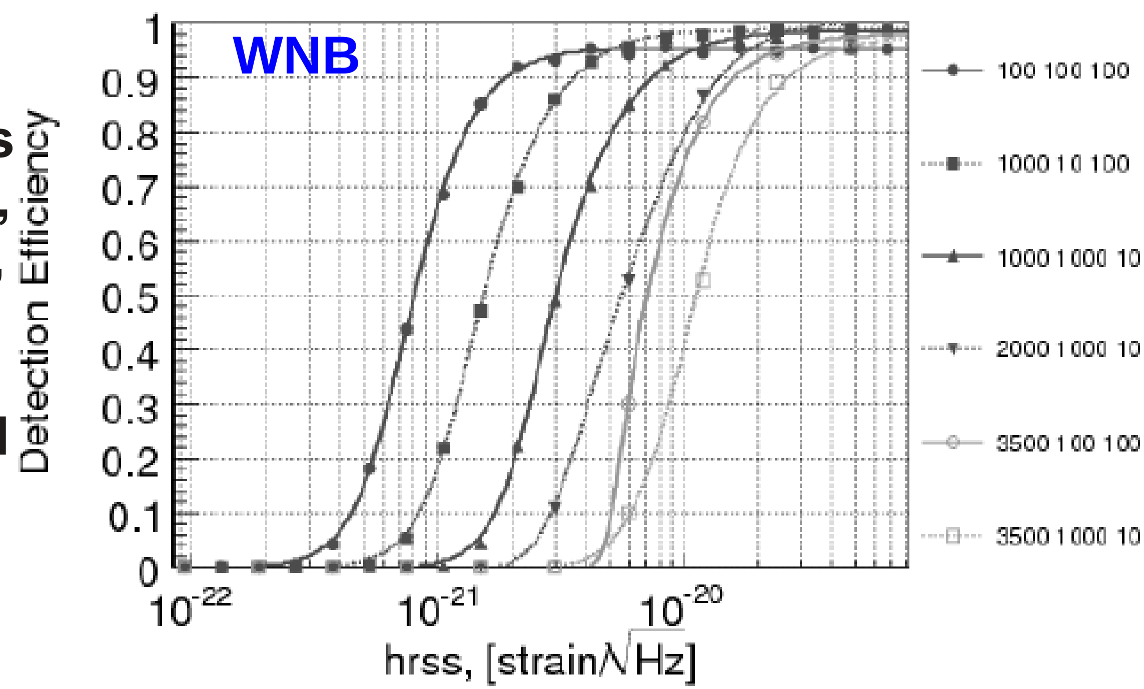


Detection Efficiency



+ ...

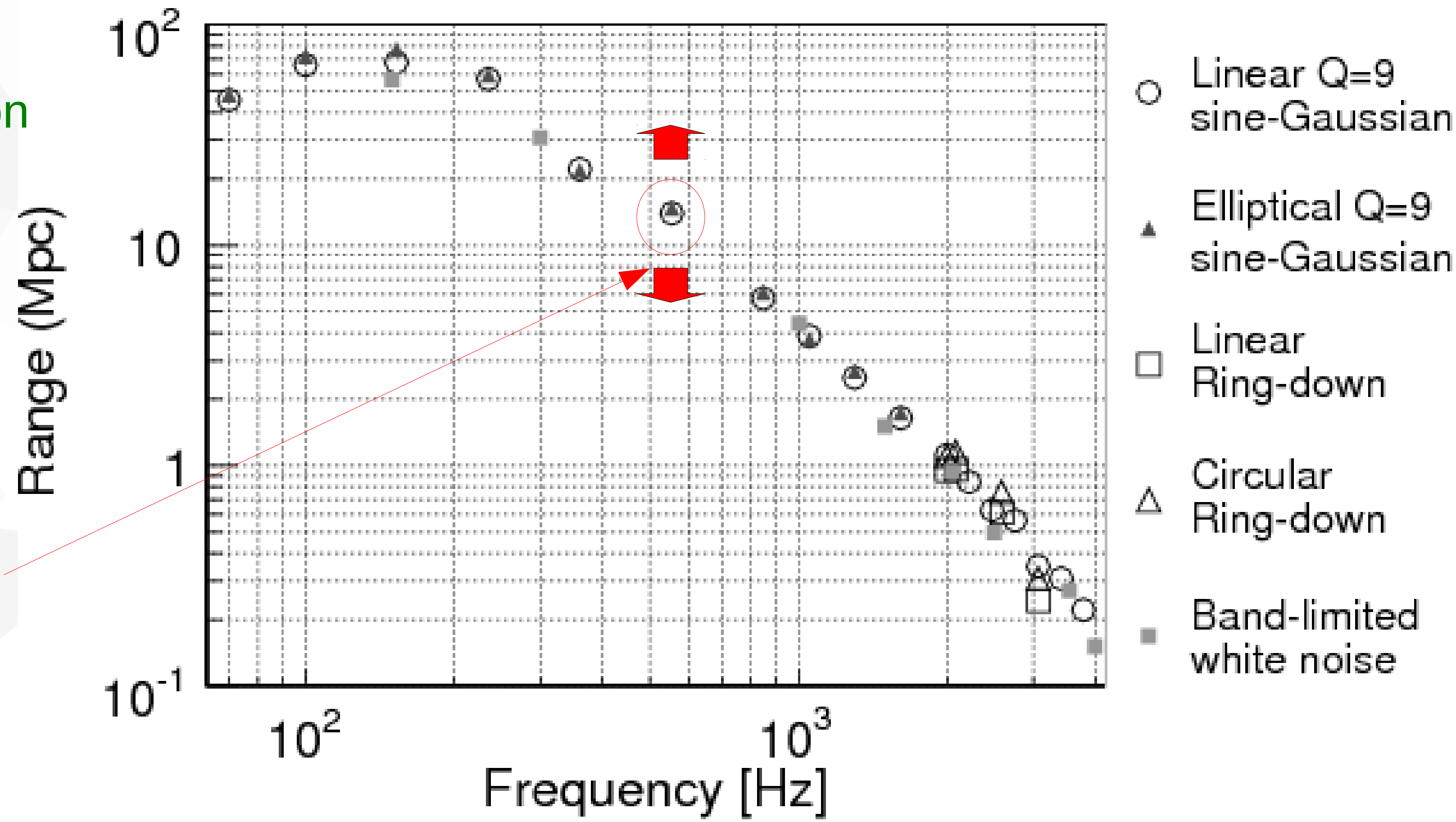
- Use **ad-hoc waveforms** (**Sine-Gaussian**, **Gaussian**, **RingDowns**, **White-Noise-Bursts** etc.) as well as **"physical waveforms"** (**EOBNR[6], numerical relativity BBH[7], CCSN, etc.**)
- **Assume different source populations: random direction and polarization on a sphere, uniform distribution in volume (up to ~600 Mpc), blue-luminosity galaxy catalog distribution (up to 50 Mpc) [8], galactic distribution => detection sensitivity**



Distance Ranges: a zeroth-order estimate (1)

Ranges for ad-hoc waveforms
- Uniform distribution
- Isotropic emission
- $E_{GW} = 1\ M_{sun} * c^2$

$$Range \propto \sqrt{\frac{E_{GW}}{M_{sun} c^2}}$$



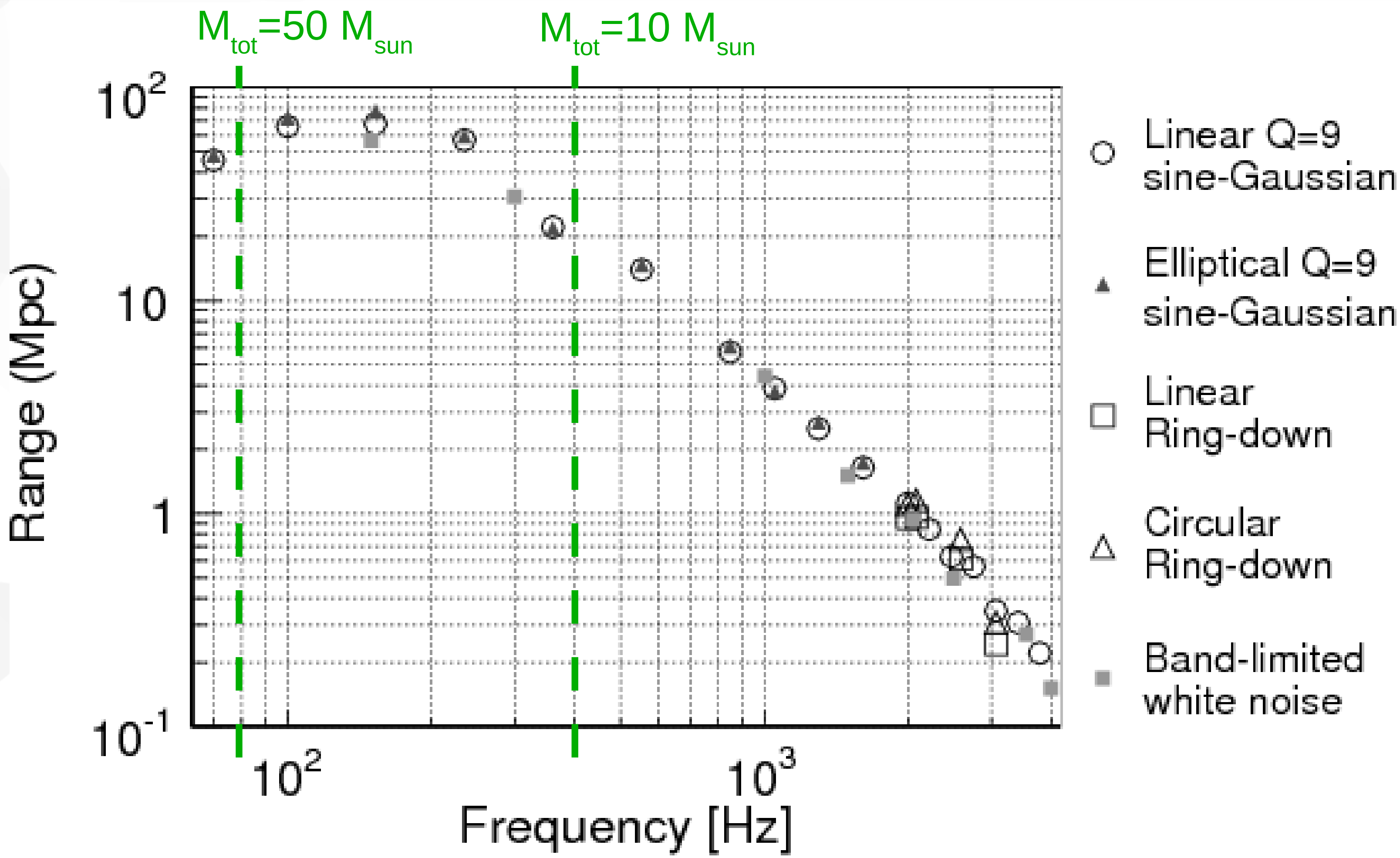
- weak dependance on the actual waveform/polarization
- strong dependance on frequency

Distance Ranges: a zeroth-order estimate (2)

In case of BBH assume:

- $f \sim f_{merger}$
- $E_{GW} \sim 0.1\ M_{tot}$

=>Good match with BBH MonteCarlo !!!

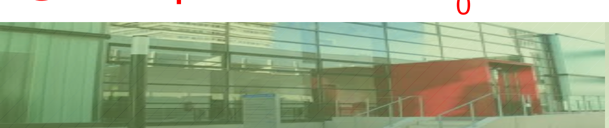


Fixing a range and calculating the E_{GW} (e.g. @ 235 Hz)

@10 kpc => 3e-8 M_0c^2

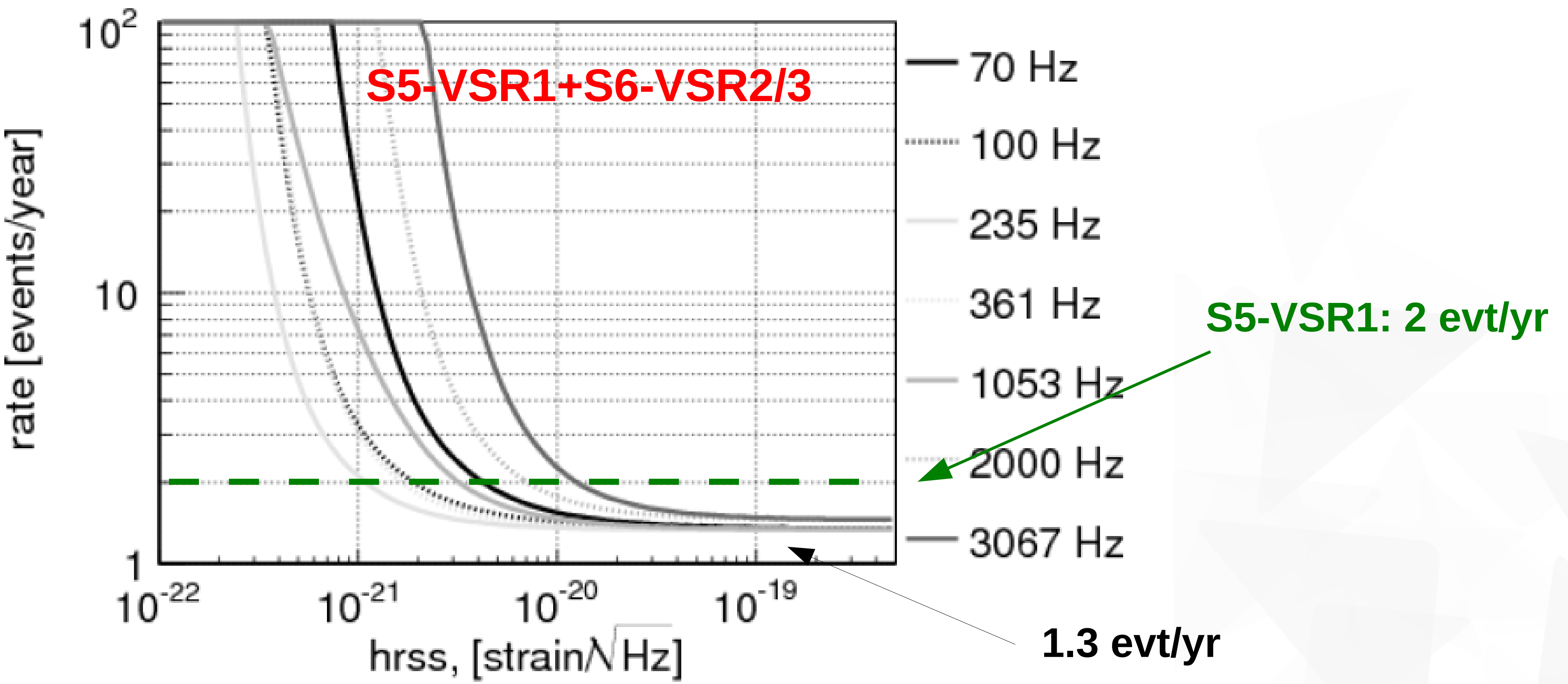
@16 Mpc => 8e-2 M_0c^2

For CCSN we need advanced detectors to see beyond our Galaxy



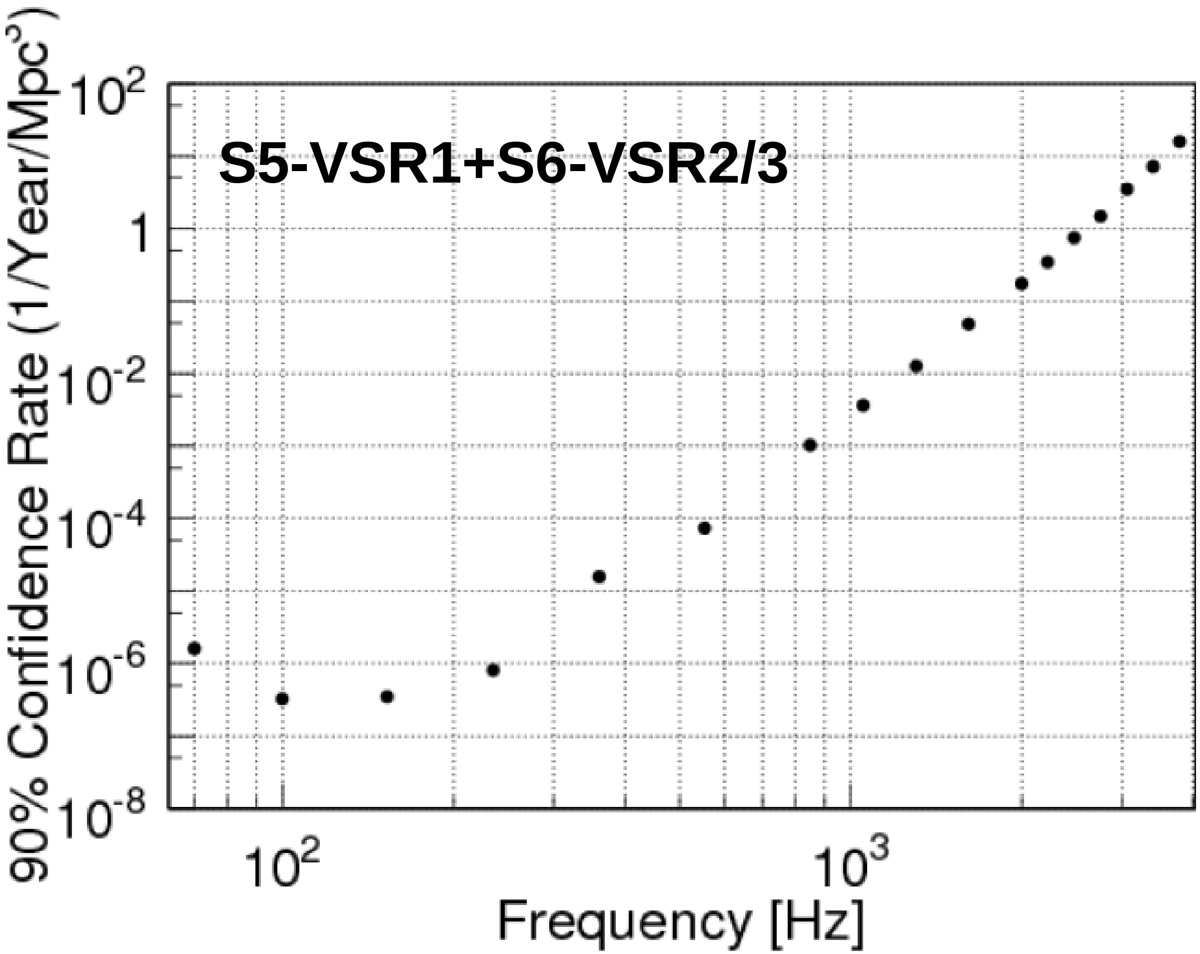
Combined upper limit on rate at the Earth

90% confidence upper limits for selected linearly polarized SineGaussians by combining results from S5/VSR1 all-sky paper



Combined Rate density Upper limit

The results is also interpreted as limits on the rate density of GW bursts (number per year and per Mpc^3) assuming a standard-candle source emitting 1 M_{sun}



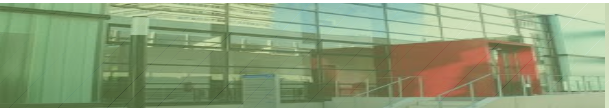
Rate density limit scales as:

$$\mathcal{R}_{90\%}(f)(M_\odot/M)^{3/2}\ \mathrm{yr}^{-1}\mathrm{Mpc}^{-3}$$

For a source emitting at 150 Hz
$E_{gw} = 0.01\ M_0\ c^2$

$$R_{90\%} = 3.5 \cdot 10^{-4}\ \mathrm{yr}^{-1}\ \mathrm{Mpc}^{-3}$$

The S6-VSR2/3 blind injection (so called "Big dog") in a burst perspective



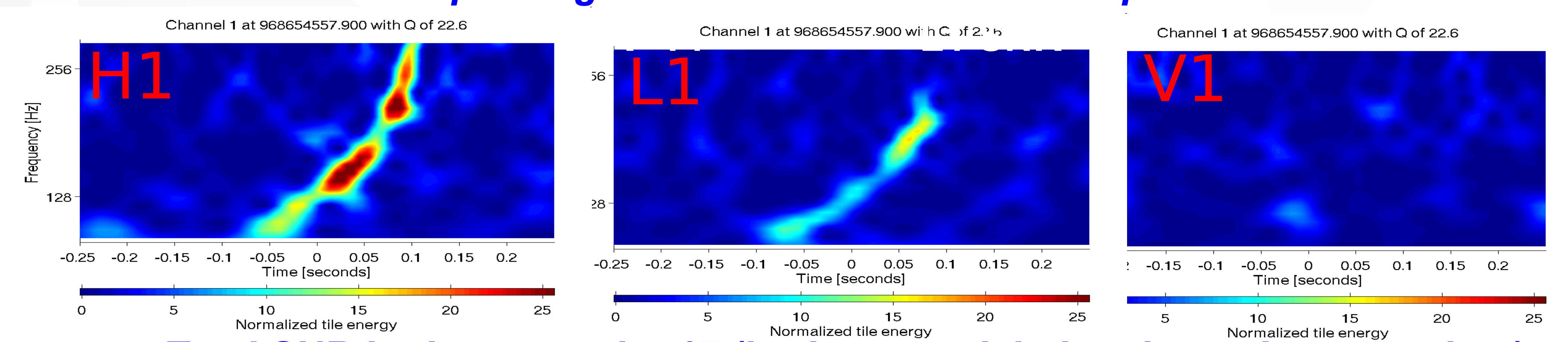
Case Study: blind injection

strong candidate Sept 16, 2010, 06:42 UTC

GW100916

- First detected and reconstructed with a latency of a few minutes by a coherent pipeline searching un-modeled bursts: SNR in (H1,L1,V1)≈(14,10,3.7)
- Low latency checking procedures confirmed the interest in the signal:
    - chirping in frequency as expected from compact binary inspiral
    - louder than most noise transient events (FAR≈2/yr)
    - detectors were operating smoothly

Spectrograms of whitened strain output:



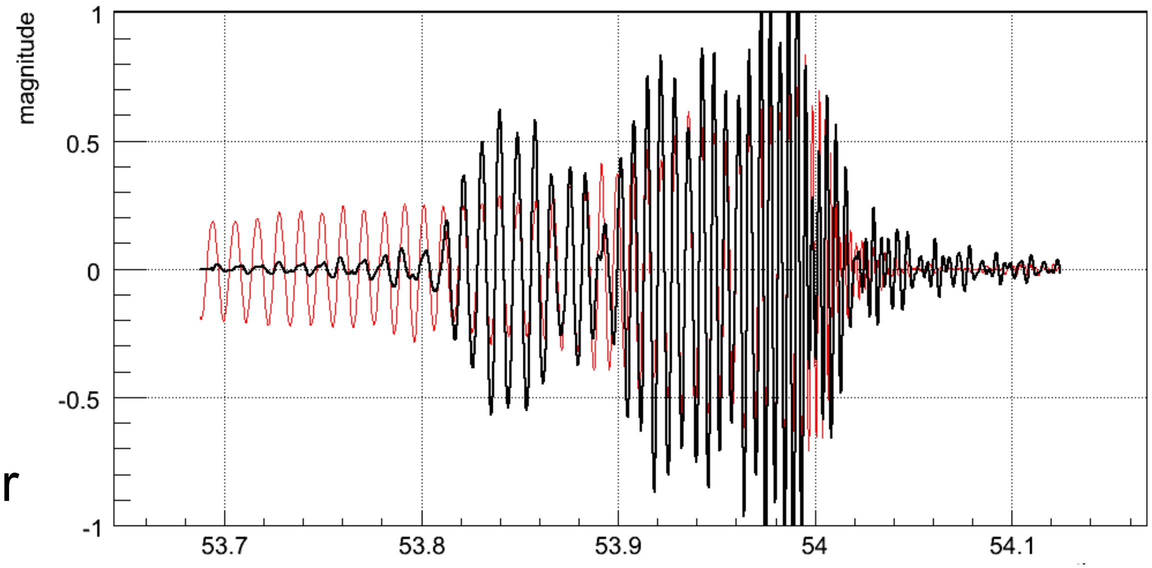
Total SNR in the network ≈17 (both un-modeled and template searches)

- information was released to partner astronomers for follow-up observations within 45 minutes

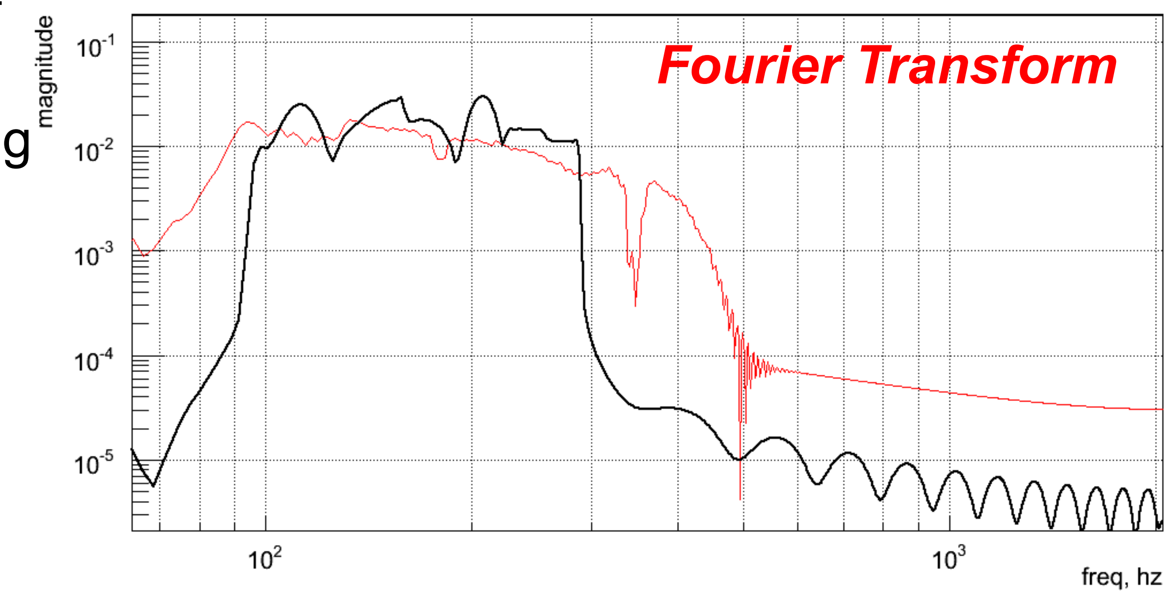
Case Study: blind injection

waveform in H1:

- injected same signal of GW100916
- reconstructed by unmodeled burst search



- Whitened strain of the detector
- most SNR comes from the 100-300Hz band (sweetspot of detectors)
- template search for coalescing compact binaries recovers similar SNR for chirp mass $\approx 4.7 M_{sun}$

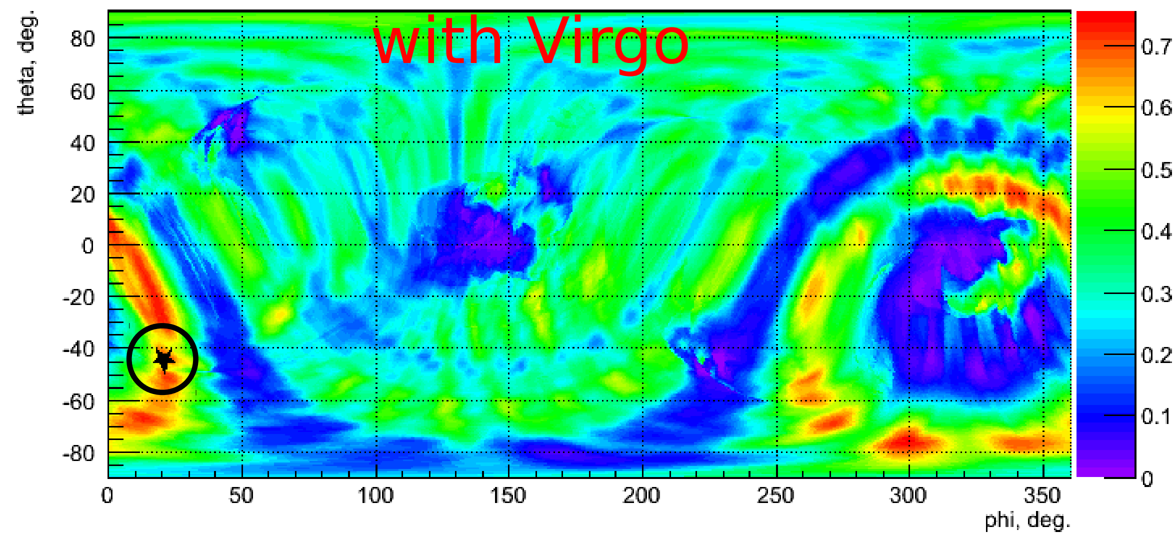


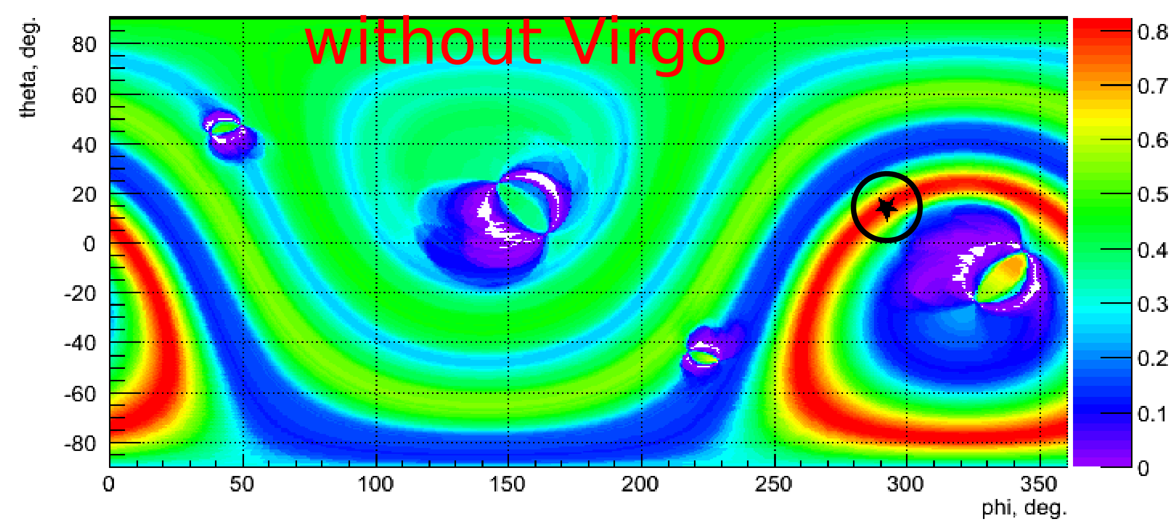
Sky maps: the role of Virgo

- During this time the Virgo sensitivity was lower than LIGO's + antenna pattern is unfavorable for detection: low SNR on V1

- Virgo contribution into reconstruction: rules out a significant fraction of the L1H1 ring

Likelihood sky maps:

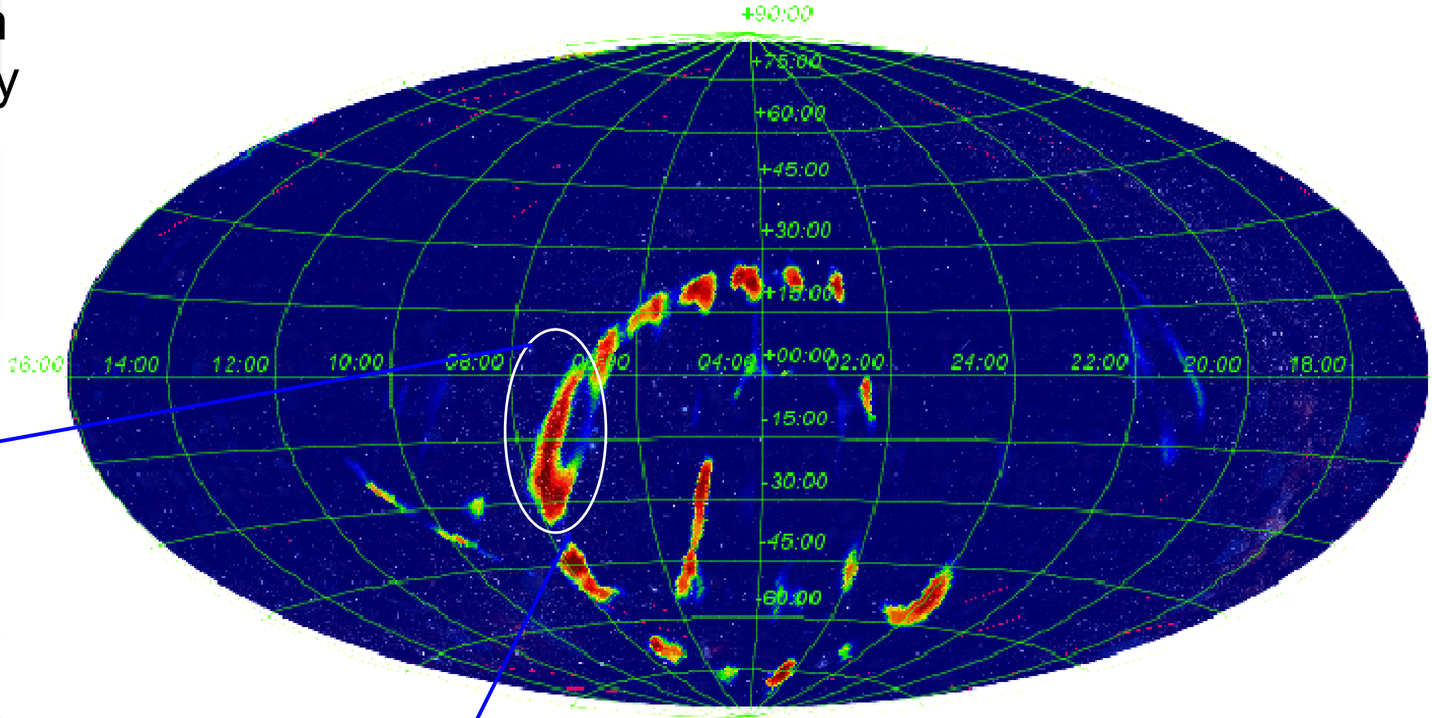


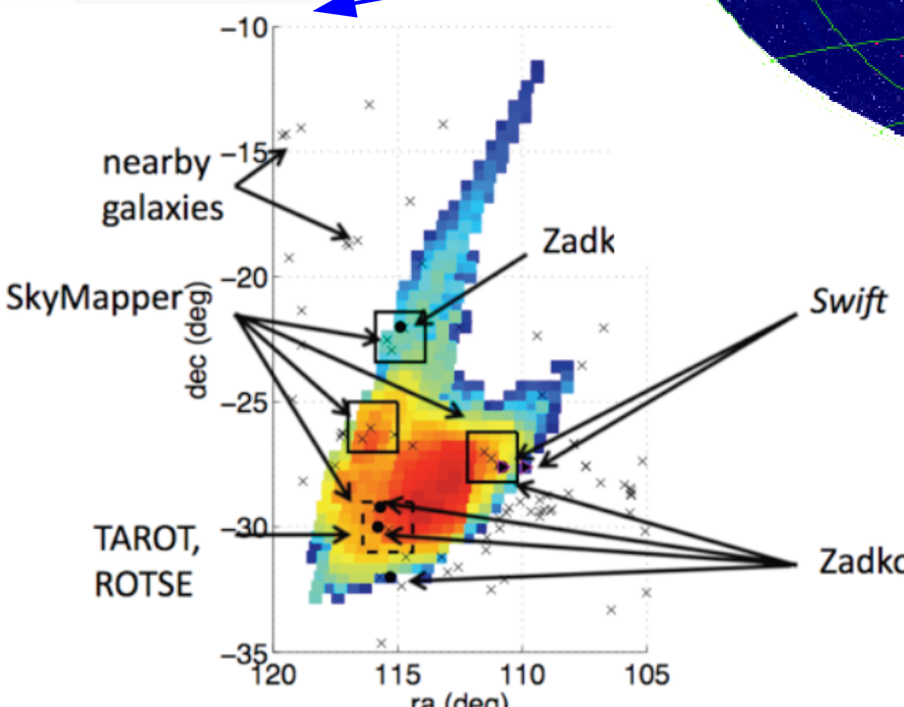


Celestial Sky map for EM follow-up

Wide spots distributed on the ring of 7ms time delay between H1 and L1

Sky map of the reconstructed source location





Telescope shots were requested on the main spot, to cover nearby galaxies

Summary and references

- Results in terms of distance ranges, ULs on the rate GW burst vs amplitude and rate density vs frequency have been presented for 1G GW networks: those limits are the most stringent to date
- The presented case study on the S6-VSR2/3 blind injection shows capabilities of the online all-sky burst search for the multi-messenger observations with the EM instruments.

References

- [1] Phys. Rev. D 80 (2009) 102001
- [2] Phys. Rev. D 80 (2009) 102002
- [3] Phys. Rev. D 81 (2010) 102001
- [4] Accepted by PRD, http://arxiv.org/abs/1202.2788
- [5] Phys. Rev. D 72, 122002 (2005)
- [6] Phys. Rev. D 76, 104049 (2007)
- [7] Phys. Rev. D 85, 102004 (2012)
- [8] Accepted by Astronomy & Astrophysics, arXiv:1112.6005