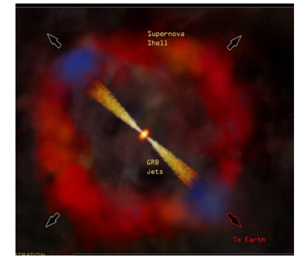


Searches for Gravitational waves associated with Gamma-ray bursts

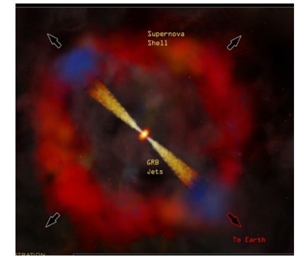
Raymond Frey

University of Oregon

for the

LIGO Scientific Collaboration and the
Virgo Collaboration

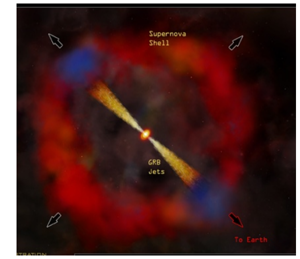
"Current" network of ground-based GW interferometers



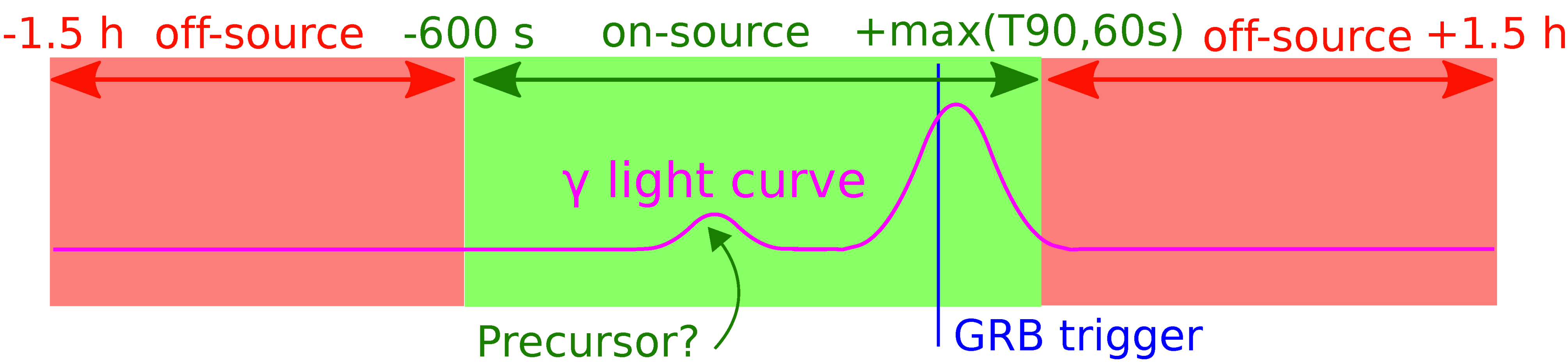
LIGO
4 km

LIGO and Virgo are down for installation of Advanced LIGO and Virgo

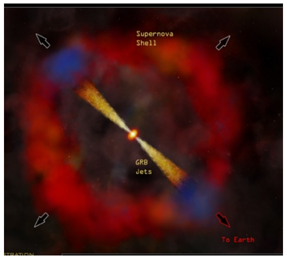
GW-GRB Search Strategy



- GRB time and position from Swift/Fermi/IPN are inputs
  - Improves sensitivity relative to all-time, all-sky searches
  - Time coincidence gives ~2 improvement for unmodeled searches
  - Position allows tight multi-detector timing constraints
- Determine significance of on-source GW candidate from surrounding off-source:

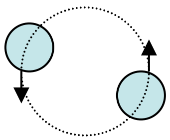


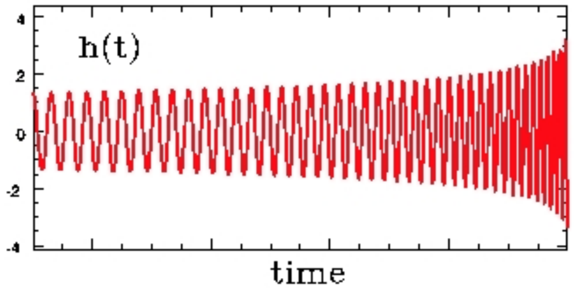
- Two GW signal models…



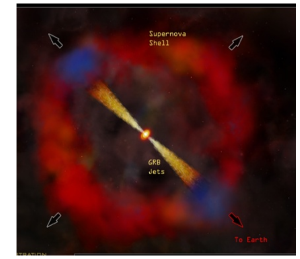
Short GRBs

- GW waveforms for pre-merger phase of NS-NS or NS-BH systems well understood



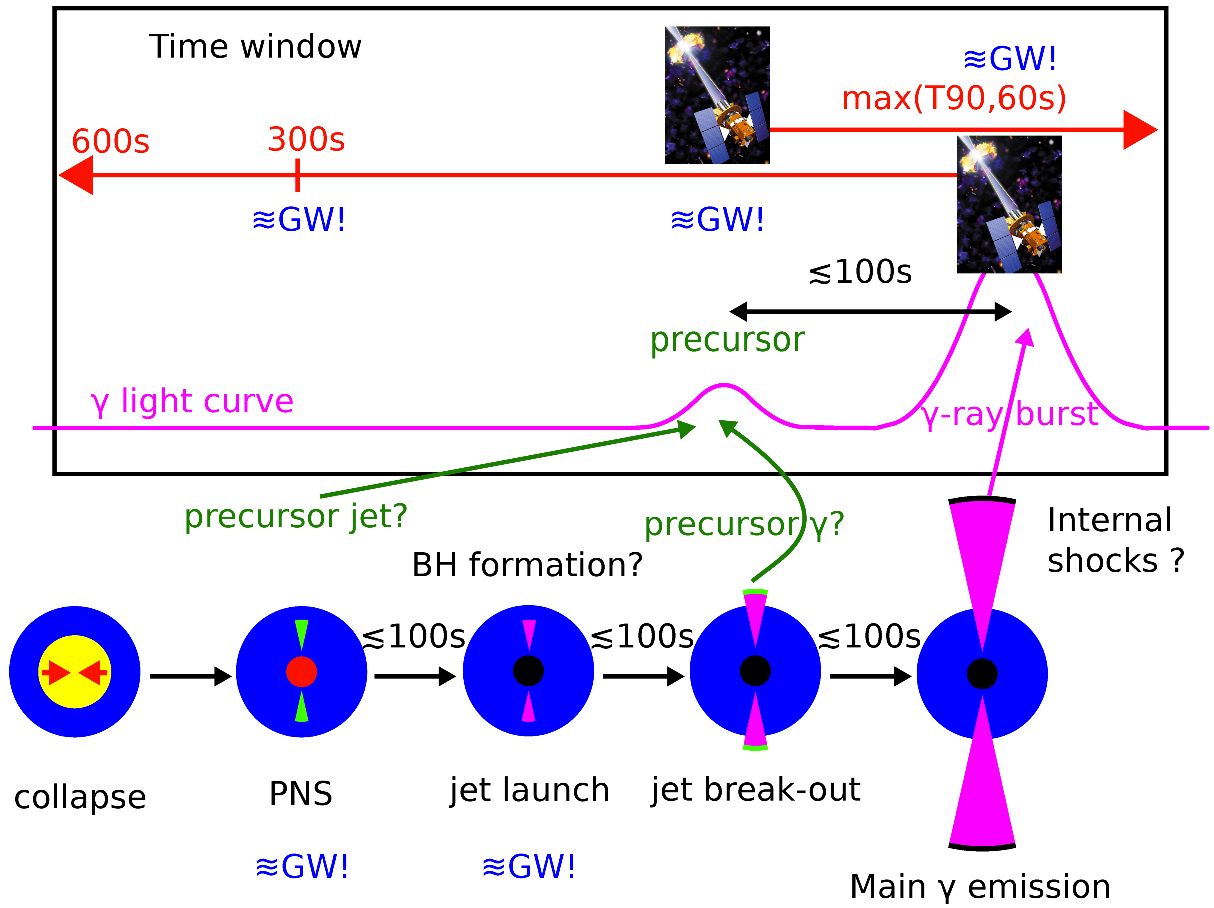


- Use optimal modeled search (templates)
  - Tight on-source window [-5,1] s
- Efficient GW radiators, $E_{GW} \sim 10^{-2}\ Mc^2$
- Distance sensitivity ~40 Mpc (initial) ~400 Mpc (Advanced) for NS-NS
  - Larger for NS-BH



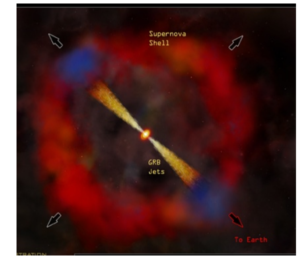
Long GRBs

- Unknown or poorly characterized GW emission
- Unmodeled GW waveform search
  - GW “bursts”
  - Wide on-source window



- Run this search on all GRB triggers, including short

- Do not expect GW emission to be as strong as binary mergers



Searches with initial detectors

- Limited sensitivity: “Golden” nearby GRBs
  - Consider all known GRBs with known time and sky position
- Searches can be promptly triggered or archival
- Low threshold or “subprime” GRBs
  - Brightness in gamma-rays does not imply GW brightness
    - E.g. Short GRBs
    - Class of low-luminosity GRBs

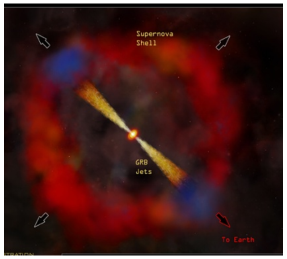
- Searches based on GCN GRBs
  - S5/VSR1 data: ApJ 715 (2010) 1453
  - S6/VSR2-3: ApJ 760 (2012) 12
- Searches based on additional IPN GRBs
  - GRB 070201: ApJ 681 (2008) 1419
  - GRB 051103: ApJ 755 (2012) 2
  - S5-S6 GRBs not in GCN: in progress

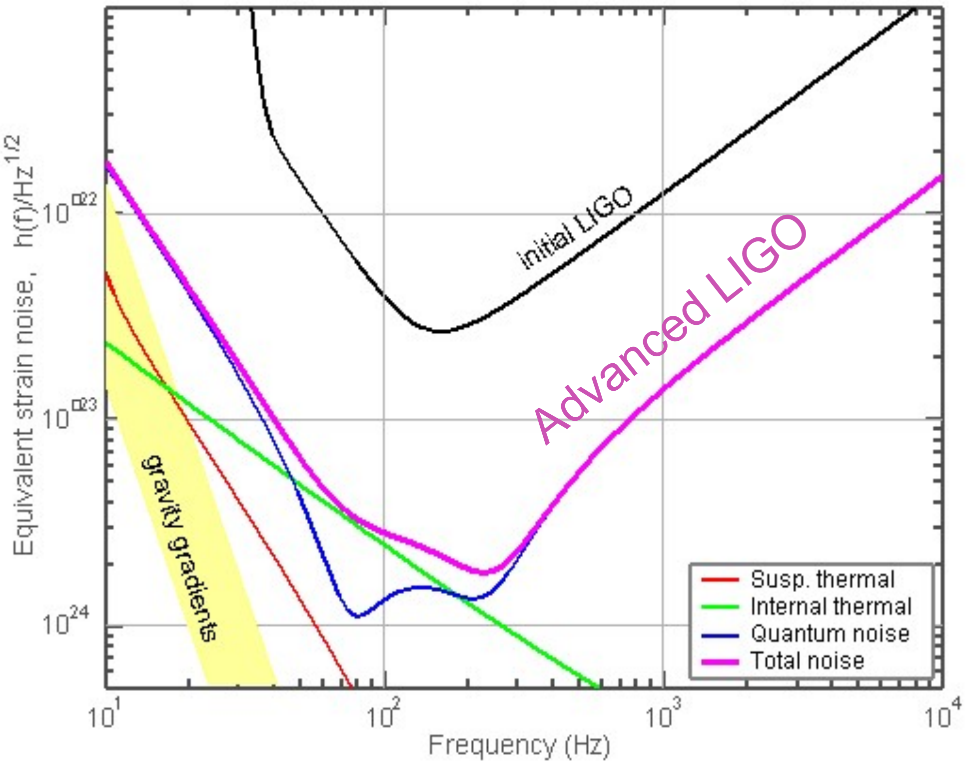
Typical 90% CL exclusion sensitivity of few x10 Mpc

Nearby (M31, M81) binary mergers excluded

- Pilot subprime searches (in progress)

Advanced LIGO and Virgo (2^{nd} gen) coming "soon"



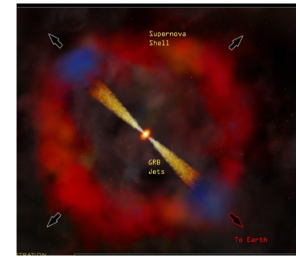


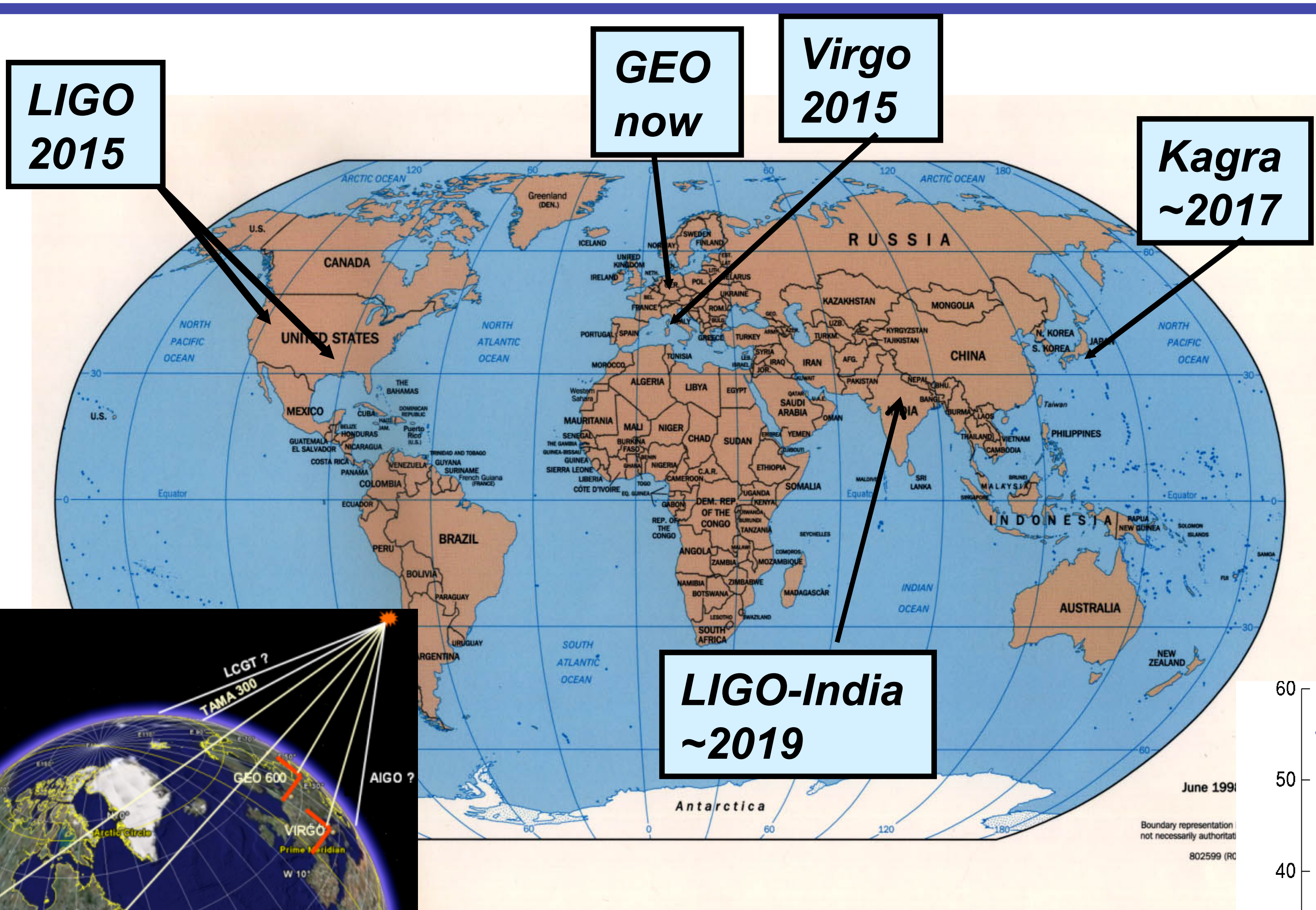
Advanced Virgo expects similar sensitivity and timeline

- 10x better sensitivity
  - and extend to lower frequency
  - limited by quantum noise
- 1000x larger observing volume

- First lock ~2014
- 4-5 year ramp to design sensitivity
  - with science runs interspersed
- Observing scenarios paper: arXiv:1304.0670
- "Realistic" all-sky NS-NS merger detection rate (at design) of 40 events per year: CQG 27 (2010) 173001; arXiv:1003.2480
  - short GRB rate depends on beaming angle

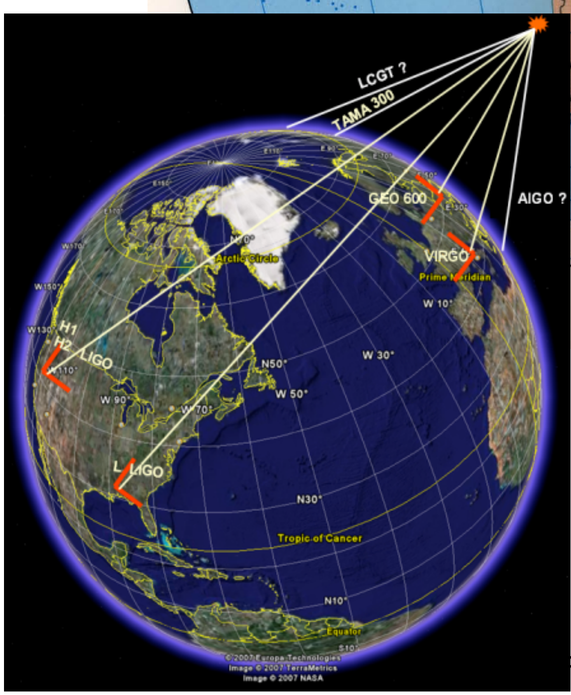
The 2nd generation GW detector network



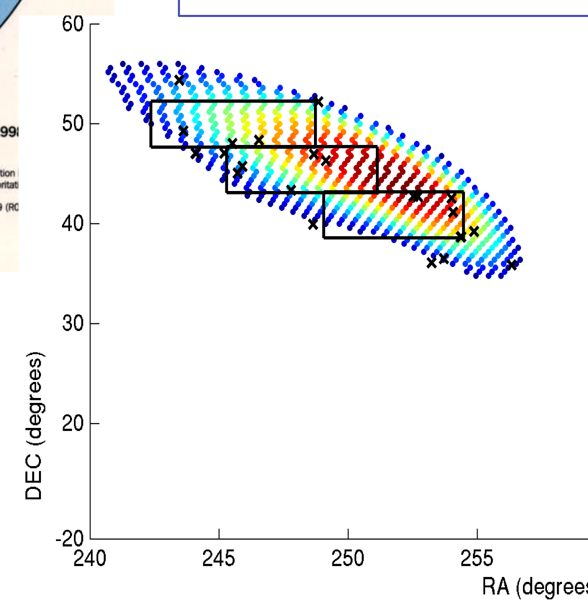


EM follow-up "tune-ups" with initial detectors with optical and x-ray:

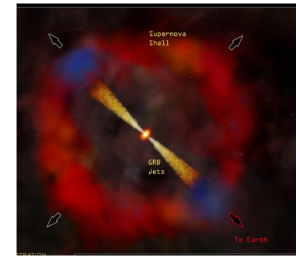
arXiv:1109.3498
arXiv:1112.6005
arXiv:1205.1124

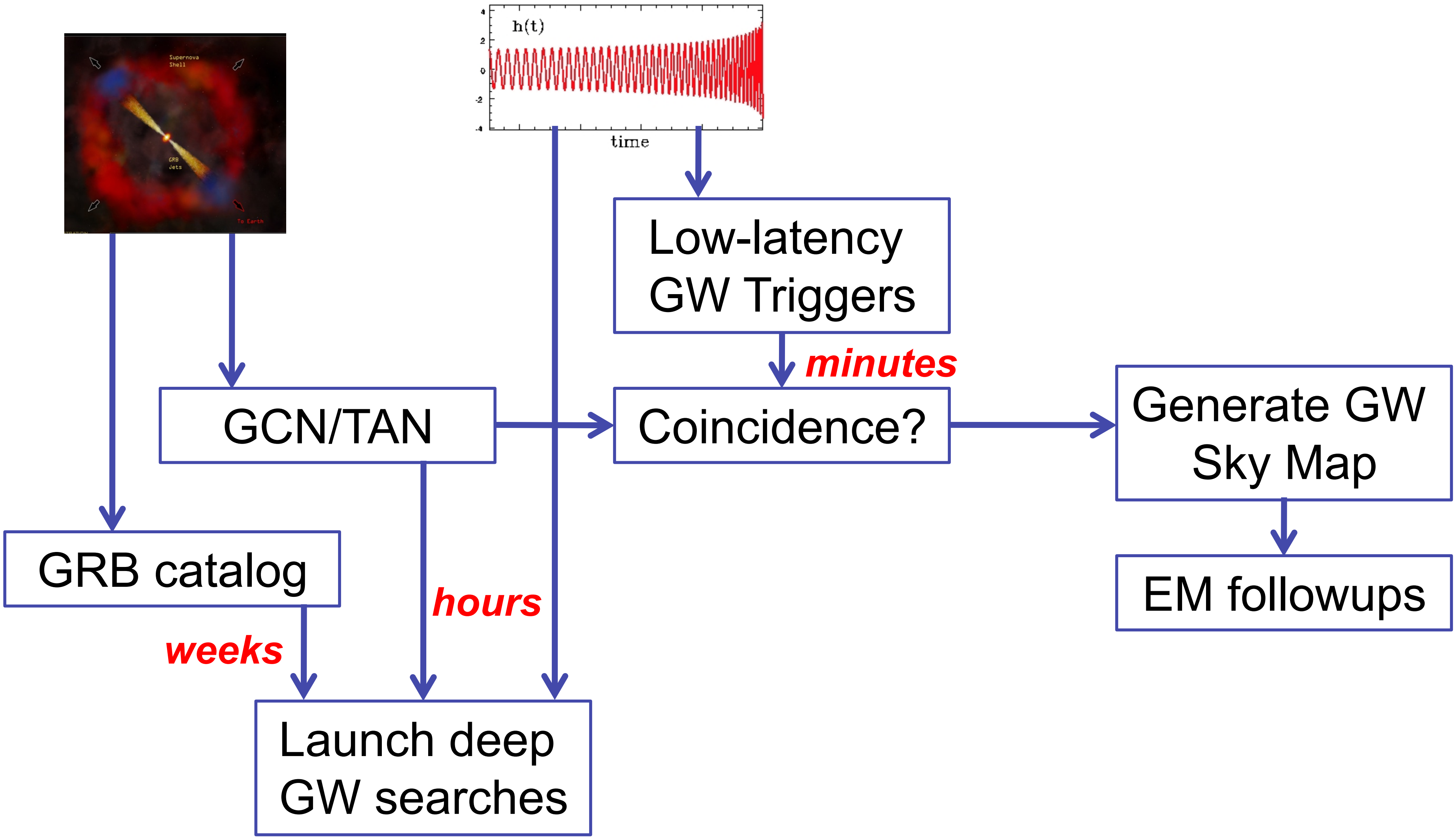


Sky maps

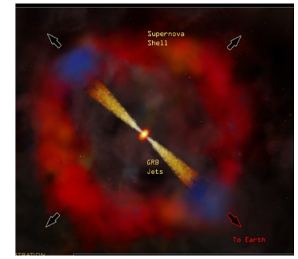


GRB analysis strategy with advanced detectors





some GRB-GW science targets

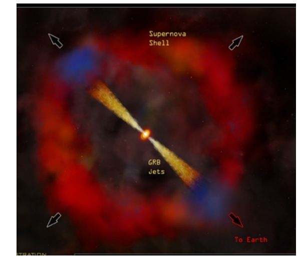


- Unlikely that short GRB will be first GW detection, but possible.
- Testing the connection of short GRBs and merging compact binaries.
- Are the binaries NS-NS or NS-BH? how much of each?
- Accuracy of D_L determination for short GRBs
- Determining the gamma-ray beaming angle

- Can we see GW from long GRBs? Any observation will advance models
- Is there a population of low-luminosity GRBs?

- Testing speed of gravity to ~10^{-16}
  - Eliminate “dark matter emulator” models
  - Tests of alt gravity?

- Testing the EM cosmological distance ladder for z up to ~0.1 or 0.2
- With enough short GRBs can make few % measurement of Ho – aids constraints on dark energy EOS (up to 40% improvement on DE FoM).



Summary

- Initial (1st gen) GW detector searches with GRB sources have not made a GW detection
- However, we have learned how to do analyses and are learning how to work with the broader astrophysical community

- Advanced (2nd gen) detectors coming online in next few years
- Great excitement about the possibilities for discovery and for advancing GRB science.