Joint searches of gravitational waves (GW) and high-energy neutrinos (HEN)

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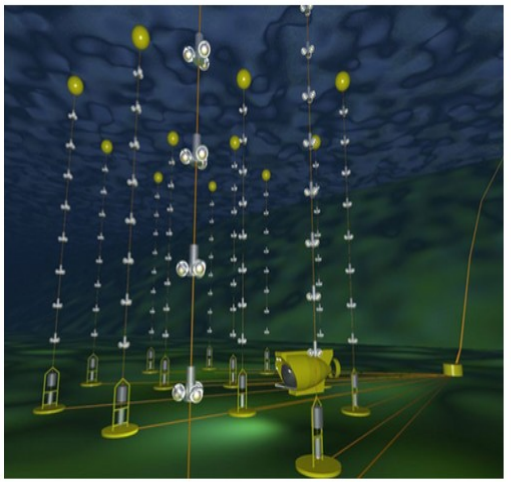
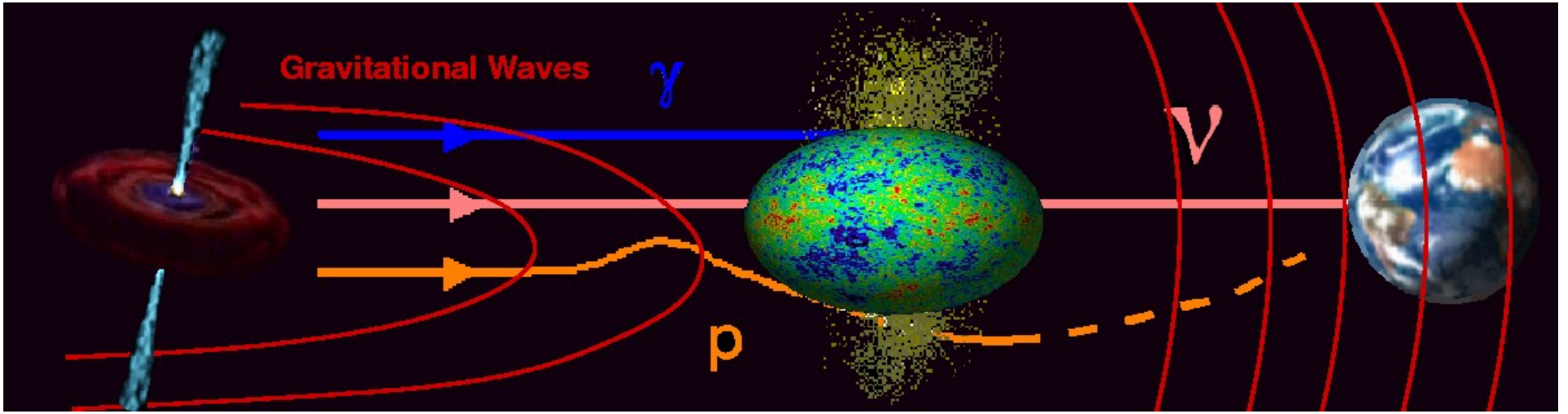





Gravitational waves and High Energy Neutrinos



GW and HEN as cosmic messengers

- *no absorption/diffusion*: travel “cosmological” distances
as opposed to photons (dust, gaz, MW or IR background)

- *no deflection* by magnetic fields: trace back
(as opposed to charged cosmic rays)

- *weakly interacting*: escape from dense objects

Potential GW+HEN sources

Requirements

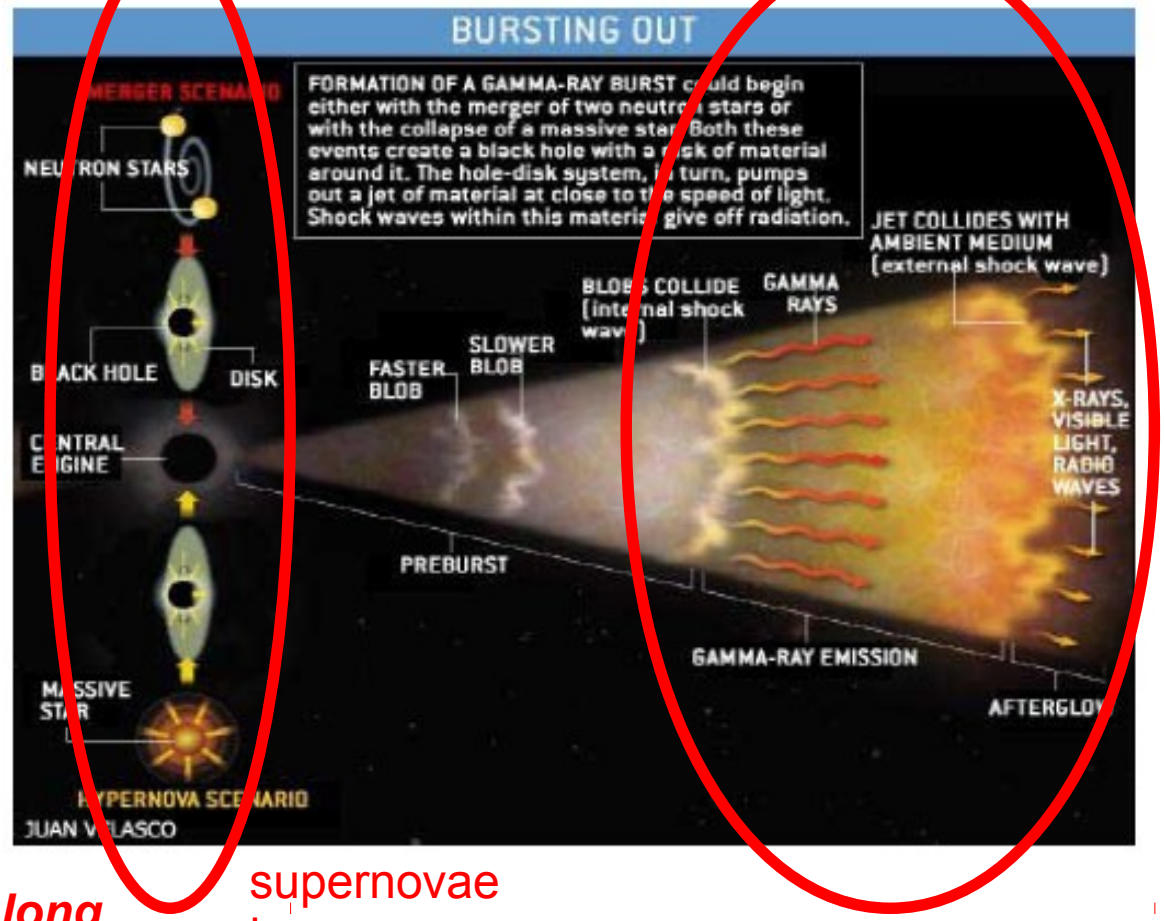
- Massive, compact, relativistic (→ GW)
- Sudden <1s (→ LIGO/Virgo)
- Baryons (→ neutrino)
- Close/frequent enough

- Galactic
  - Soft γ repeater
  - Micro quasar
- Extra-galactic
  - *Long GRBs*
  - Short GRBs
  - *Low-lumin. GRBs*

GW+HEN sources (1) : GRBs

short

binary mergers



long

supernovae hypernovae

GW

high-energy radiation γ+ν

Fireball model: colliding relativistic shells

accel. electrons produce **gamma rays** by synchrotron

accel. protons interact and produce pions, which decay in **high-energy neutrinos HEN**

caveat: Fermi observations puts the “internal shock model” in troubles. Basic scenario under reconsideration

GW+HEN sources (2) : "failed" GRBs

- Why GRB jets are relativistic? (compactness pb)

  non-relativistic: optical depth due to absorption $\gamma\gamma \rightarrow e^- e^+$ >> 1

  includ. relativistic effects, optical depth is x $\Gamma^{-2-2\alpha}$ (Lorentz fact.)

  optically thin if Γ = O(100), required to see flash of γ-rays

- Baryon (heavy) pollution → mildly relativistic jet Γ = O(1)

  optically thick, photon don't escape! No GRB. ("*failed*")

  more baryons means more neutrinos

- Events hidden from conventional telescopes

  accessible only to GW+HEN observation

  unknown rate, could be large

Ref: Ando & Beacom, PRL 2005

GW+HEN sources (3): connection between SN and GRB?

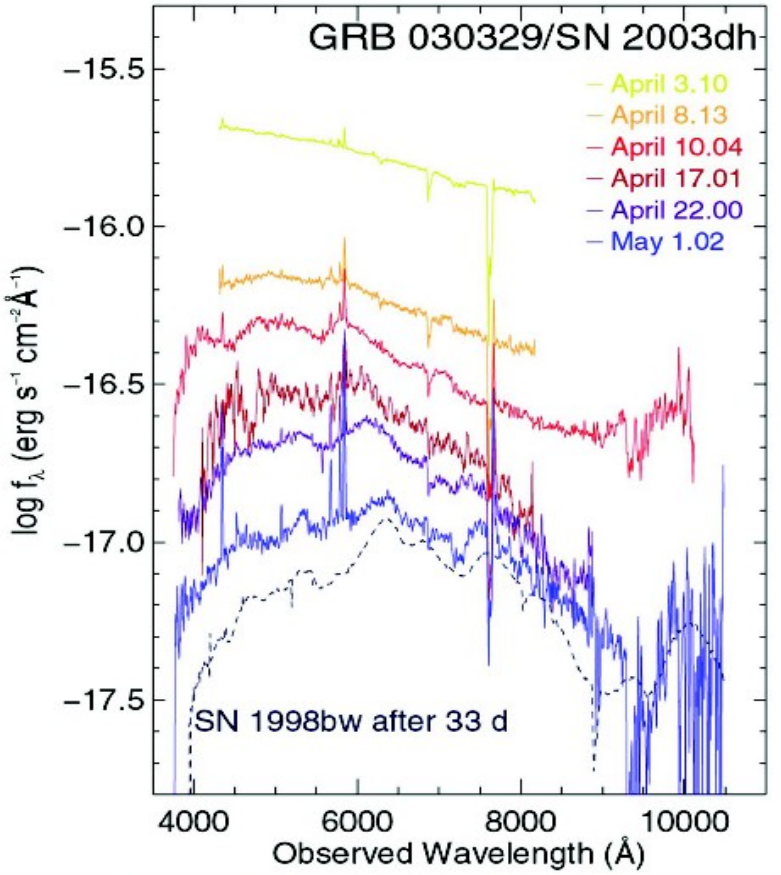
	SN	"Failed" GRB	GRB
Energy	10^{51} erg	10^{51} erg	10^{51} erg
Rate/gal	$\sim 10^{-2}\ \mathrm{yr}^{-1}$	10^{-5}–$10^{-2}\ \mathrm{yr}^{-1}$	$\sim 10^{-5}\ \mathrm{yr}^{-1}$
Γ	~1	~3–100	~100–10^3

Barion rich
Nonrelativistic
Frequent

Similar kinetic energy

Baryon poor
Relativistic jets
Rare

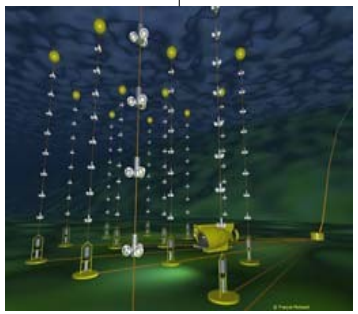
taken from Ando (2009)

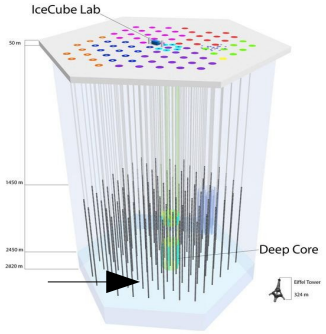


Hjorth et al. 2003; Stanek et al. 2003

missing link between SN and GRB?

Common data sets with HEN telescopes





ANTARES
(mediterranean sea)

IceCube
(south pole)

2007 LIGO Virgo S5/VSR1 | ANTARES 5 strings | IceCube 22 strings

2009 eLIGO Virgo+ S6/VSR2 | ANTARES 12 strings | IceCube 59 strings

2015 aLIGO adVirgo | Km3net ? | Ice Ray ?

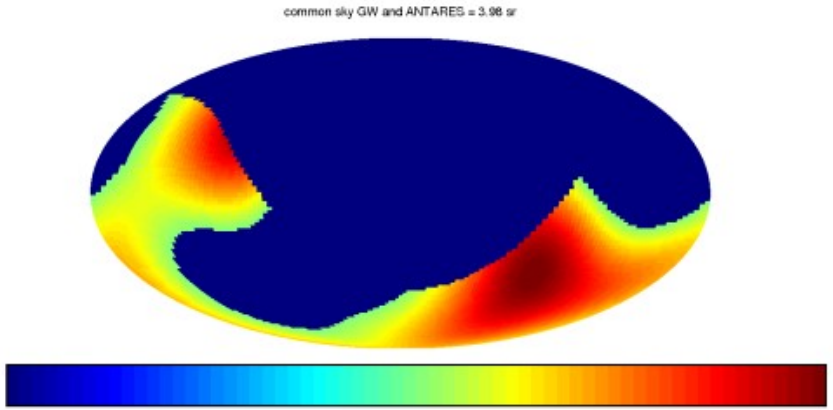
2020? Einstein telescope & LISA

time

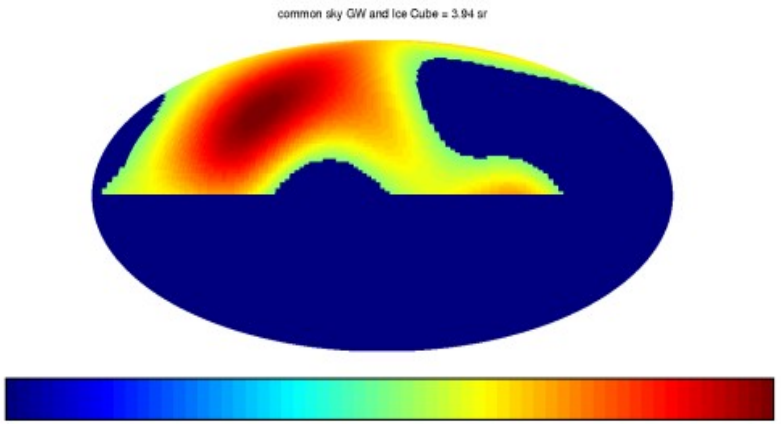
Data exchange agreement being finalized

Feasibility: basic ingredients

ANTARES & GW det.



IceCube & GW det.



Sky coverage

- ANTARES and IceCube sky complementary
- Each have ~30 % common sky with GW det.

Resolution of source localization

- ANTARES has sub-degree error box
- IceCube has ~ degree error box

- GW network has few degree error box

Exploring possible data analysis strategies

- GW and HEN = same search style

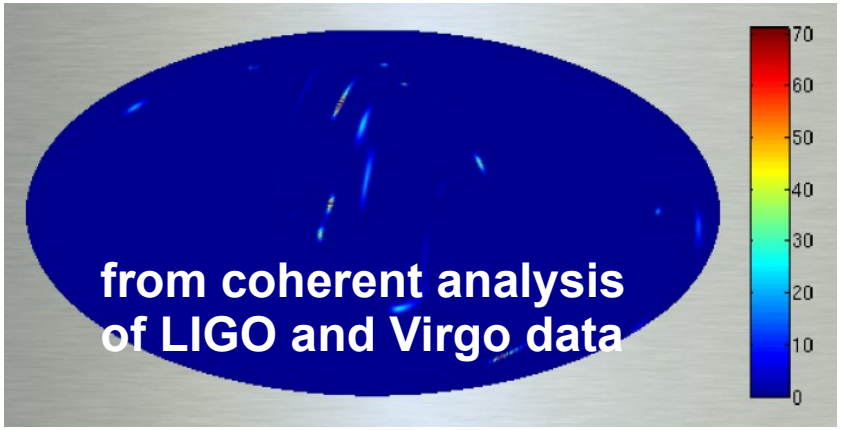
  few small signal buried in background noise

- *rationale for a coincidence search :*
  independent detectors : prob. of accidental coincidence (backgrounds) is **very low**
  if coinc. observed, high confidence in detection

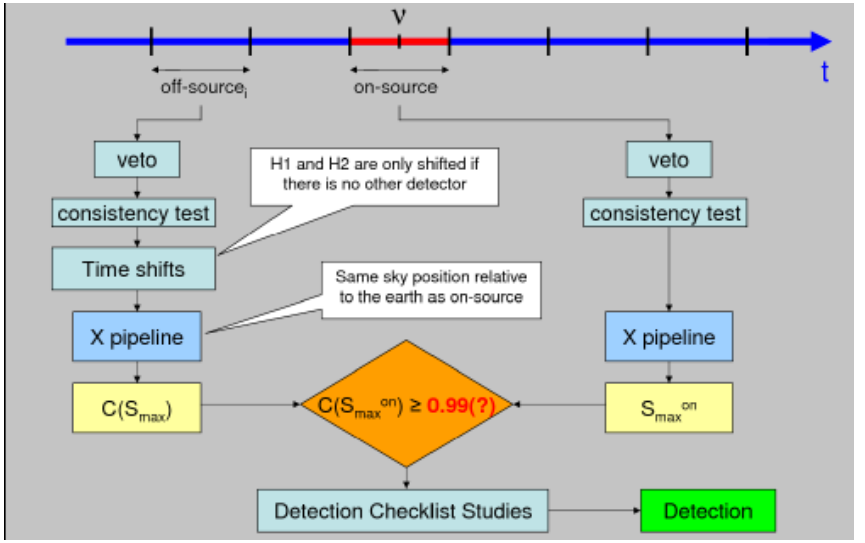
- first studies initiated within LIGO/Virgo and Icecube and independently within ANTARES

  detect an excess of time/spatial coincidence

  reduce false alarm rate, dig deeper into background

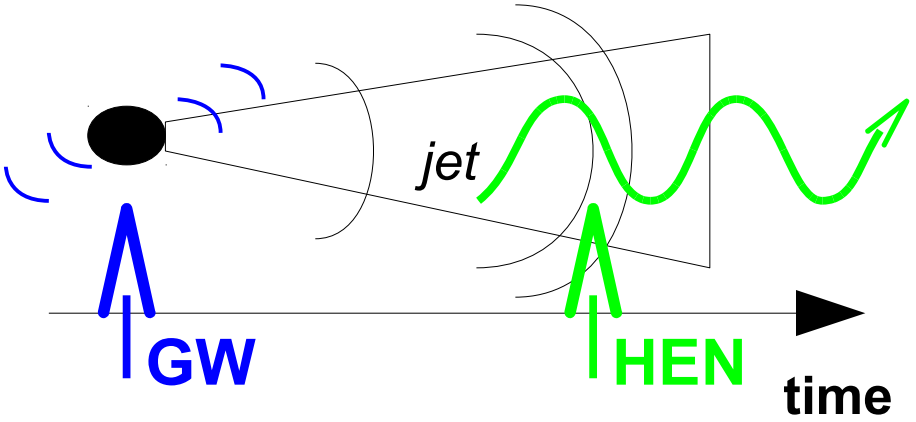


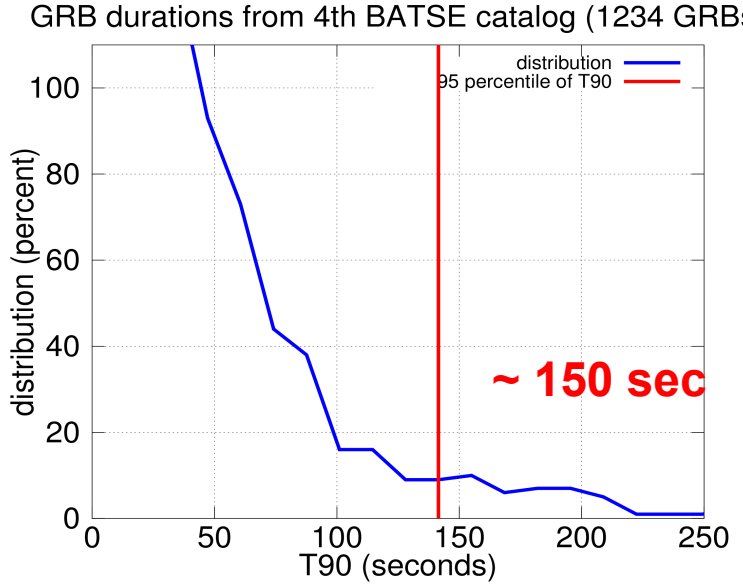
Investigate the use of X pipeline currently used for burst searches in coincidence with GRB

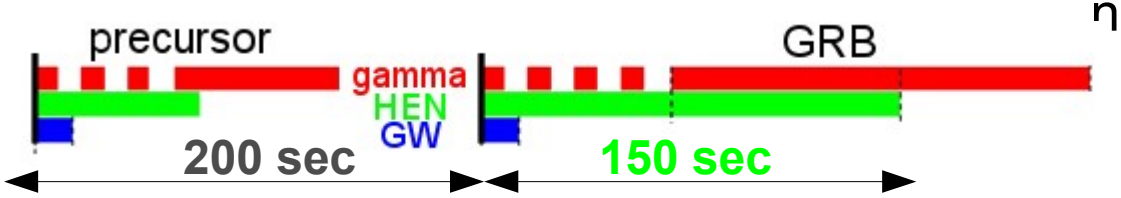


Y. Aso et al. APS'08 arXiv:0711:0107v2
Pradier arXiv:0807.2567v1

Coincidence time window







- Time delay between GW and HEN
- Source/model dependent
- Case study: *long GRBs* (Bartos et al.)

  GW emission is prompt

  Neutrinos emission simultaneous to γ

  GRB duration as indicator for time window: <~ 150 sec (from 4th BATSE catalog)
- GRB may be preceded by precursor

  final window is [-350, +200] sec
- Reconsider this window in light of Fermi observations (low statistic for now)

Conclusions

- Working group joining GW and HE neutrinos (IceCube and ANTARES) just formed
- In the process of signing data exchange agreement
- Individuate scenarios for potential joint sources
- Propose procedure for the time/spatial coincidence of GW and HEN events
- Pathfinder effort for advanced detectors