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

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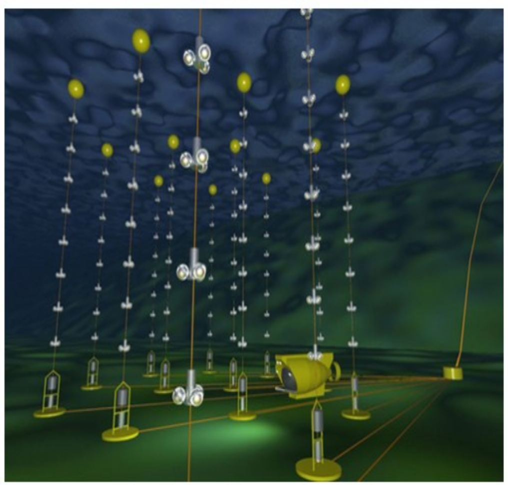
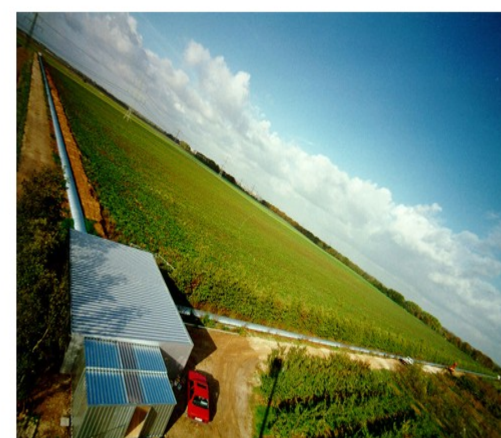
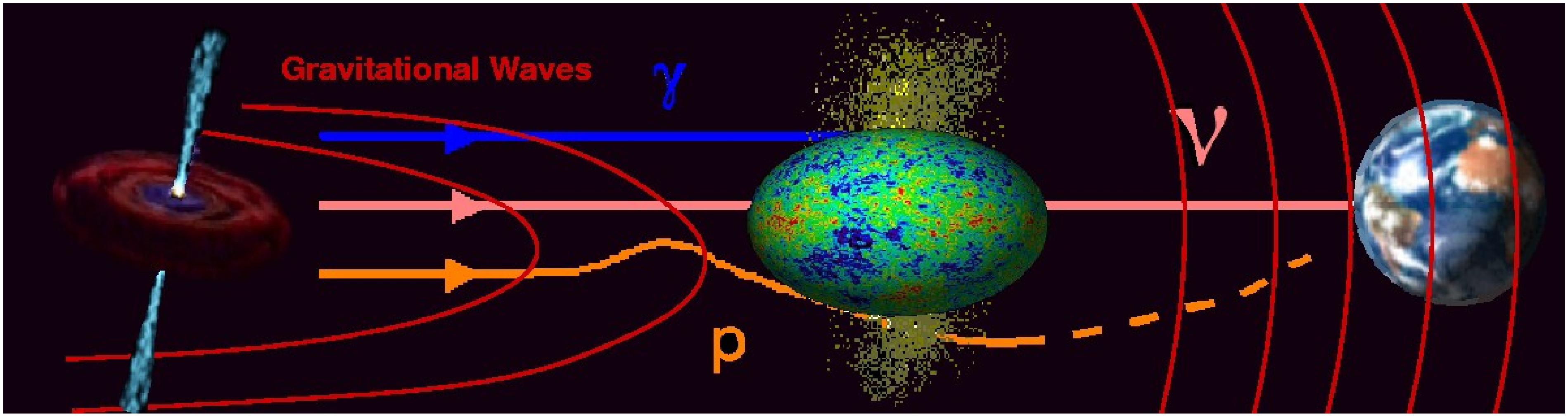
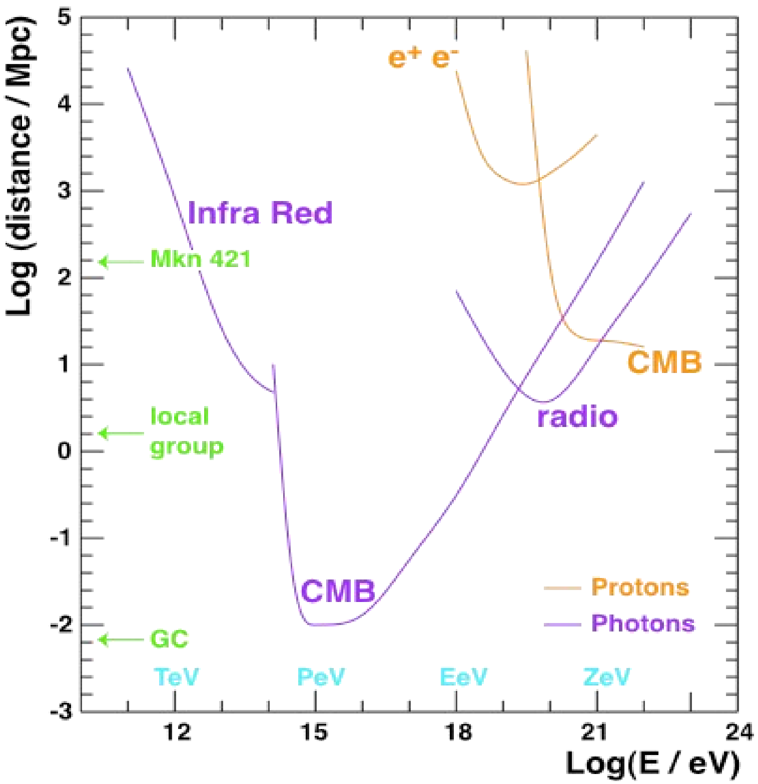




GW and HEN



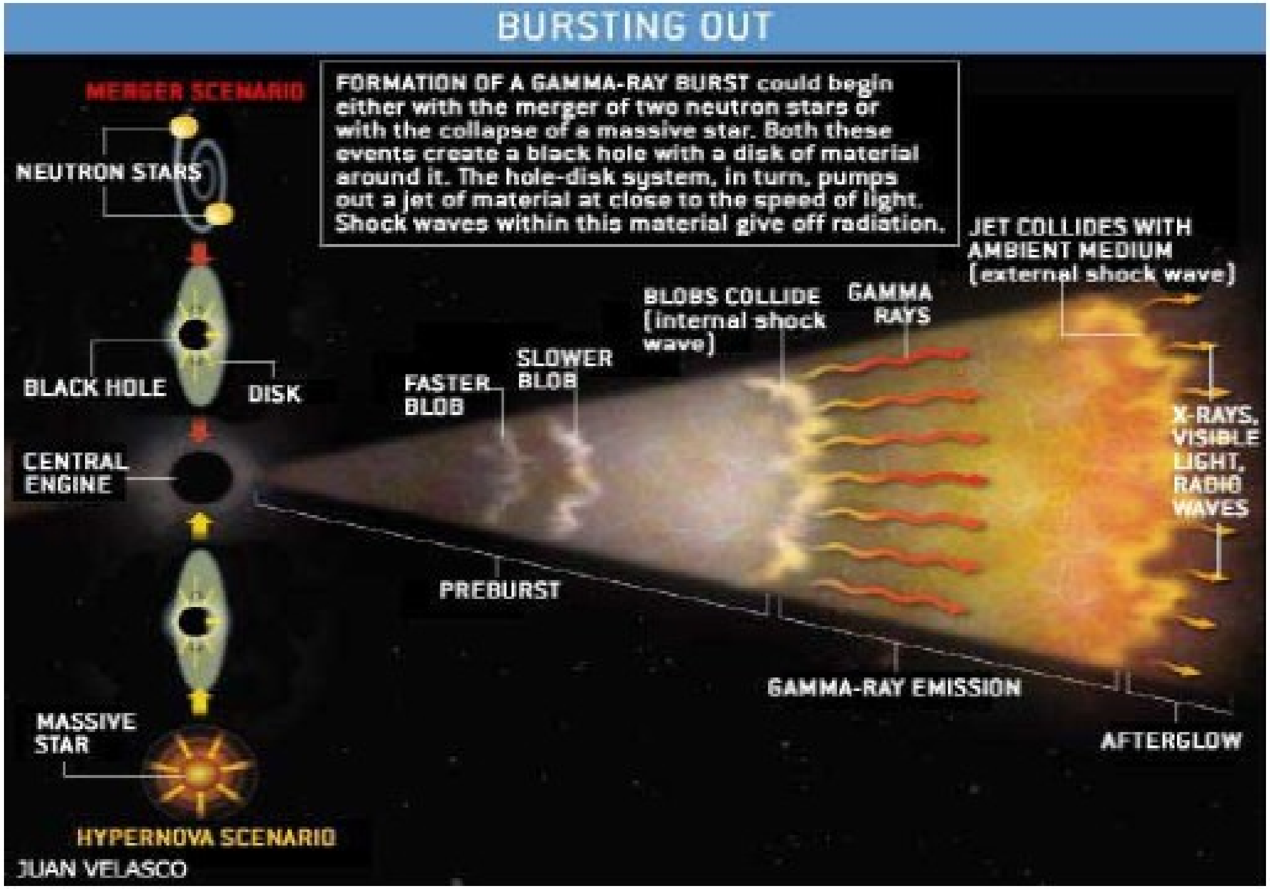


GW and HEN as cosmic messengers

- no absorption: travel cosmological distances
- no deflection by magnetic fields: trace back
- weakly interacting: escape from dense object

GW+HEN sources (1) : GRBs

Fireball model: internal shock of relativistic shells



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

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

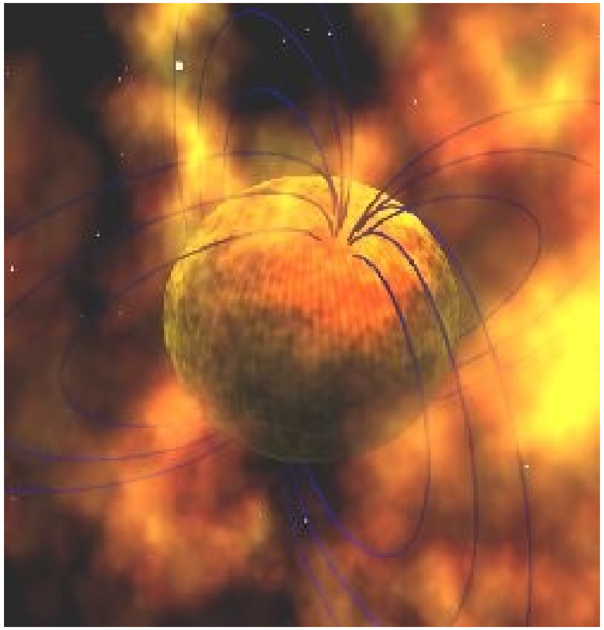
GW+HEN sources (2): "Failed GRBs"

- GRBs are emitted from an ultra-relativistic (Lorentz factor from 100 to 1000) ejecta launched from the central source.
- to boost the ejecta at ultra-relativistic speed, *jets have to be extremely baryon-poor*
- very difficult requirement: this issue is not well understood.

- *Baryon-rich jets are slower* (midly relativistic: Lorentz factor < 10). Jet becomes optically thick: No gamma-ray can escape.
- Possible scenario:
- Gamma-ray observatories only observe the (possibly small?) fraction of the sources producing baryon-poor jets
- Remaining population hidden from any conventional telescopes? Accessible only by GW+HEN observations
- More baryons imply an *enhanced production of neutrinos*

Ref: Ando and Beacom, astro-ph/0502521

GW+HEN sources (3): Soft gamma-ray repeaters

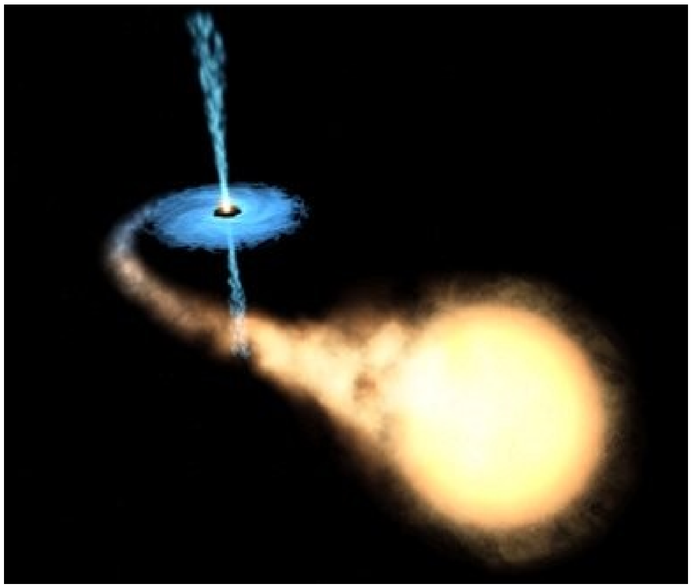


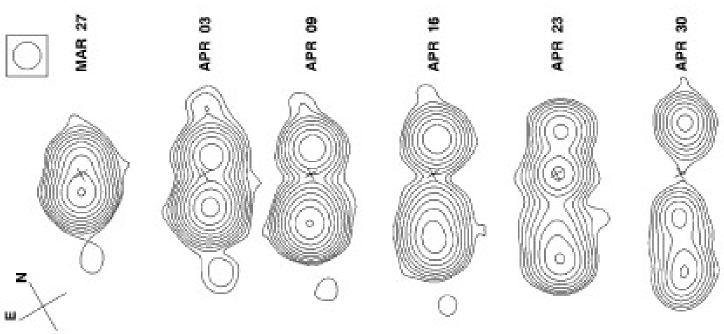
- SGRs are X-ray stars that emit bright, repeating flashes of soft (i.e. low-energy) gamma rays.
- 3+1 SGRs in our Galaxy. Had giant flares.
- magnetar model = super-magnetized NS
- large B leads to “crust quakes” $\rightarrow$ flares :
  - rearrangements of B accelerate e and p, thus producing gamma and neutrinos
  - shear vibrations in the kHz freq range, excite non-radial modes damped by GW.
- Estimate few events from SGR1806-20 in AMANDA/ANTARES size detector
- UL on GW placed by LIGO S5 is 10^{45} erg

to be compared to EM lum 10^{44} to 10^{46} erg

Refs:
Halzen et al. astro-ph/0503348v1
LSC, arXiv:0808.2050

GW+HEN sources (4)
Micro-quasar flares





Mirabel & Rodriguez, 1999

- X-ray and radio/IR flares from stellar-mass BH accreting from companion.
- Coupled accretion/ejection explain observations
  - X-ray = inner accretion disk
  - radio/IR = ultra-relativistic (Lorentz fact = 5.0) ejection of blobs of plasma (ballistic motion).
- GW emission from microquasar?

"cannonball model" $$h \sim 4.0 \times 10^{-21} \frac{\gamma}{5.0} \frac{m}{\mathbf{10^{-6}} M_0} \frac{10\, kpc}{d}$$

excitation of BH normal modes?

- If e and p jet, emission of high-energy gamma and neutrinos. TeV gamma observed by Hess/EGRET

Refs: Mirabel & Rodriguez, 1999, Pradier, arXiv:0807.2562v1 Segalis & Ori, 2001

Common data sets

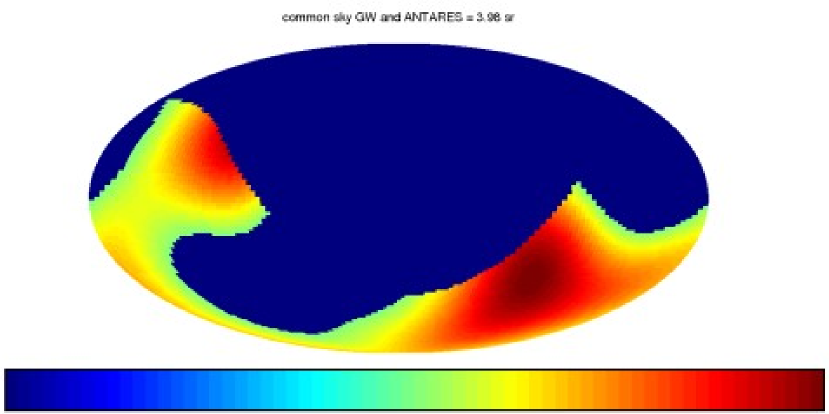
2007	LIGO Virgo S5/VSR1	ANTARES 5 strings	Ice Cube 22 strings
2009	eLIGO Virgo+ S6/VSR2	ANTARES 12 strings	Ice Cube 50? strings
2015	aLIGO adVirgo	Km3net ?	Ice Ray ?
2020?	Einstein telescope & LISA		

No official data exchange agreement yet

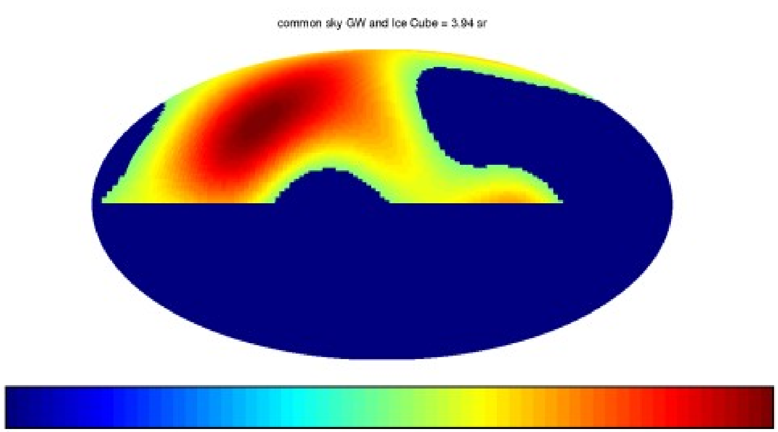
time

Feasibility: basic ingredients

ANTARES & GW det.



IceCube & GW det.



Sky coverage

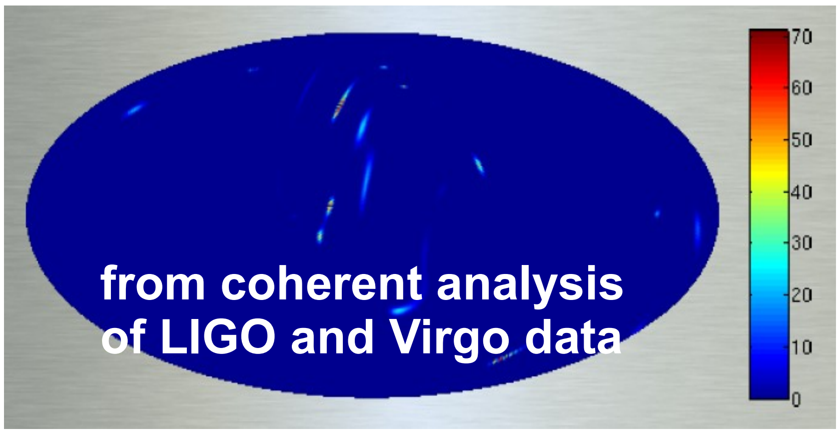
- ANTARES and IceCube sky complementary
- Each have ~30 % common sky with GW det.

Resolution of source localization

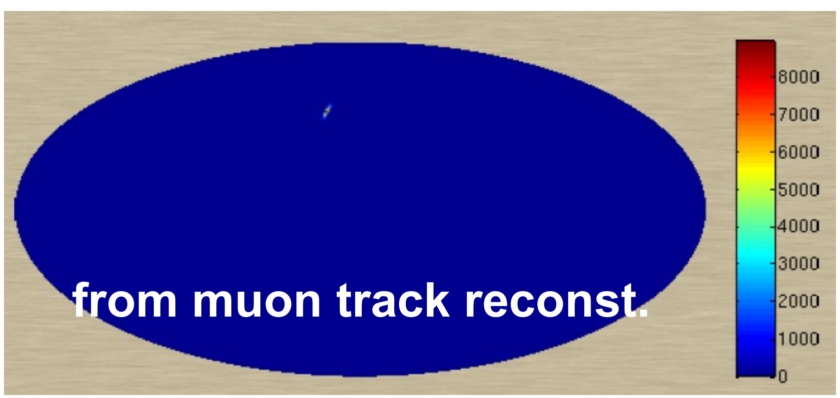
- ANTARES has sub-degree error box
- IceCube has ~ degree error box
- GW network has few degree error box

Project for a joint analysis

LIGO & Virgo



ANTARES and/or Icecube



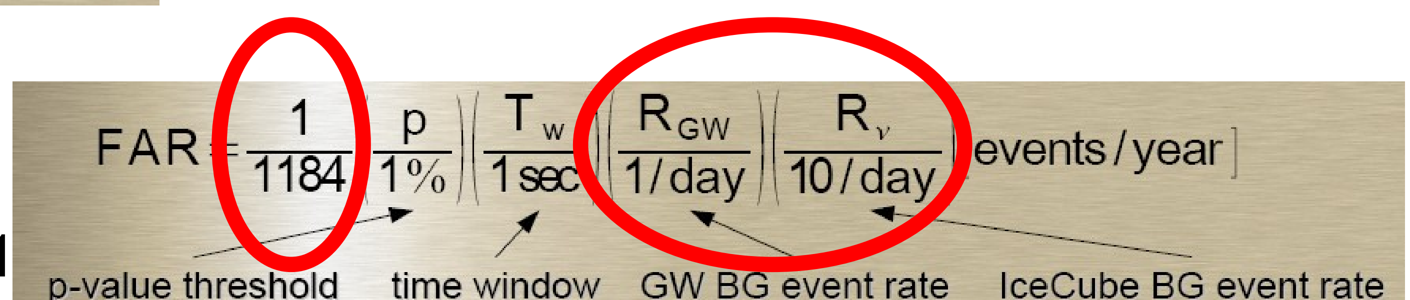
- GW and HEN = same search style
  few small signal buried in background noise

- *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

  - time coinc.: model dep., use several time win
  - Spatial coinc. : overlap post. sky maps

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



Conclusions

- Summary of first investigations of GW and HEN coincidences
- Individuate scenarios for possible common sources
- Common data sets are/will be available
- First discussions in view of MoU agreements
- Propose procedure for the time/spatial coincidence of GW and HEN events. Tests using simulated data with preliminary results for IceCube and on-going efforts to include ANTARES.
- Small FAR, relaxed threshold, dig into background noise

GW+HEN Workshop

May 18-20 2009 at APC Paris
review astrophysics, detectors, data analysis
promote scientific exchange

Workshop on Gravitational Waves and High Energy Neutrinos

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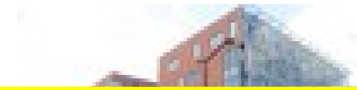
Many of the astrophysical sources and violent phenomena observed in our Universe are potential emitters of gravitational waves and high-energy cosmic radiation, in the form of photons, hadrons, and presumably also neutrinos. Both gravitational waves and high-energy neutrinos are alternative cosmic messengers that

GW+HEN Workshop



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also neutrinos. Both gravitational waves and high-energy neutrinos are alternative cosmic messengers that