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

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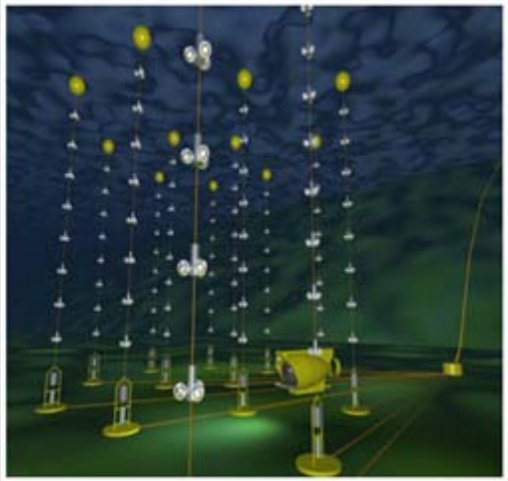
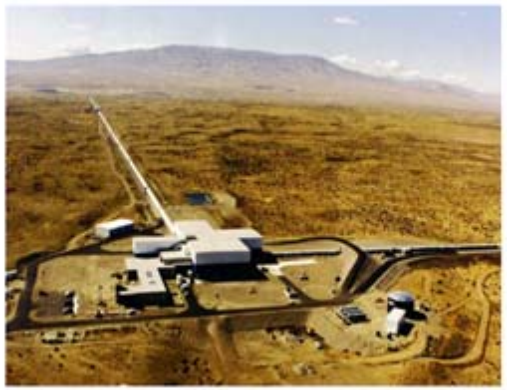
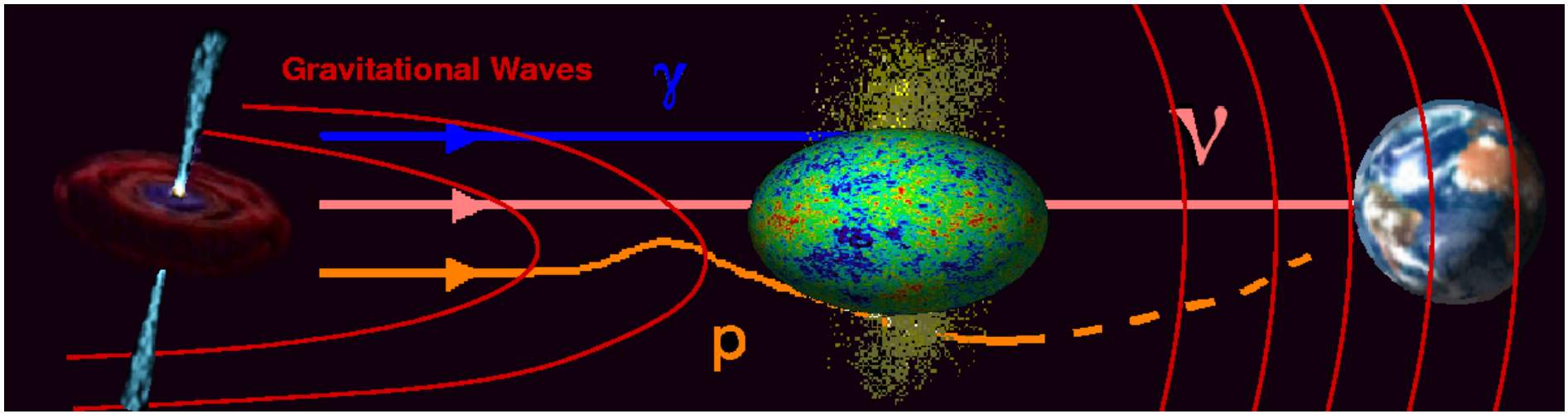
References: http://gwhen-2009.org






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

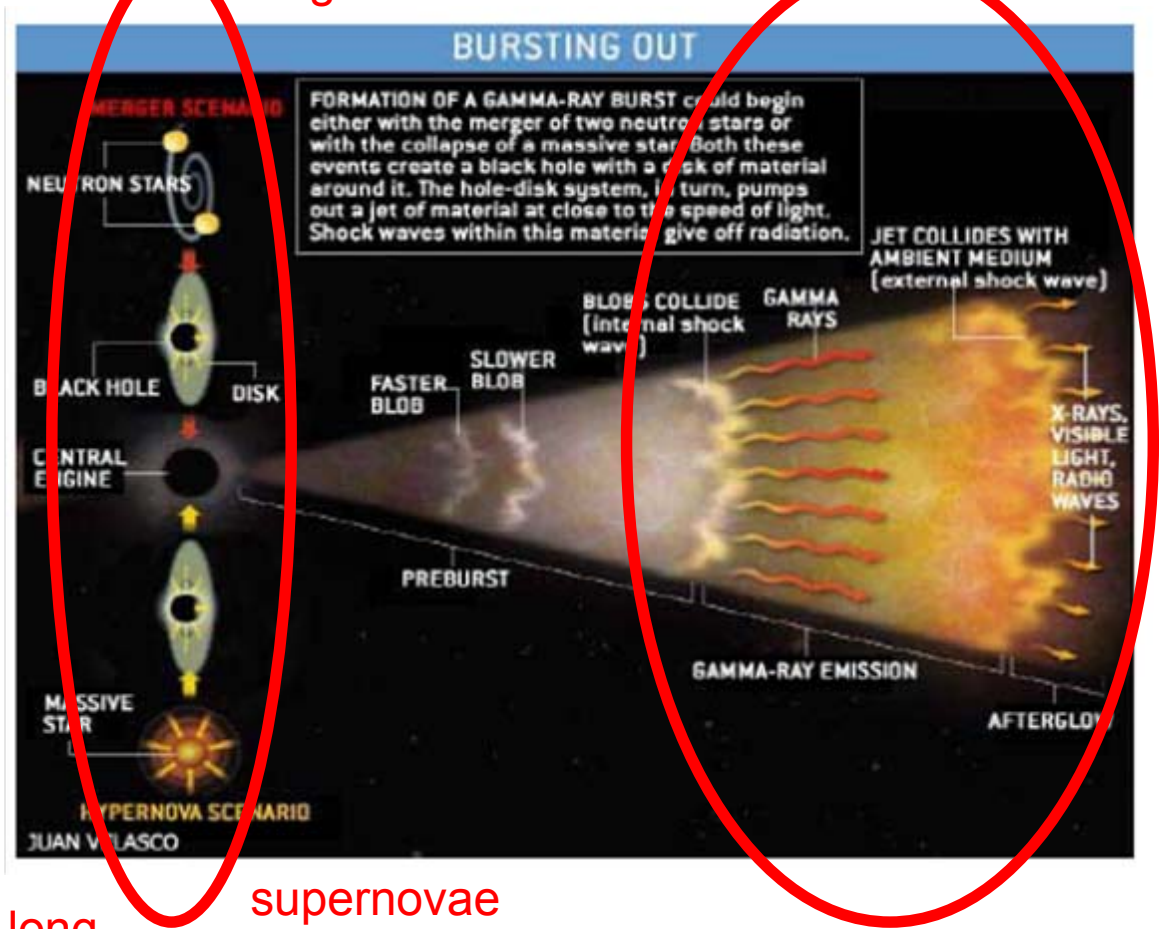
- Massive, compact, relativistic (→ GW)
- Sudden <1s (→ LIGO/Virgo)
- Baryons (→ neutrino)
- Close/frequent enough

- 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**

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?

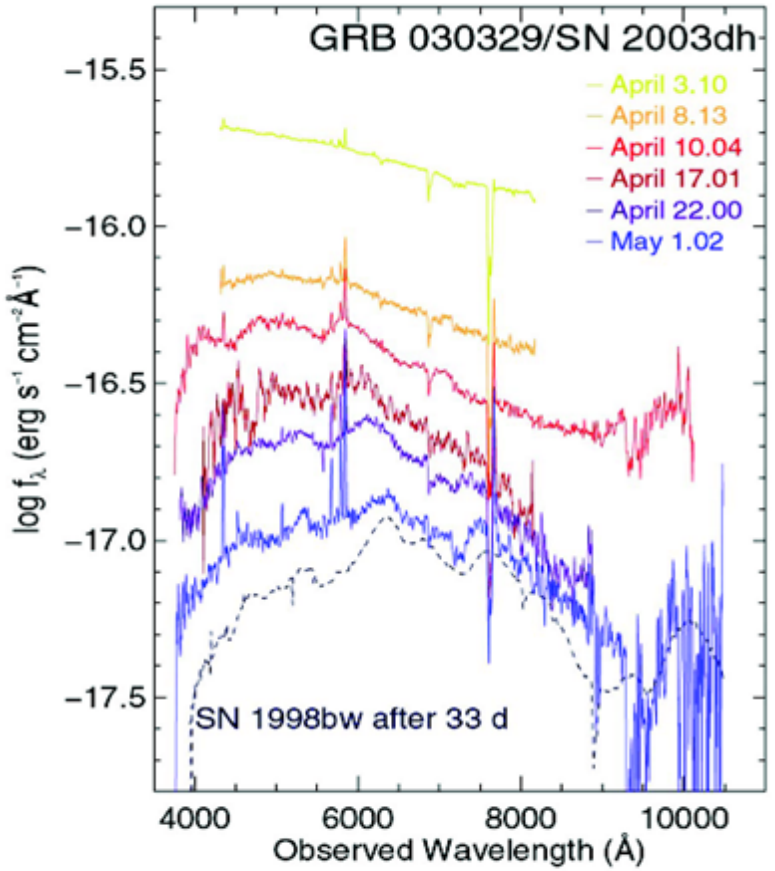
	SN	"Failed" GRB	GRB
Energy	10^{51} erg	10^{51} erg	10^{51} erg
Rate/gal	$\sim 10^{-2}$ yr^{-1}	10^{-5}–10^{-2} yr^{-1}	$\sim 10^{-5}$ yr^{-1}
Γ	~1	~3–100	~100–10^3

Barion rich
Nonrelativistic
Frequent

Similar kinetic energy

Baryon poor
Relativistic jets
Rare

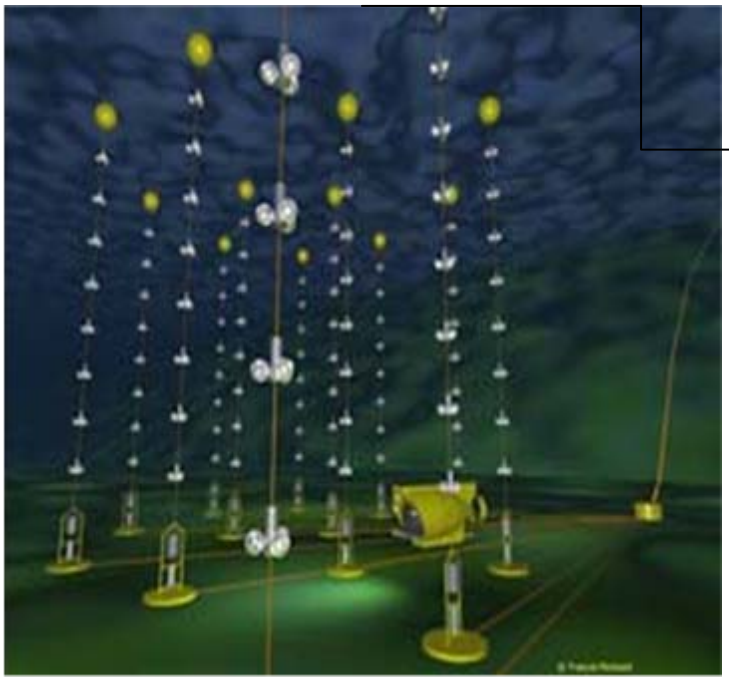
taken from Ando (2009)



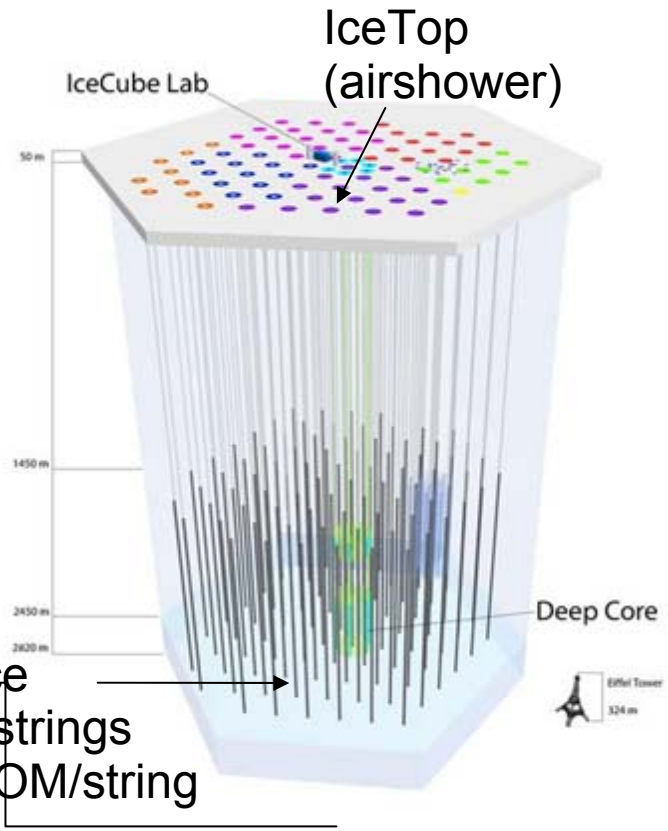
Hjorth et al. 2003; Stanek et al. 2003

missing link between SN and GRB?

HEN telescopes



12 lines
75 OM/string

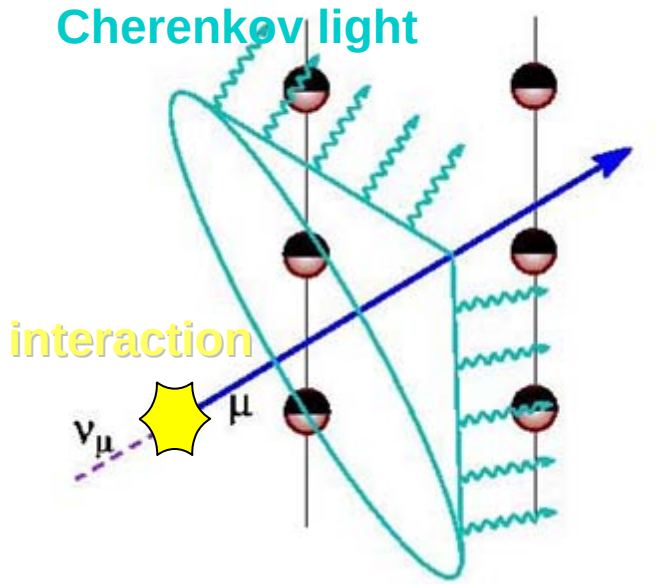


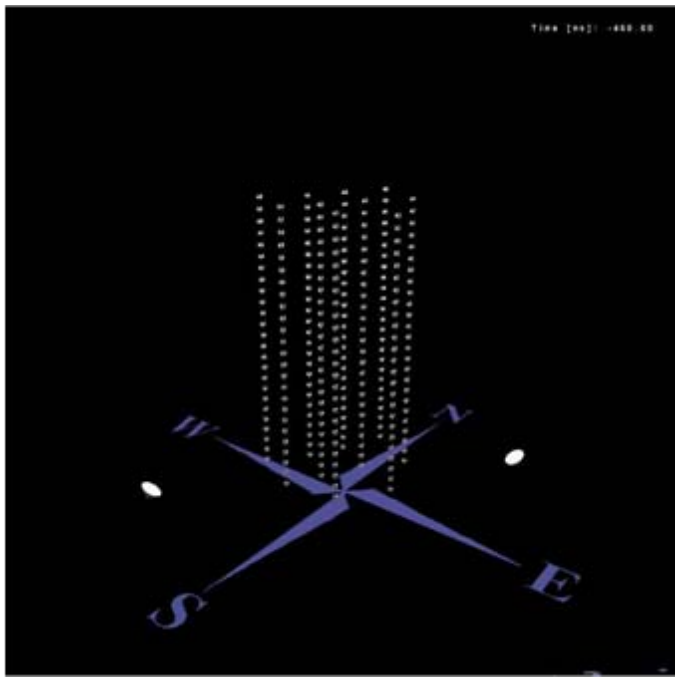
InIce
80 strings
60 OM/string

ANTARES
(mediterranean sea)

IceCube
(south pole)

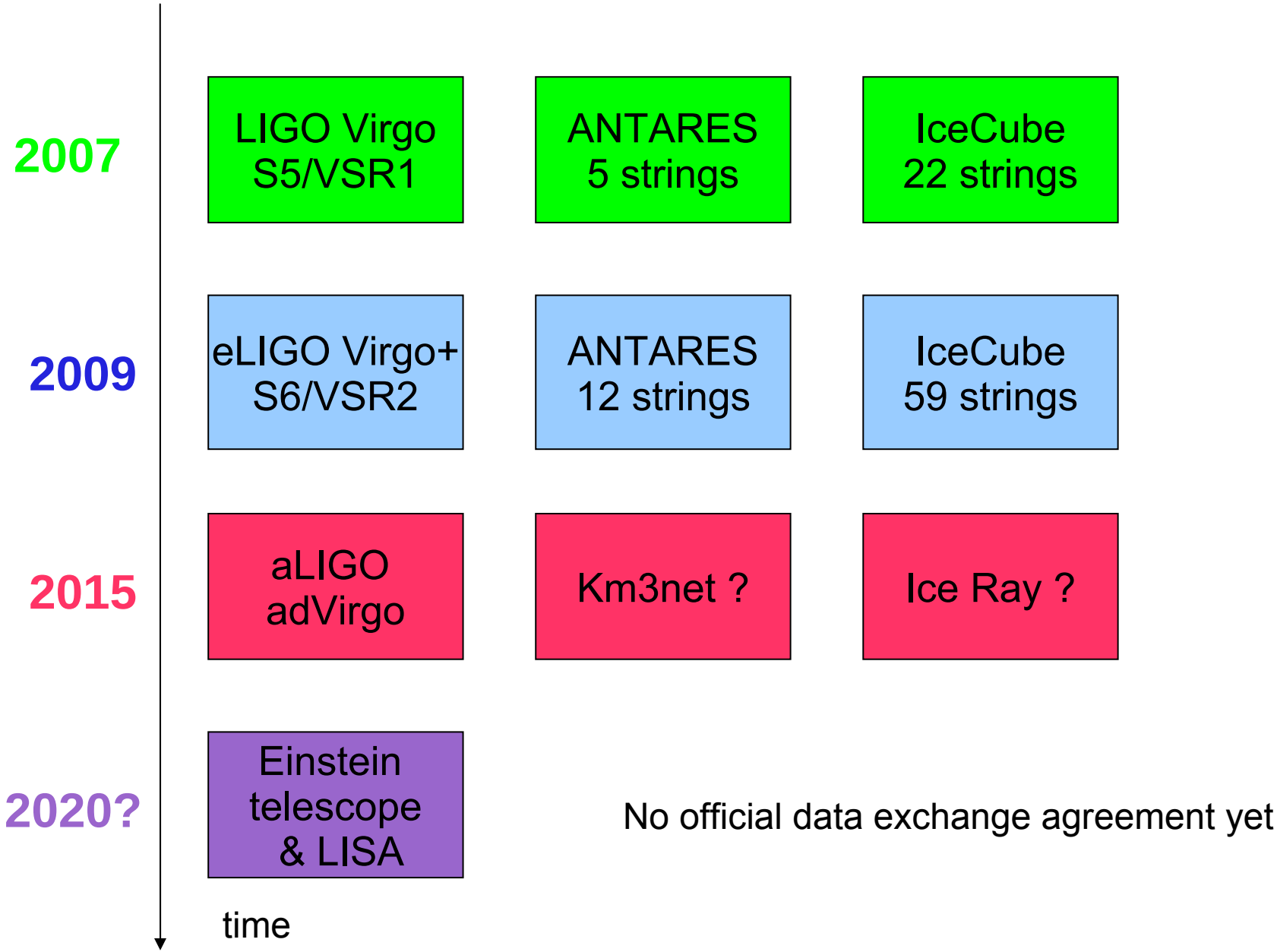
HEN detection principle





- neutrino → muon → cherenkov → photomultiplier
- muon track reconstruction based on local flash coincidences compatible with the Cherenkov light front
- sensitive in a broad region about TeV
- reconstruct neutrino direction with typical error
  Icecube ~ 1 degree
  ANTARES ~ .3 degree
- look downward
  IceCube northern sky
  ANTARES southern sky
- foregrounds: atmospheric muons (cosmic rays), atmospheric neutrinos → look for statistical excess

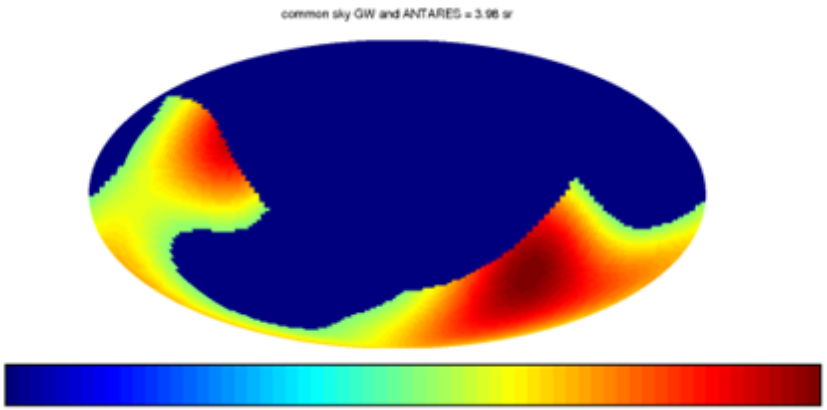
Common data sets



No official data exchange agreement yet

Feasibility: basic ingredients

ANTARES & GW det.

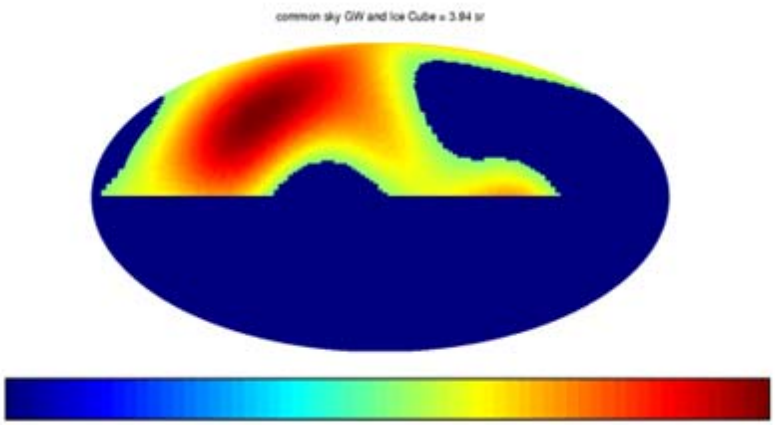


ky coverage

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

Resolution of source localization

IceCube & GW det.

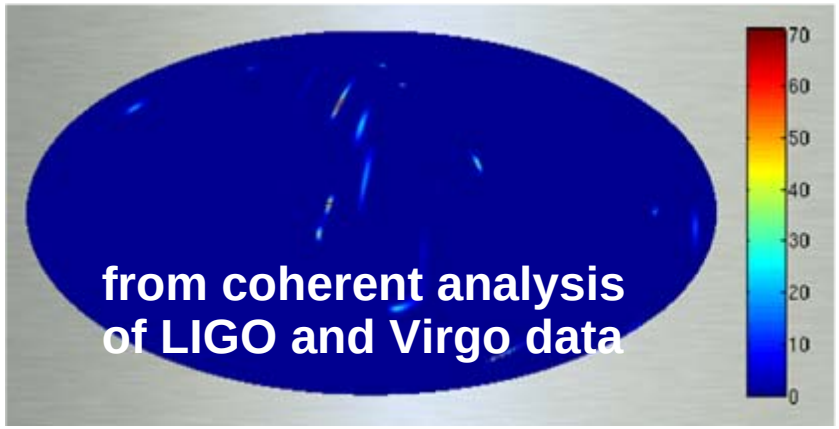


- ANTARES has sub-degree error box
- IceCube has ~ degree error box

- GW network has few degree error box
  (see presentations by A Searle & S Klimenko)

Project for a joint analysis

LIGO & Virgo



- 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

ANTARES and/or Icecube

- 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

$$FAR = \frac{1}{1184}\left(\frac{p}{1\%}\right)\left(\frac{T_w}{1\,\mathrm{sec}}\right)\left(\frac{R_{GW}}{1/\mathrm{day}}\right)\left(\frac{R_\nu}{10/\mathrm{day}}\right)\ [\mathrm{events/year}]$$

p-value threshold time window GW BG event rate IceCube BG event rate

Conclusions

- First investigations in view of GW and HEN coincidences
- Individuate scenarios for potential joint sources
- Common data sets are/will be available
- Collaborative efforts with IceCube and ANTARES being set-up, pathfinder for advanced detectors
- Propose procedure for the time/spatial coincidence of GW and HEN events

small FAR, allow to relax threshold, dig into backgd noise

- Synergy/complementarity with other multi-messenger projects (GW + γ-ray, low-energy neutrinos, optical follow-up, ...)