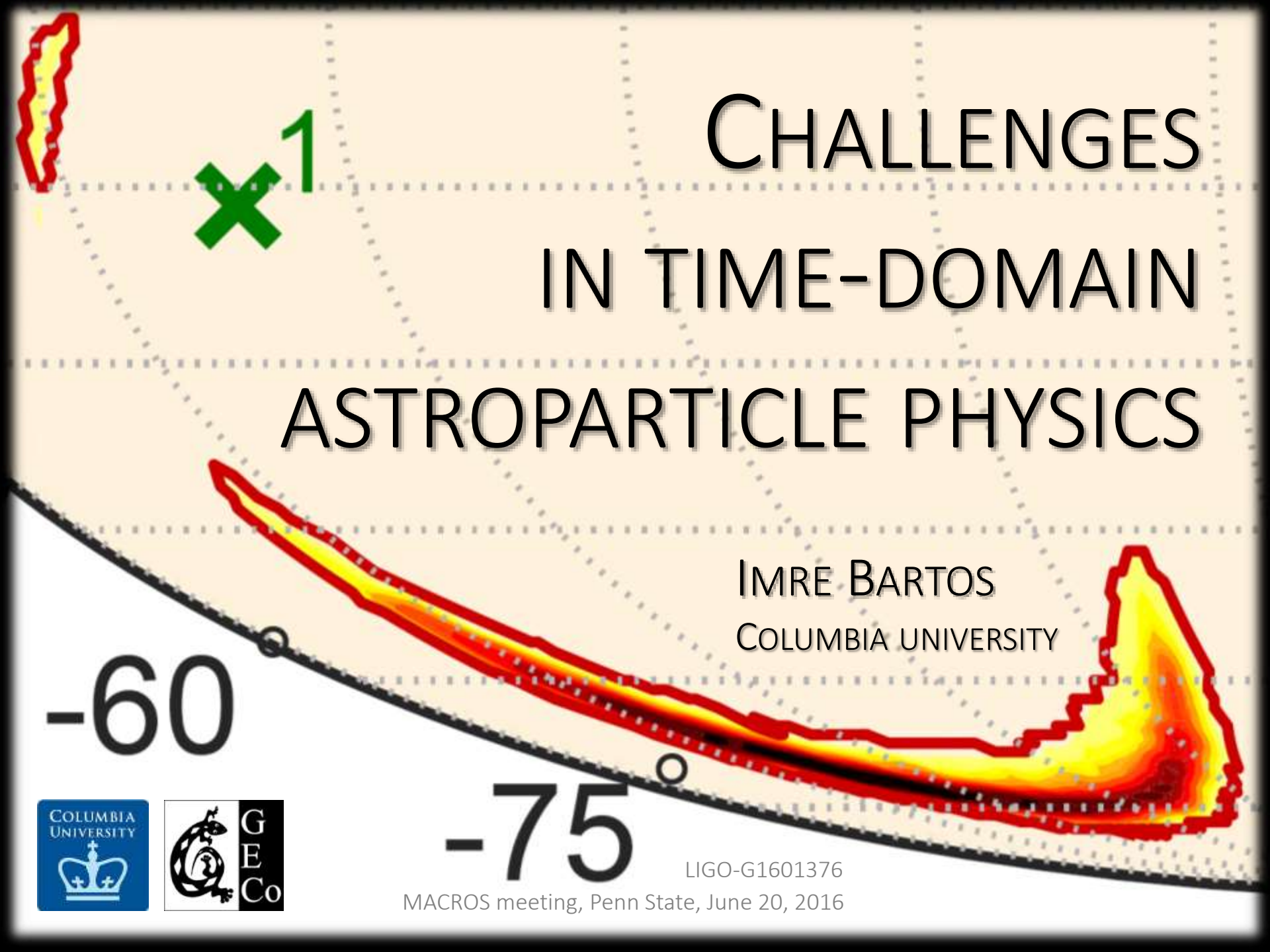


CHALLENGES IN TIME-DOMAIN ASTROPARTICLE PHYSICS

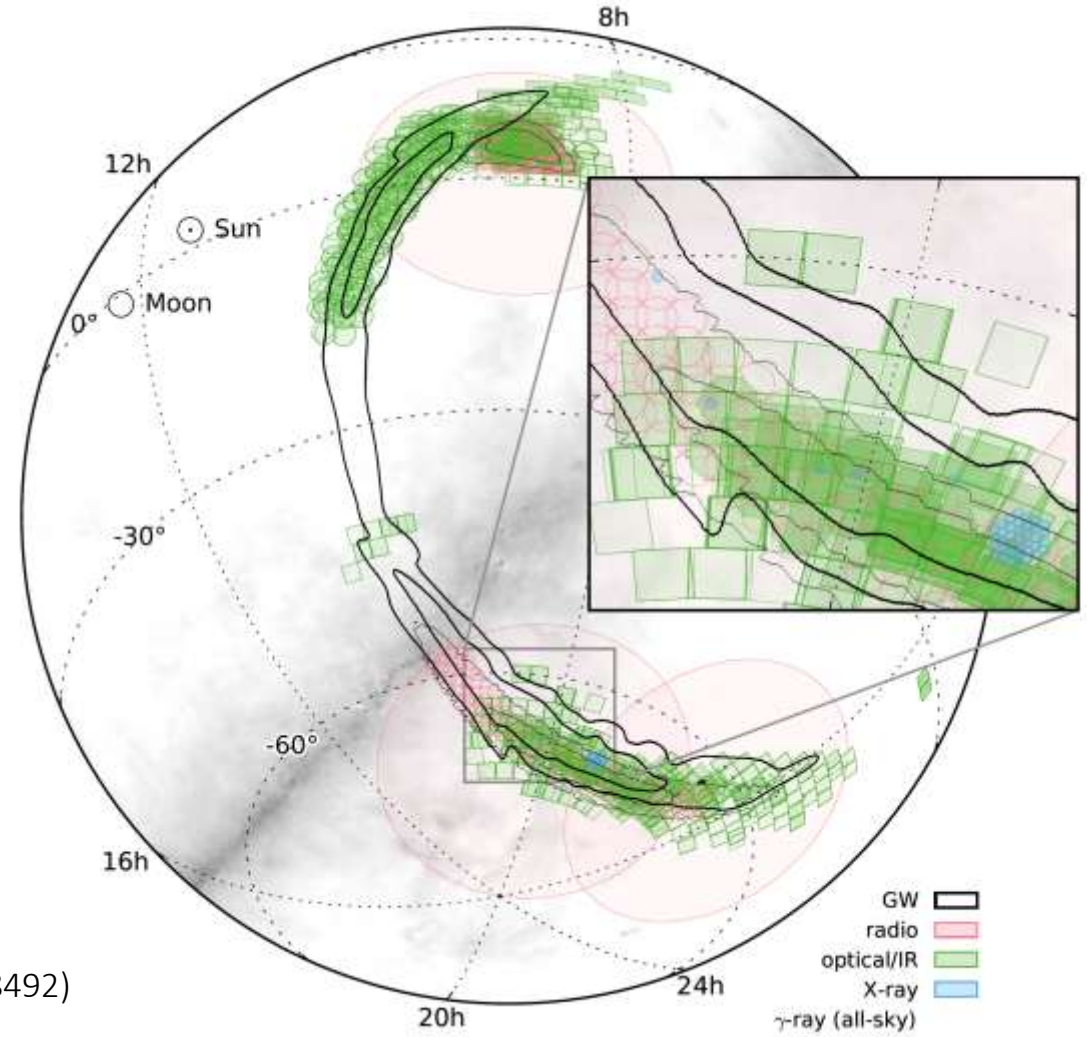
IMRE BARTOS
COLUMBIA UNIVERSITY

LIGO-G1601376
MACROS meeting, Penn State, June 20, 2016

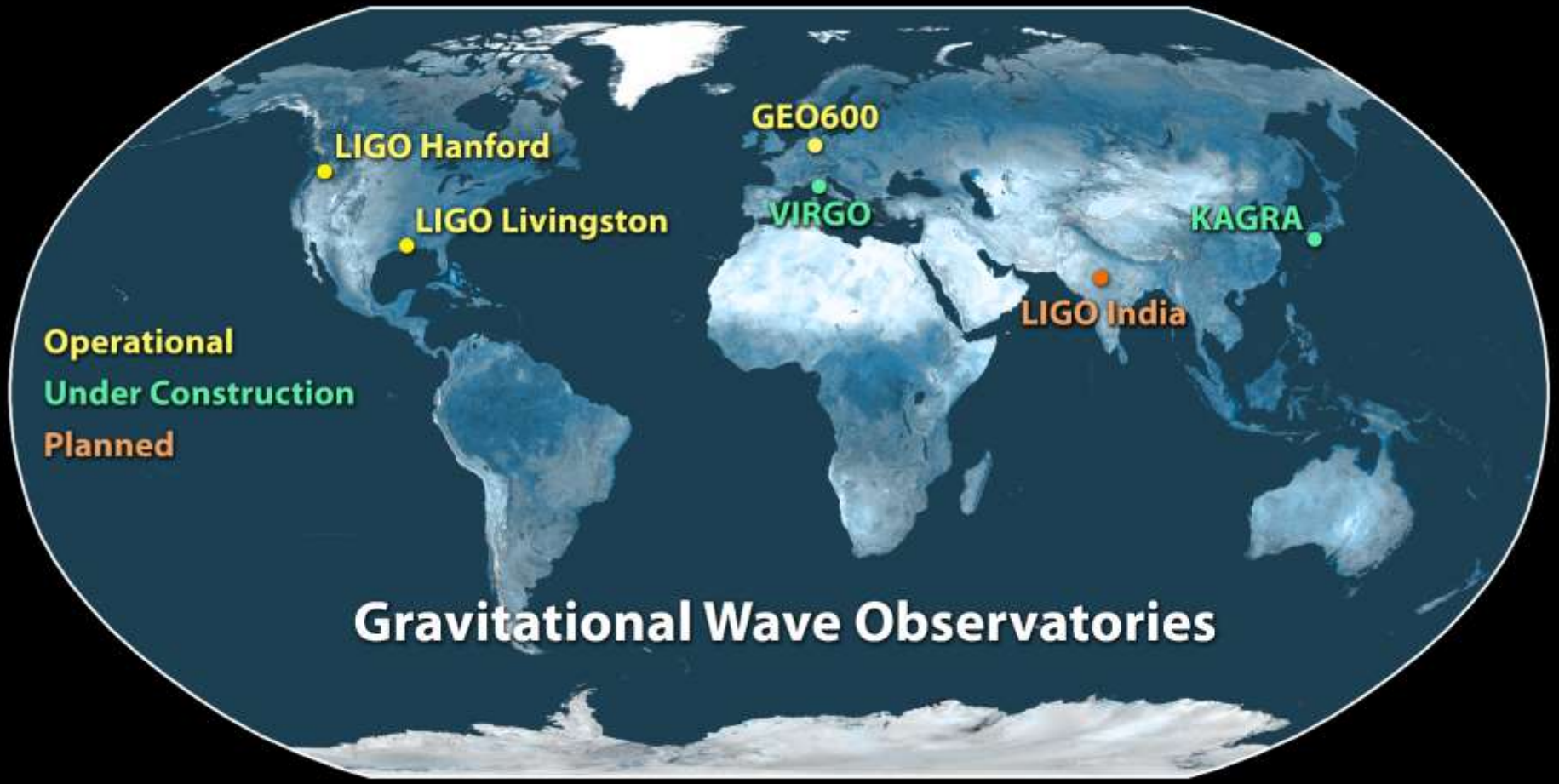
- EM follow-up of GWs
- The question about black holes
- Galaxy catalogs
- Neutrino-multimessenger follow-up
- Astrophysical information

Electromagnetic follow-up of gravitational waves

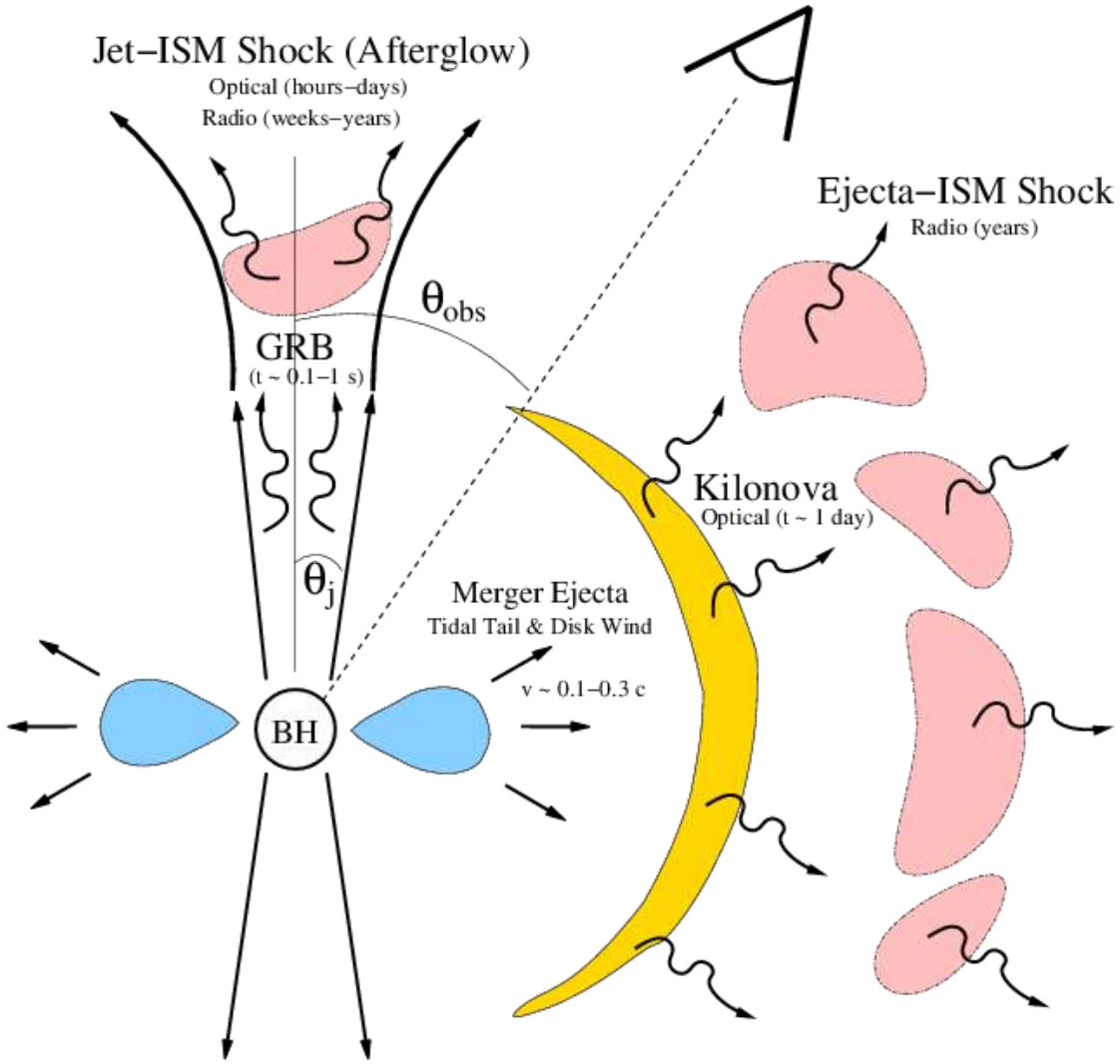
REDUNDANT EM FOLLOW-UPS



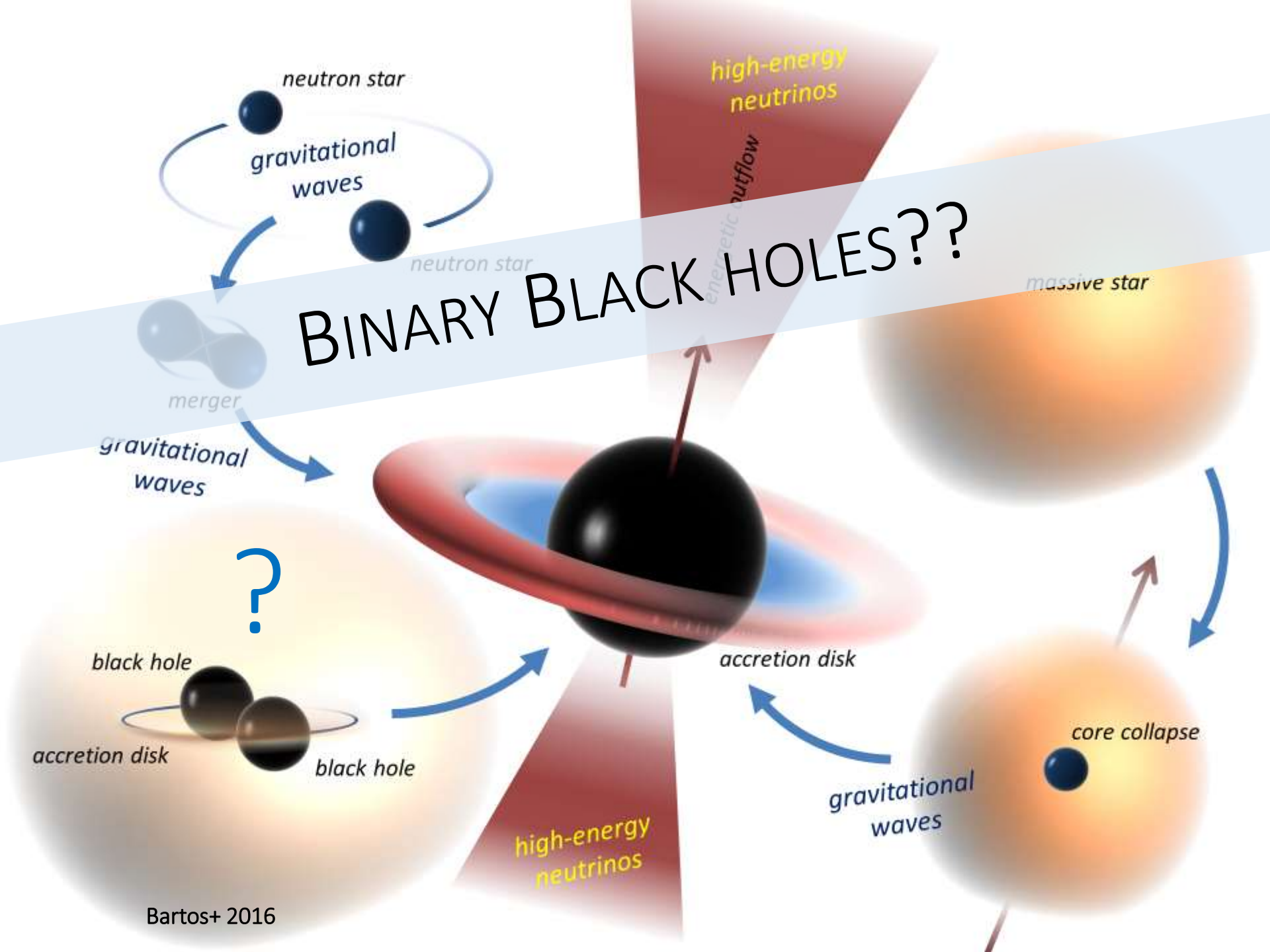
Abbott et al. 2016 (1602.08492)


LIGO Hanford
LIGO Livingston
GEO600
VIRGO
KAGRA
LIGO India
Operational
Under Construction
Planned
Gravitational Wave Observatories

GUIDE FOLLOW-UP WITH EM MODELS

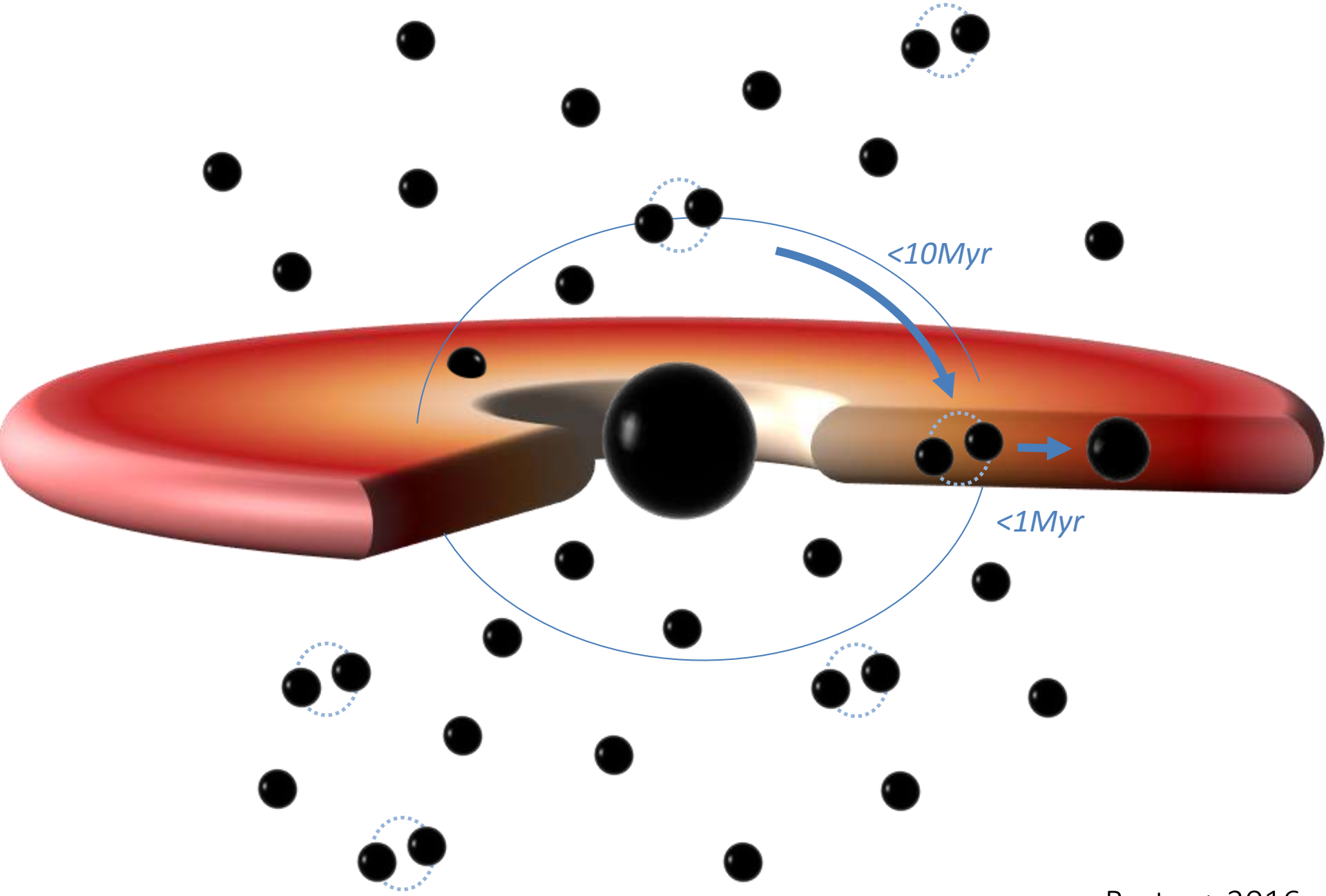


Metzger & Berger 2012



BINARY BLACK HOLES??

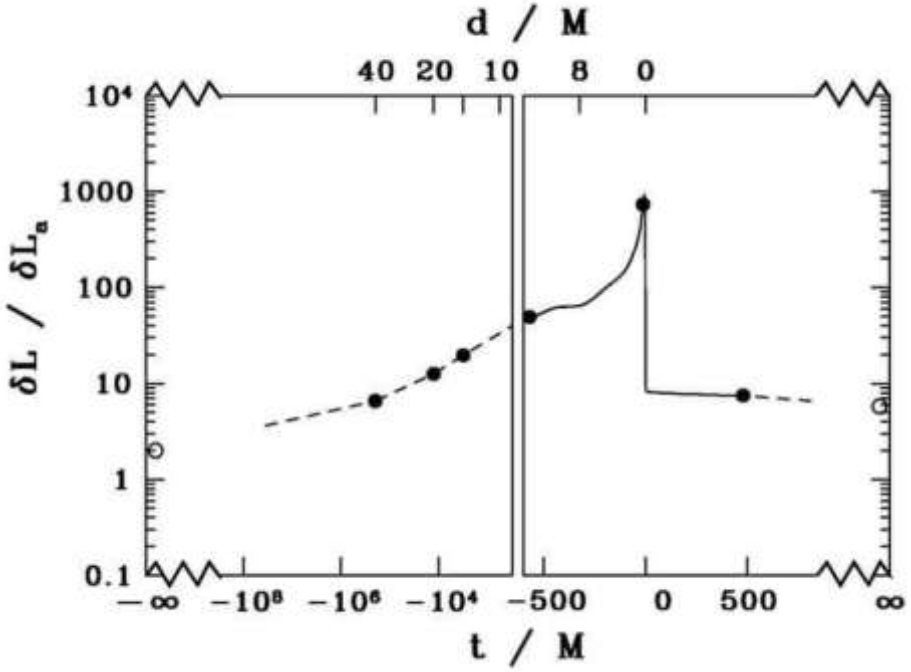
Bartos+ 2016



Bartos+ 2016

POTENTIALLY PROMISING

Disk accretion: super Eddington accretion and luminosity is possible (e.g., Jiang+ 2014)



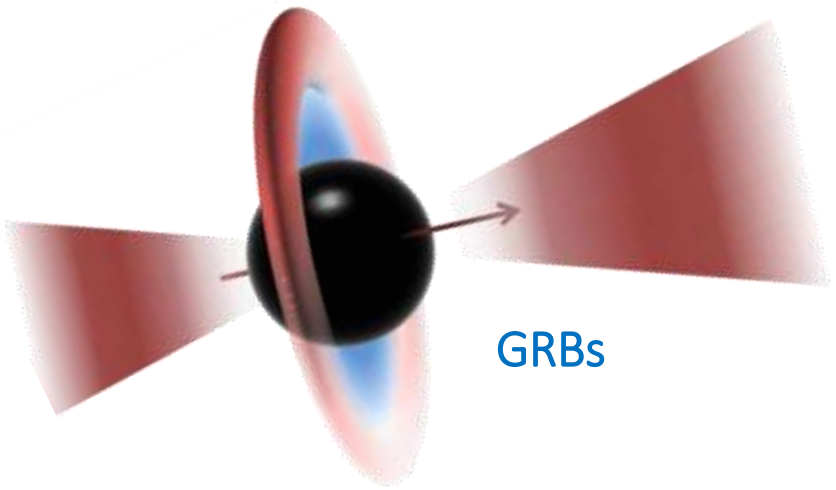
Luminosity enhancement over single BH
Uniform gas simulation (Farris+ 2009)

$$L_{\rm bol} = \eta_{bol} L_{\rm Edd}$$

Flux at Earth:

$$\Phi_\gamma = 10^{-14}\,\eta_{bol} F \left[\frac{M_{\rm bh}}{100\,{\rm M}_\odot}\right]\left[\frac{d_L}{100\,{\rm Mpc}}\right]^{-2} \frac{\rm erg}{\rm cm^2 s}$$

Hyper-Eddington accretion is necessary.



O1 → 2 binary black hole mergers

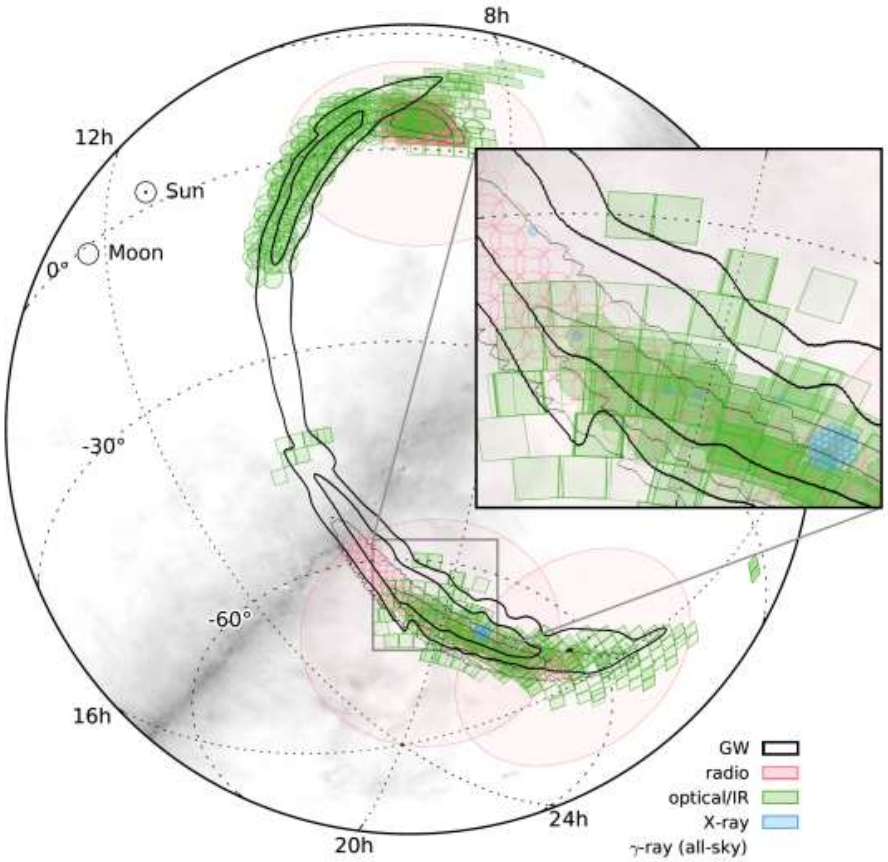
O2 → × 1.5 greater range
× 2 longer observation
× $(1.5)^3$ × 2 × 2 ≈ 14 more events

O4 → × 3 greater range
× 4 longer observation / year
× $(3)^3$ × 4 × 2 > 200 events / year

can't follow up all... (but very exciting...)

Abbott+ PRL 116, 061102 (2016)

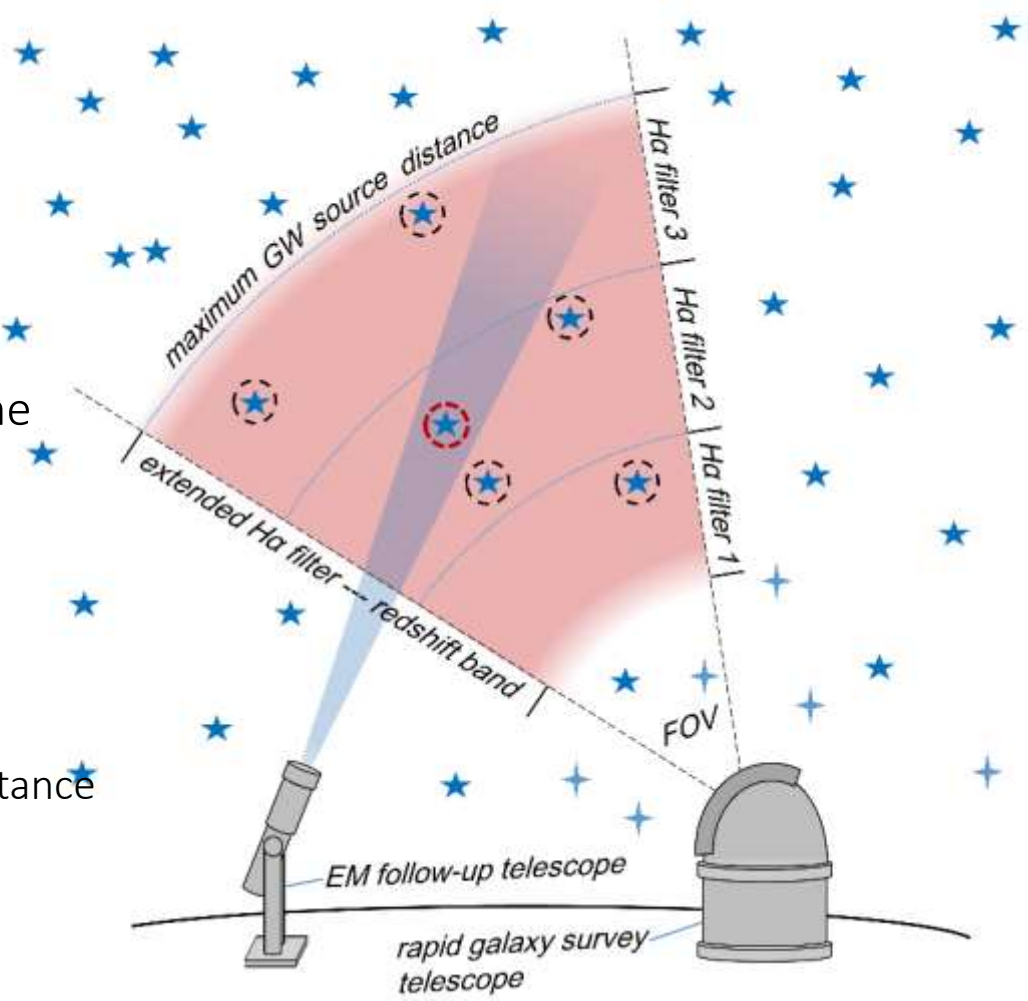
False positives



- Large number of false positive transients
- Spectroscopic follow-up
  - high cost
  - coordination between multiple instruments
- galaxy catalogs
  - GLADE
  - CLU
  - on-the-fly catalog?
- selective follow-up?
  - binary black holes
  - high-significance events

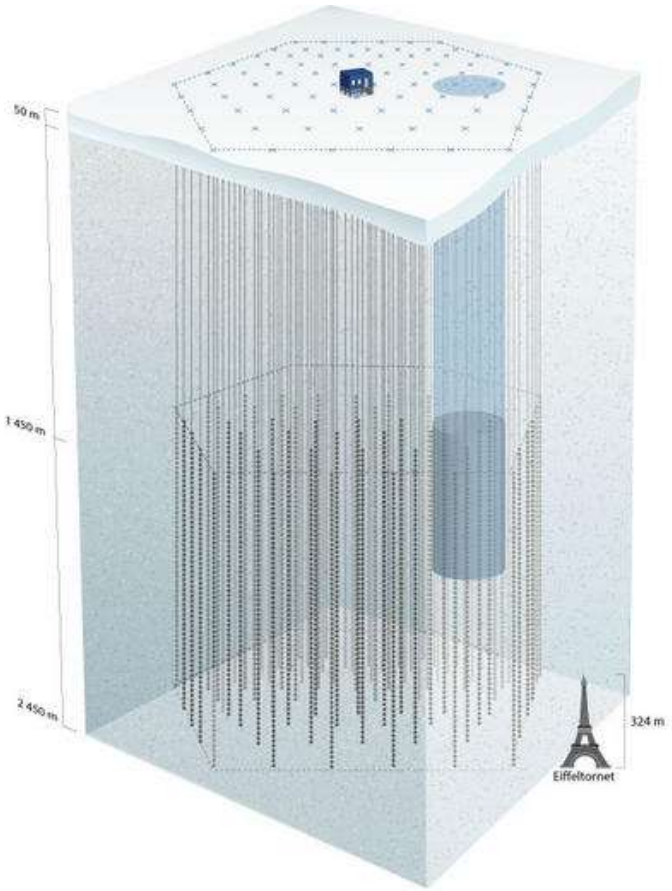
On-the-fly Galaxy Catalog

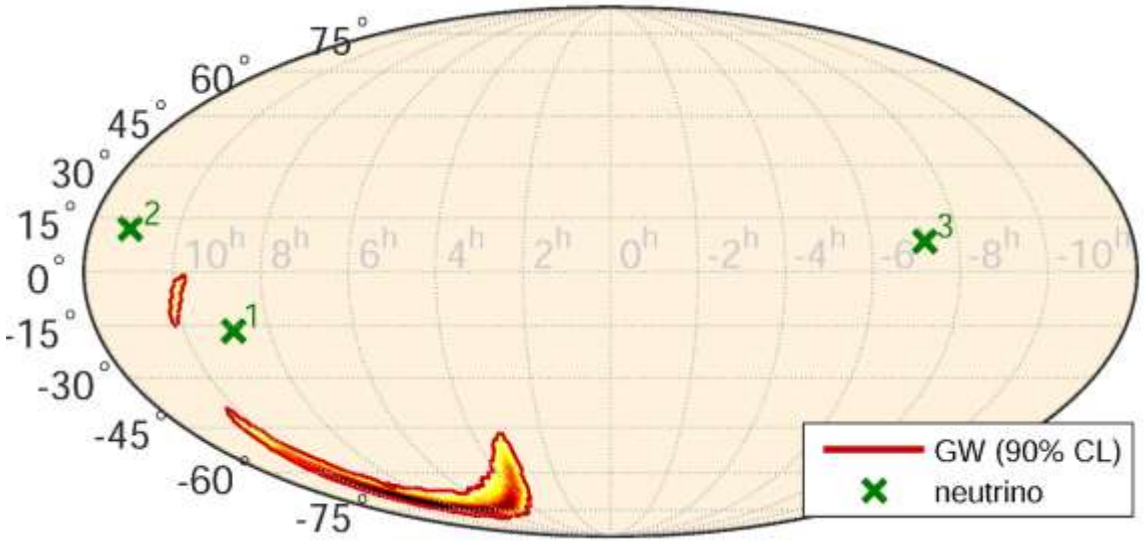
- Benefits
  - Target for small FoV telescopes
  - Decrease false positive rate
- Catalogs / plans
  - GWGC (White+ 2011)
  - GLADE (Raffai+ in prep)
  - CLU (Caltech)
- Very limited completeness (200 Mpc)
- Can we make a catalog in the right time frame, distance range and sky area?
  - ✓ 1 week
  - ✓ 200-500 Mpc
  - ✓ 100 deg^2
- Extended H-alpha survey (R-band comparison)
  - Only want galaxies within horizon distance
  - Only need source direction
- Meter class telescopes work.
- Don't need very high completeness (Hanna+ 2014)



Bartos+ ApJ Lett. 2015

NEUTRINO-MULTIMESSENGERS





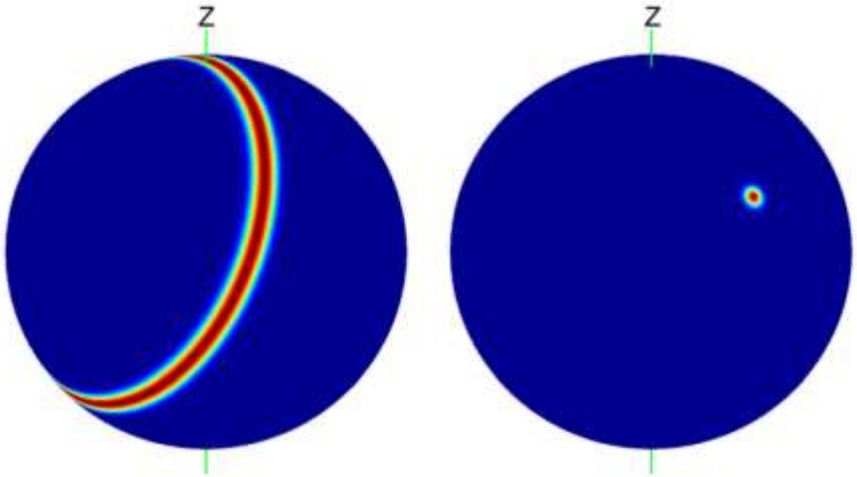
#	ΔT [s]	RA [h]	Dec [°]	$\sigma_\mu^{\mathrm{rec}}$ [°]	E_μ^{rec} [TeV]	fraction
1	+37.2	8.84	−16.6	0.35	175	12.5%
2	+163.2	11.13	12.0	1.95	1.22	26.5%
3	+311.4	−7.23	8.4	0.47	0.33	98.4%

ANTARES+IceCube+LIGO+Virgo 2016 (1602.05411)

GW and neutrino detectors are “all-sky”

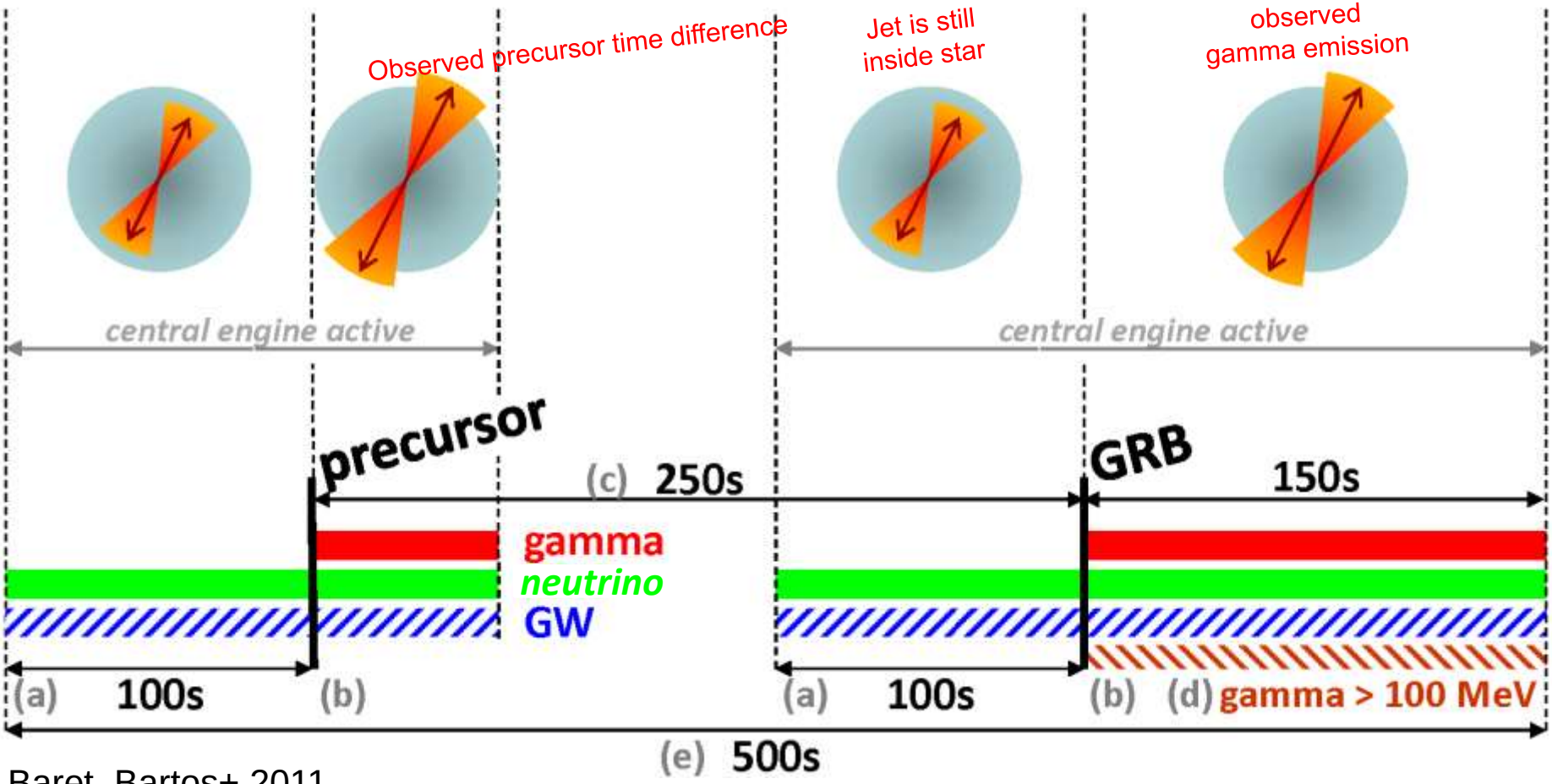
“all-sky” GW+ν search

GW+NEUTRINO TRIGGER FOR EM FOLLOW-UP



prompt search for significant events

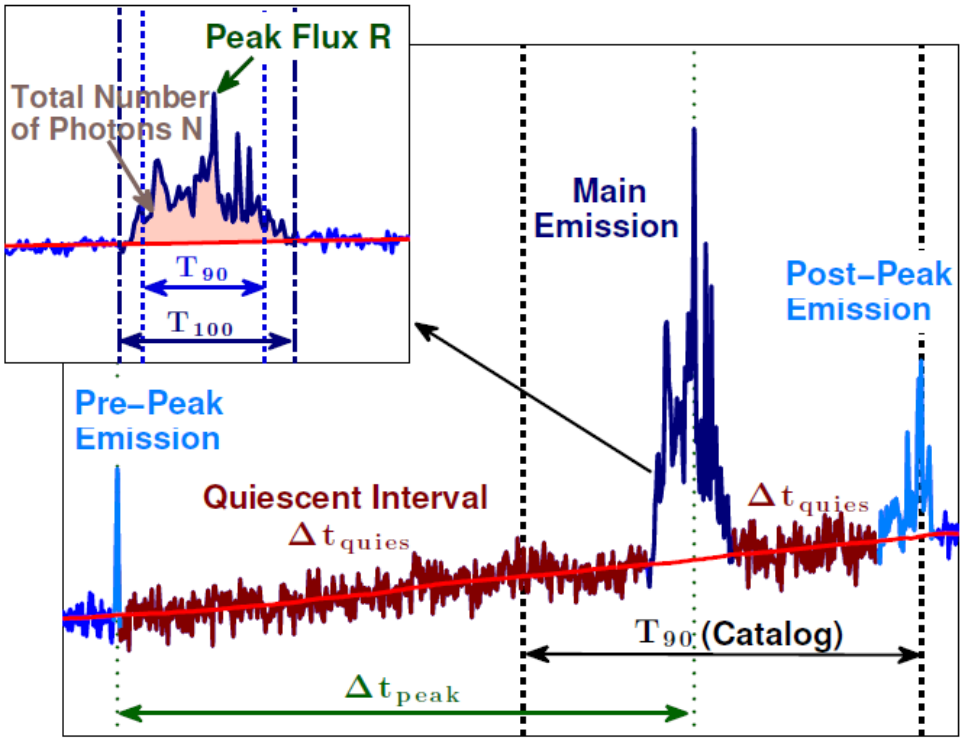
astrophysical search optimization

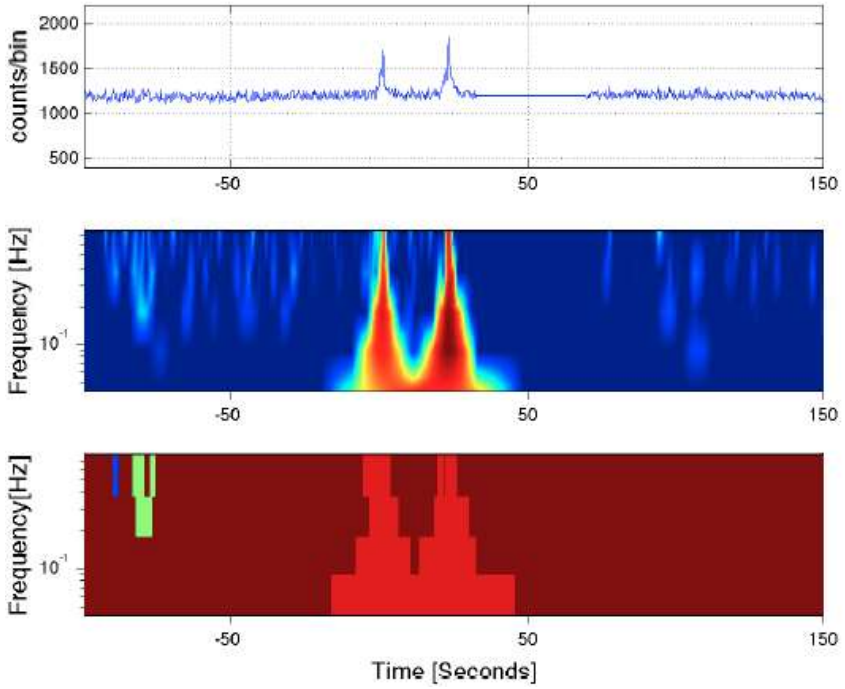


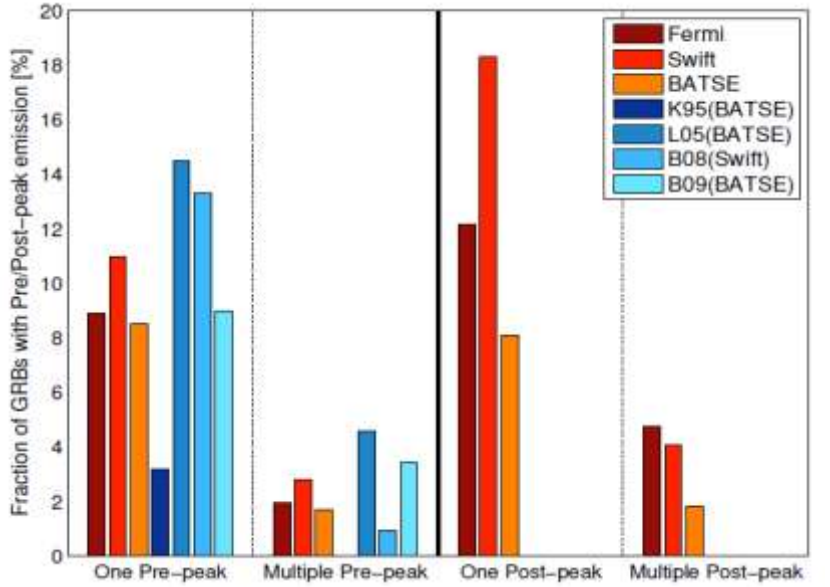
Baret, Bartos+ 2011

Coincidence time window: 500s

GRB EMISSION EPISODES (PRECURSORS)



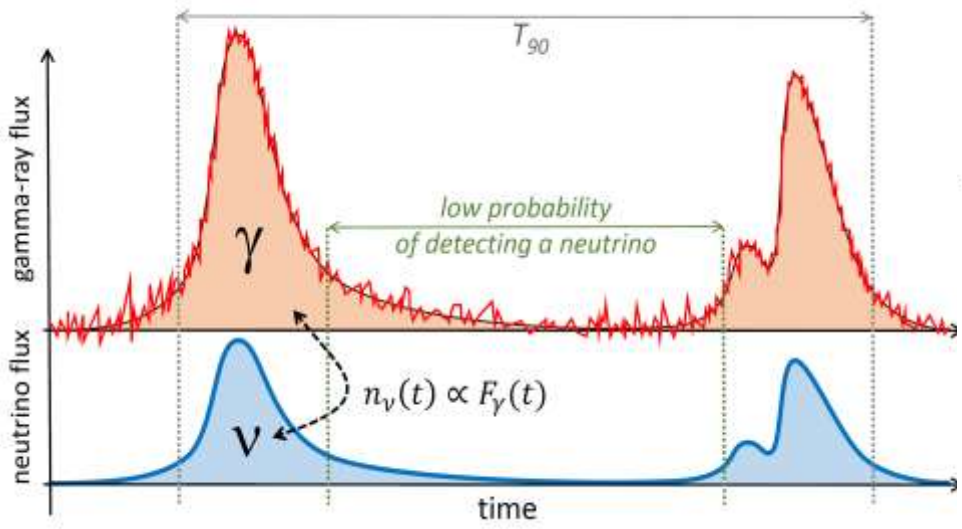




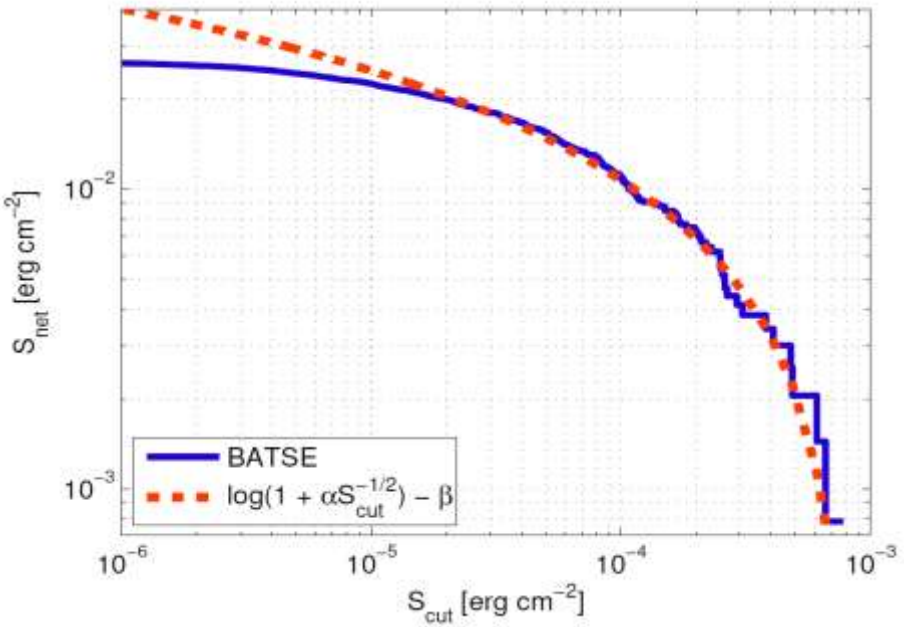
Automated survey of BATSE, Fermi and Swift GRBs (2710)
Conclusion --- precursors likely from same central engine activity

Charisi, Marka, Bartos MNRAS 2014

INCORPORATE TEMPORAL CORRELATION



Bartos+ PRL 2013

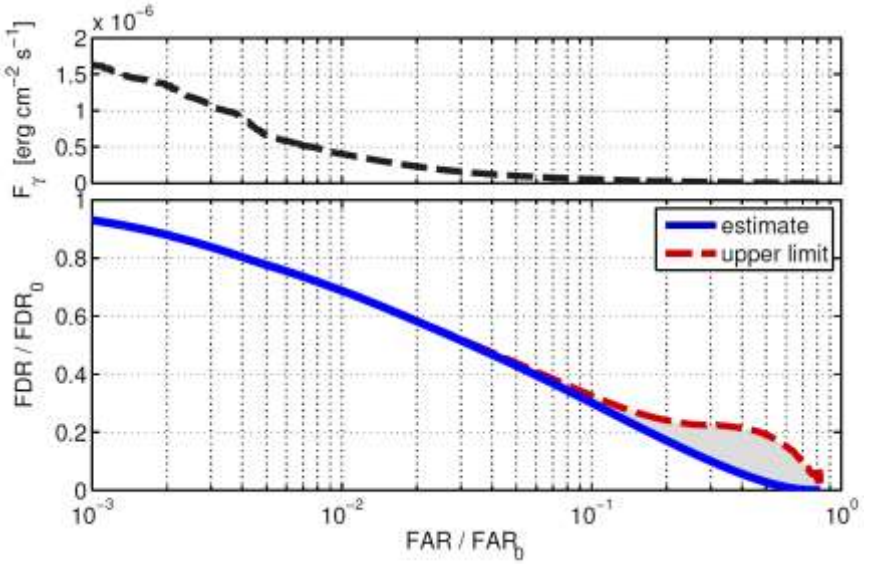


Gamma-ray --- neutrino emission mechanism is connected → temporal correlation

--- GRB fluence & neutrino fluence linearly correlated (117 GRBs, from Hummer+ PRL 2012)

Using temporal correlation can decrease False Alarm Rate by x100

Discovery potential for GRBs = 1 TeV neutrino
~ few GeV neutrino



Bartos, Marka PRD(R) 2014

TAKEAWAY

- understand and incorporate astrophysical expectations
- coordinate more than two instruments (a la AMON!)
- *(binary black holes can be interesting!)*