Fast Radio Bursts w/ Giant Radio Array for Neutrino Detection?

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Fermilab

GRAND mini workshop
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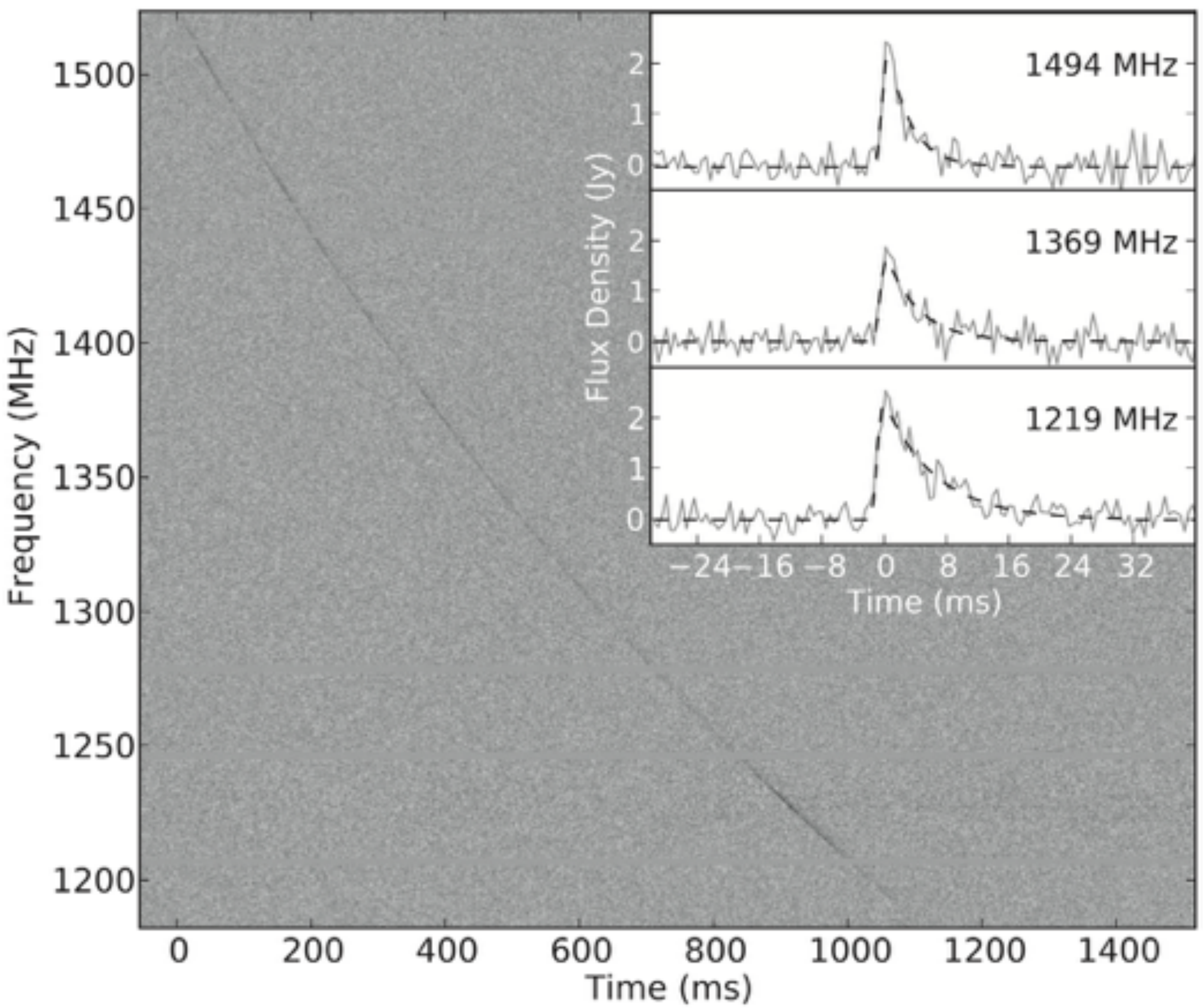
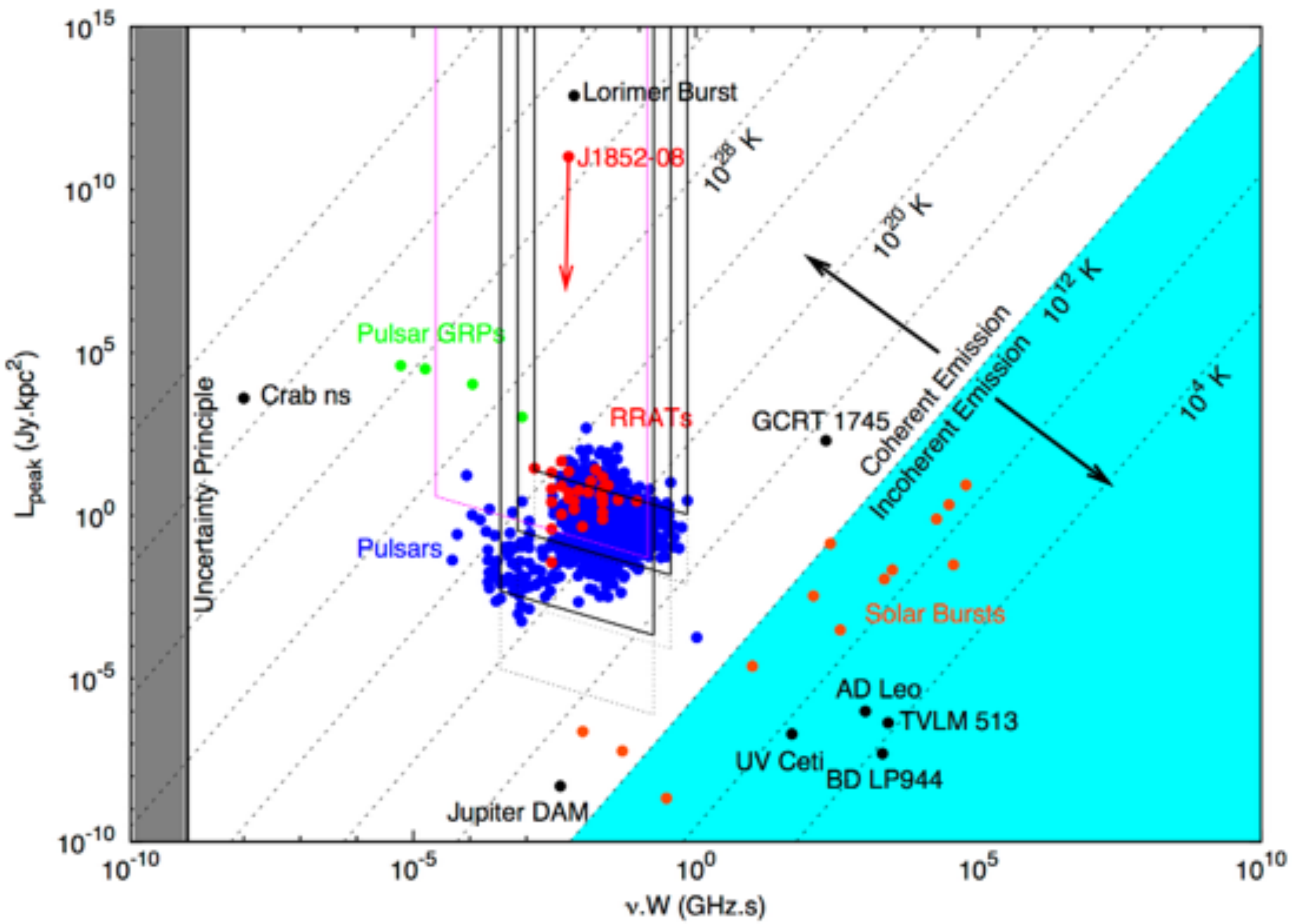
Chicago, USA

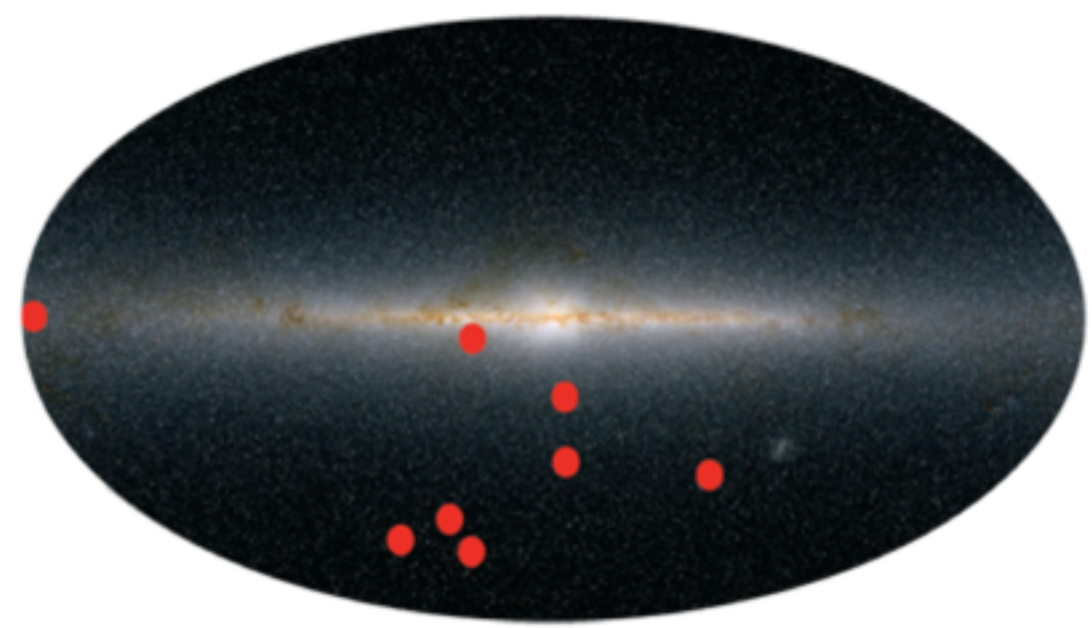
Fast Radio Bursts (FRBs)



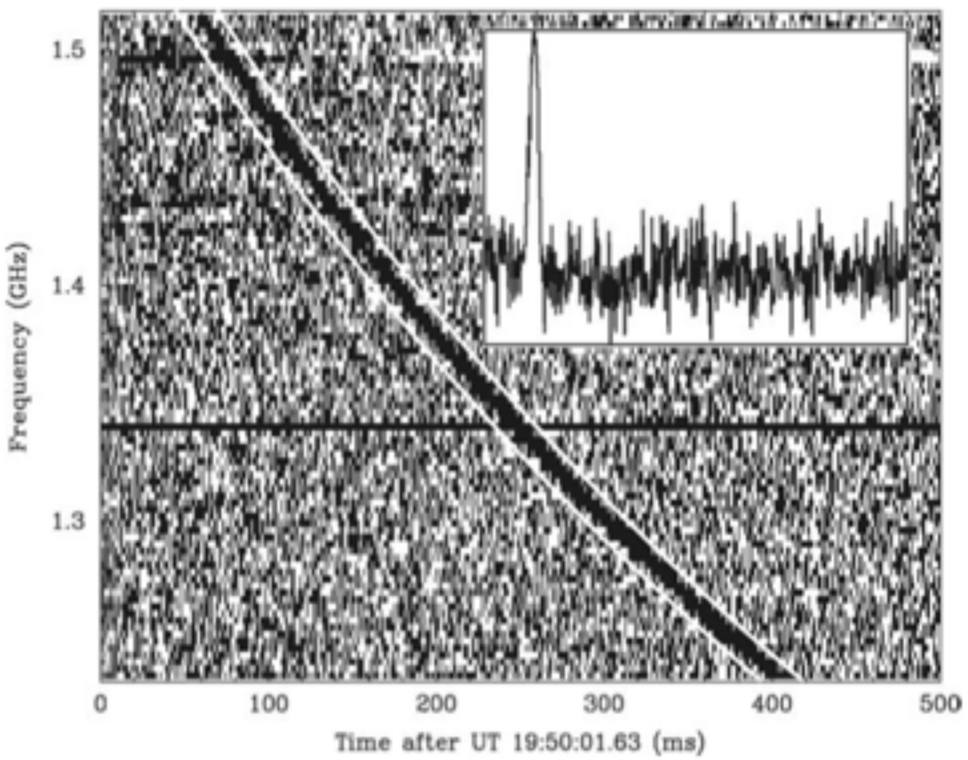
FRBs: bright (& non-Galactic?)



Fast radio bursts



Fast Radio Bursts: Cosmological Dispersion Measure?



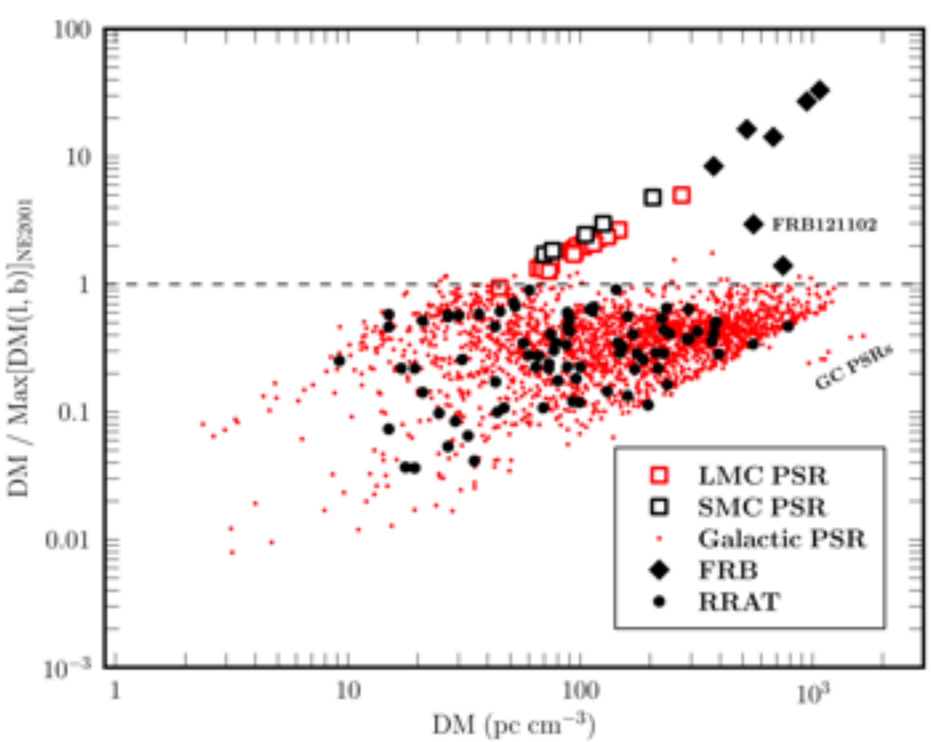
$$\Delta t_{\mathrm{delay}} = \frac{e^2}{2\pi m_e c^3}\left(\lambda^2\,\mathrm{DM}\right)$$

$$= 1.5\times10^{-24}\,\mathrm{s}\left(\lambda^2\,\mathrm{DM}\right)$$

$$\mathrm{DM} \equiv \int d\ell\, n_e = 375 \pm 1\ \mathrm{cm}^{-3}\,\mathrm{pc}$$

$$\delta t_{\mathrm{width}} = 4.6\,\mathrm{ms}\left(\frac{\nu}{1.4\,\mathrm{GHz}}\right)^{-4.8\pm0.4}$$

$$\int dt\, I_\nu \simeq 150 \pm 50\ \mathrm{Jy\,ms}\ \ @\ 1.4\ \mathrm{GHz}$$



Detected Fast Radio Bursts

	DM (pc cm	scope	v (MHz)	Δv (MHz)	Δt (ms)	fluence (Jy-ms)	redshift	energy (erg)	notes
FRB010220	375- 25-100	Parkes	1373	288	5		~0.27	~10	Lorimer burst
FRB010621	745-533-100	Parkes	1373	288	7		~0.12	~10	disqualified
FRB011025	790-110-100	Parkes	1373	288	5	>2.3	~0.86		
FRB090625	899- 32-100	Parkes	1300	340	<1.9	>2.2	~1.0		
FRB110220	944- 34-100	Parkes	1382	400	5.6	8.0	~1.1	~10	
FRB110523	623- 45-100	GBT	800	200			~0.57		RM
FRB110627	723- 46-100	Parkes	1382	400	<1.4	0.7	~0.61	~10	
FRB110703	1103- 31-100	Parkes	1382	400	<4.3	1.8	~0.96	~10	
FRB120127	553- 32-100	Parkes	1382	400	<1.1	0.6	~0.45	~10	
FRB121002	1629- 74-100	Parkes	1300	340	<0.3	>2.3	~3.1		
FRB121102	557-188-100	Arecibo	1375	323	3.0		~0.26	~10	
FRB131104	779- 77-100	Parkes	1382	400	[1.5,2.8]	1.0	~0.6		
FRB130626	952- 67-100	Parkes	1300	340	<0.12	>1.5	~1.1		
FRB130628	470- 53-100	Parkes	1300	340	<0.005	>1.2	~0.35		
FRB130729	861- 31-100	Parkes	1300	340	<4	>3.5	~0.97		
FRB140514	562- 35-100	Parkes	1300	340	[2.1,6.2]		~0.40	~10	0.2V realtime

FRBs: frequent

Lorimer (2013) extrapolated to all sky: 10^4/day ~ 4×10^6/year

4 *D. R. Lorimer et al.*

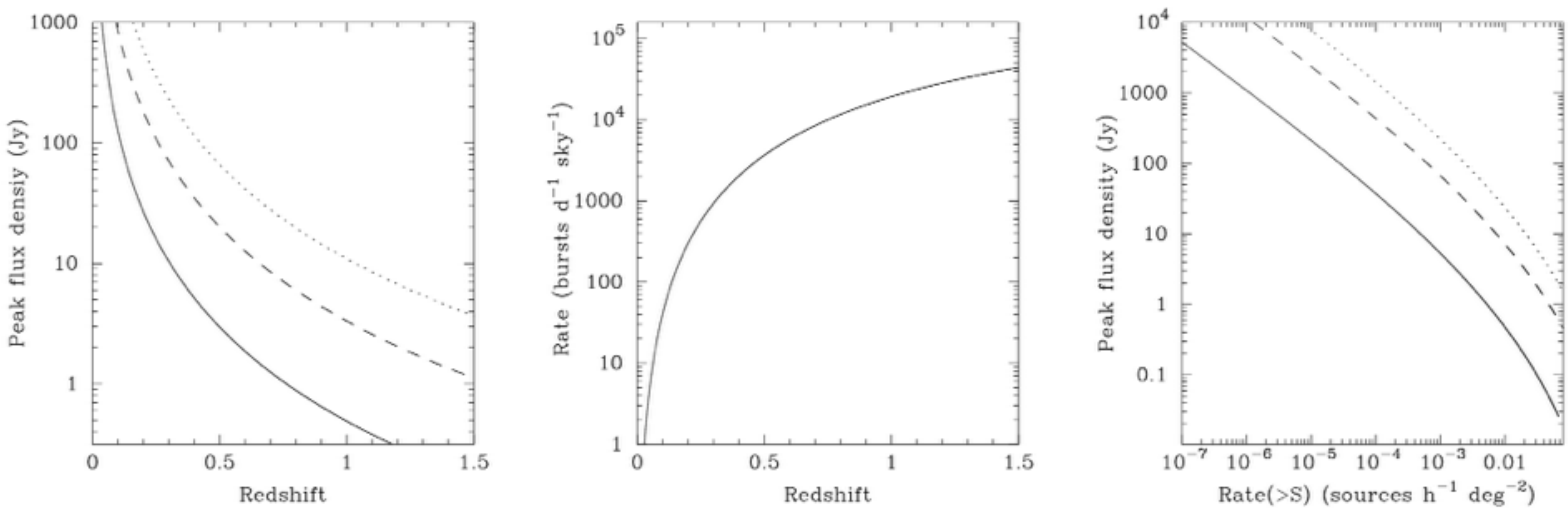


Figure 2. Predictions from our FRB population model. The left panel shows flux–redshift relationships for surveys carried out at 1400 MHz (solid line), 350 MHz (dashed line) and 150 MHz (dotted line). The centre panel shows the event rate normalized such that at $z = 0.75$ the implied event rate is 10,000 FRBs per day per sky as inferred by Thornton et al. (2013). The right panel shows the predicted burst rates above some threshold flux density S at 1400 MHz (solid line), 350 MHz (dashed line) and 150 MHz (dotted line).

Lorimer (2013) extrapolated to all sky: 10^4/day ~ 4×10^6/year

FRBs: what are they?

reasoning by rates

R_{FRB} ⇒ 10^4/sky/day @ 3 Jy ms

⇒ 10^4/sky/day (3 Jy ms/F)^(3/2) (assume Euclidean)

⇒ 10^4/Gpc^3/day (believe extraGalactic distances)

⇒ 10^{-3}/MWEG/yr (believe extraGalactic distances)

MWEG = Milky Way Equivalent Galaxy

Gamma Ray Bursts: $R_{FRB} \gg R_{GRB} = 10^{-6}$/MWEG/yr (GRBs beamed)

Core Collapse Supernovae: $R_{FRB} \ll R_{CC} = 10^{-2}$/MWEG/yr

Compact Binary Coalescence: $R_{FRB} \sim R_{CBC} \in 10^{-4+1/-2}$/MWEG/yr (NS+NS➔NS/BH)

extragalactic: subclass of CCs (SURON/Blitzar), nearly all CBCs, magnetar masers

galactic: flaring stars, erratic pulsars (debris), white dwarf mergers

solar system: colliding mini-asteroids

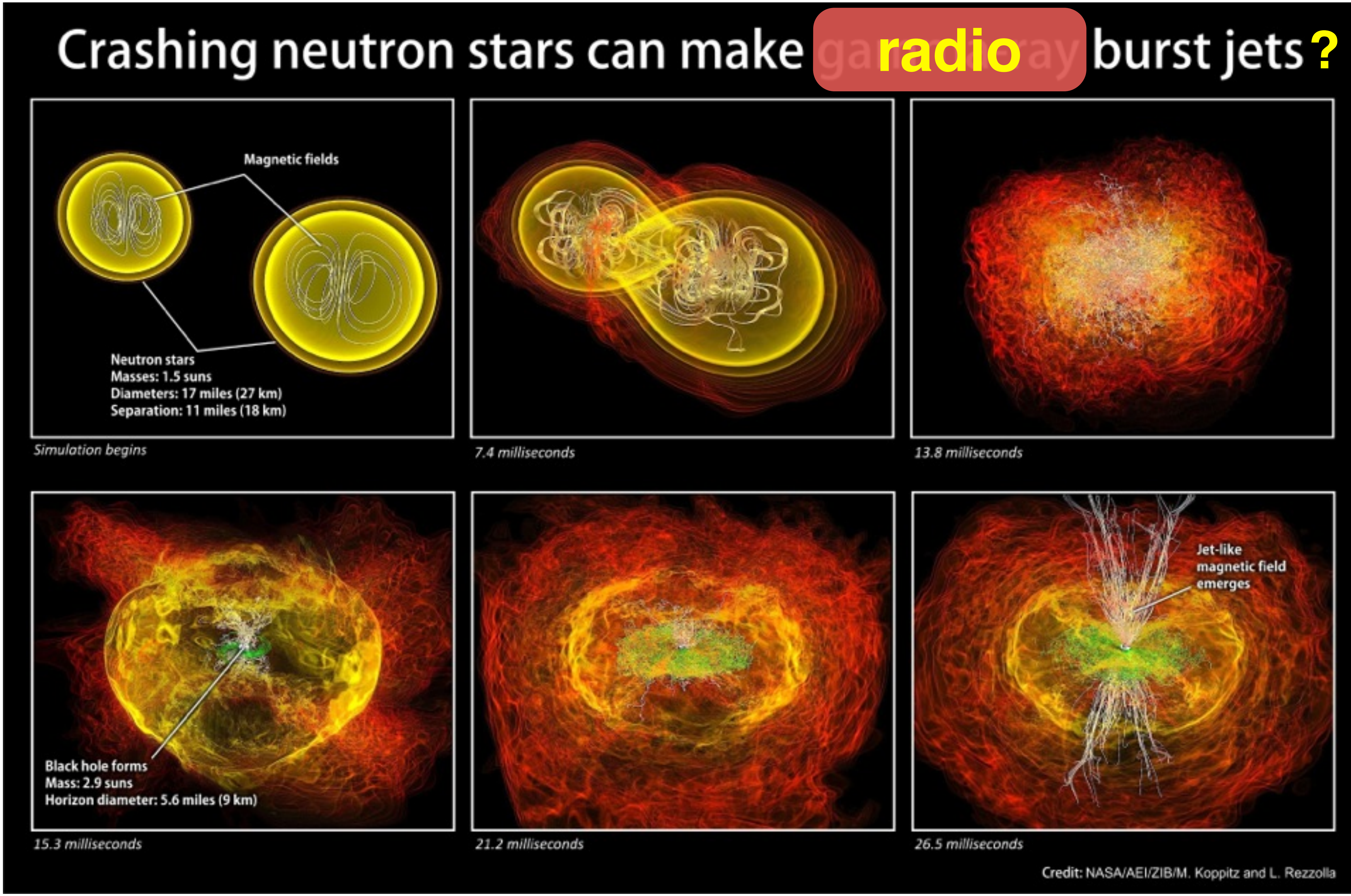
terrestrial: perytons

Loeb et al. 2013
Kashiyama et al. 2013
Lyubarsky 2014
Zhang 2014
Falke et al. 2014
Kulkarni et al. 2014
Guillochon 2014

FRB Priority #1

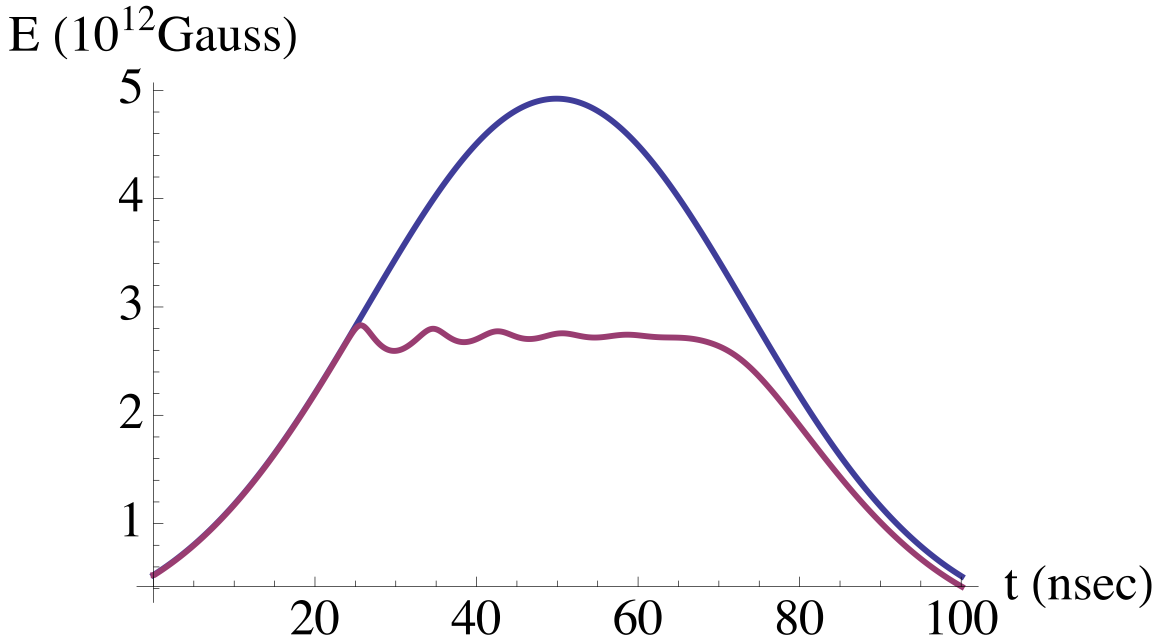
- Find out what they are!
- Look for counterparts (optical, γ-rays, whatever).
- Current intensive effort on radio detection of more.
- Excellent case for co-observing.

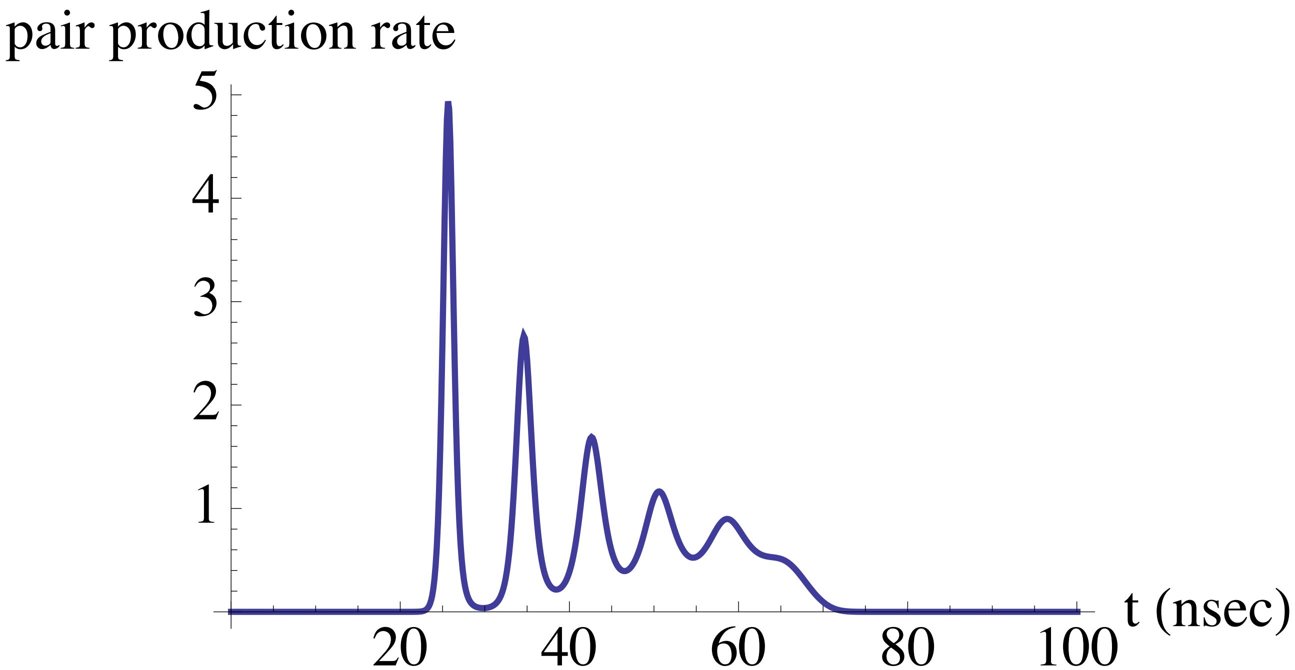
My best guess

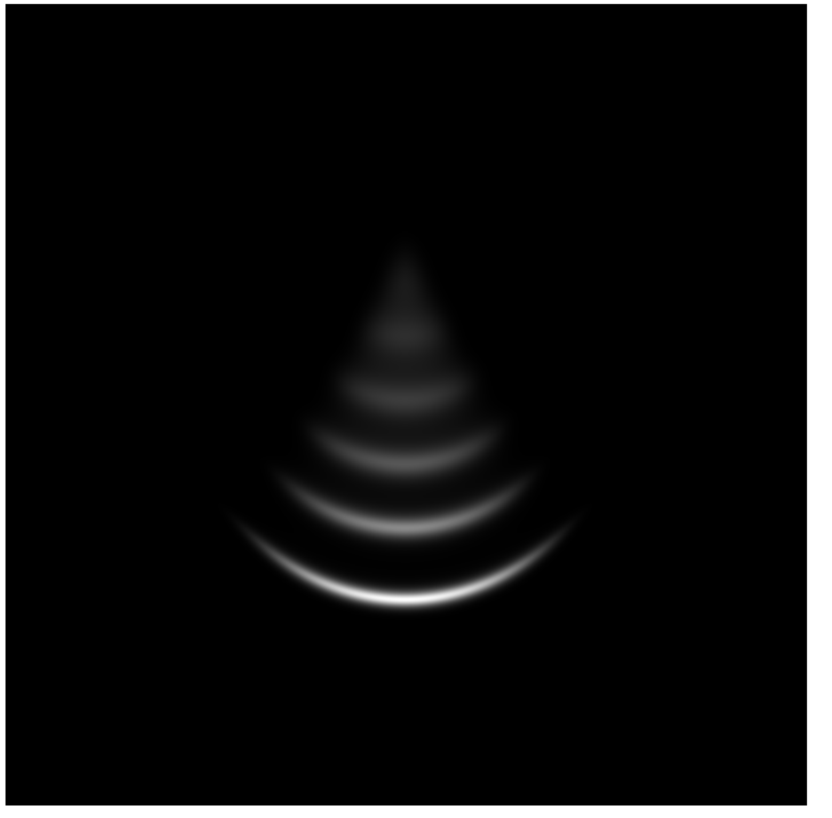


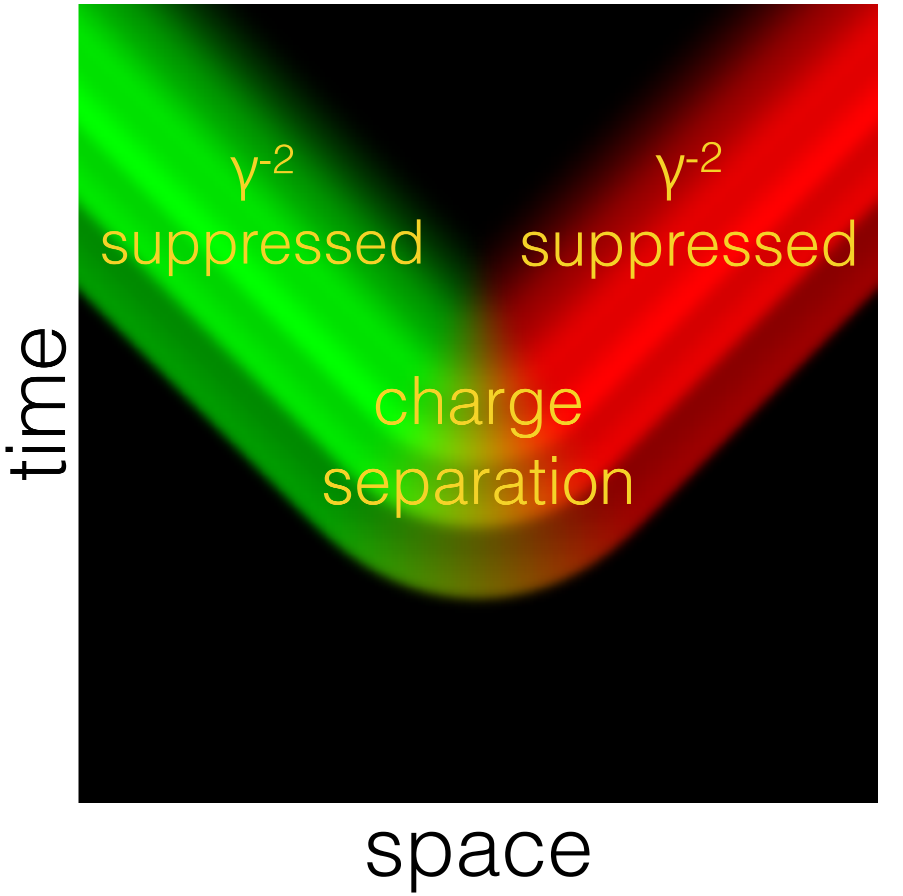
Schwinger Sparks may play a role

perhaps same as pulsar nsec pulses
(Stebbins, Yoo 2015)



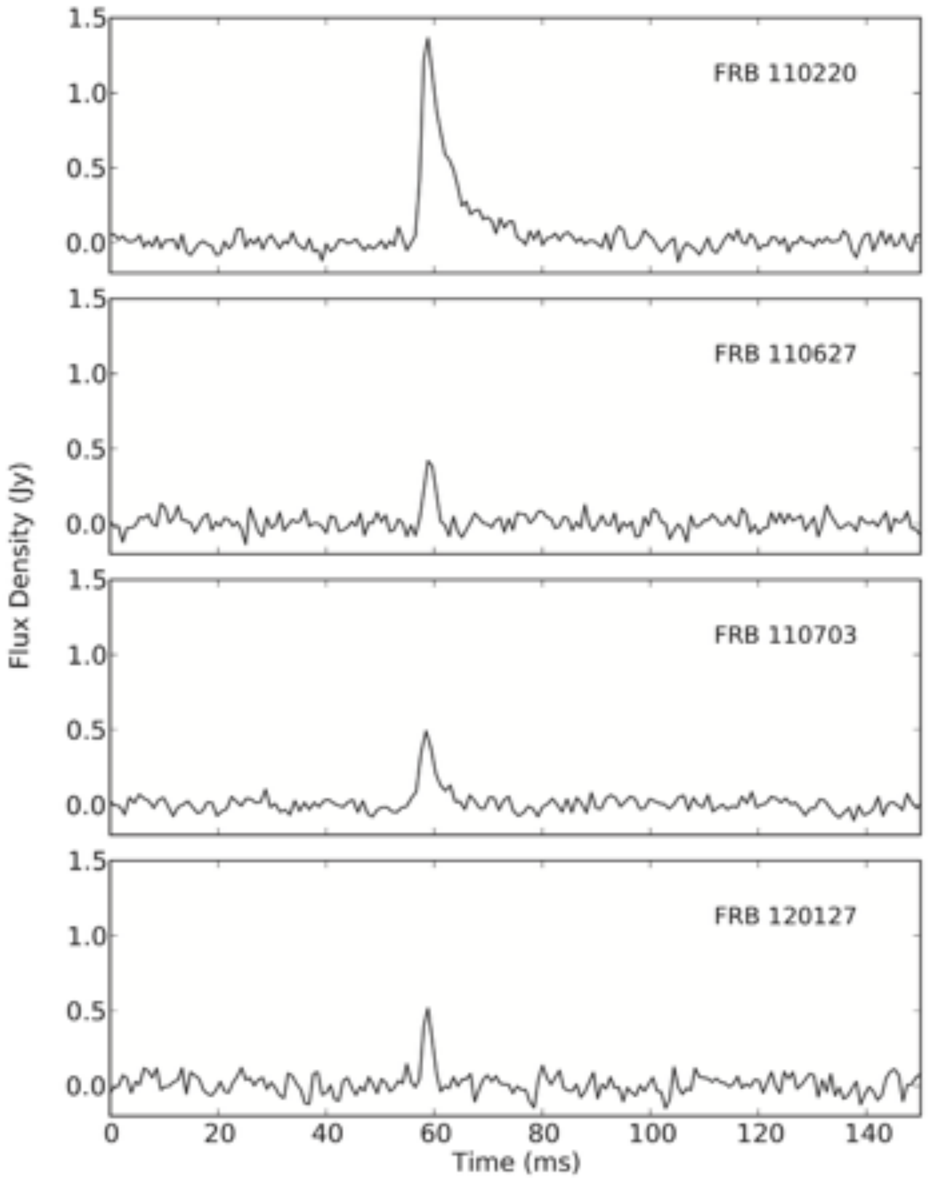


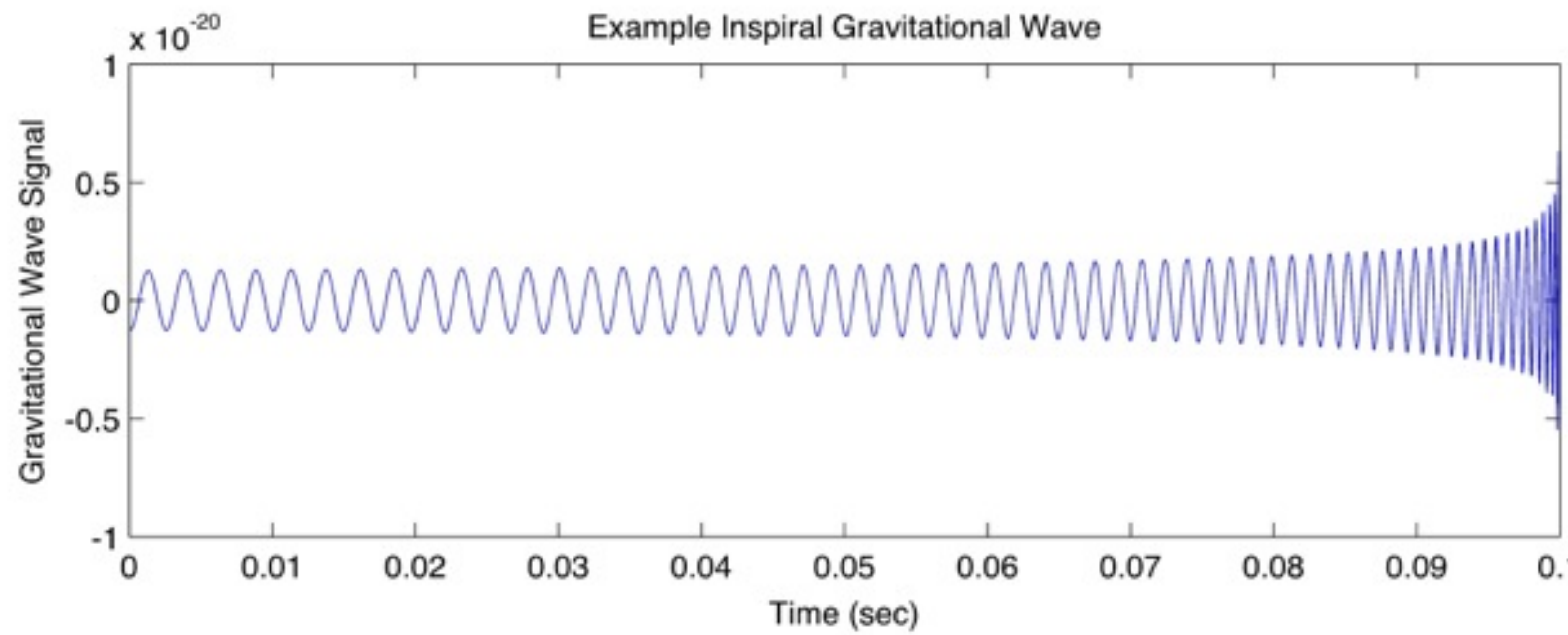


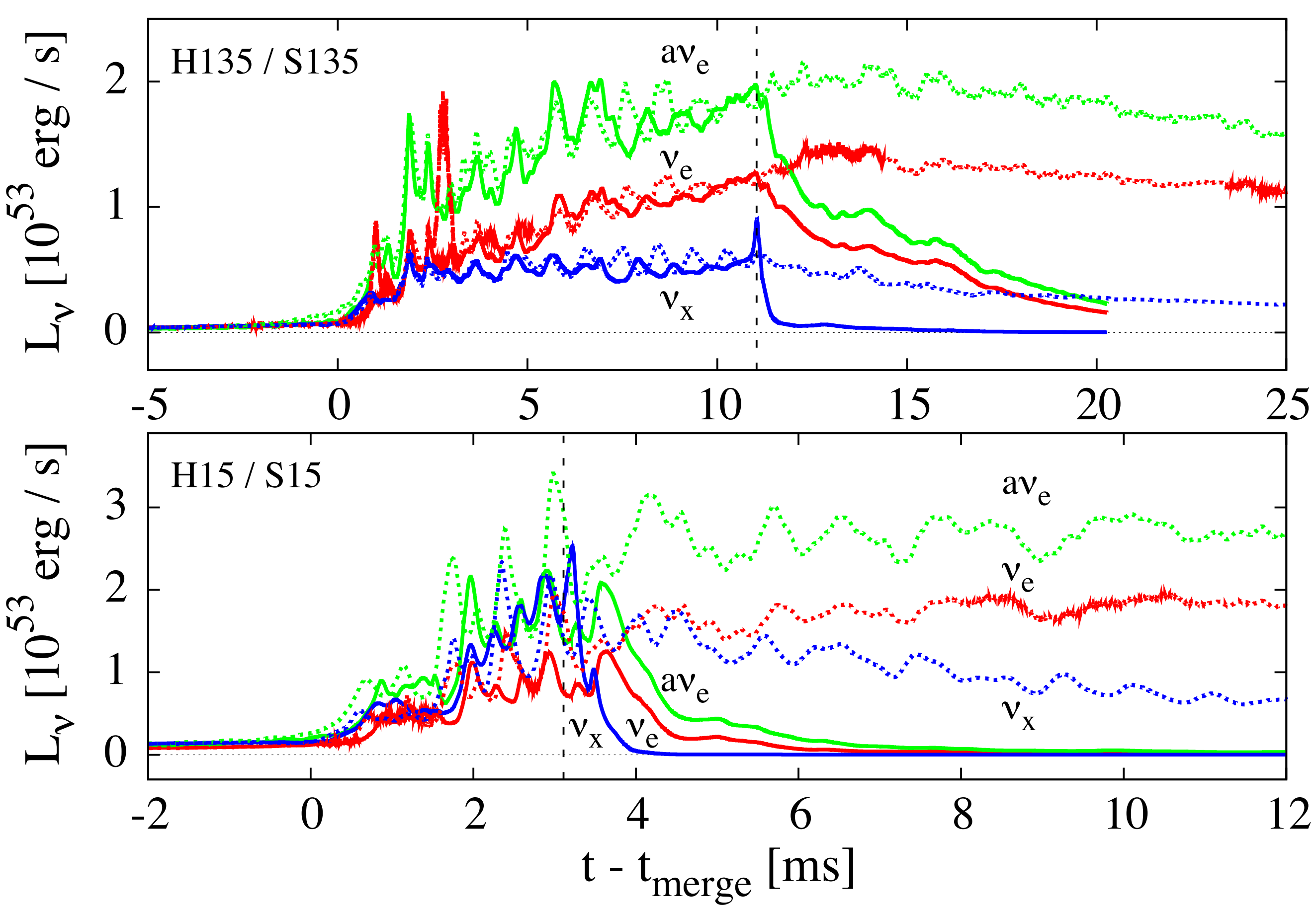


will produce PeV neutrinos!

Coincidence of Timescales for NS+NS⇒NS CBCs



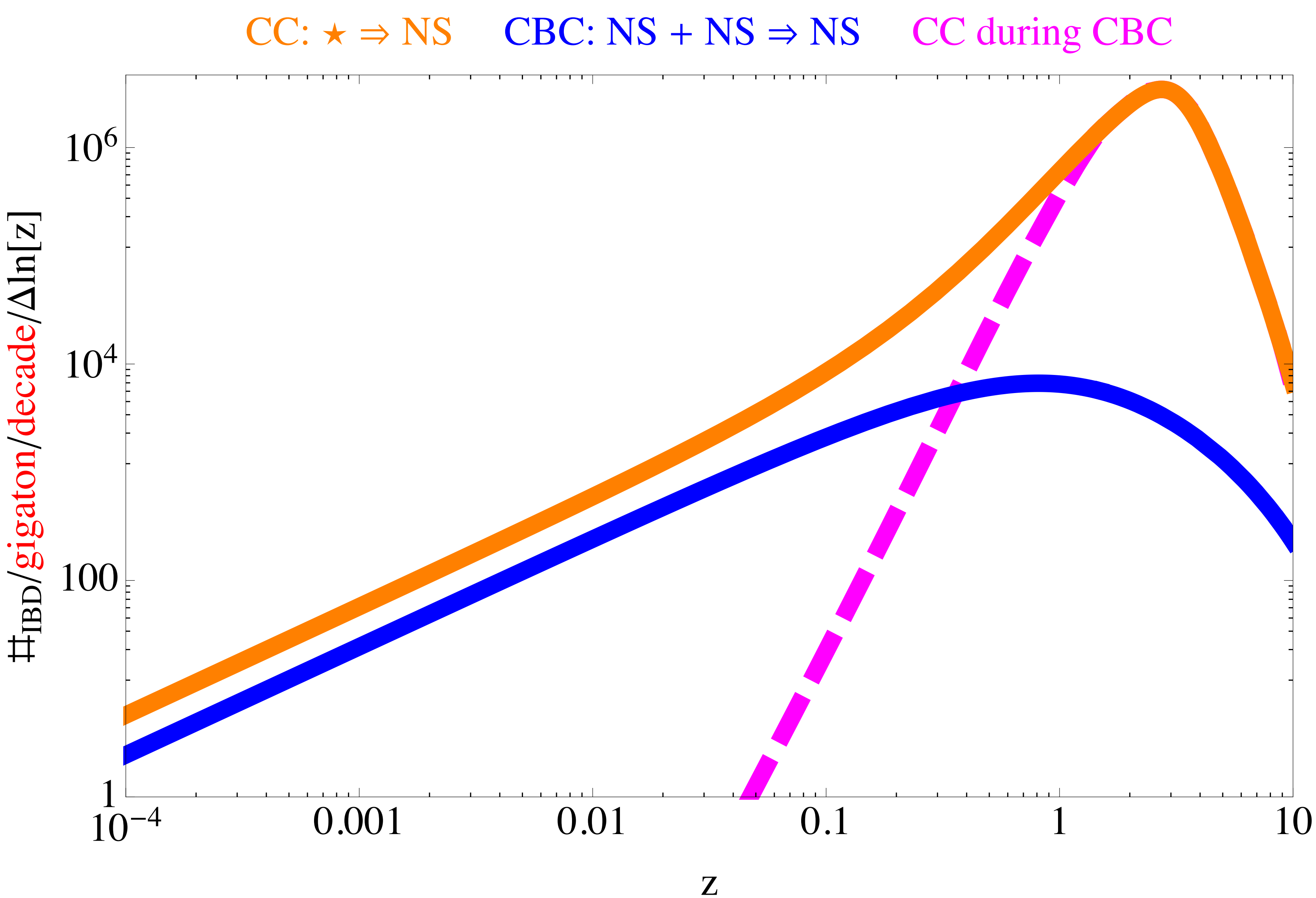




Kiuchi et al. 2012

FRB Triggers Increase Reach of Gravity Wave Telescopes
NOW w/ advanced LIGO

FRB Triggers Increase Reach of Neutrino Telescopes
future with Hyper-K+



With FRB triggers "negligible" backgrounds for z≲0.2

Many Radio Arrays are Gearing Up to Look for FRBs

Tianlai
may in the future

FoV of these
are typically smaller than
about 10^2 sq. deg
less than 1% of the sky

Very radio quiet site

GRAND?

- A FRB is not a single EMP waveform (it may be a superposition of many many EMPs)
  - like most radio sources it is broad band radio noise
- S/N ~ $(T_{FRB}/T_{sys})\sqrt{(\Delta t\ \Delta\nu\ N_{feed})}$ $N_{feed} \sim 10^5$
- large FoV (~π sr)
- $kT_{FRB} \sim f_\nu/(8\pi k)(c/\nu)^2$
- S/N ~ 5 $(f_\nu/\mathrm{Jy})(\pi/\mathrm{FoV})(50\mathrm{MHz}/\nu)^2\sqrt{(\Delta t/2\mathrm{msec})(\Delta\nu/50\mathrm{MHz})(N_{feed}/10^5)(50\mathrm{K}/T_{sys})}$
  - this is for z~0.5 nearby population should be brighter!
- need to de-disperse! Separate back end? Share antenna/LNA/GPS?
  - low cost electronic solutions
    - @FNAL exploring software defined radio (I/Q mixer) / Raspberry Pi on small dishes.
- 10^2 km baselines does not localize well compared to terrestrial 10^4 km VLB
- RISK: 100MHz FRB properties completely unexplored to date.