

# Could GRB 170817 be really correlated to a NS NS merging?

Could GRB170817A be really correlated to  
an NS–NS merging?

D. Fargion<sup>\*,†,‡,§,¶</sup>, M. Khlopov<sup>‡</sup> and P. Oliva<sup>†,§,¶</sup>

<sup>\*</sup>*Physics Department & INFN Rome1, Rome University 1  
P.le A. Moro 2, Rome 00185, Italy*

<sup>†</sup>*MIFP, Via Appia Nuova 31, Marino, 00040 Rome, Italy*

<sup>‡</sup>*Center for Cosmoparticle Physics Cosmion  
National Research Nuclear University MEPhI  
Kashirskoe Sh., 31, Moscow 115409, Russia*

<sup>§</sup>*Niccolò Cusano University, Via Don Carlo Gnocchi 3  
Rome 00166, Italy*

<sup>¶</sup>*Department of Sciences, University Roma Tre  
Via Vasca Navale 84, Rome 00146, Italy  
[daniele.fargion@roma1.infn.it](mailto:daniele.fargion@roma1.infn.it)*

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**Could GRB 170817° be really  
correlated to a NS NS merging?**

**Journal of Modern Physics D, subm. 11 October,**

- **Related to earlier:**
- **May GWs signals by BH-BH merging be associated with any gamma or neutrino burst? *arXiv:1603.09639***
- **And related to:**

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**Solving the missing GRB neutrino and GRB-SN puzzles**

**Daniele Fargion • Pietro Oliva [arXiv:1605.00177](https://arxiv.org/abs/1605.00177) (Nuclear Phys and Particles, 2017)**

Could GRB170817A be really correlated to  
an NS–NS merging?

***arXiv:1710.05909*** (submitted 11 October 2017)

By ***DF, M.Khlopov, P.Oliva***

***Why such a  
puzzled title?***

***Because :***

Because *(among the other)*

- **GWs** are almost *spherical* signals.



- **While GRBs** are *beamed jet blaze*.



- **Therefore: How could the very first GWs by NS-NS discovered by LIGO-VIRGO be within a narrow jet just pointing to us?** [arXiv:1603.09639](https://arxiv.org/abs/1603.09639)

# Could GRB 170817 be really correlated to a NS NS merging?

- *The GW 170817 and GRB170817A occurred within a short time almost in the same sky windows. It has been the nearest Short GRB observed, the first NS NS collapse merging, the softer SGRB, the weakest one and the first GRB GW correlated event within just a year or even a month of VIRGO detection. An amazing lucky event hard to be accepted at first view. Moreover the huge spread (8 order of magnitude) in apparent luminosity among thousands GRB call for a thin blazing jet source able to embrace (with the same NS-NS or NS-BH collapse) the vast variability observed by its geometry (in axis , off axis) view. May the case of GRB170817 be associated to such an extreme off axis detection?*
- *Many authors , and us, agree on this possibility. However there maybe an additional unexpected novel geometry in GRB explosion making the GRB observation at near distance much more probable: a twin gamma disk-cone blazing in wide solid angles in addition to the inner thin precessing jets event.*

**Rarest first GW 170817**  
**versus first Rarest GRB 170817A**

*The arXiv received above **117** preprints*  
*: most **since 16 October** (**65** papers)*

***The most cited* article in three months!**

***<https://arxiv.org/find/all/1/all:+GW170817/0/1/0/all/0/1>***

# A very Exceptional event

- (a) it is the nearest short GRB (SGRB) ever detected (40 Mpc) 
- (b) it is among the weakest fluency SGRB ever recorded 
- (c) it is the most soft SGRB in whole known SGRB catalogs 
- (d) it is the first NS–NS (or more rare NS–BH) merging GW event ever detected 
- (e) it is the nearest GW event observed 
- (f) it is the first NS–NS merging into a new born NS or a new BH 
- (g) it is (probably) the most powerful energy fluency GW signal ever observed by LIGO–VIRGO 
- (h) it is the very first GWs correlated with an electromagnetic burst and afterglows ( $\gamma$ , X, optical). 

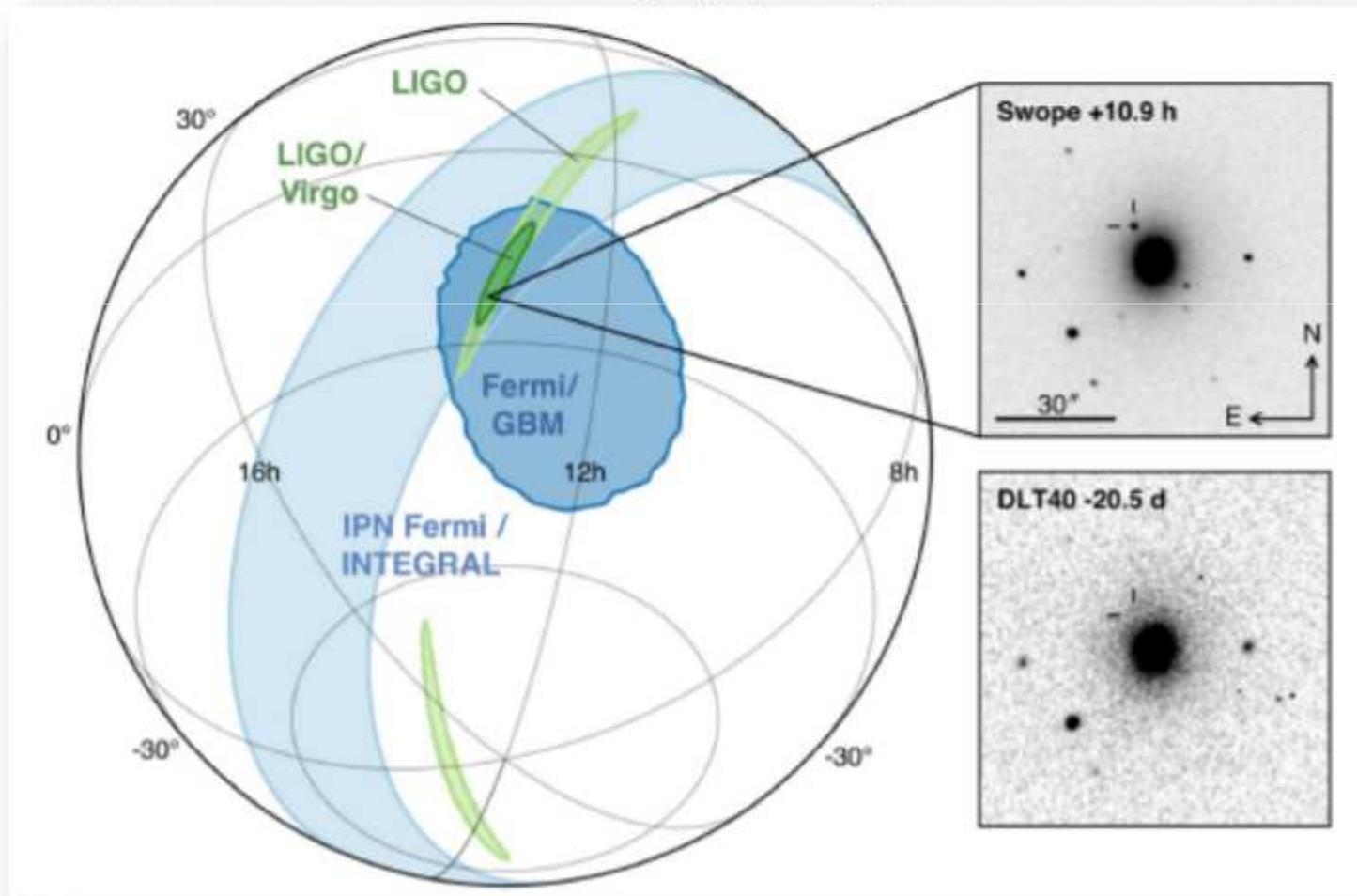
**i) It is the first SGRB to be localized NOT by its X ray afterglow**

**ii) (coming very lated days after)**

**iii) But it has been detected just via its Optical transient ten hour later.**

# A Connection **first** by its Optical Transient, **not** with its late X afterglow

LIGO, VIRGO + ALL "Multi-Messenger paper" ApJLett

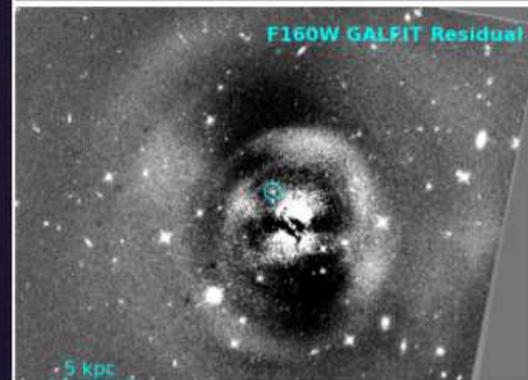
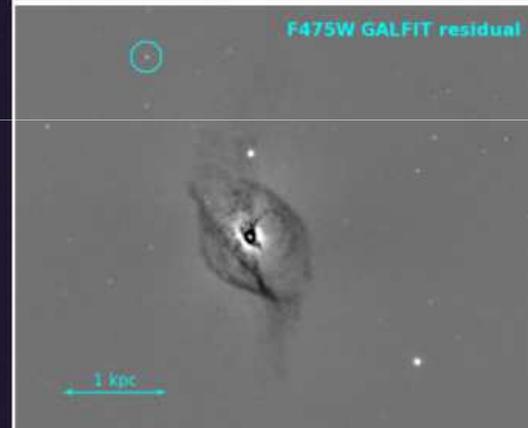
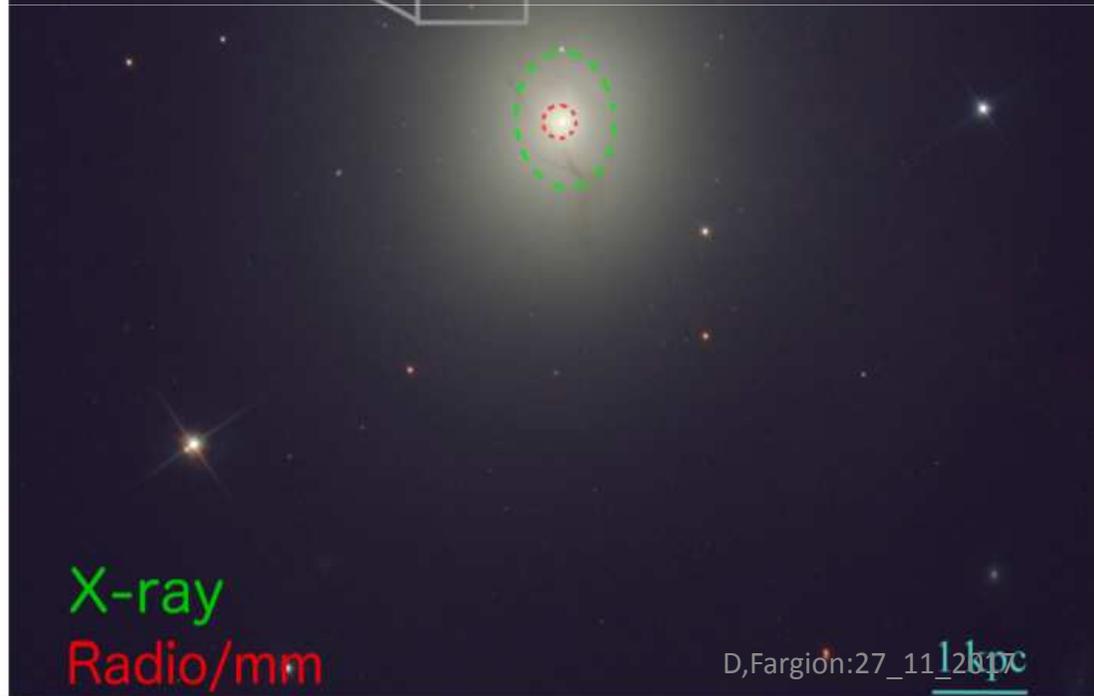


GW 170817 Optical Counterpart

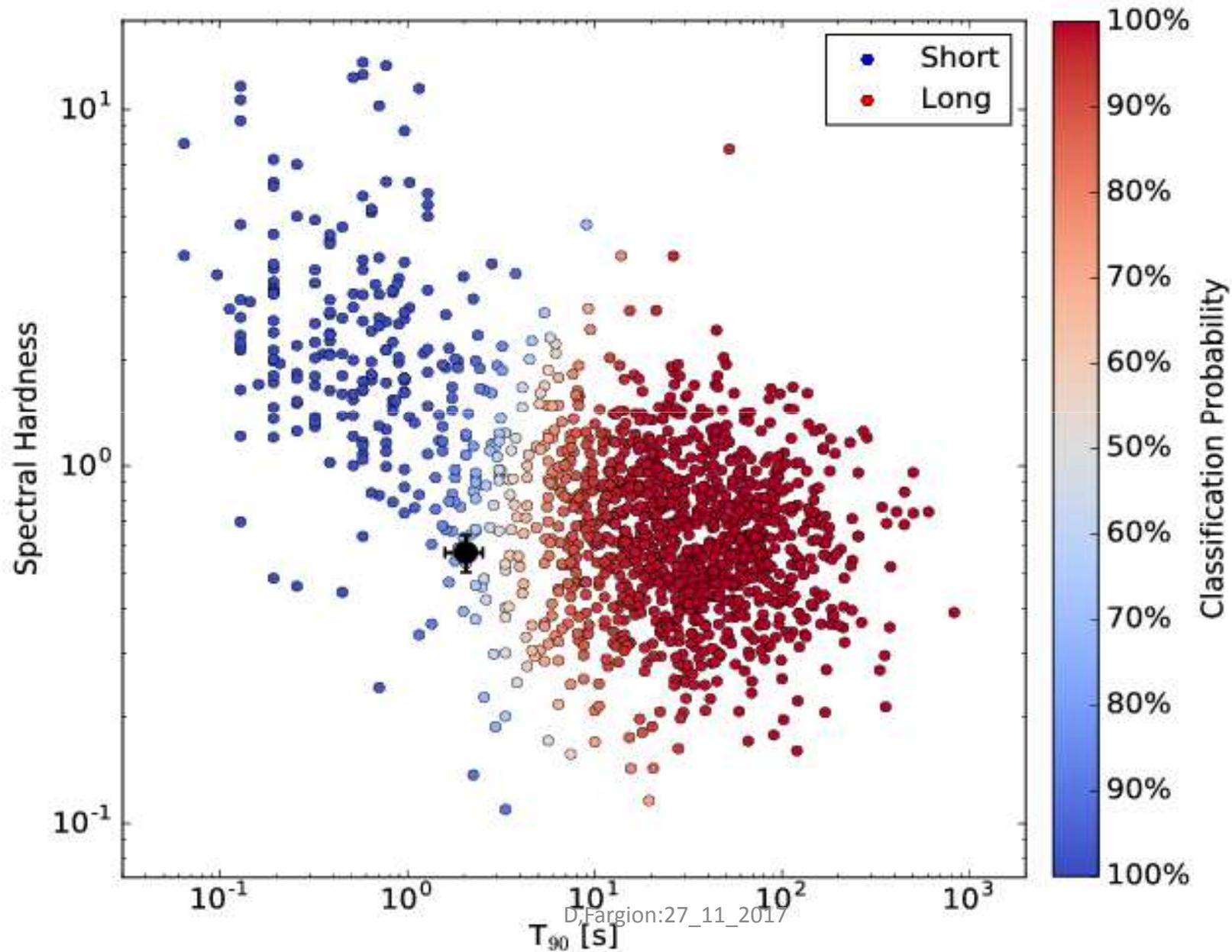
NGC 4993

HST/ACS

d = 39.5 Mpc



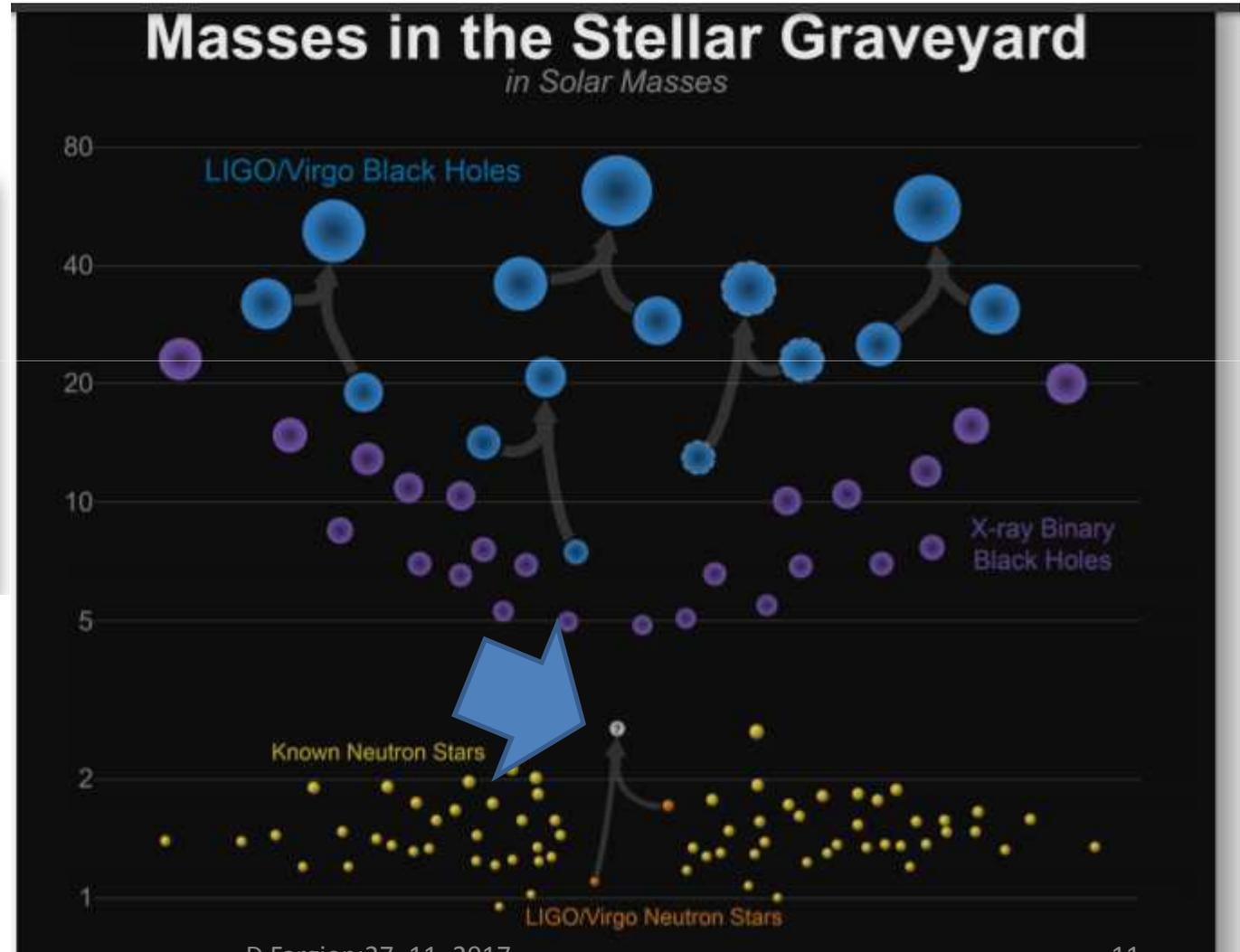
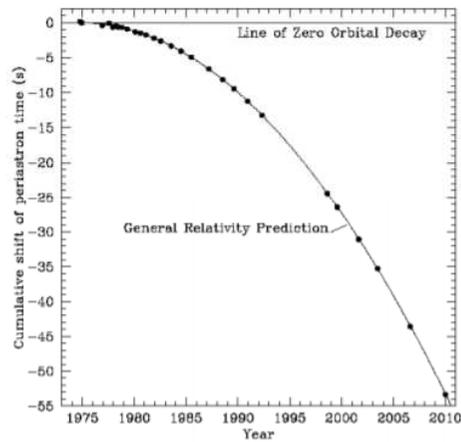
# Also a rare SHORT or LONG GRB?



# NS and BH: *Where we all shall go one day*

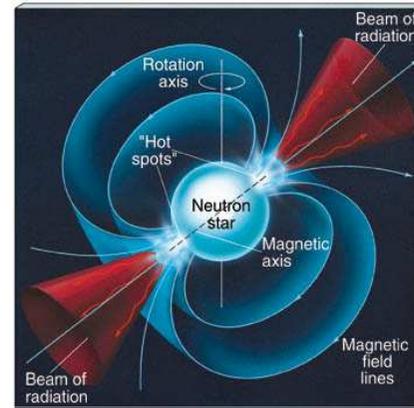
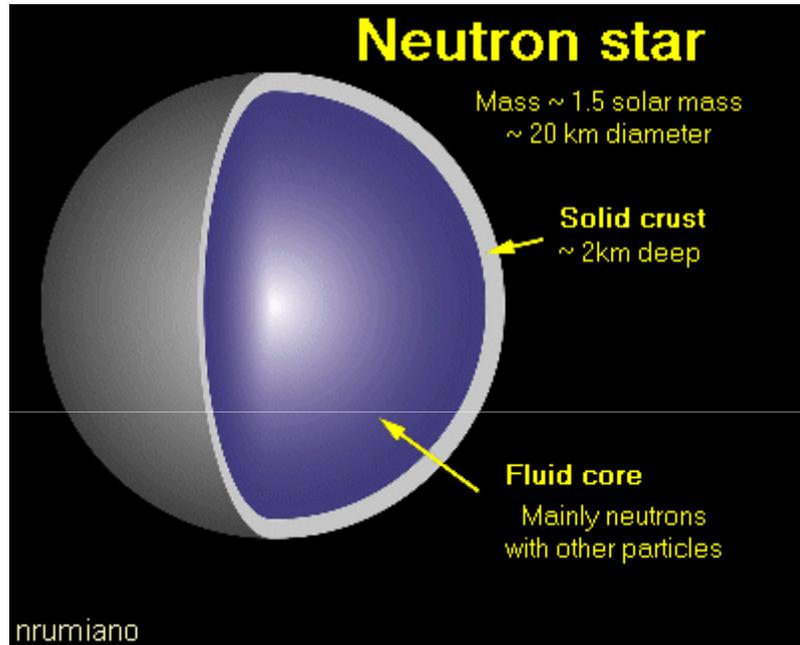
**BINARY PSR 1913+16**

$P = 59 \text{ ms}$ ,  $P_b = 7.75 \text{ hr}$ ,  $e = 0.615$



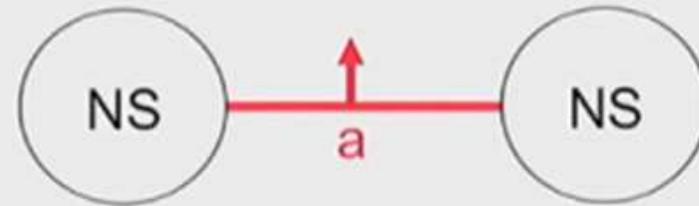
# *How a NS is and How NS NS collapse*

## *Pulsar in the radio sky*

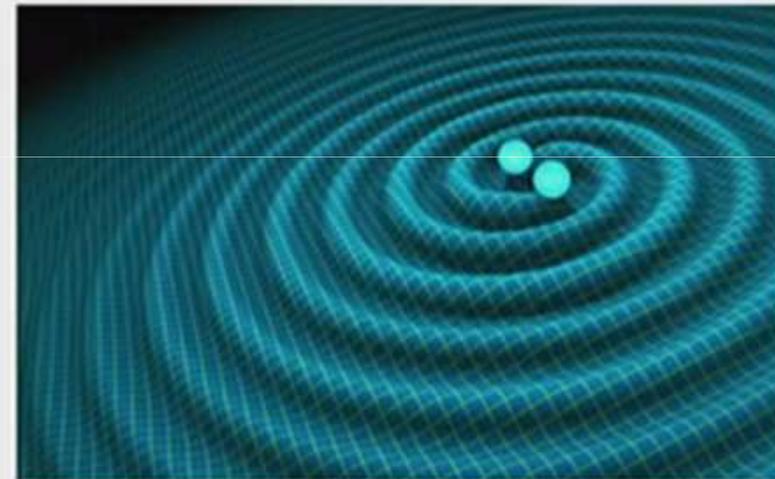
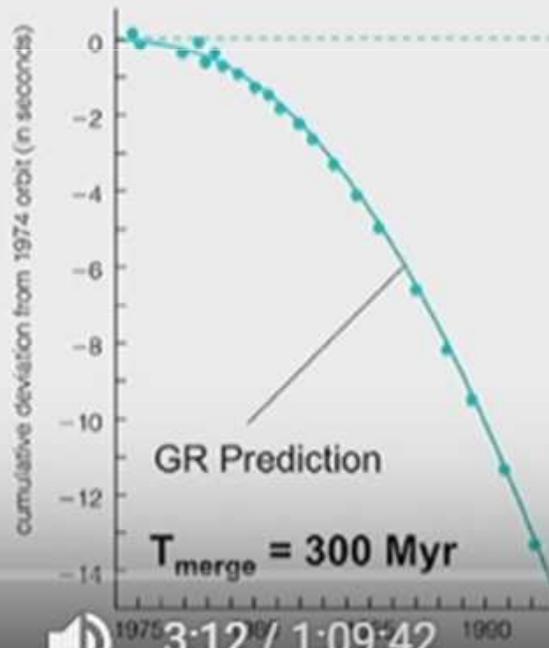


# Binary Neutron Stars

$$\frac{1}{P} \frac{dP}{dt} = \frac{128}{15} \frac{G^3 M^3}{c^5 a^4}$$



Hulse-Taylor Binary Pulsar



$$\dot{N}_{\text{NS-NS}} \sim 10^{-5} - 10^{-4} \text{ yr}^{-1}$$

$$\Rightarrow \dot{N}_{\text{LIGO}} \sim 0.3 - 200 \text{ yr}^{-1}$$

(e.g. Kalogera et al. 2004, Abadie et al. 2010)



# We knew that NS must merge with other NS

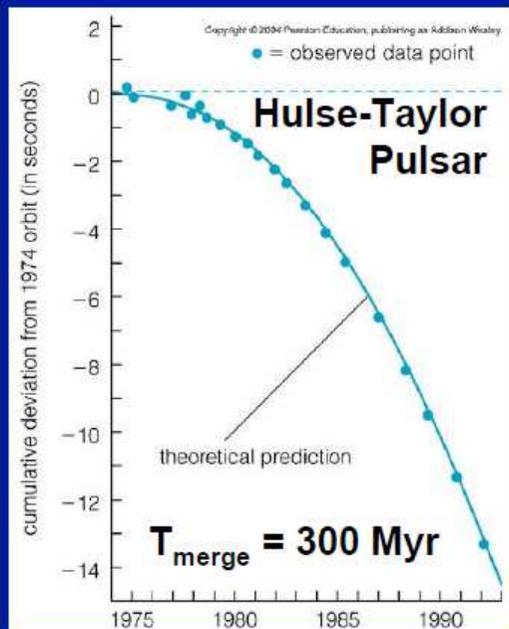
## Binary Compact Object Mergers

NS

NS

BH

NS



### 10 Known Galactic NS-NS Binaries

(Lorimer 2008)

	J0737-3039	J1518+4904	B1534+12	J1756-2251	J1811-1736
$P$ [ms]	22.7/2770	40.9	37.9	28.5	104.2
$P_b$ [d]	0.102	8.6	0.4	0.32	18.8
$e$	0.088	0.25	0.27	0.18	0.83
$\log_{10}(\tau_c/\text{yr})$	8.3/7.7	10.3	8.4	8.6	9.0
$\log_{10}(\tau_g/\text{yr})$	7.9	12.4	9.4	10.2	13.0
Masses measured?	Yes	No	Yes	Yes	Yes

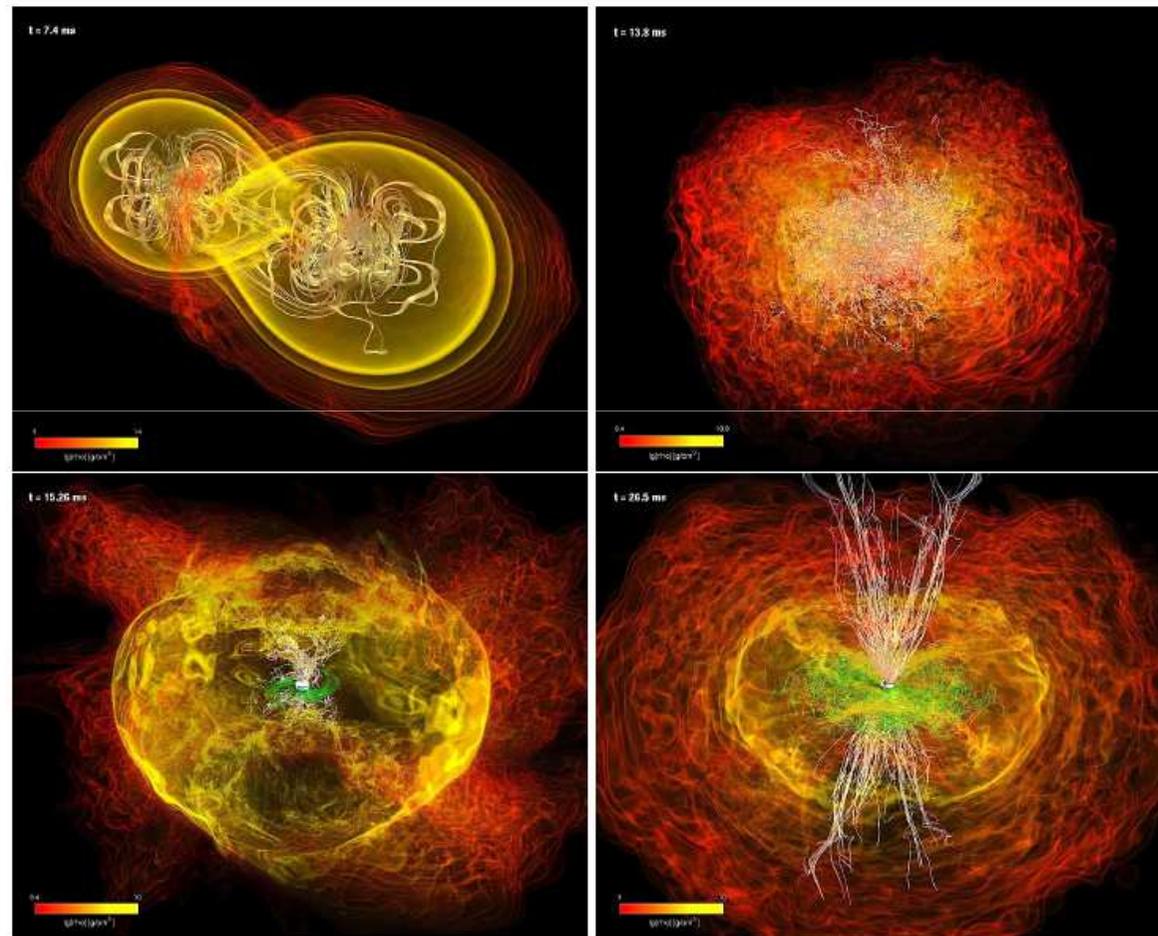
  

	B1820-11	J1829+2456	J1906+0746	B1913+16	B2127+11C
$P$ [ms]	279.8	41.0	144.1	59.0	30.5
$P_b$ [d]	357.8	1.18	0.17	0.3	0.3
$e$	0.79	0.14	0.085	0.62	0.68
$\log_{10}(\tau_c/\text{yr})$	6.5	10.1	5.1	8.0	8.0
$\log_{10}(\tau_g/\text{yr})$	15.8	10.8	8.5	8.5	8.3
Masses measured?	No	No	Yes	Yes	Yes

$$\dot{N}_{\text{merge}} \sim 10^{-5} - 10^{-4} \text{ yr}^{-1}$$

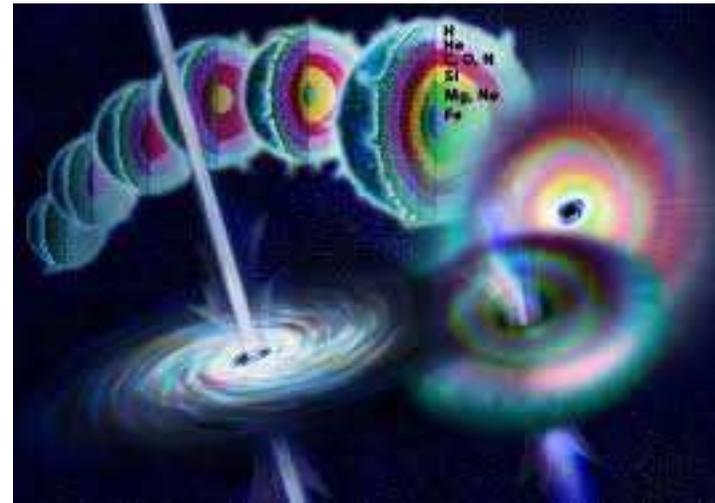
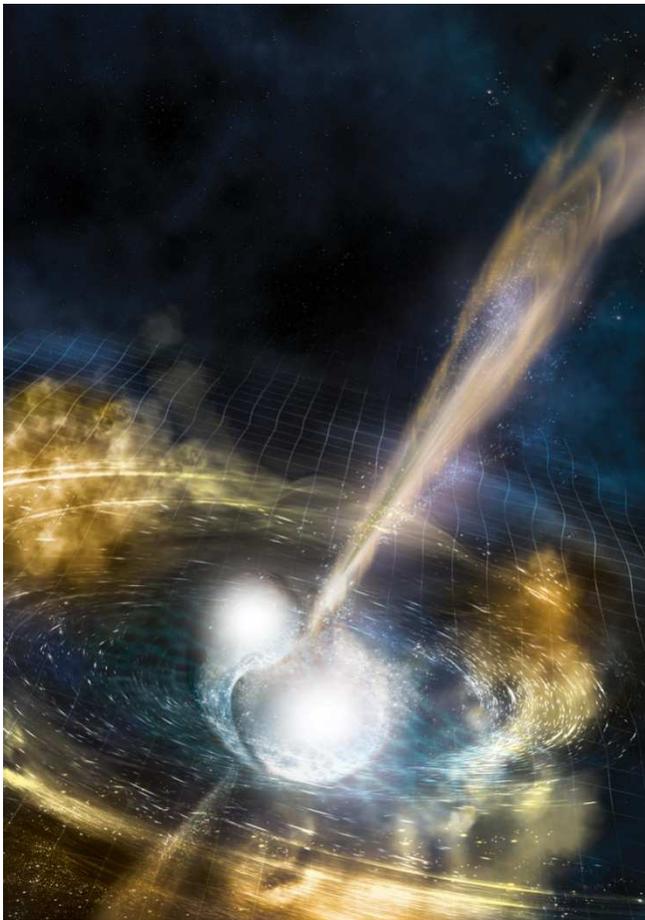
D,Fargion:27\_11\_2017  
(e.g. Kalogera et al. 2004)

# Magnetic Field making the Jet collimation (but not the GRB jet itself)



**Figure 13:** Evolution of the density in a NS-NS merger, with magnetic field lines superposed. The first panel shows the binary shortly after contact, while the second shows the short-lived HMNS remnant shortly before it collapses. In the latter two panels, a BH has already formed, and the disk around it winds up the magnetic field to a poloidal geometry of extremely large strength,  $\sim 10^{15}$  G, with an half-opening angle of  $30^\circ$ , consistent with theoretical SGRB models. Image reproduced by permission from Figure 1 of [241],  
D. Fargion: 27, 11, 2017

**How do NS NS explode? Into NS or BH?**  
**What are their GW , gamma,X, OT signals?**  
**The Jet morphology it is the reading key**



# Summary of the talk

- How an almost unbelievable rare correlated event (GW-GRB) at its very first discover (Observed at the detection edge values)
- It is , just **because of its extreme signals,** nevertheless a very probable one.

**First: List of the GW-GRB versus NS\_NS data**

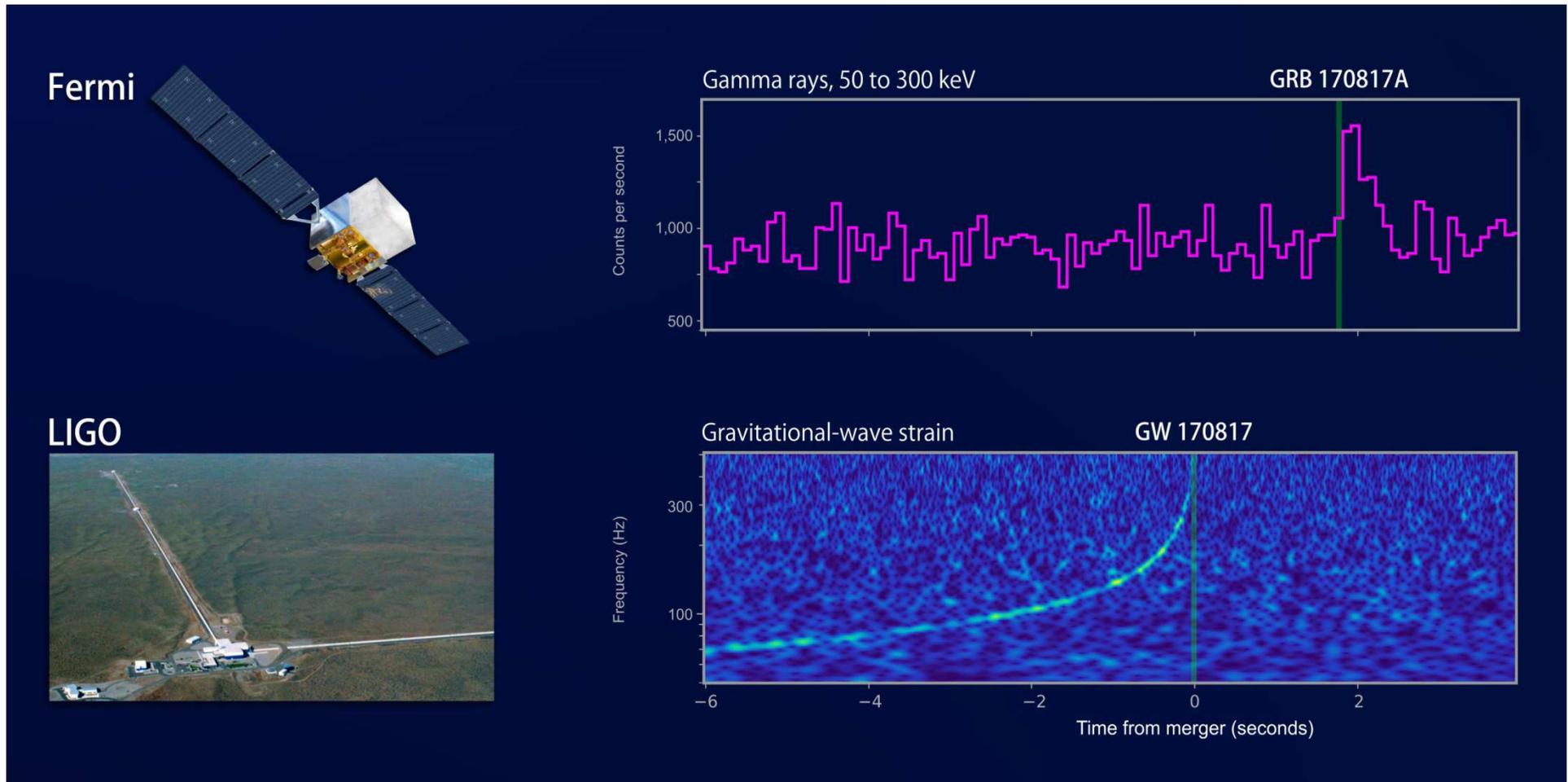
**Second: Possible explanations**

**In other words, how a GRB seen by a peculiar off axis dark side may shine in an unexpected way.**

# GW GRB 170817°: GW and Gamma

## A rare international multi detection

### 100 seconds, few thousand oscillations



# More than 70 detector observed GRB- GW 170817: 65 article in a day : 16 Oct.



# All particle play a role: Heavy Element birth on NS skin crust

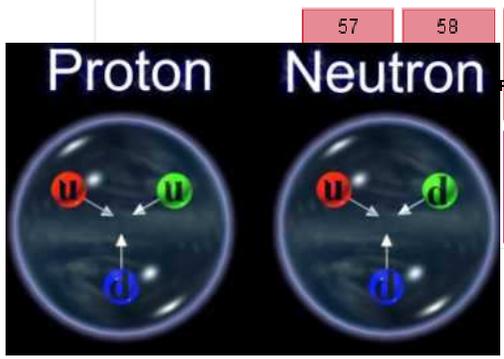
Periodic Table

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 <b>H</b> Hydrogen 1.008																	2 <b>He</b> Helium 4.00260
3 <b>Li</b> Lithium 6.940	4 <b>Be</b> Beryllium 9.01218												6 <b>C</b> Carbon 12.011	7 <b>N</b> Nitrogen 14.007	8 <b>O</b> Oxygen 15.999	9 <b>F</b> Fluorine 18.99840	10 <b>Ne</b> Neon 20.1797
11 <b>Na</b> Sodium 22.98977	12 <b>Mg</b> Magnesium 24.305												14 <b>Si</b> Silicon 28.085	15 <b>P</b> Phosphorus 30.97376	16 <b>S</b> Sulfur 32.060	17 <b>Cl</b> Chlorine 35.450	18 <b>Ar</b> Argon 39.948
19 <b>K</b> Potassium 39.0983	20 <b>Ca</b> Calcium 40.078	21 <b>Sc</b> Scandium 44.95591											32 <b>Ge</b> Germanium 72.630	33 <b>As</b> Arsenic 74.92160	34 <b>Se</b> Selenium 78.971	35 <b>Br</b> Bromine 79.904	36 <b>Kr</b> Krypton 83.798
37 <b>Rb</b> Rubidium 85.4678	38 <b>Sr</b> Strontium 87.62	39 <b>Y</b> Yttrium 88.90584											50 <b>Sn</b> Tin 118.710	51 <b>Sb</b> Antimony 121.760	52 <b>Te</b> Tellurium 127.60	53 <b>I</b> Iodine 126.90447	54 <b>Xe</b> Xenon 131.293
55 <b>Cs</b> Cesium 132.90545	56 <b>Ba</b> Barium 137.327	71 <b>Lu</b> Lutetium 174.967											82 <b>Pb</b> Lead 207.2	83 <b>Bi</b> Bismuth 208.98040	84 <b>Po</b> Polonium [209]	85 <b>At</b> Astatine [210]	86 <b>Rn</b> Radon [222]
87 <b>Fr</b> Francium [223]	88 <b>Ra</b> Radium [226]	103 <b>Lr</b> Lawrencium [262]											114 <b>Fl</b> Flerovium [289]	115 <b>Mc</b> Moscovium [288]	116 <b>Lv</b> Livermorium [293]	117 <b>Ts</b> Tennessine [294]	118 <b>Og</b> Oganesson [294]

## Elementary Particles

Quarks	mass	2.4 MeV/c <sup>2</sup>	1.27 GeV/c <sup>2</sup>	171.2 GeV/c <sup>2</sup>	0	7 GeV/c <sup>2</sup>
	charge	2/3	2/3	2/3	0	0
	spin	1/2	1/2	1/2	0	0
name	<b>u</b> up	<b>c</b> charm	<b>t</b> top	<b>γ</b> photon	<b>H</b> Higgs boson	
Leptons	mass	4.8 MeV/c <sup>2</sup>	104 MeV/c <sup>2</sup>	4.2 GeV/c <sup>2</sup>	0	91.2 GeV/c <sup>2</sup>
	charge	-1/3	-1/3	-1/3	0	0
	spin	1/2	1/2	1/2	0	0
name	<b>d</b> down	<b>s</b> strange	<b>b</b> bottom	<b>g</b> gluon	<b>Z<sup>0</sup></b> Z boson	
	mass	<2.2 eV/c <sup>2</sup>	<0.17 MeV/c <sup>2</sup>	<15.5 MeV/c <sup>2</sup>	0	80.4 GeV/c <sup>2</sup>
	charge	0	0	0	0	±1
	spin	1/2	1/2	1/2	0	1
	name	<b>ν<sub>e</sub></b> electron neutrino	<b>ν<sub>μ</sub></b> muon neutrino	<b>ν<sub>τ</sub></b> tau neutrino	<b>W<sup>±</sup></b> W boson	

I II III  
Three Generations of Matter



57 <b>Pr</b> Praseodymium 140.90766	58 <b>Nd</b> Neodymium 144.242	59 <b>Pm</b> Promethium [144.91276]	60 <b>Sm</b> Samarium 150.36	61 <b>Eu</b> Europium 151.964	62 <b>Gd</b> Gadolinium 157.25	63 <b>Tb</b> Terbium 158.92535	64 <b>Dy</b> Dysprosium 162.500	65 <b>Ho</b> Holmium 164.93033	66 <b>Er</b> Erbium 167.259	67 <b>Tm</b> Thulium 168.93422	68 <b>Yb</b> Ytterbium 173.04
91 <b>Pa</b> Protactinium 231.03588	92 <b>U</b> Uranium 238.02891	93 <b>Np</b> Neptunium [237]	94 <b>Pu</b> Plutonium [244]	95 <b>Am</b> Americium [243]	96 <b>Cm</b> Curium [247]	97 <b>Bk</b> Berkelium [247]	98 <b>Cf</b> Californium [251]	99 <b>Es</b> Einsteinium [252]	100 <b>Fm</b> Fermium [257]	101 <b>Mendelevium</b> [258]	102 <b>Nobelium</b> [259]

# A Rich **Unified Science Mosaica**: 2017

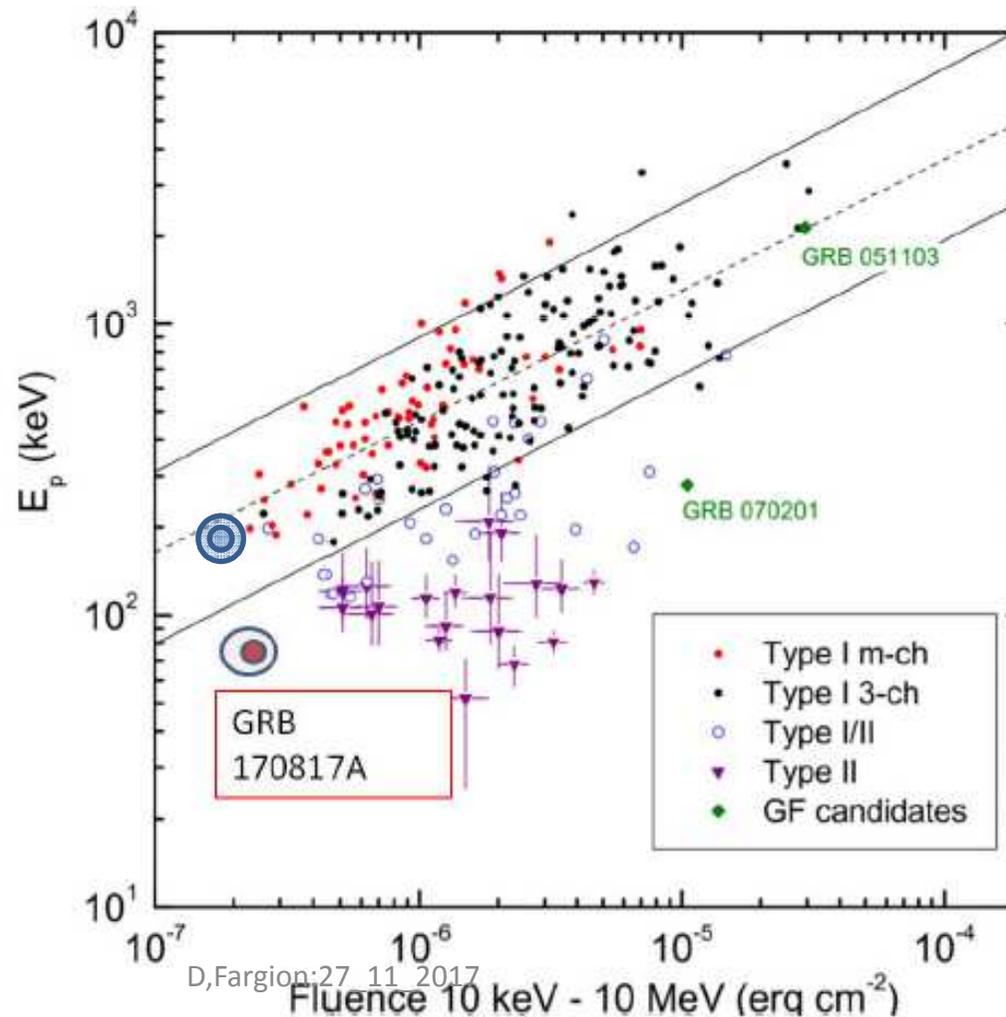
- ***Rate of NS-NS collapse in the Universe by GW 170817***
- ***Rate of NS NS merging by known binary***
- ***Rate of Heavy Nuclei Chemical Pollution***
- ***Rate of Kick NS or BH velocities***
- ***Rate of Short GRB in the near Universe***
- ***Anisotropy of GRB Jet (Kick velocity of NS)***
- ***GRB afterglow as a Kilonova . UV,X,IR,Radio***
- ***Gamma Jet and Geometry of Beaming solid angle***
- ***Time delay GW GRB***
- ***ICS, Synchrotron Radiation, Lorentz factor, GRB Energy Spectra***
- ***GRB polarization***
- ***Thermal Neutrino and UHE Neutrino by GRB***
- ***Beaming View and Probability to be observed***

## *Our main message*

- The rarest values of the GRB 170817a
- Make somehow more acceptable the event by an **off axis** view of the jet
- **It might require an additional Jet component hortogonal to the jet (wider jet disk):**
- *The synchrotron gamma disk*

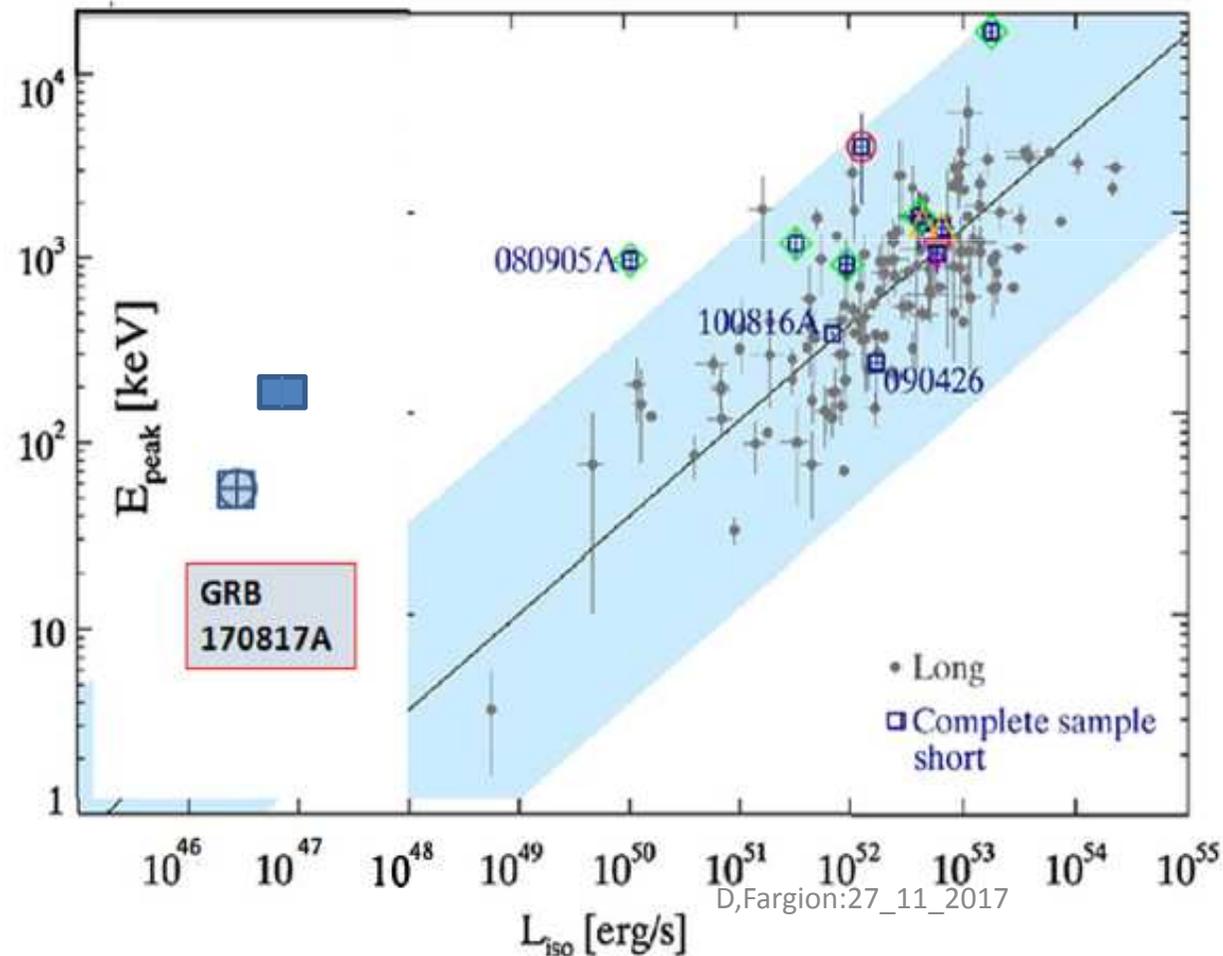
# GRB170817a :The *most weak fluence* SGRB observed

*D. Fargion, M. Khlopov & P. Oliva*

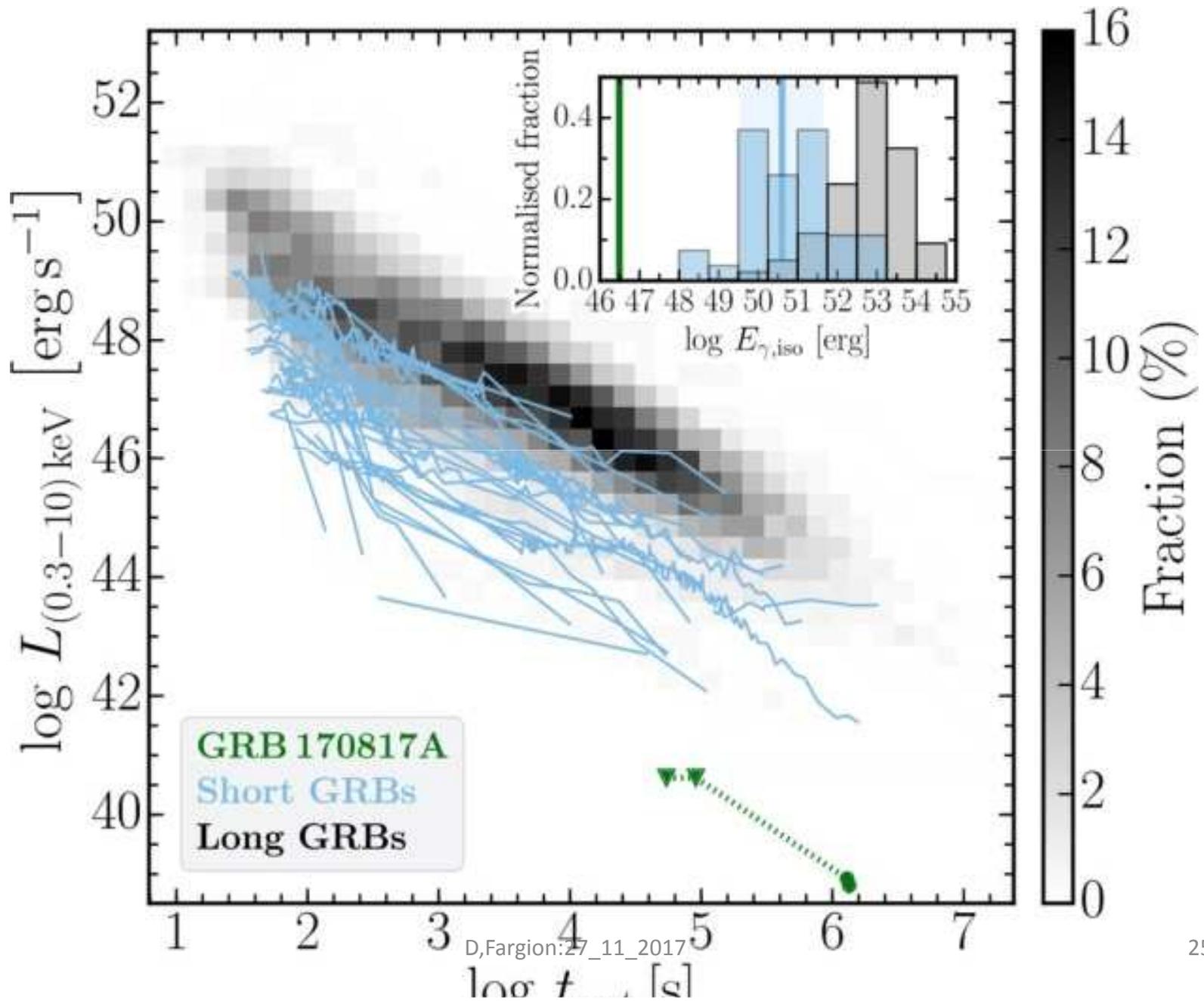


# The most extreme Luminosity peak

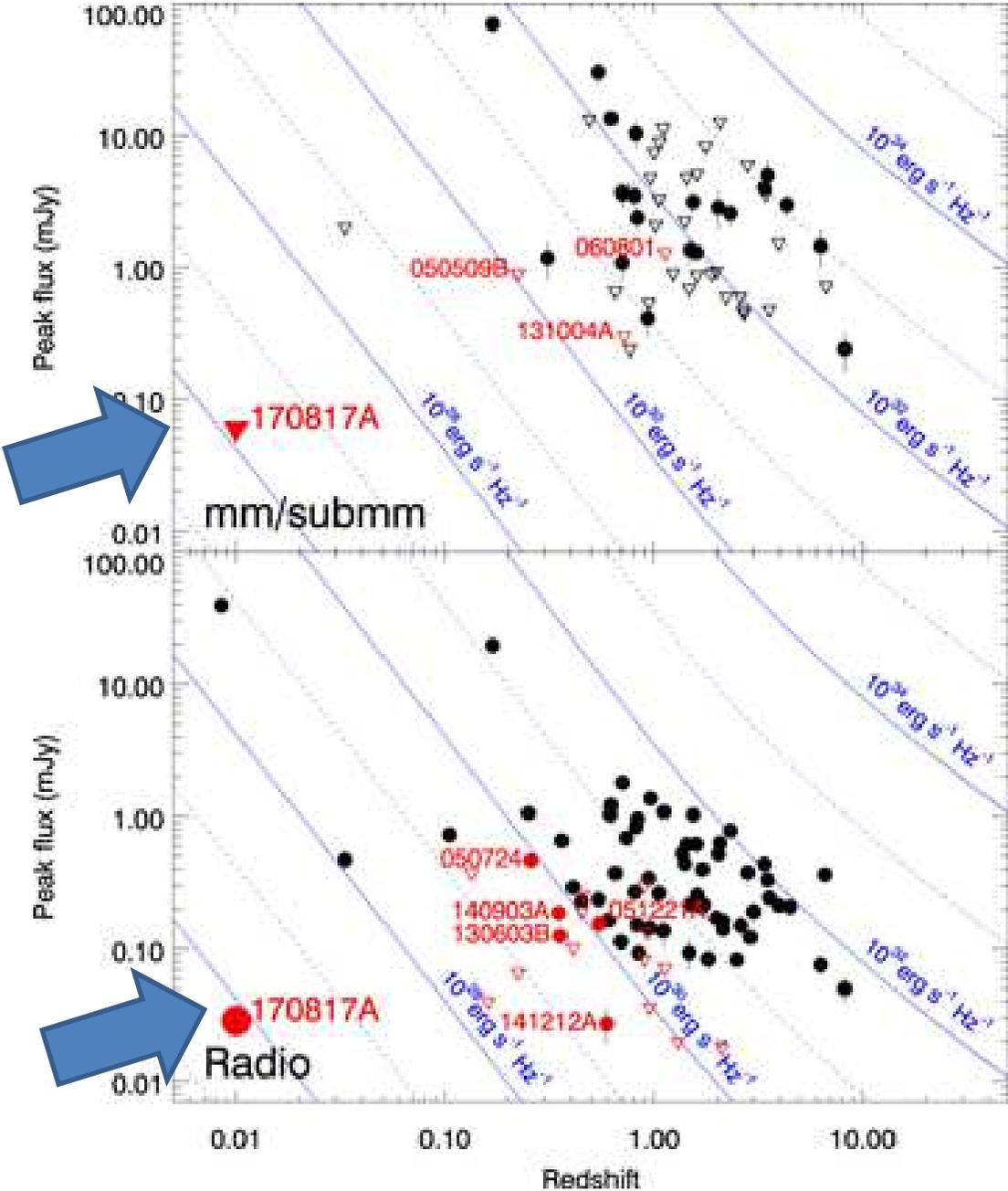
*Could GRB170817A be really correlated to an NS-NS merging?*



# A very rare X ray afterglow



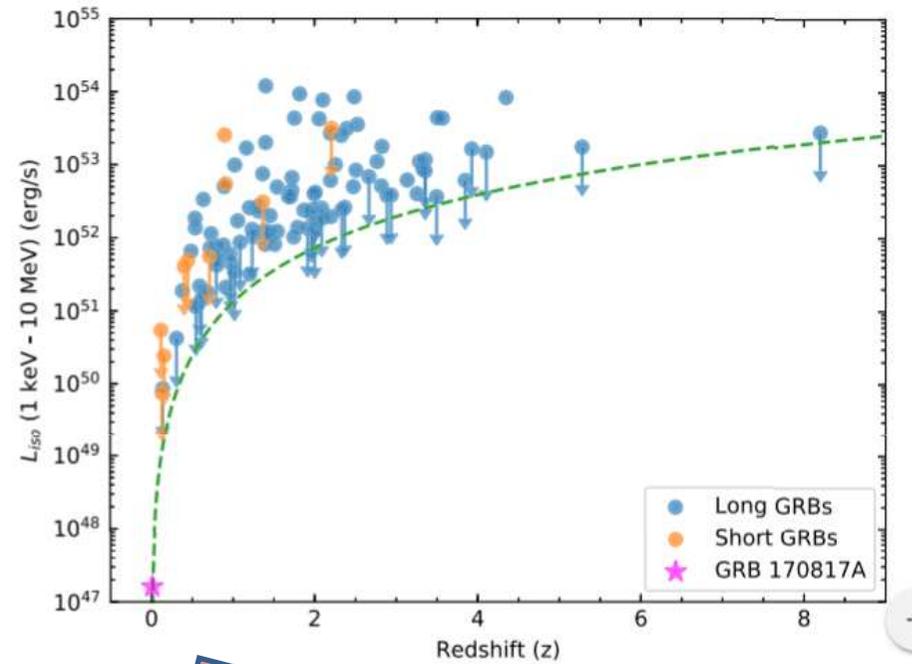
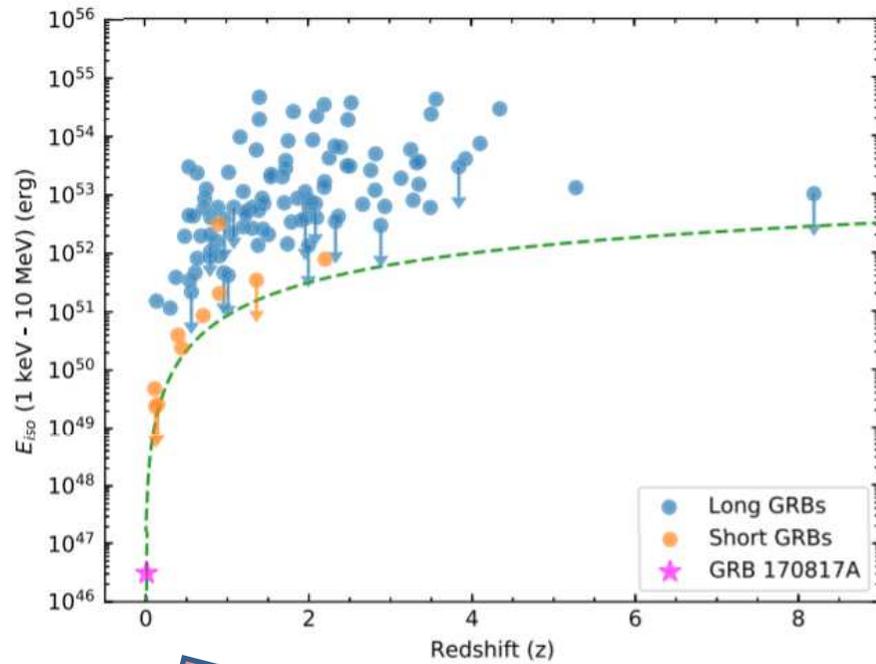
# The *rarest* IR and Radio Afterglow



# The nearest GW and SGRB ever observed

THE ASTROPHYSICAL JOURNAL LETTERS, 848:L13 (27pp), 2017 October 20

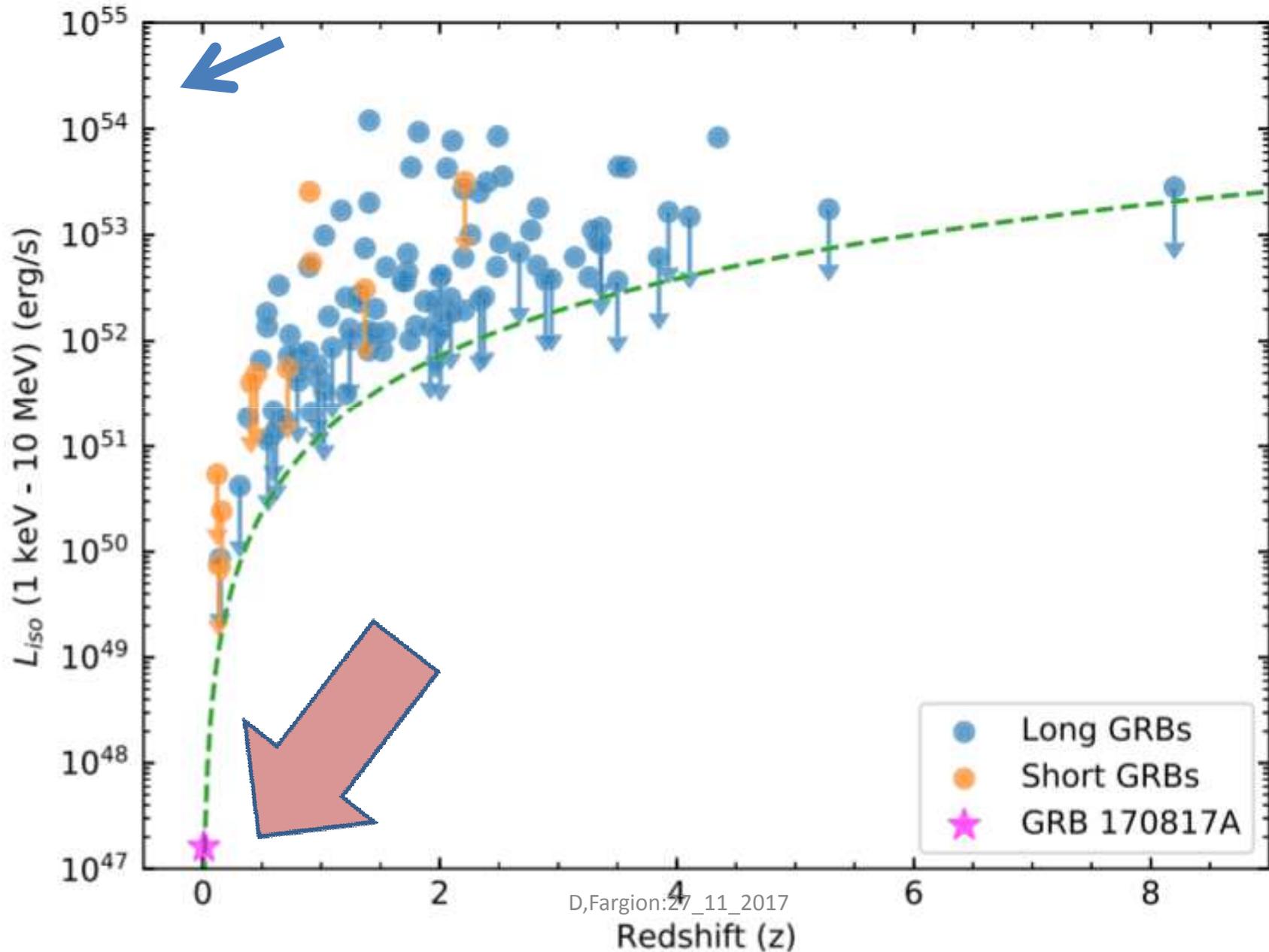
Abbott et al.



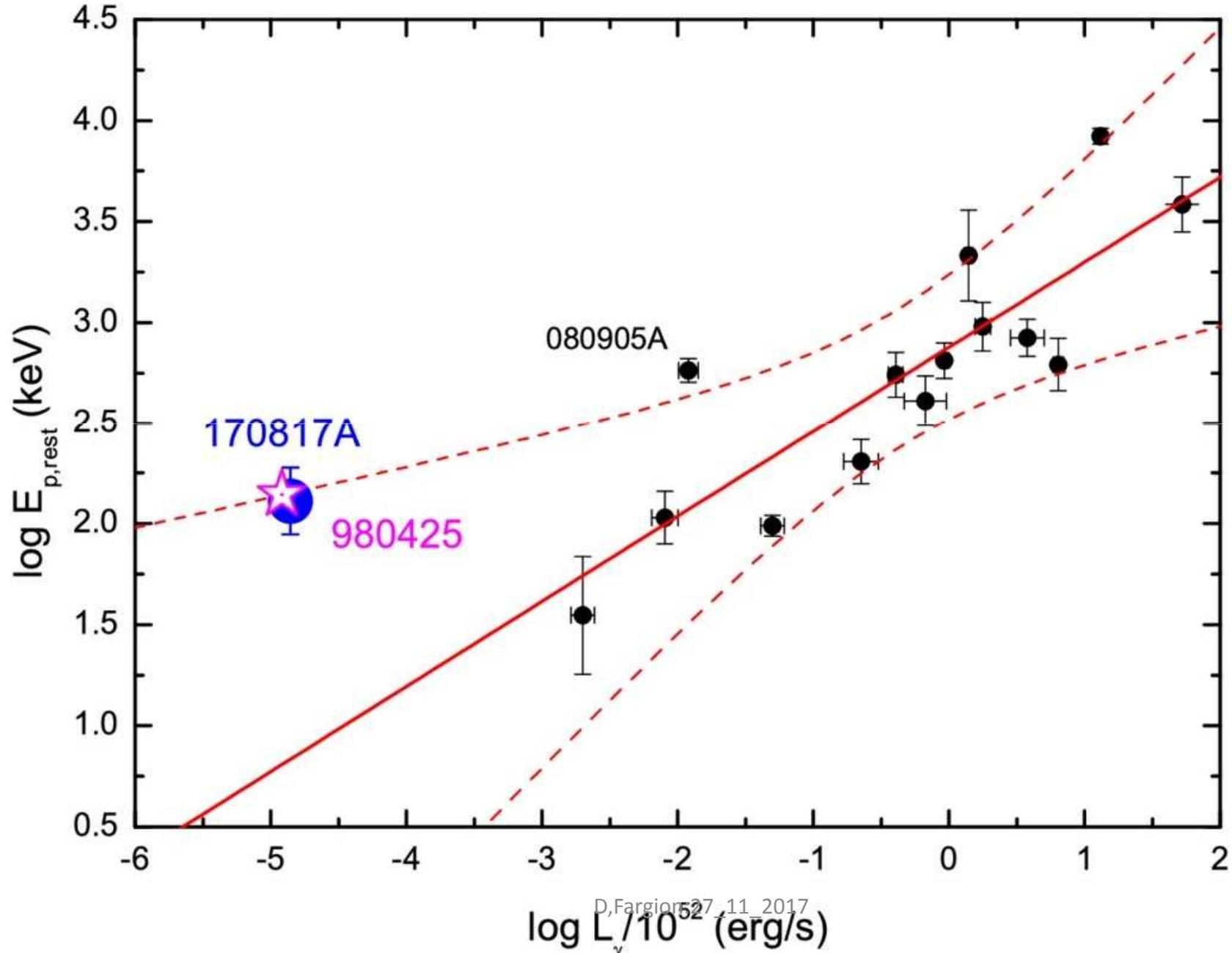
# ***IMPORTANT LESSON by GRBS***

- *There is a common way to address to each GRBs as an unique one, forgetting all the thousands earlier ones.*
- *These 2000 GRBs requires an unified model that cannot be adapted by ad hoc condition each time for event spread by their apparent Luminosity out 7-8 order of manitudes*
- *One must keep the whole GRB hystory lesson alive!*
- *It is possible an electron power law spectra ranging few thousands Lorentz fator to tens one. The solid angle spread from  $(1/3000)^2$  almost 7 order of magnitude*

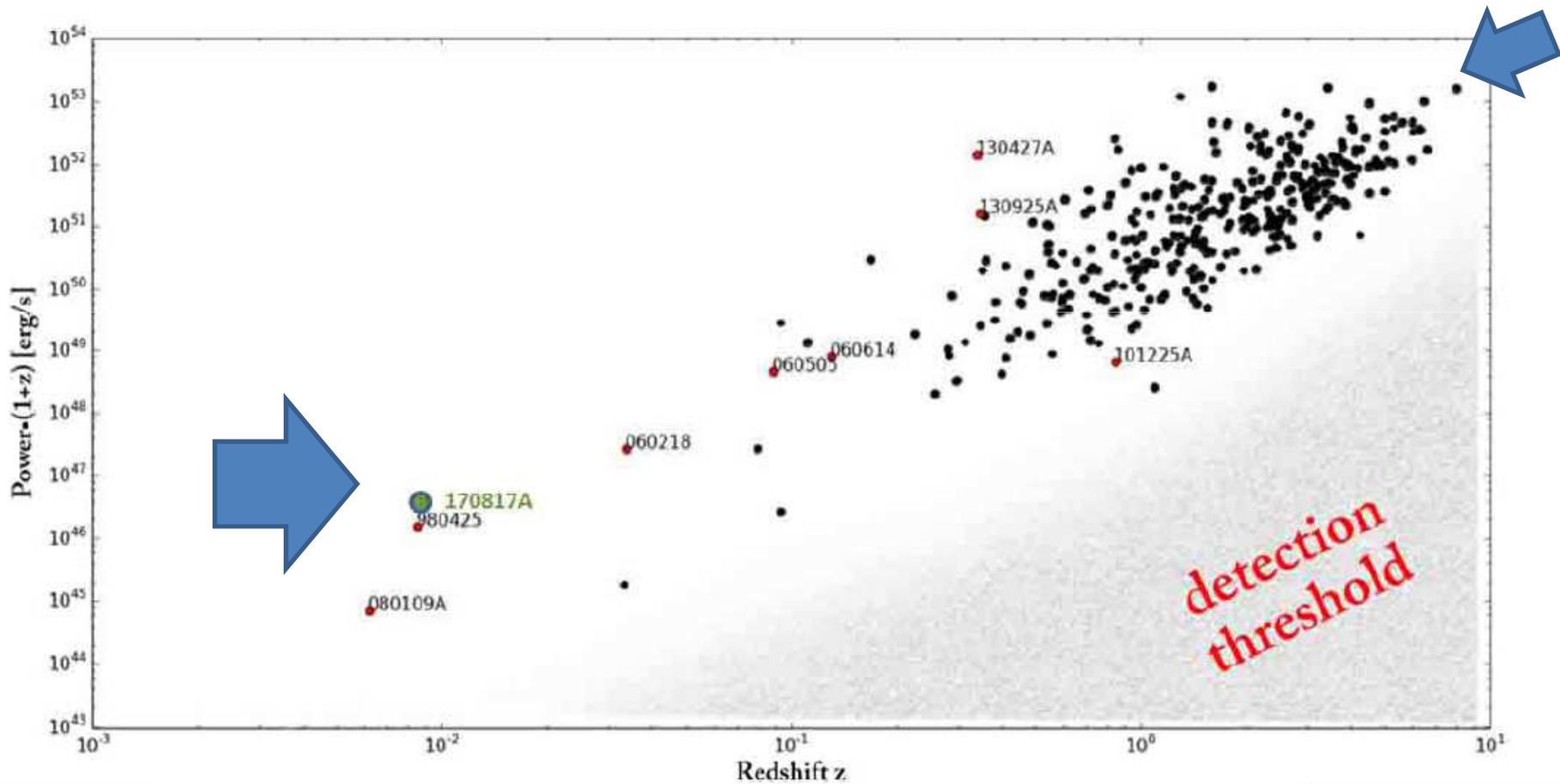
# Apparent Power versus Distance conspiracy



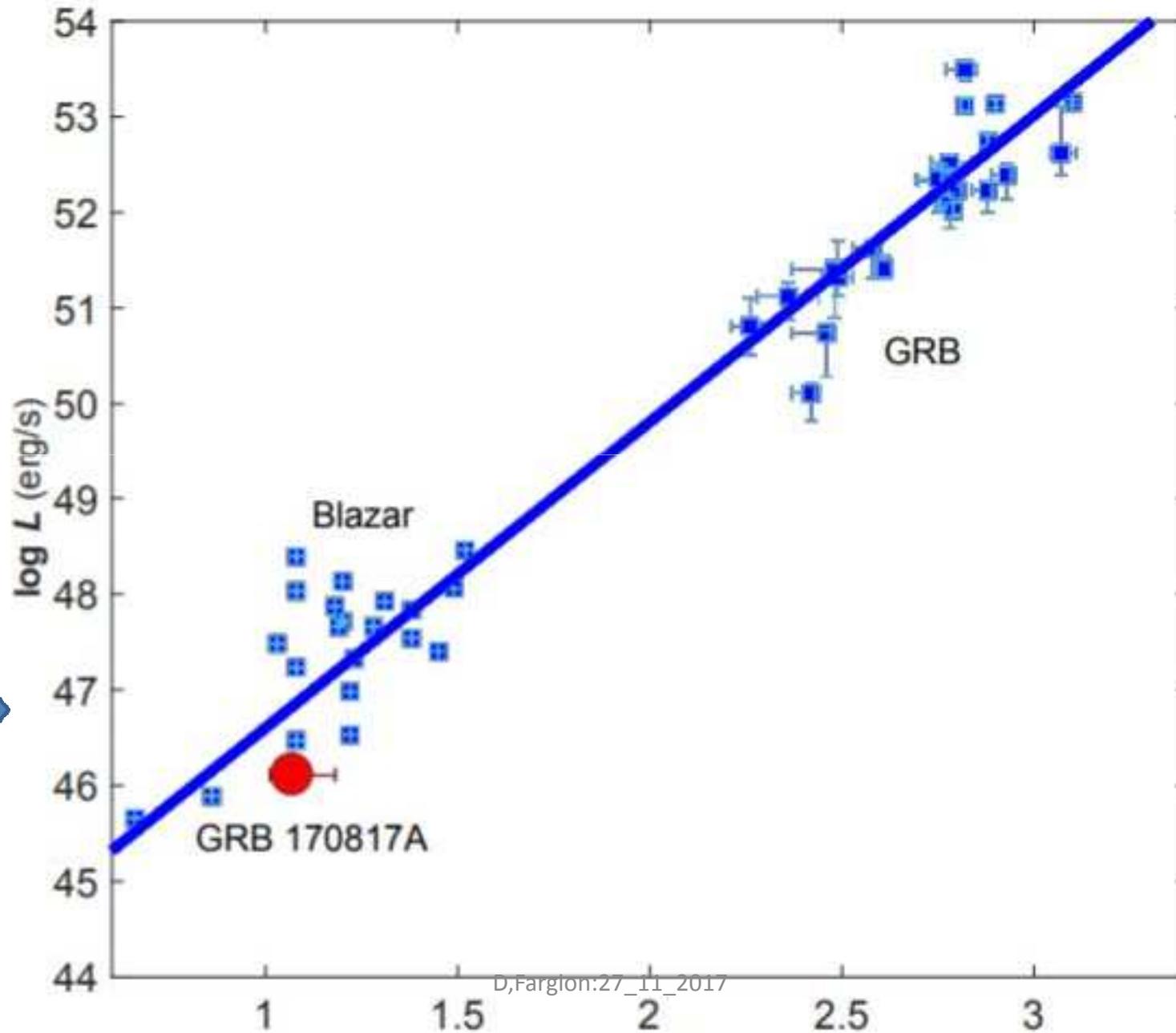
# 25 April 1998-GRB -170817A- connection



*The Nearest and Less Powerful event.  
We claimed on 1999 the GRB 980425 off  
axis nature: 8 order-Solid angle!*



# *Also a Blazar unified connection*



# NS-NS-Rates by unique GRB170817a event

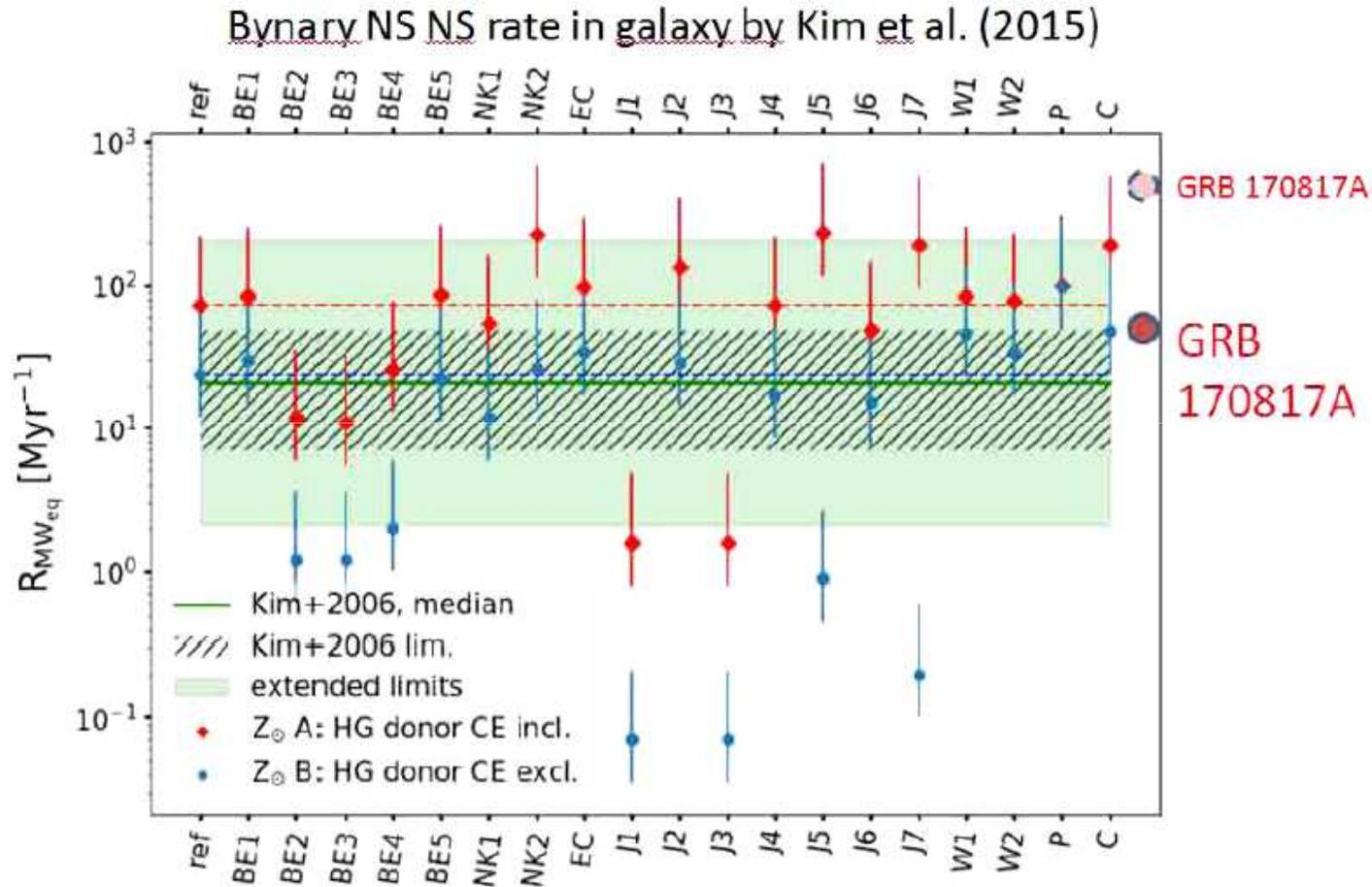
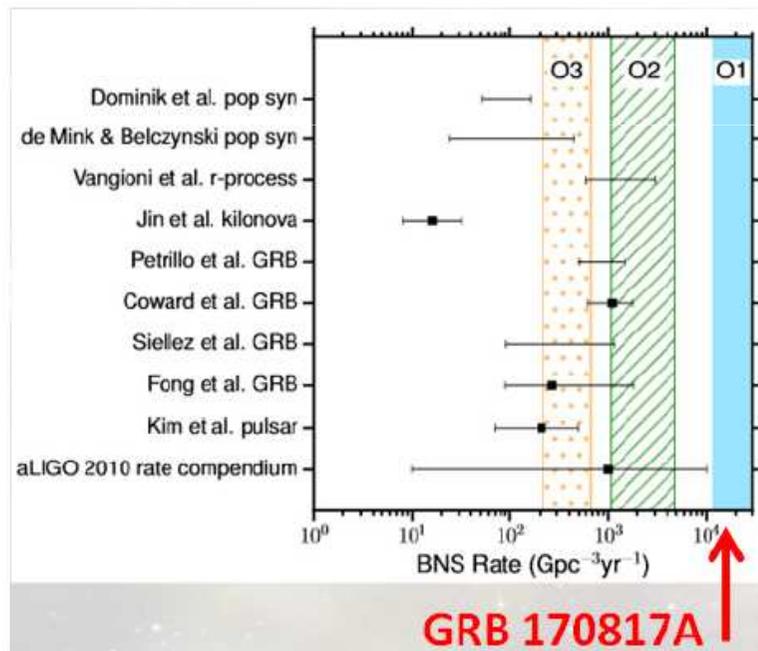


Fig. 8. The consequent NS–NS collapse rate derived by the unique GRB170817A event, assumed

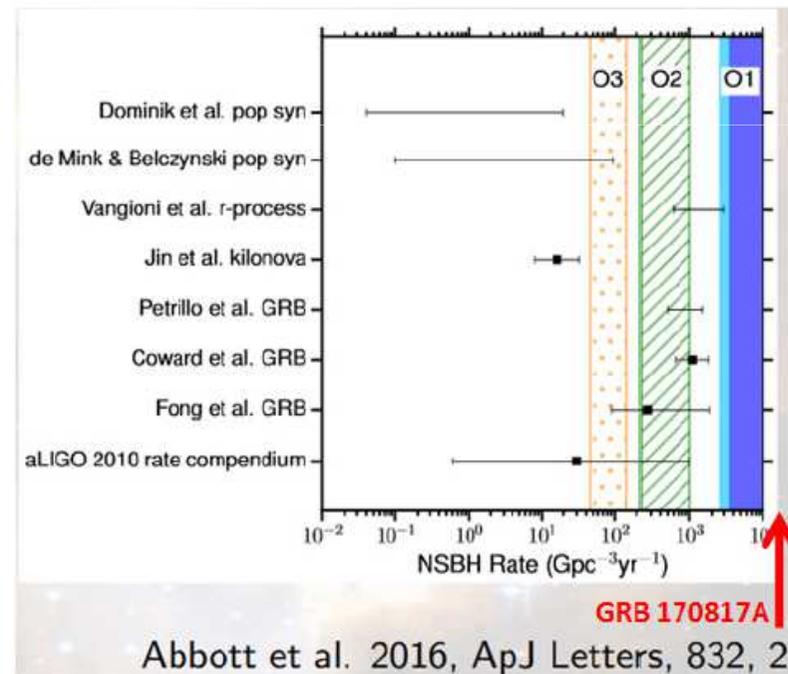
# The different expected NS NS rate

upper limit on merger rates based on non-detection

NS-NS



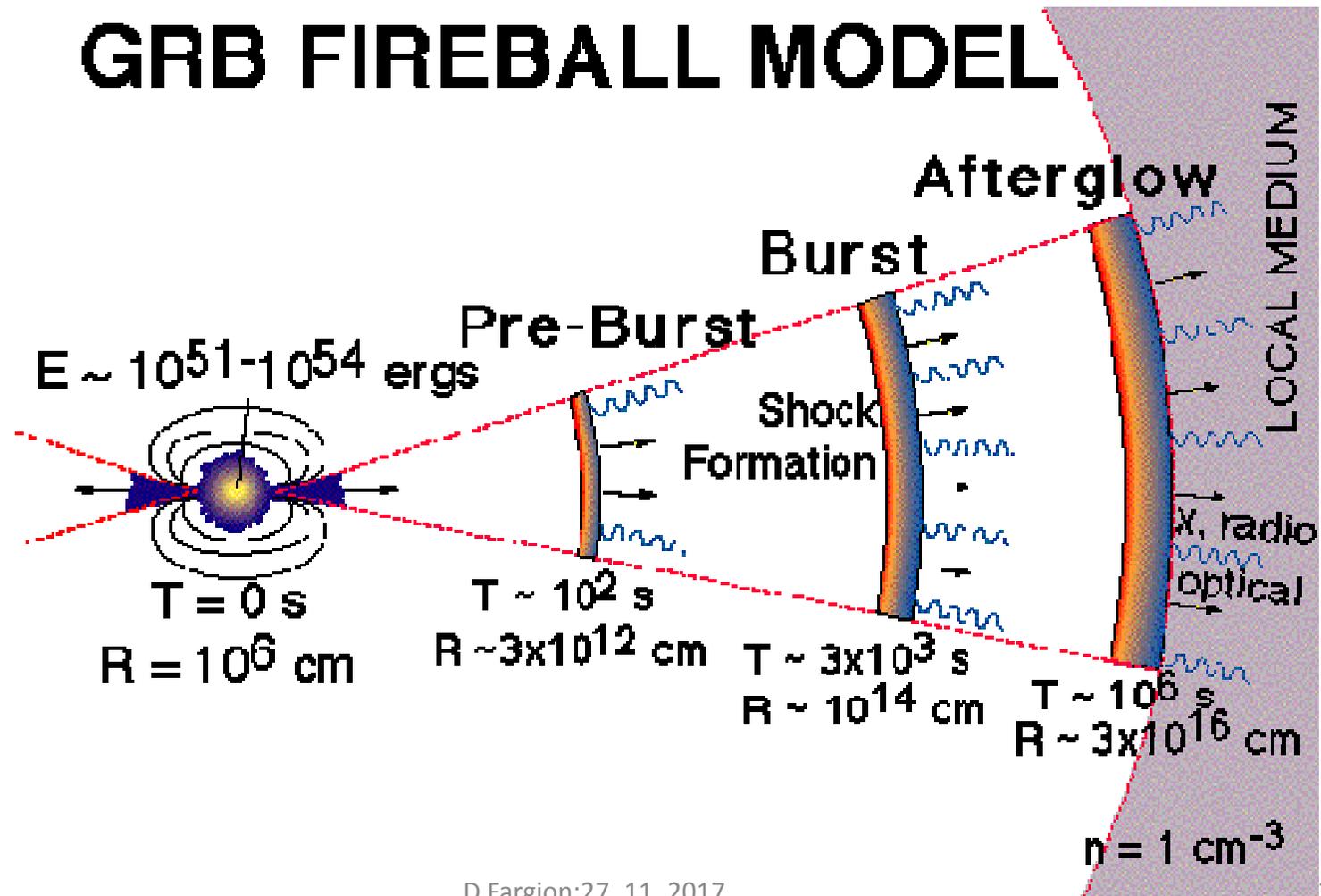
NS-BH



OLD GRB MODEL out of fashion now

# The failure of the Fountain GRB Fireball

## GRB FIREBALL MODEL



***Thin Precessing Beaming it is the key of the  
apparent GRB powers huge diversity***



## ***GRB peaked, rebrightening signature***

- ***A thin precessing Jet may by geometry at once explain sharp variability and multi peaked events.***
- ***The maximal Lorentz factor of the electron in the Jet beam offer the maximal energy and alignment of the GRB. The most far way, the largest sample, the most aligned and apparent brightest ones.***
- ***The thin precessing jet span a solid angle as large as a millionth of steradian.***

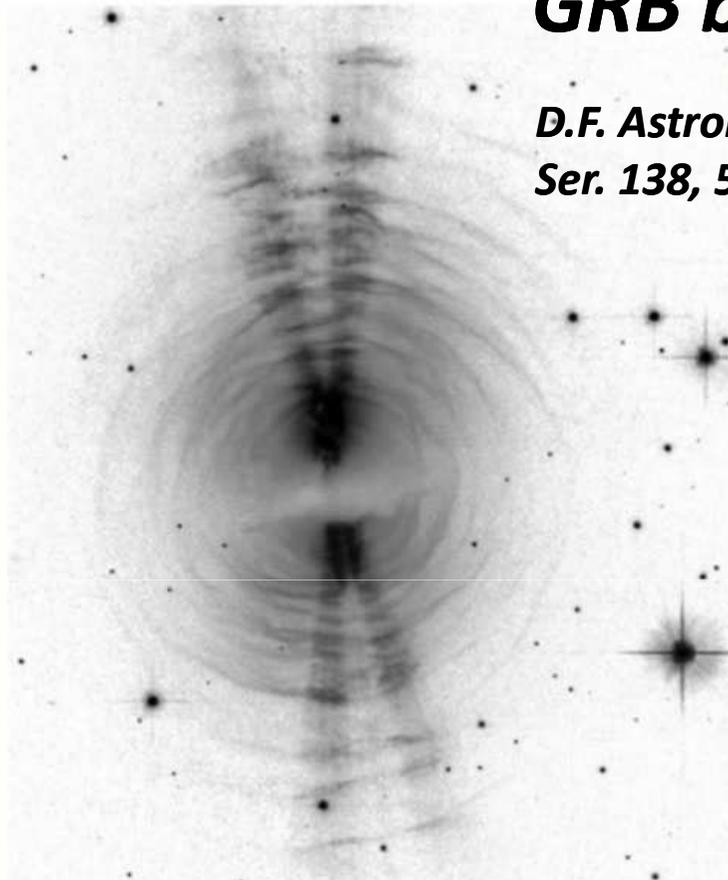
## **On the nature of GRB-SGRs blazing jets**

***D.F.Astron. Astrophys. Suppl. Ser. 138, 507–508(1999),***

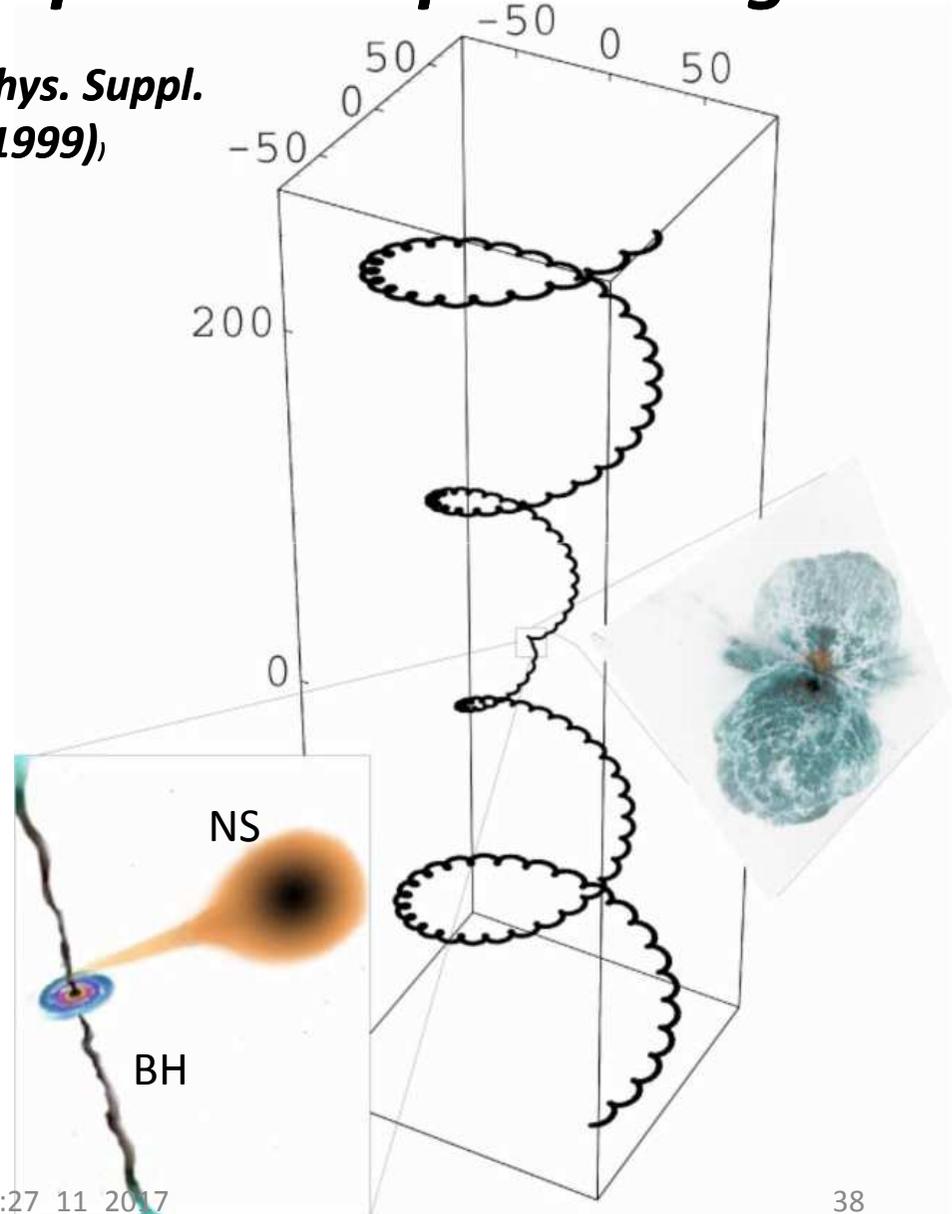
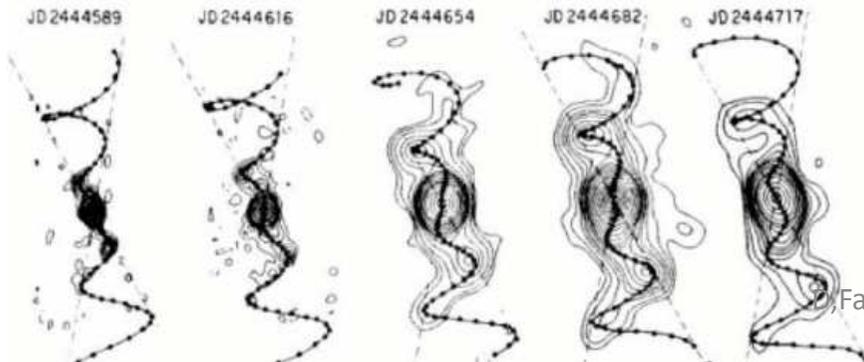
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# GRB by thin persistent precessing Jet

*D.F. Astron. Astrophys. Suppl.  
Ser. 138, 507–508(1999),*

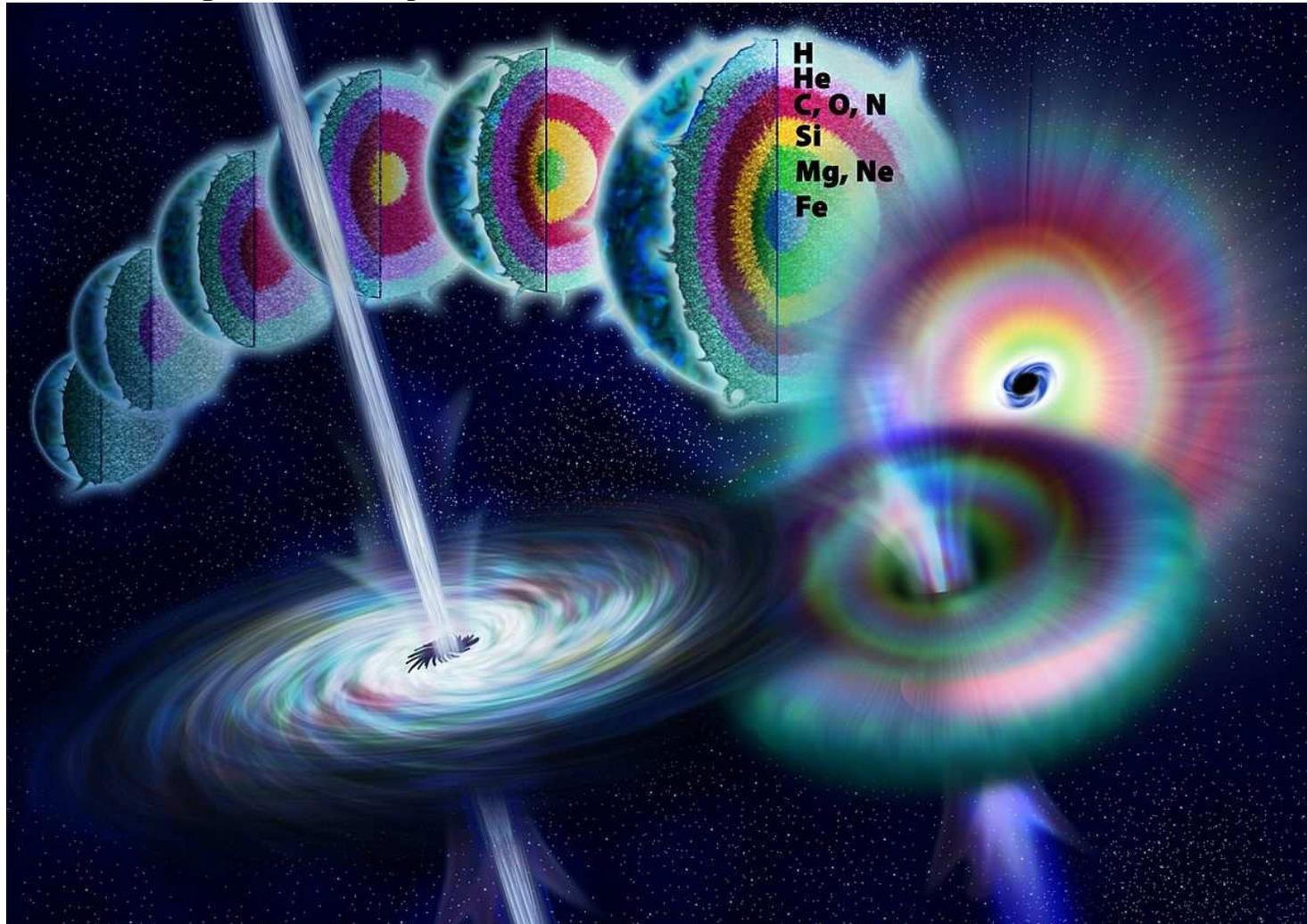


The SS433 precessing jet



Fargion:27\_11\_2017

# GRB jet by models NASA 2015

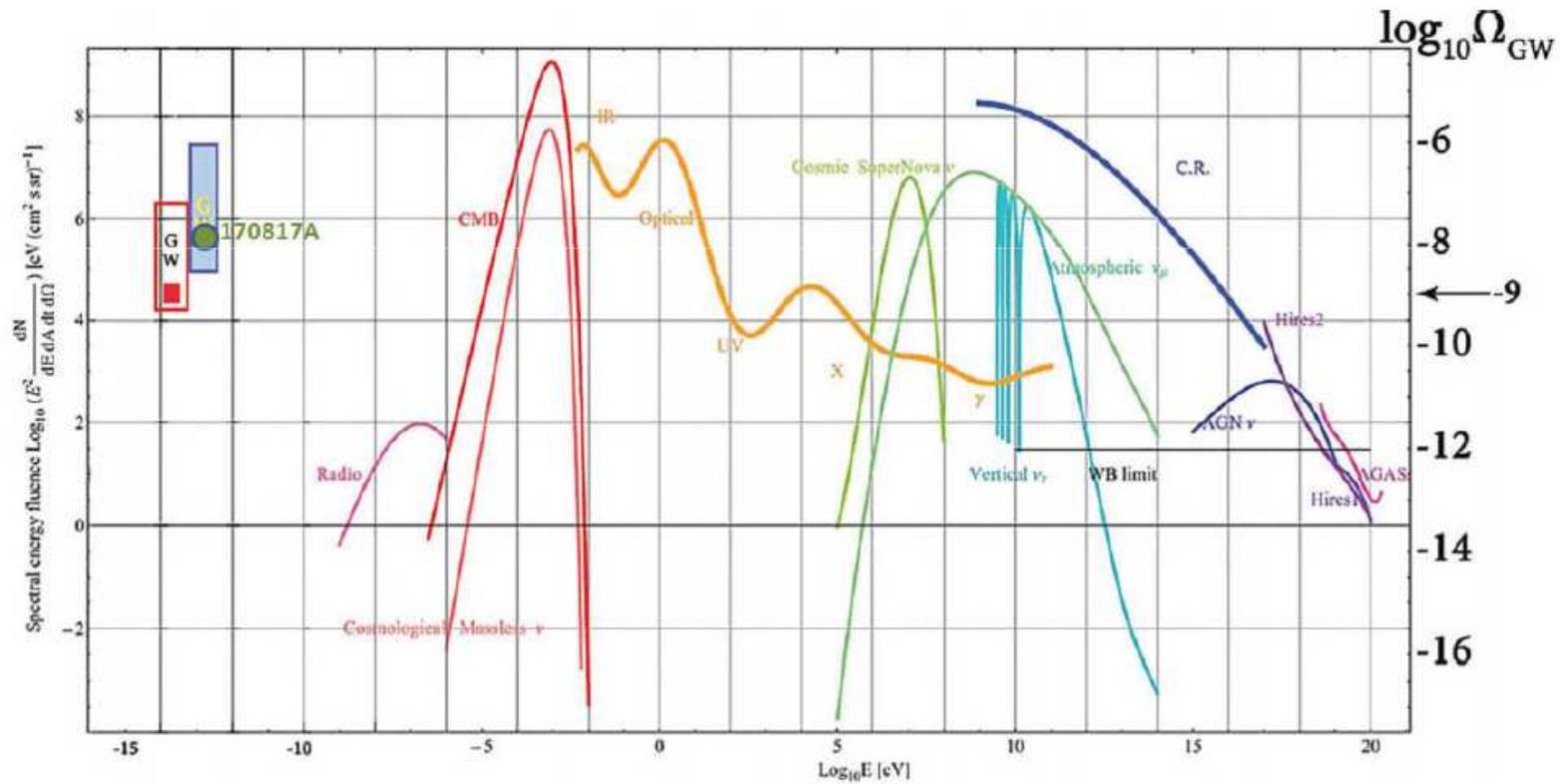


# Main message: To fit GRB in unique model thin Jet is needed

- *To embrace 8 order of magnitude in all apparent luminosity GRBs we need **or 8 order of magnitude in mass**: (unable to explain short GRBs durations because larger Schwarchild time scales)*
- *Or to require a very thin Jet in GRB whose solid angle **is 8 order of magnitude** observation may spread in a wide geometrical amplifications for any given view.*
- *Thin precessing Jet may also explain short scale multi-variability : a Must! The spin precessing explain the variability:*
- *(X Precursors, Gamma-X-optical rebrightening)*

# The GW contribute in Universe

*D. Fargion, M. Khlopov & P. Oliva*



# The graviton number flux rule over Cosmic BBR

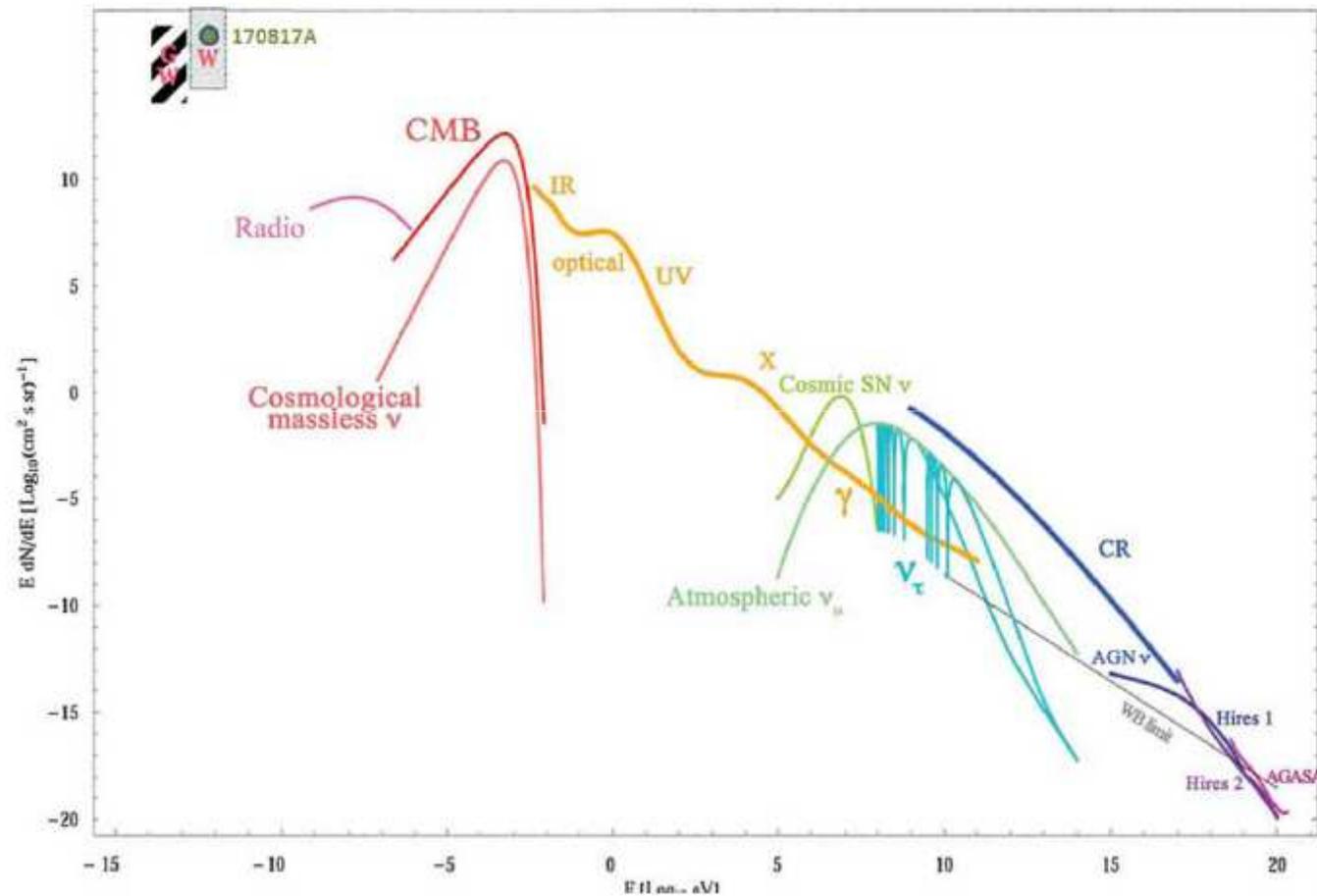
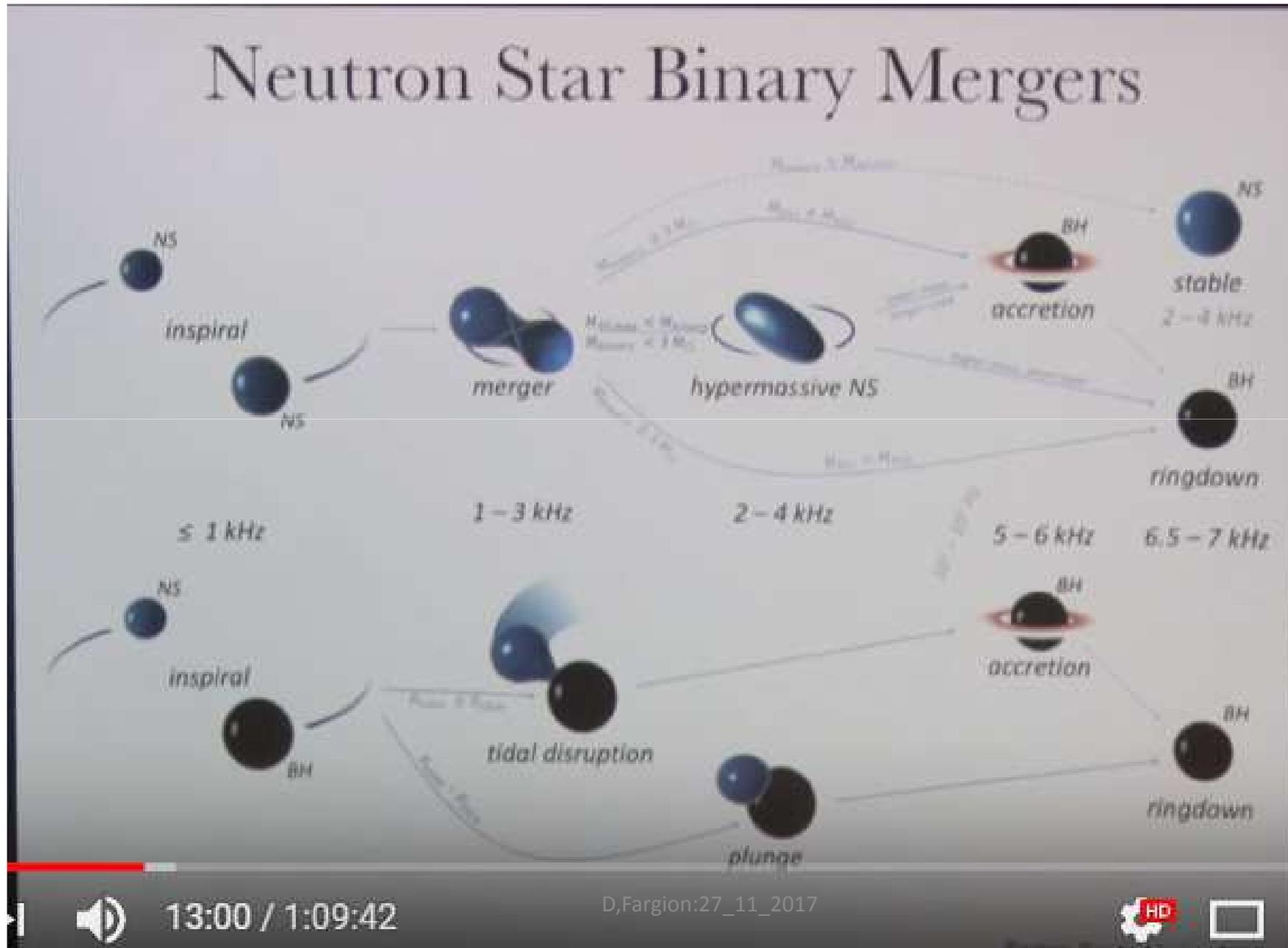


Fig. 11. The GW GRB170817A flux number density contributes by extrapolating its  $(40 \text{ Mpc})^3$  volume and an event a year on average along all the universe.

# NS NS Collapse: Usually no Jet considered



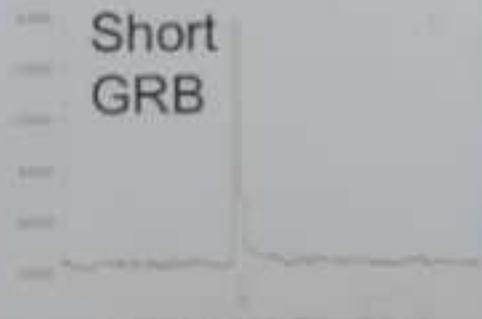
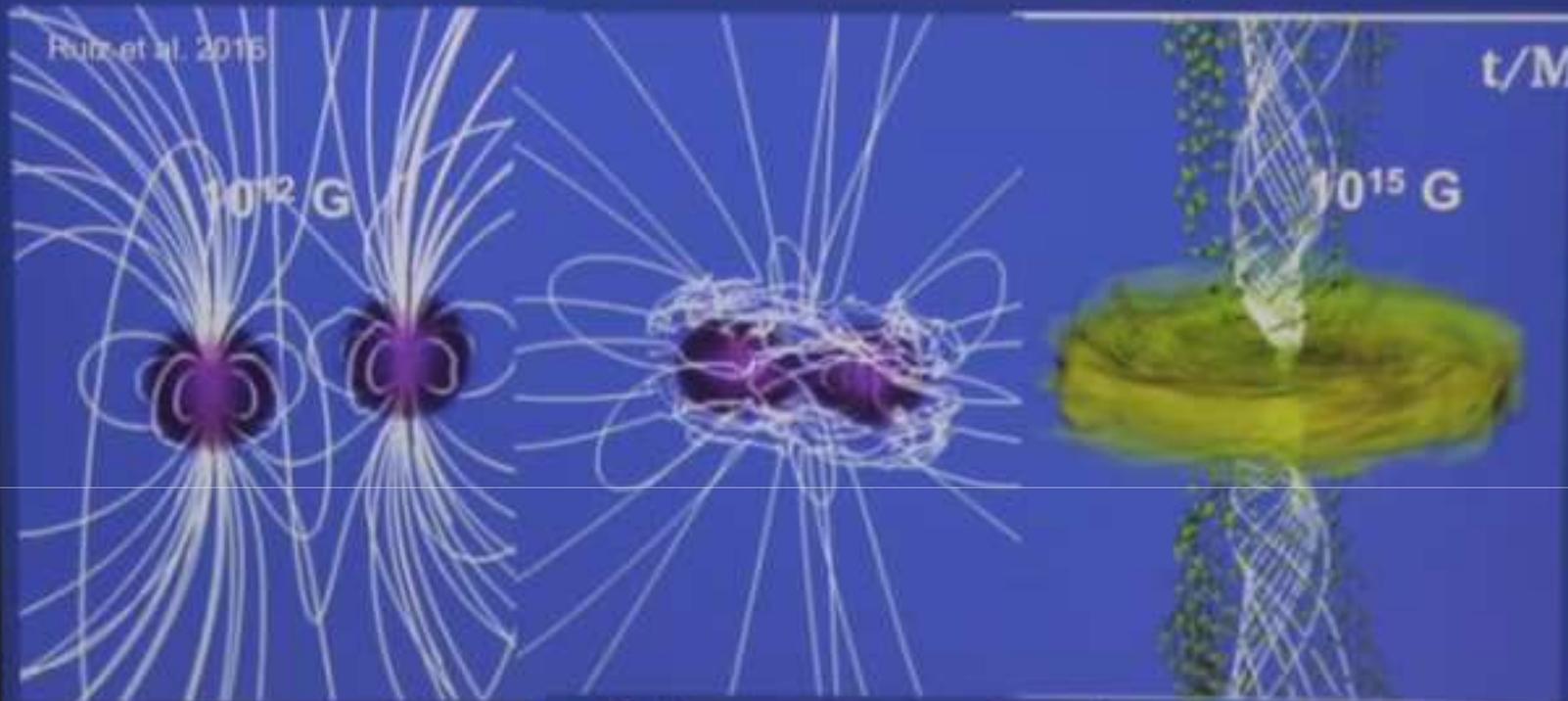
13:00 / 1:09:42

D,Fargion:27\_11\_2017



# Relativistic Jets & Gamma-Ray Bursts

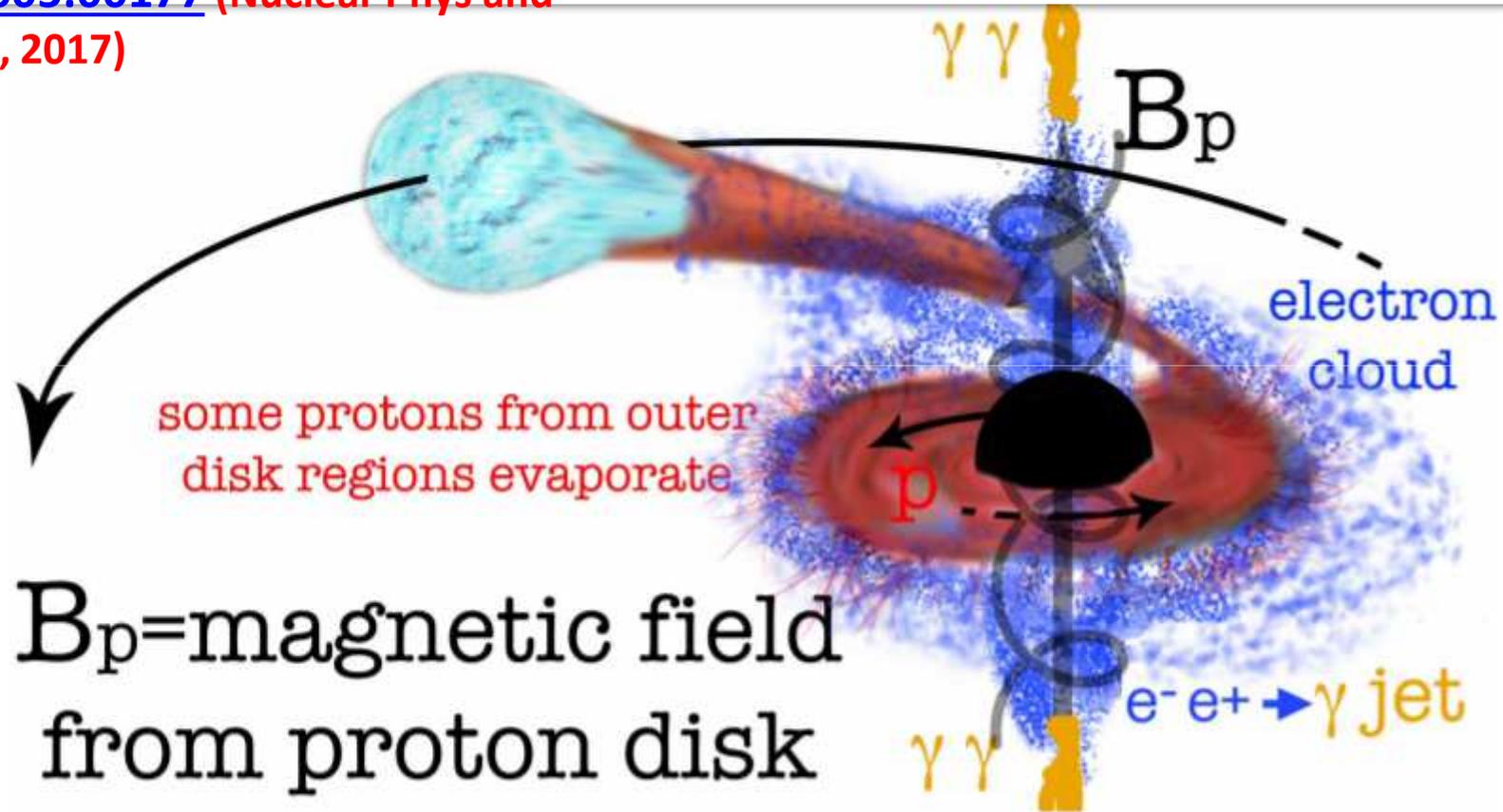
Rutir-et al. 2016



- Both young star-forming & old elliptical host galaxies
- No coincident supernova explosion
- Offset of GRB location from galaxy, consistent with NS birth kicks (e.g. Fong+13)  
See Berger 2014, ARA&A

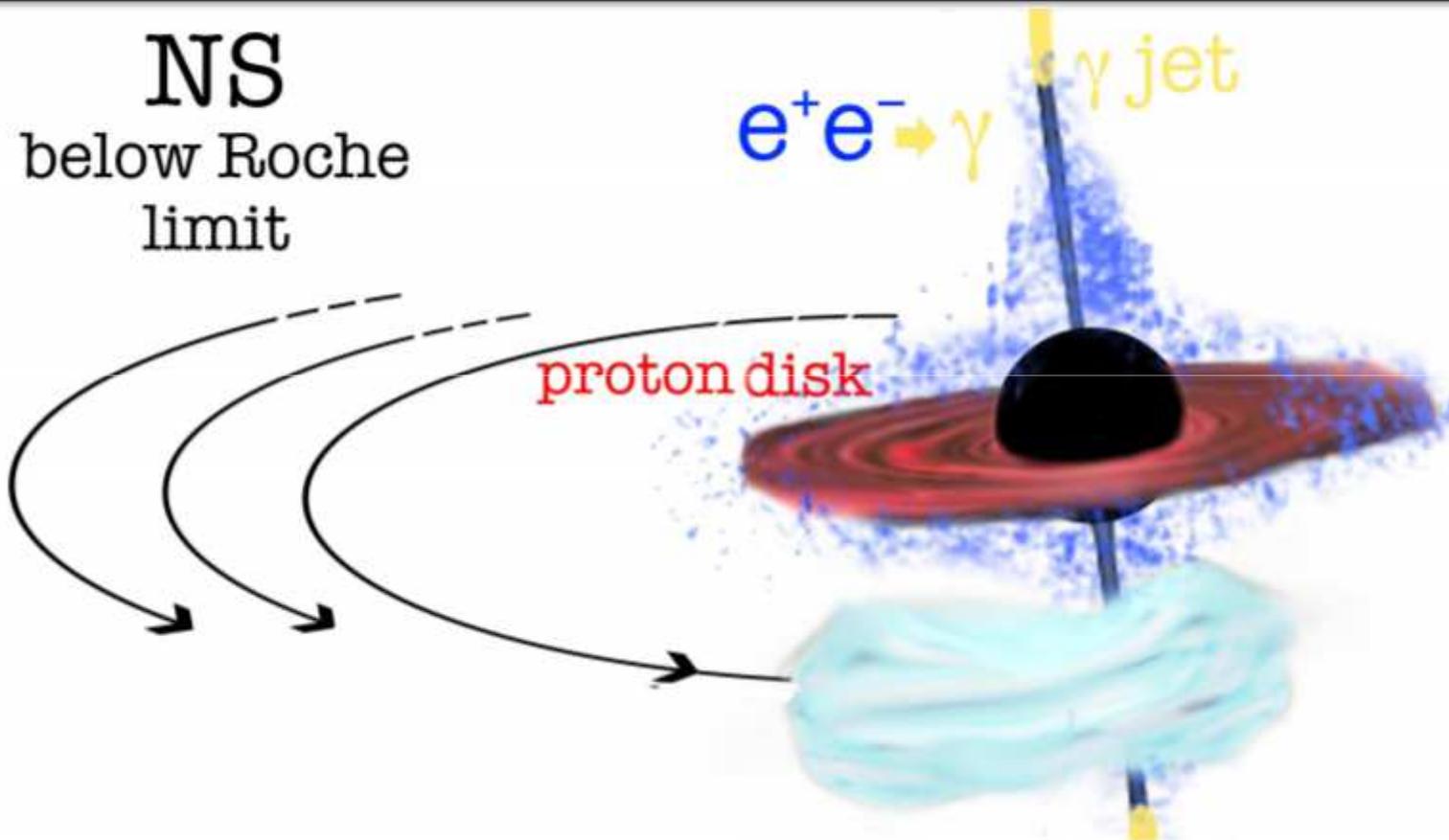
# *Our model for GRB avoiding neutrino: a tidal disruption in NS BH or in NS NS*

[arXiv:1605.00177](https://arxiv.org/abs/1605.00177) (Nuclear Phys and  
Particles, 2017)

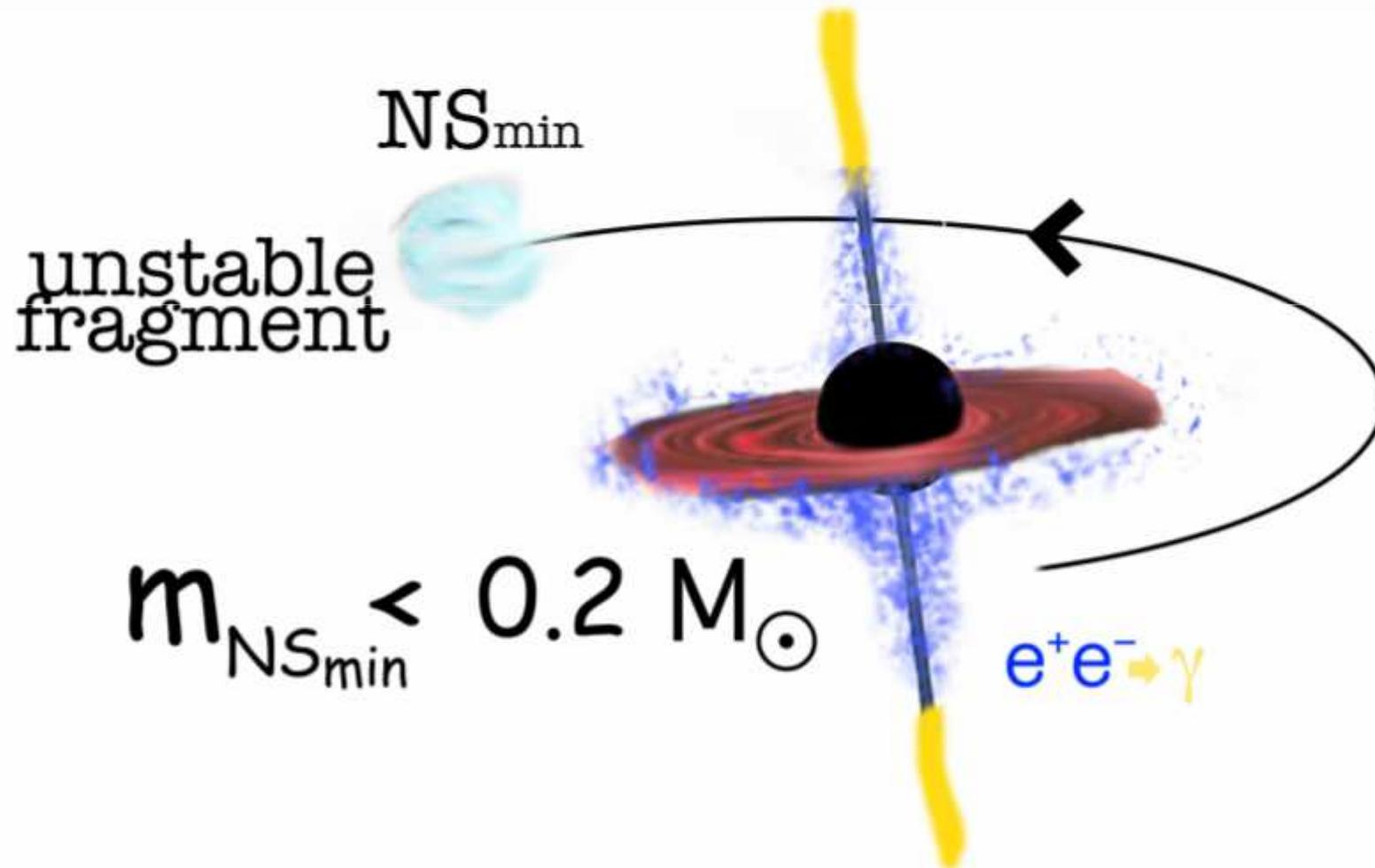


**Fig. 3** Protons follow their ring trajectory while in  $\beta$ -decay form-

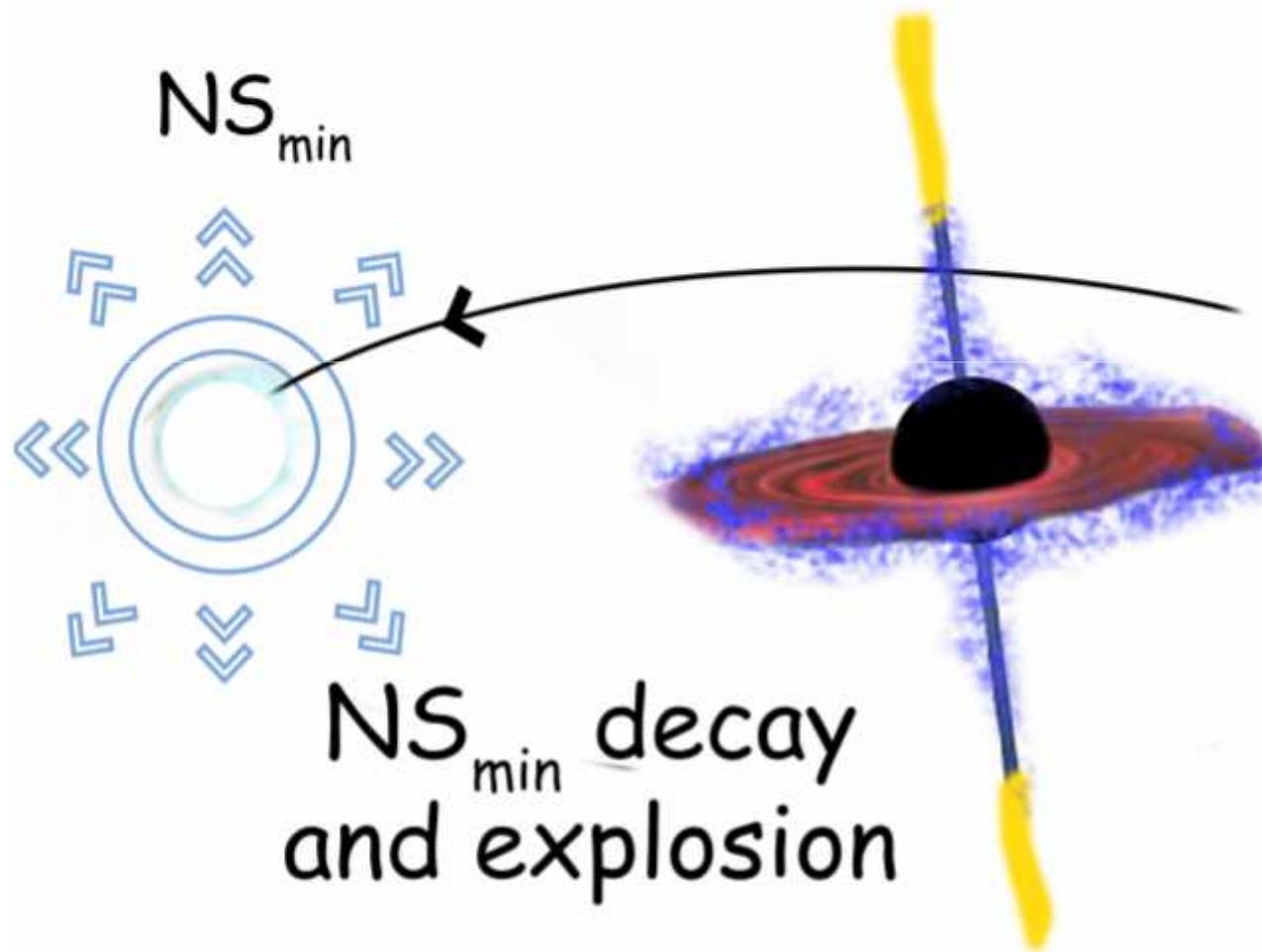
# Thin Precessing Jet (neutrino free) B made by a charged proton disk



# *A final NS-NS Collapse ; a “Fragment-Nova”*



# Unstable NS fragment exploding like a Kilonova or a SN: a NS-Fragment-Nova

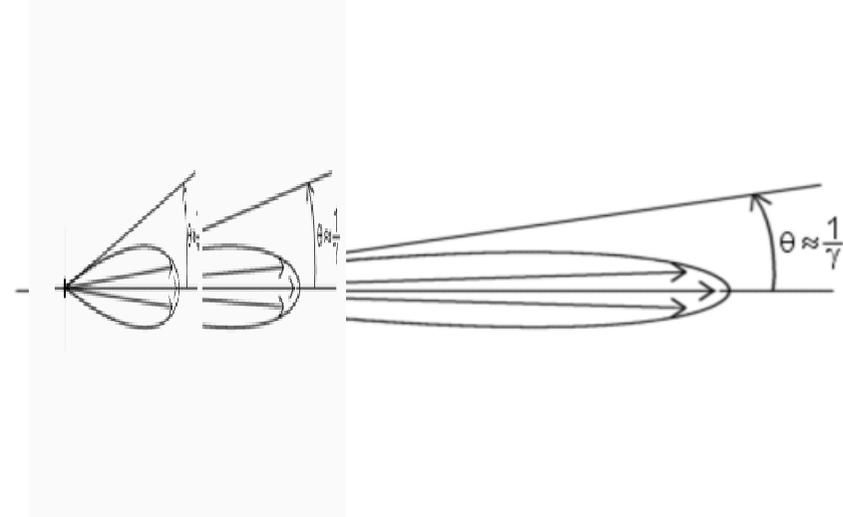
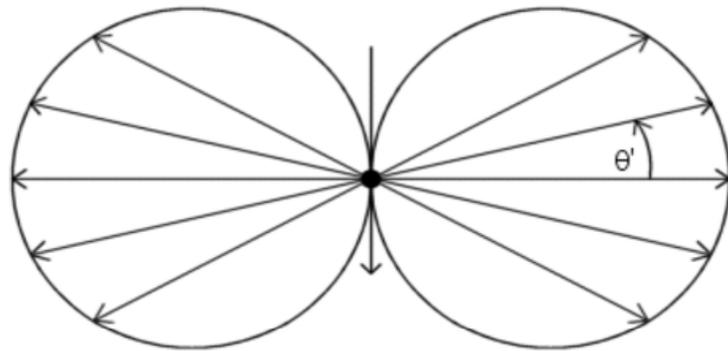


# *The Off axis case*

- *The hundreds keV GRB 170817 require a hundred or tens Lorentz factor*
- *The on axis anyway cannot be too much large.*
- *The observed case may need a help to increase the probability to be observed even if off axis*

# ***The simplest beaming jet***

## ***A Power spectra and off axis***



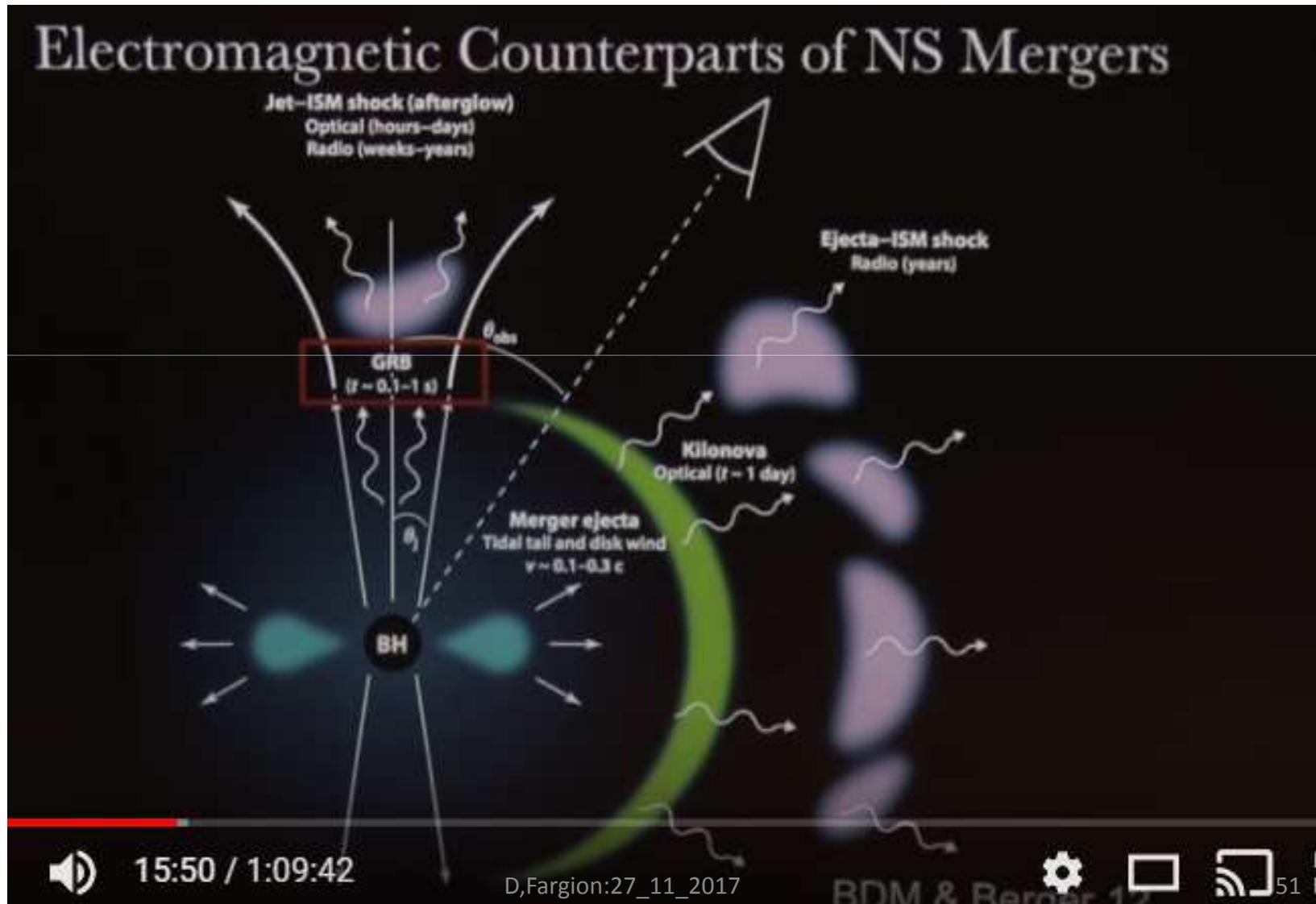
$$\tan\theta = \frac{\sin\theta'}{\gamma(\beta + \cos\theta')}$$

$$\theta \approx \frac{1}{\gamma}$$

half-opening angle in radians

***Different Lorentz factor, different beaming, different apparent Luminosity Peak: THERE MUST BE A Power Spectra in electron jet and consequent spread gamma jet too.***

***Still the popular Fountain jet it is not consistent with most powerful GRBs***



# *What are the relic of the NS NS and GRB explosion?*

- *Heavy Nuclei formation*
- *Kilonova (or SN) OT*
- *Radioactive luminous blue red tails*
- *Kick velocity of NS and BH*
- *Late X ray afterglow*
- *Late radio signals*

## *Off Axis; The simplest solution:*

- **An off axis detection of the GRBs it is natural**
- **However at large Lorents factor (thousands or hundreds) the Jet it is very narrow and its output decay with rapidity out of the beam**
- **(Theta <sup>-2</sup>): Power law may help; but**
- **The hardness require a Lorentz factor 30-100**
- **The probability to be inside the cone it is still small anyway!**

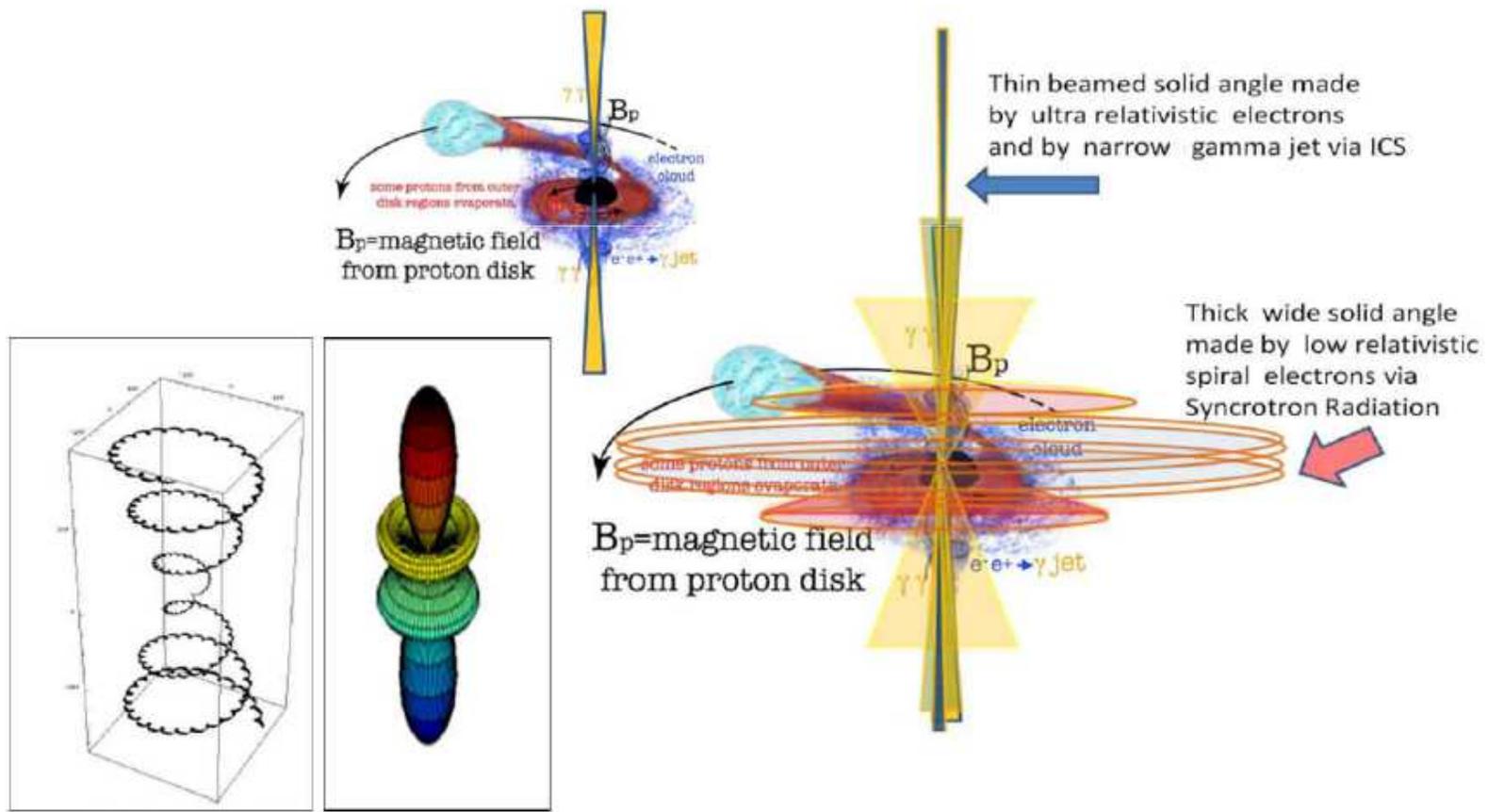
## *A more fitting solution:*

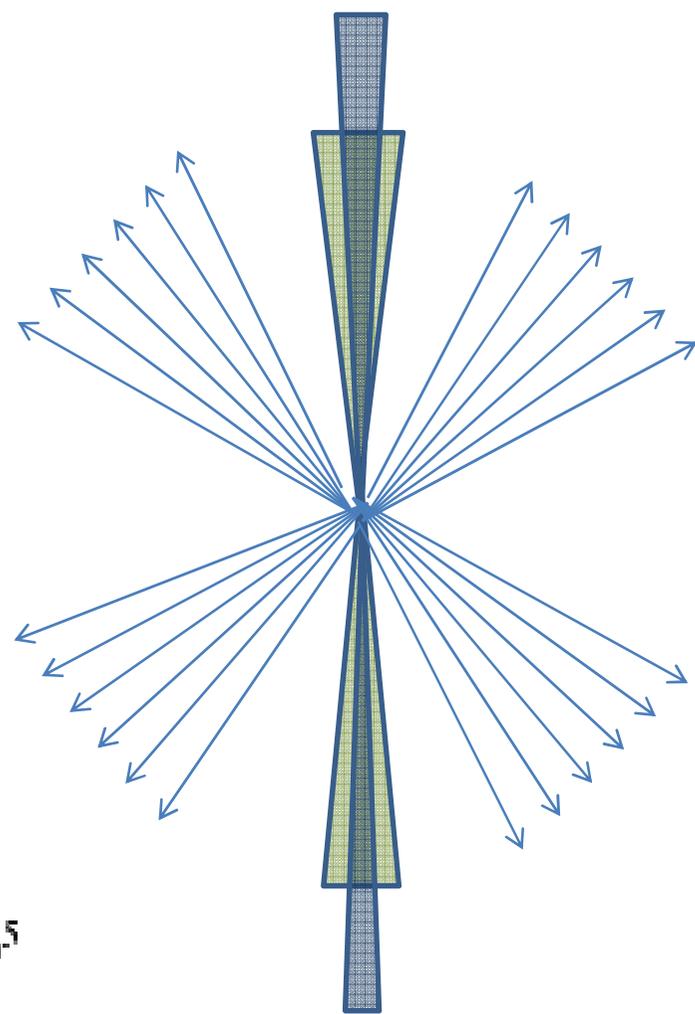
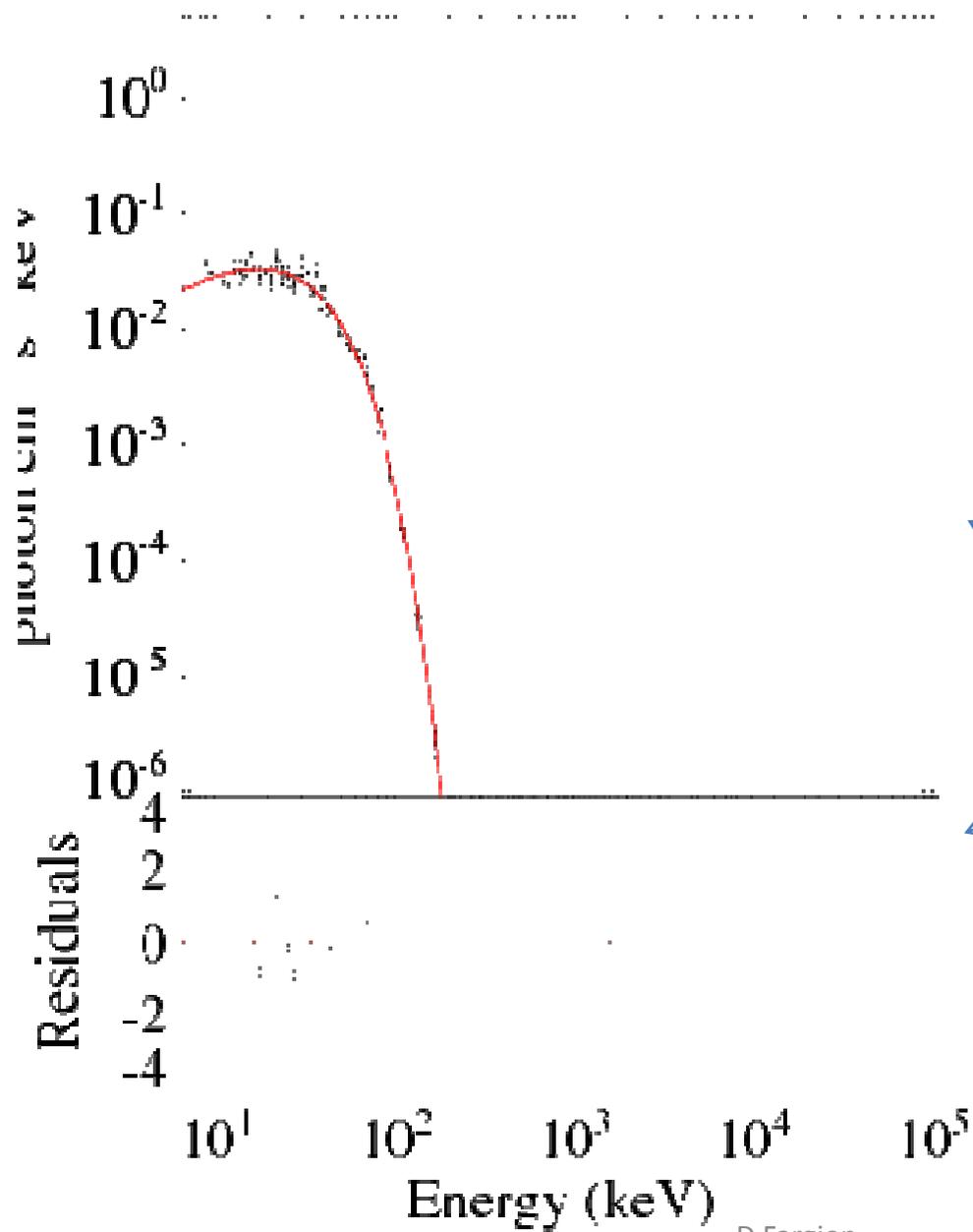
### *A wide synchrotron radiation twin gamma ring disk*

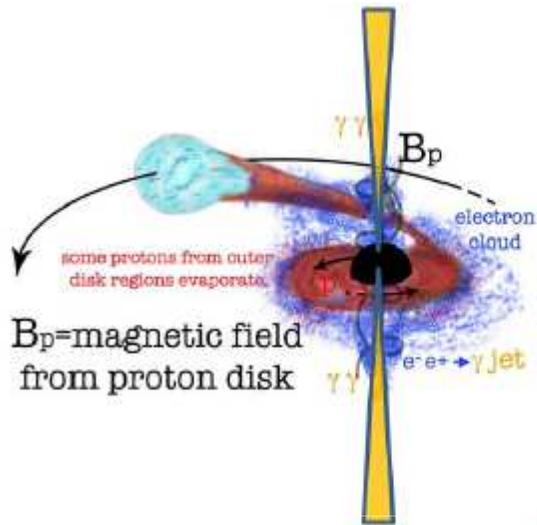
- *The Jet should consist of two component:*
- *A Top Hat electron ejecting photons by ICS within a thin cone jet by a spread of energy power law (up to Thousands factors Gamma):*  
*Delta Omega= 1/ Gamma^2 (very thin beam)*
- *A Ring Spiralling electron component*  
*around the Top Hat whose synchrotron radiation*  
*ejection it is spread in a wider gamma cones hortogonal*  
*to the Jet itself:*  
*Delta Omega= 1/ Gamma (very wide solid angle)*

# *A different «dress of light» around the GRB 170817 A Jet*

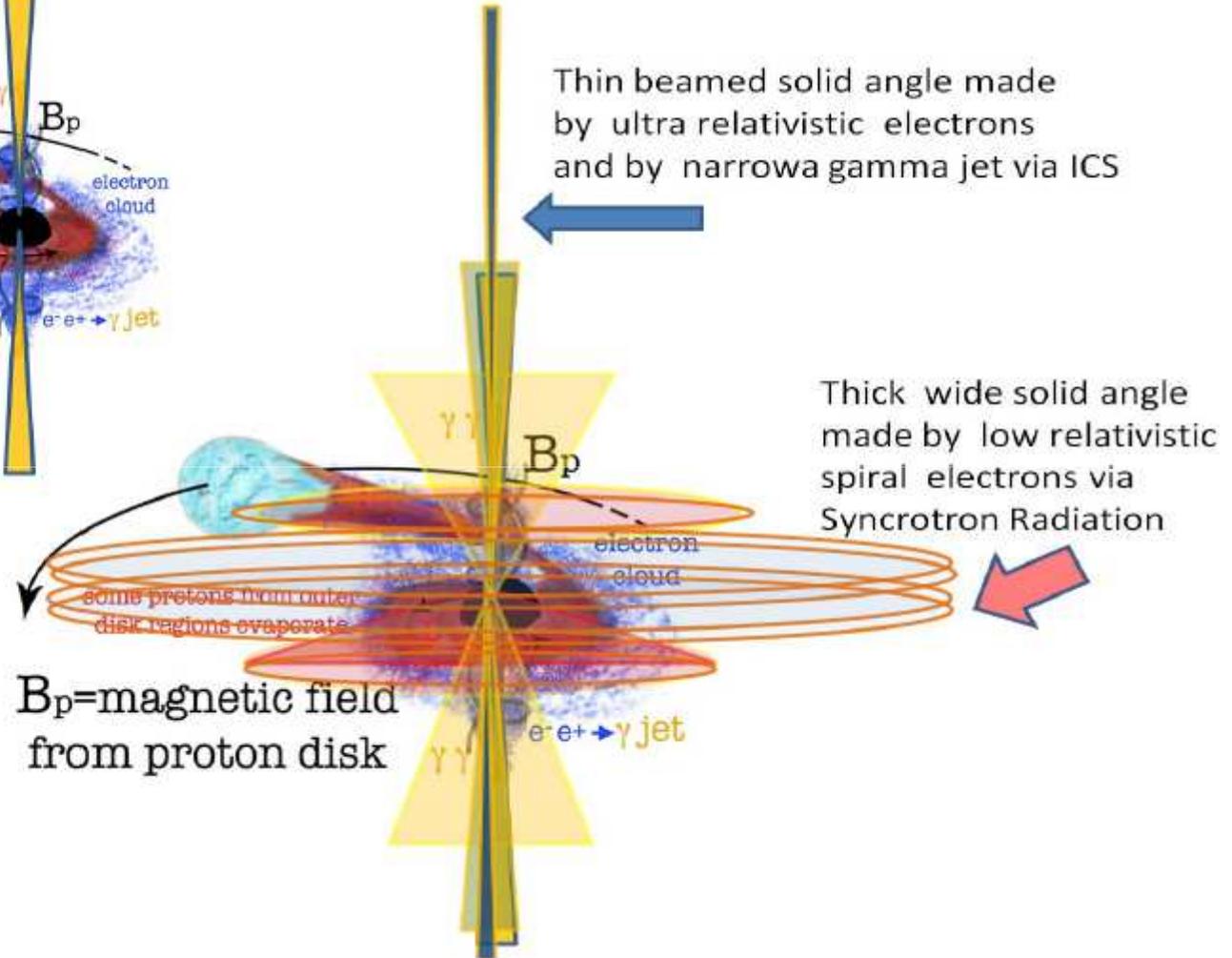
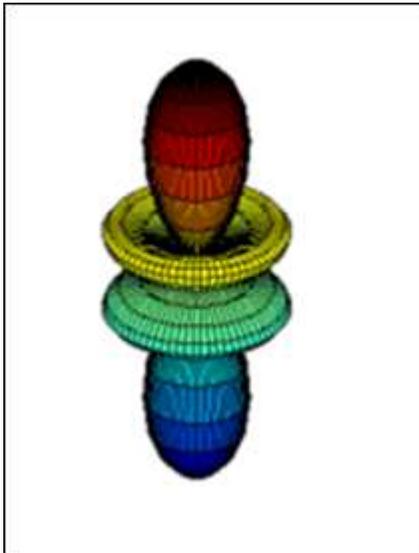
*Could GRB170817A be really correlated to an NS-NS merging?*







Thin beamed solid angle made by ultra relativistic electrons and by narrow gamma jet via ICS



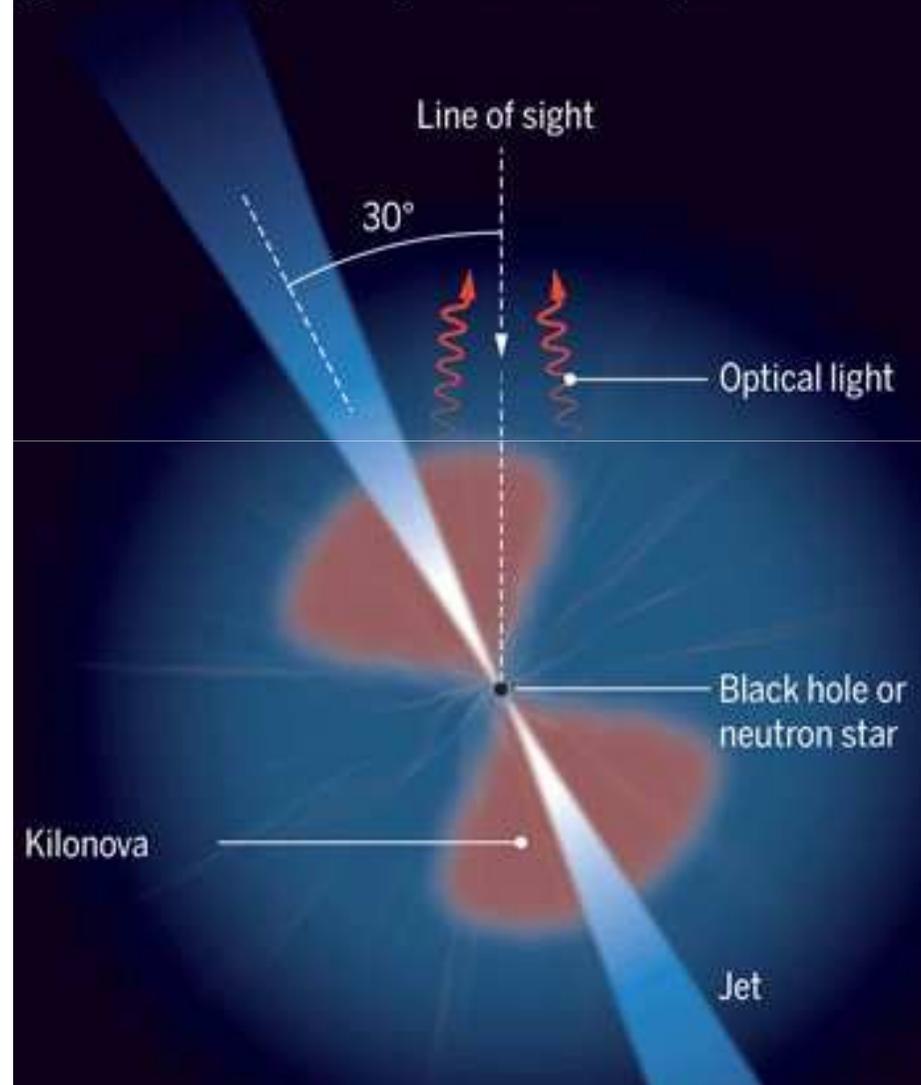
Thick wide solid angle made by low relativistic spiral electrons via Synchrotron Radiation



Shape it is the key

### A many splendored explosion

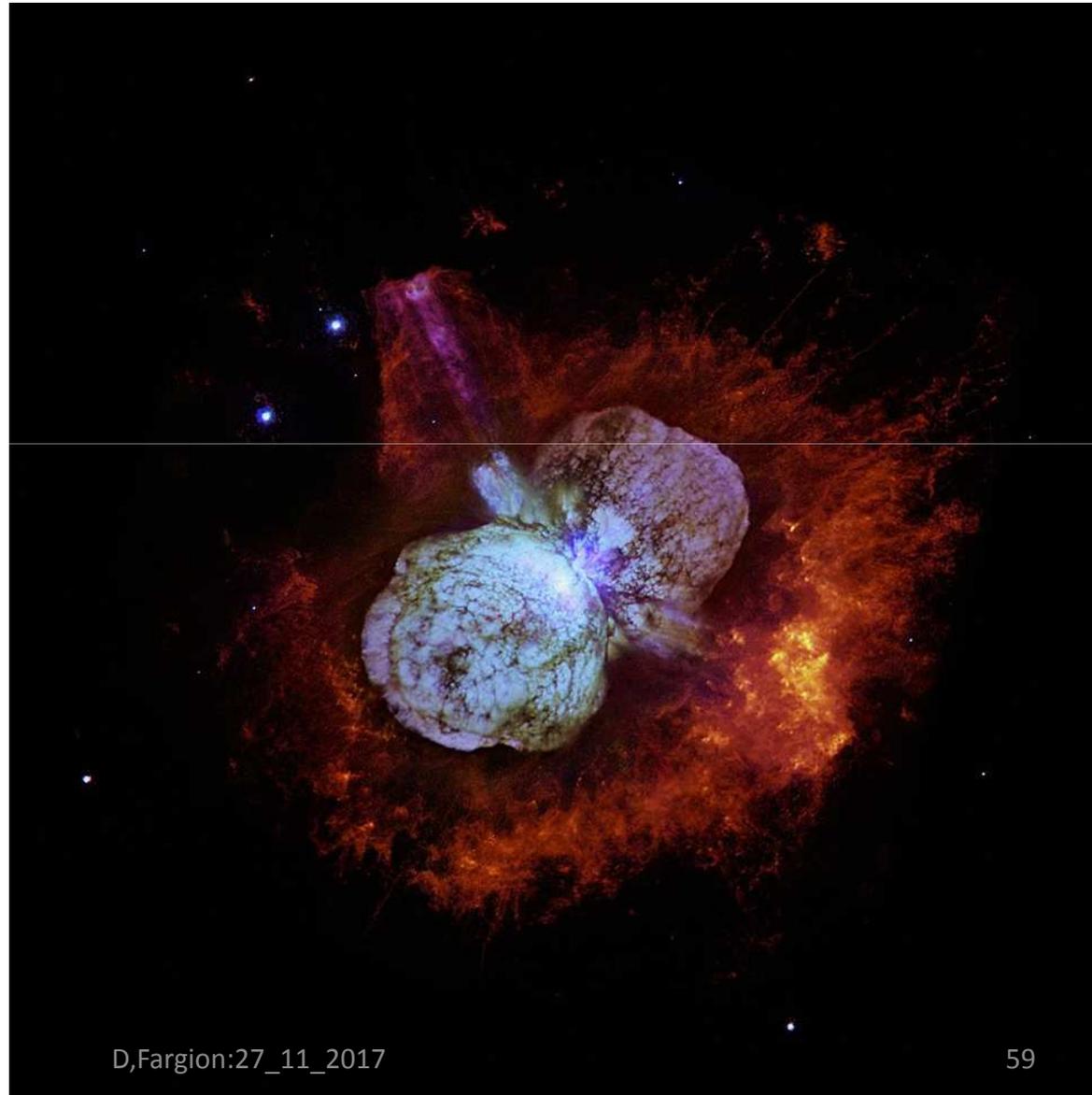
The merging neutron stars powered a seconds-long gamma-ray burst that beamed radiation into space. They also sparked a kilonova that glowed for days as it generated heavy elements.



## **Conclusions:**

**Does the  
GRB170817A  
Surprisingly an  
Off-Axis event  
Showing a first  
Gamma Disk  
Blaze?**

**An example:  
Eta Carina  
Twin lobes made  
by inner jets and  
horthogonal disk  
wind**



## Could GRB170817A be really correlated to an NS–NS merging?

D. Fargion<sup>\*,†,||</sup>, M. Khlopov<sup>‡</sup> and P. Oliva<sup>†,§,¶</sup>

*\*Physics Department & INFN Rome1, Rome University 1  
P.le A. Moro 2, Rome 00185, Italy*

*†MIFP, Via Appia Nuova 31, Marino, 00040 Rome, Italy*

*‡Center for Cosmoparticle Physics Cosmion  
National Research Nuclear University MEPhI  
Kashirskoe Sh., 31, Moscow 115409, Russia*

*§Niccolò Cusano University, Via Don Carlo Gnocchi 3  
Rome 00166, Italy*

*¶Department of Sciences, University Roma Tre  
Via Vasca Navale 84, Rome 00146, Italy  
[||daniele.fargion@roma1.infn.it](mailto:daniele.fargion@roma1.infn.it)*

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**Thank You for the kind attention**