



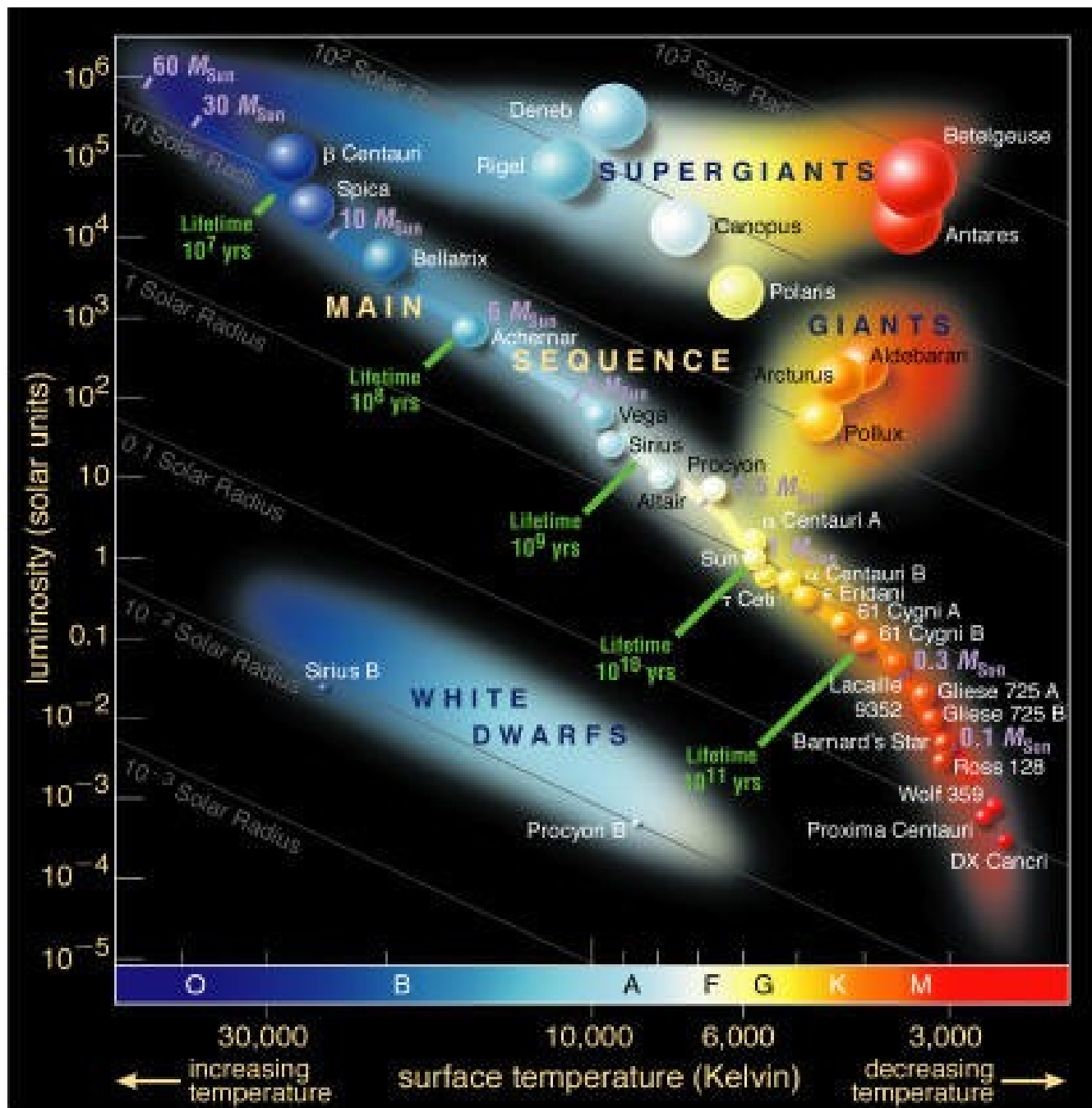
# Mostri che divorano stelle e altre misteriose esplosioni cosmiche

---

Cristiano Guidorzi

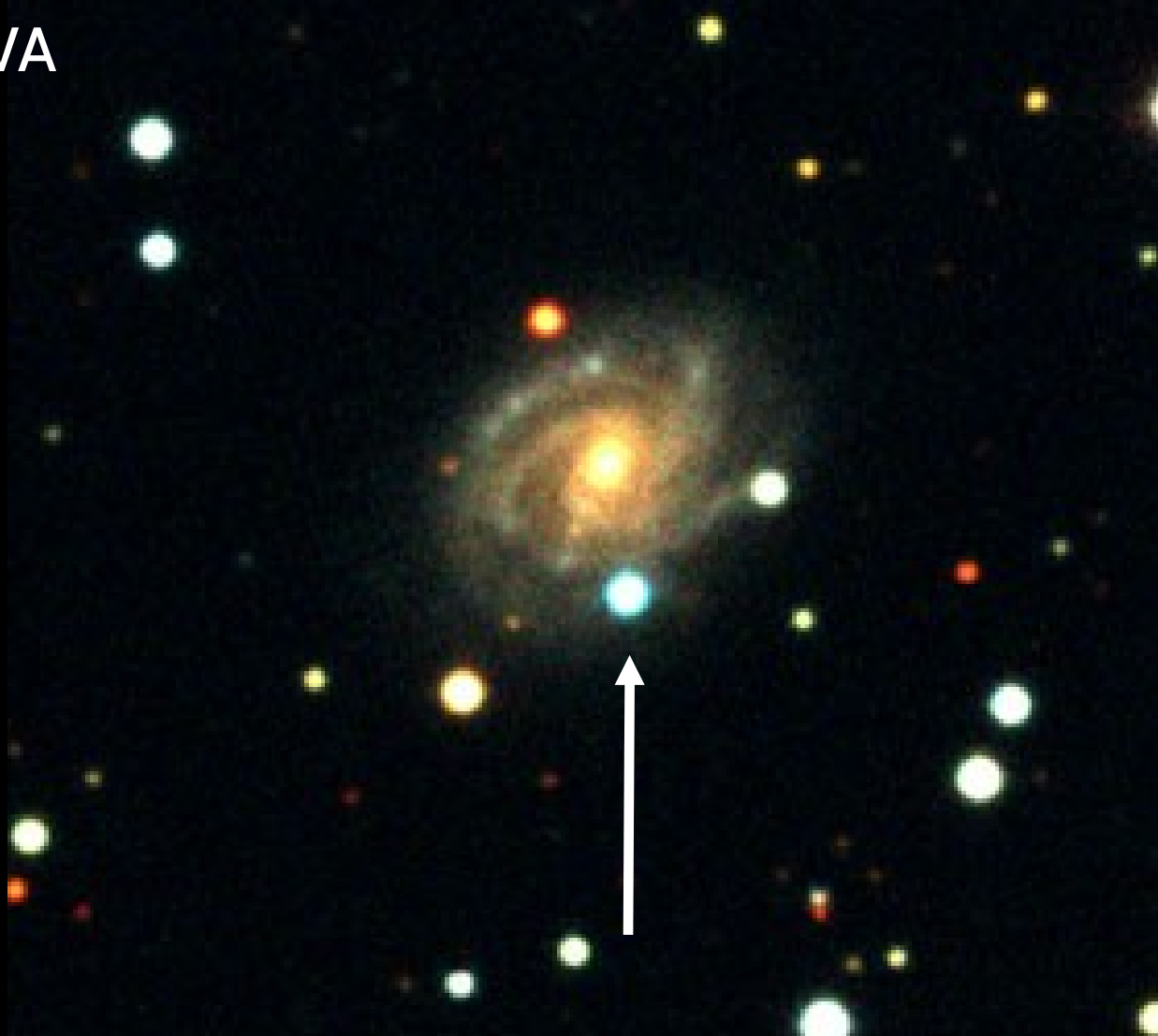
Corso Eccellenza 2016

# I diversi tipi di stelle visibili



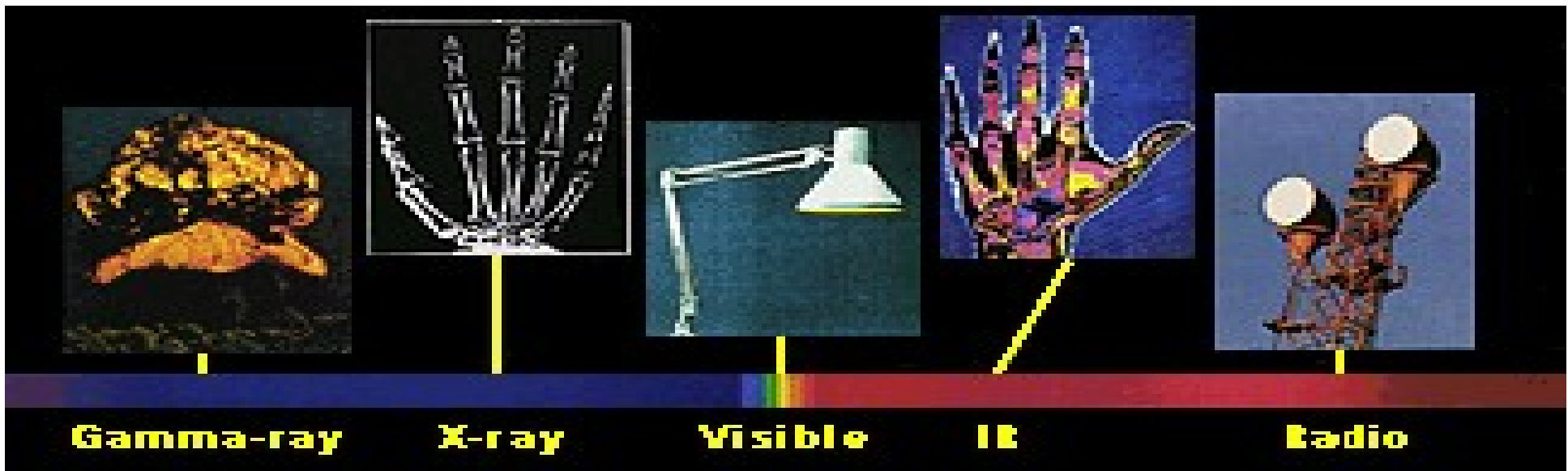
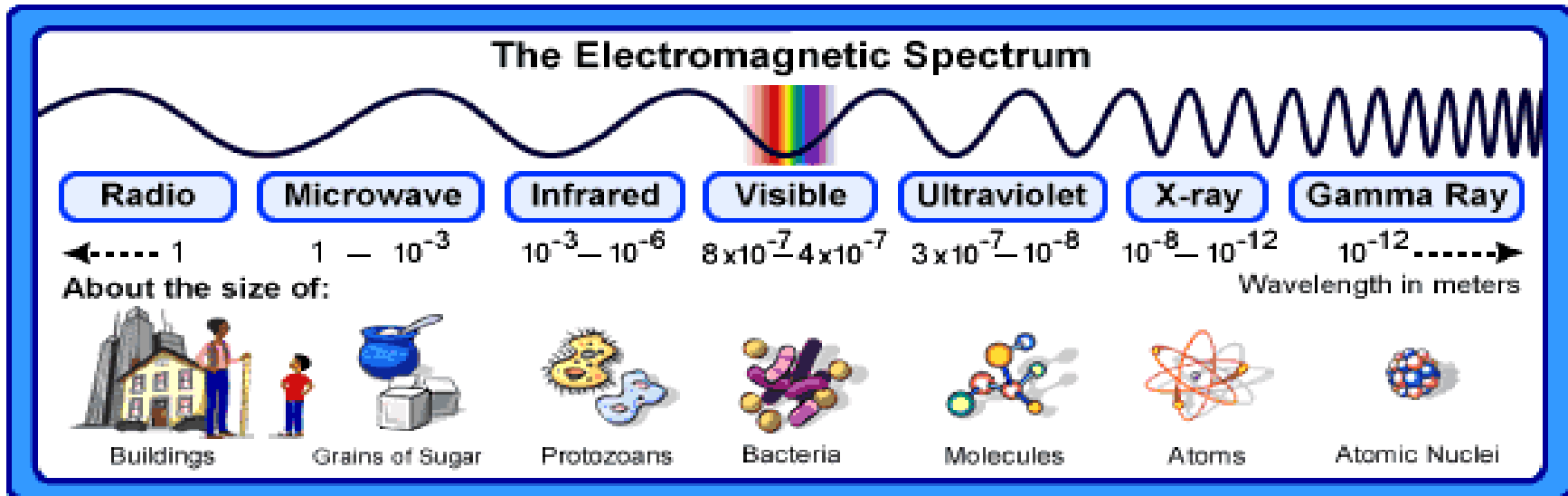
# Esplosione di una SUPERNOVA

**1933 BAADE & ZWICKY:** SUPERNOVAE - STELLE DI NEUTRONI  
L'IMPLOSIONE DEL NUCLEO STELLARE ALIMENTA LA  
SUPERNOVA

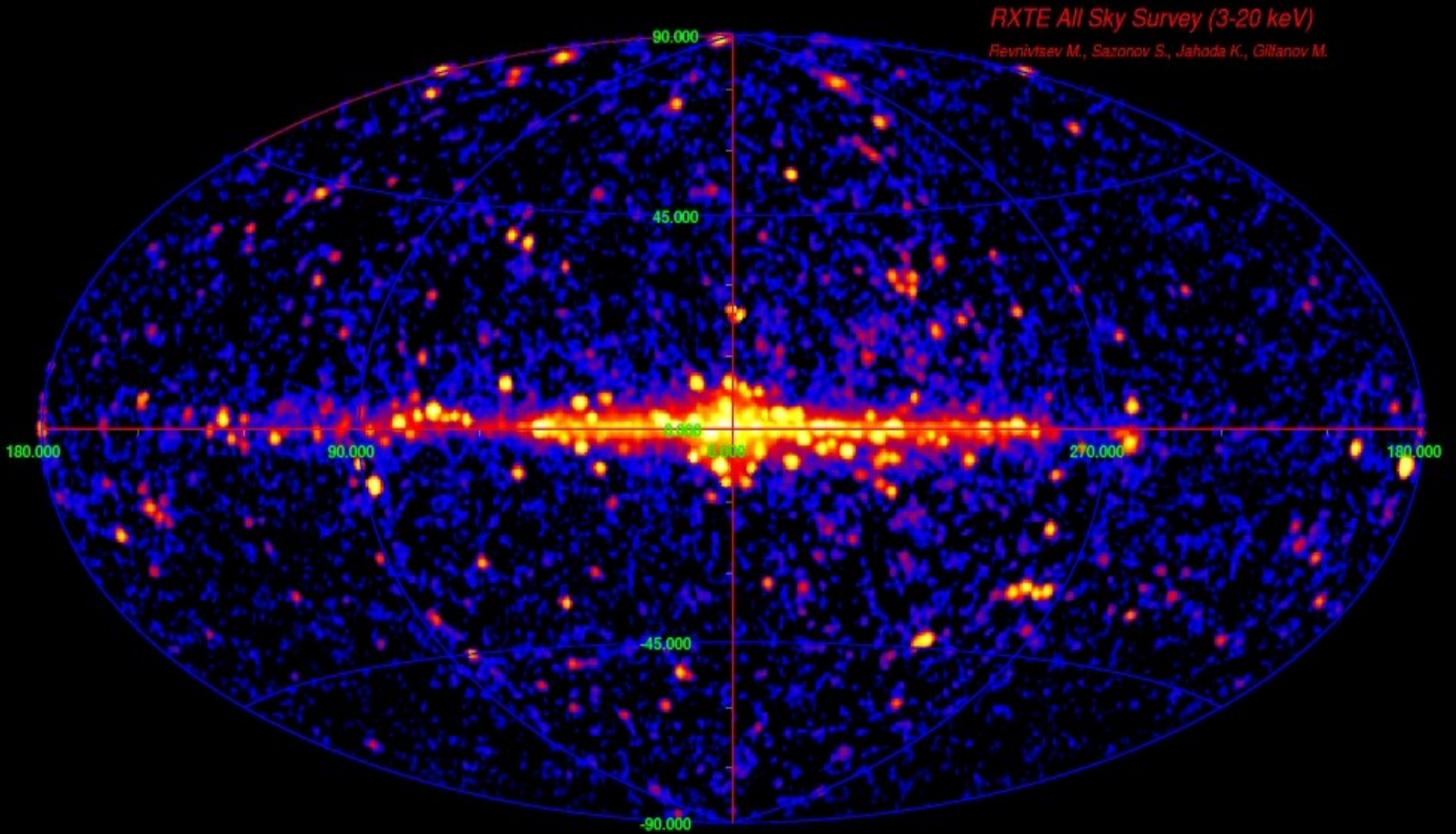




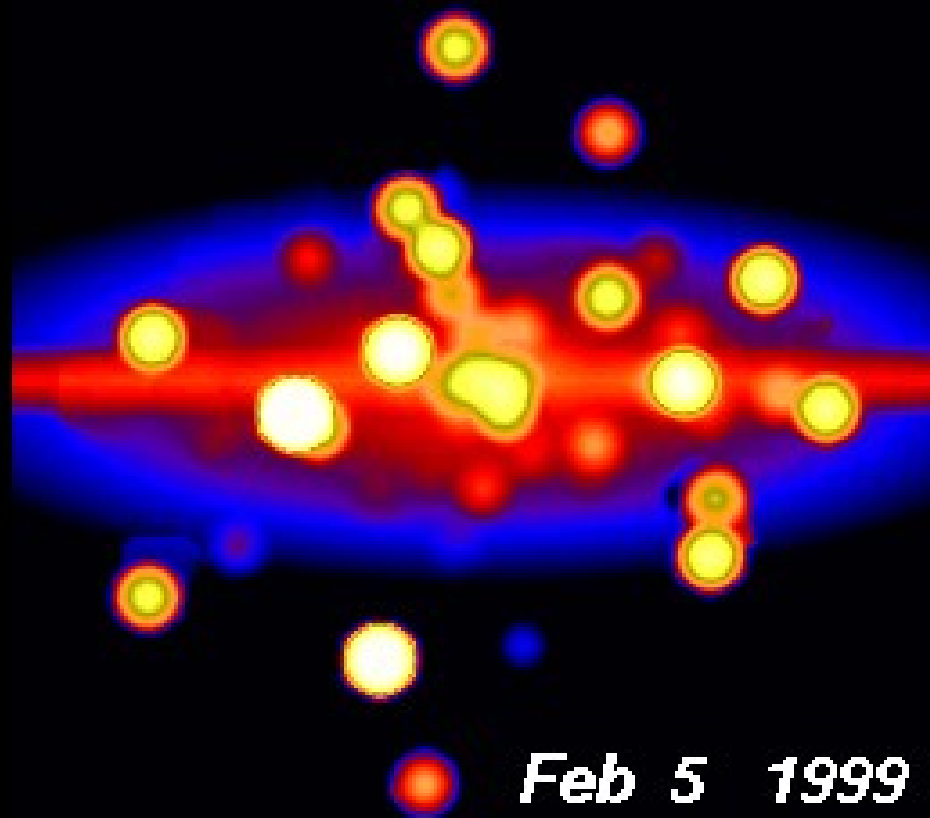
# Il messaggero dell'universo: la radiazione elettromagnetica



# Il cielo in raggi X



# L'universo violento in raggi X/gamma



# Accrescimento di massa

Massa della  
stella  
compagna ha  
momento  
angolare e non  
può cadere  
direttamente  
sulla compatta  
Si scalda per  
attrito e  
spiraleggia  
attraverso un  
disco di  
accrescimento





# Esplosioni cosmiche e come funziona l'Universo

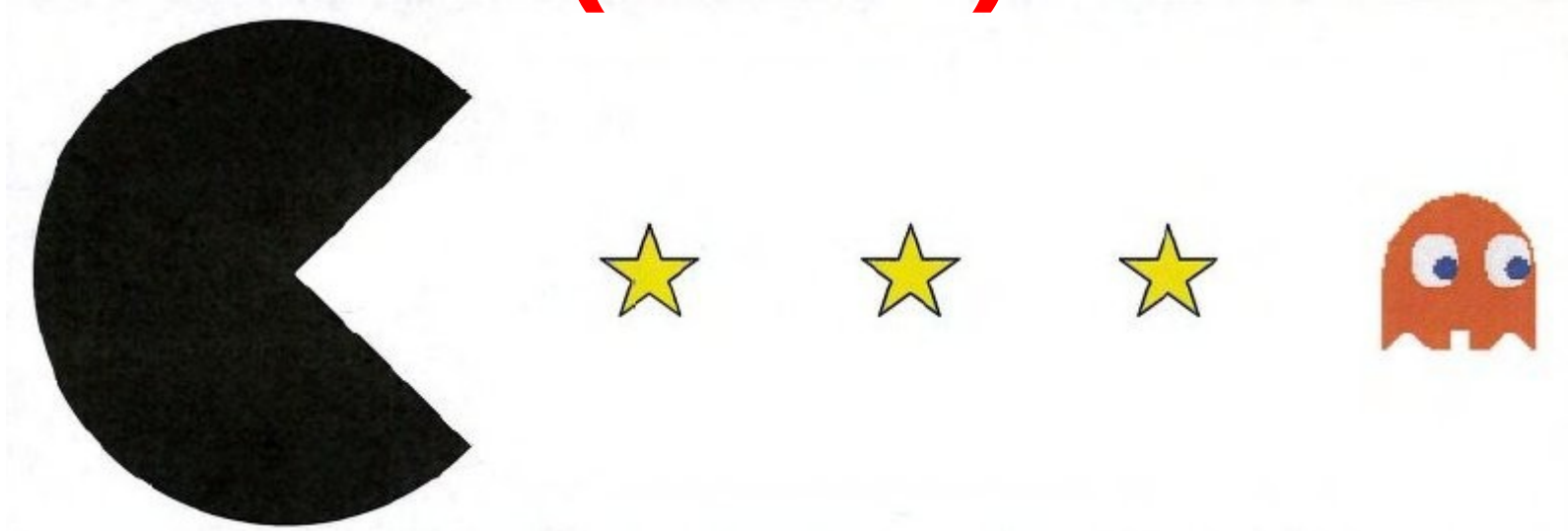
---

“La vita di quest'universo è un perpetuo circuito di produzione e distruzione, collegate ambedue tra sé di maniera, che ciascheduna serve continuamente all'altra, ed alla conservazione del mondo.”

(G. Leopardi, Dialogo della Natura e di un islandese)



# Tidal Disruption Events (TDEs)



Storia di eventi catastrofici previsti da tempo  
e finalmente osservati

Quasi ogni galassia ospita al proprio centro un buco nero supermassiccio (SMBH)



# Super Massive Black Holes (SMBHs)

Tutte (o quasi) le galassie ospitano un SMBH ( $10^6$ - $10^9 M_{\odot}$ ) al proprio centro.

Prodigiosa quantità di radiazione prodotta dal gas che accresce il SMBH



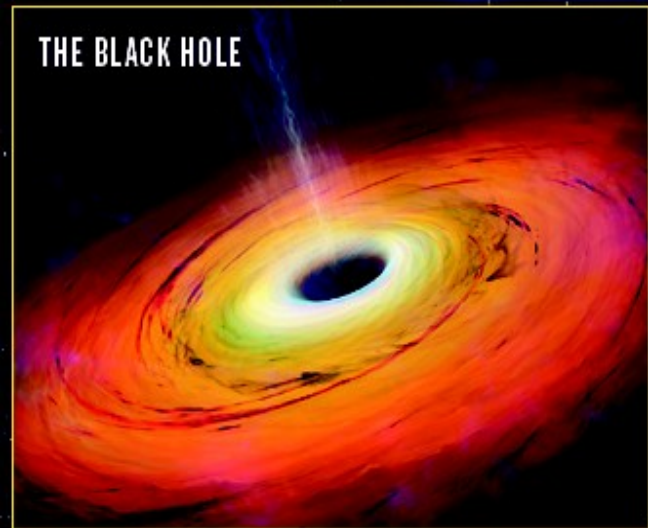
# Super Massive Black Holes (SMBHs)

## THE MONSTER IN THE MIDDLE

By tracking stars near the mysterious object at the centre of the Milky Way, astronomers have shown that they move in years-long orbits; 8 examples are shown here. These orbits prove that the object packs the mass of 4.1 million Suns into a space smaller than the Solar System, and can only be a black hole.

Tutte (o quasi) le galassie ospitano un SMBH ( $10^6$ - $10^9$  M<sub>☉</sub>) al proprio centro.

## THE BLACK HOLE



Galactic Centre

Orbits of

## THE MILKY WAY

Our Solar System

Galactic Centre

Misura dinamica della massa del SMBH attraverso lo studio delle orbite delle stelle vicine

# Super Massive Black Holes (SMBHs)

## THE MONSTER IN THE MIDDLE

By tracking stars near the mysterious object at the centre of the Milky Way, astronomers have shown that they move in years-long orbits; 8 examples are shown here. These orbits prove that the object packs the mass of 4.1 million Suns into a space smaller than the Solar System, and can only be a black hole.

Orbits of stars

Ma come fare se l'ambiente circostante è povero di gas?

## THE BLACK HOLE

C'è un altro modo per spiare questi mostri dormienti (nel senso che non accrescono gas regolarmente)?

Galactic Centre

Our Solar System

Galactic Centre

# Tidal Disruption: le basi

Una stella che passa troppo vicino viene sventrata dal SMBH:

$$\frac{GM}{R_T^3} R_* = \frac{Gm_*}{R_*^2}$$

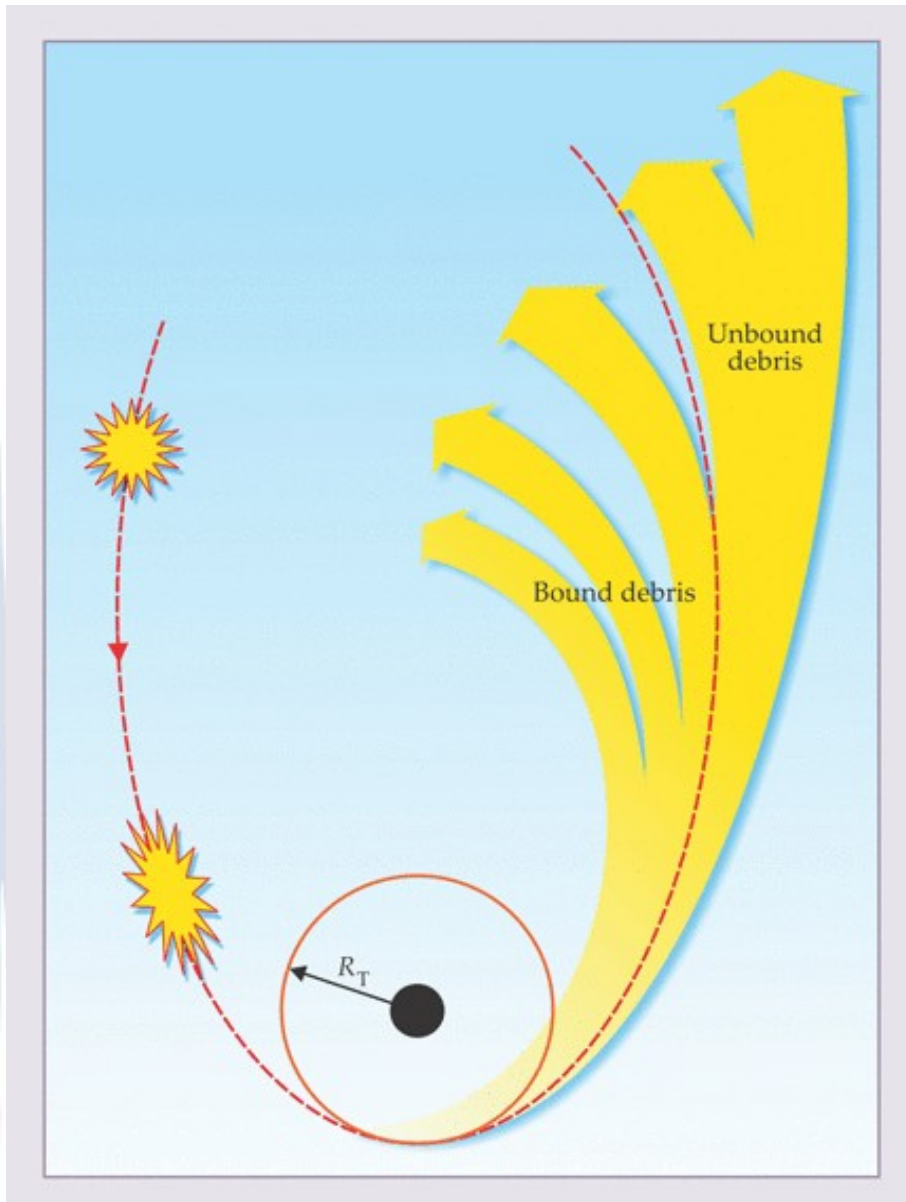
- $M$  = BH mass
- $R_T$  = tidal disruption radius
- $R_*$  = star radius
- $m_*$  = star mass

$$R_T = \left( \frac{M}{m_*} \right)^{1/3} R_*$$

- Esempio:

$$M = 4 \times 10^6 m_*; R_* = R_{\odot}$$

$$\Rightarrow R_T \approx 1 \text{ AU}$$



# Distrutta o inghiottita?

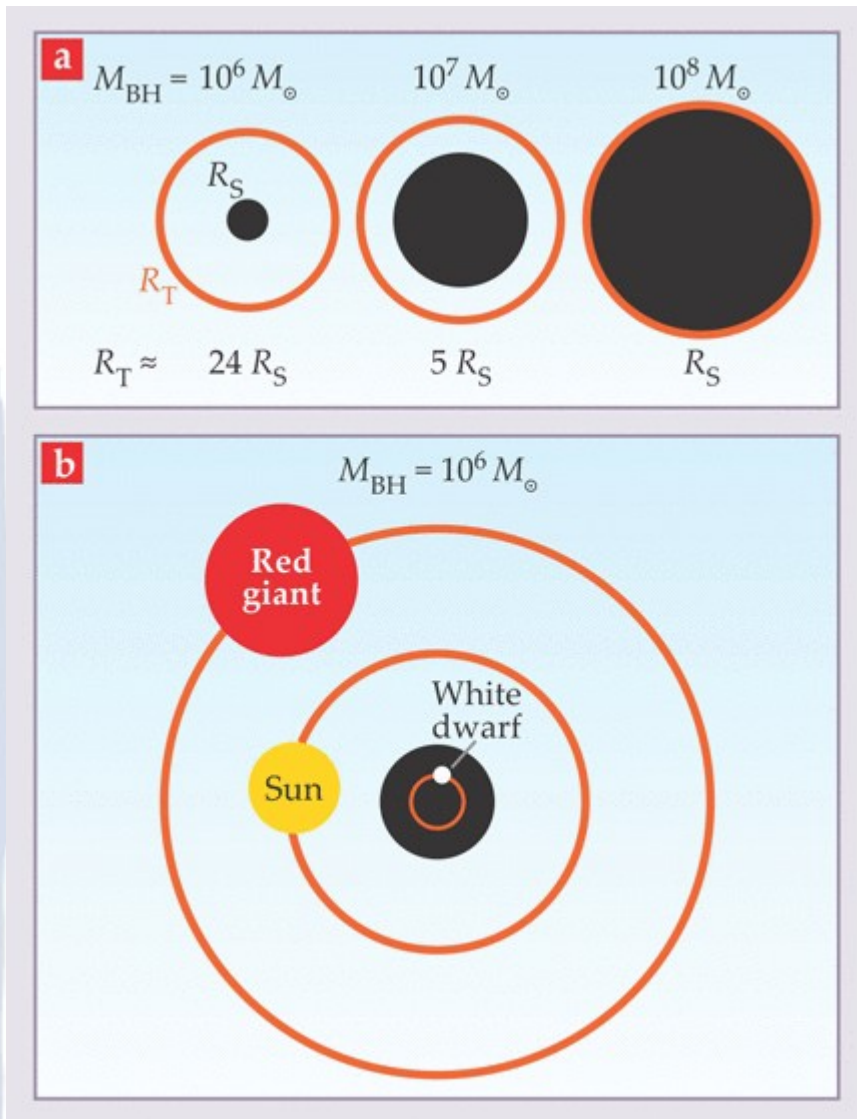
Se il SMBH è troppo massiccio, la stella viene inghiottita e non sventrata!

Affinchè questo non avvenga:

$$R_T = \left( \frac{M}{m_*} \right)^{1/3} R_* > R_s = \frac{2GM}{c^2}$$

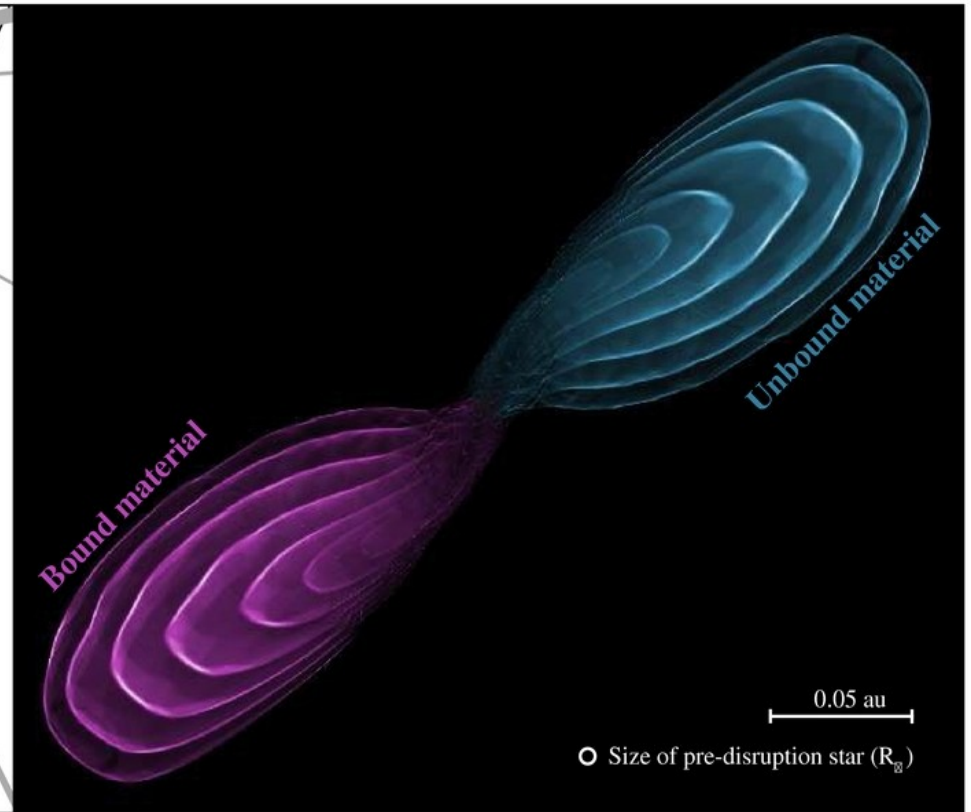
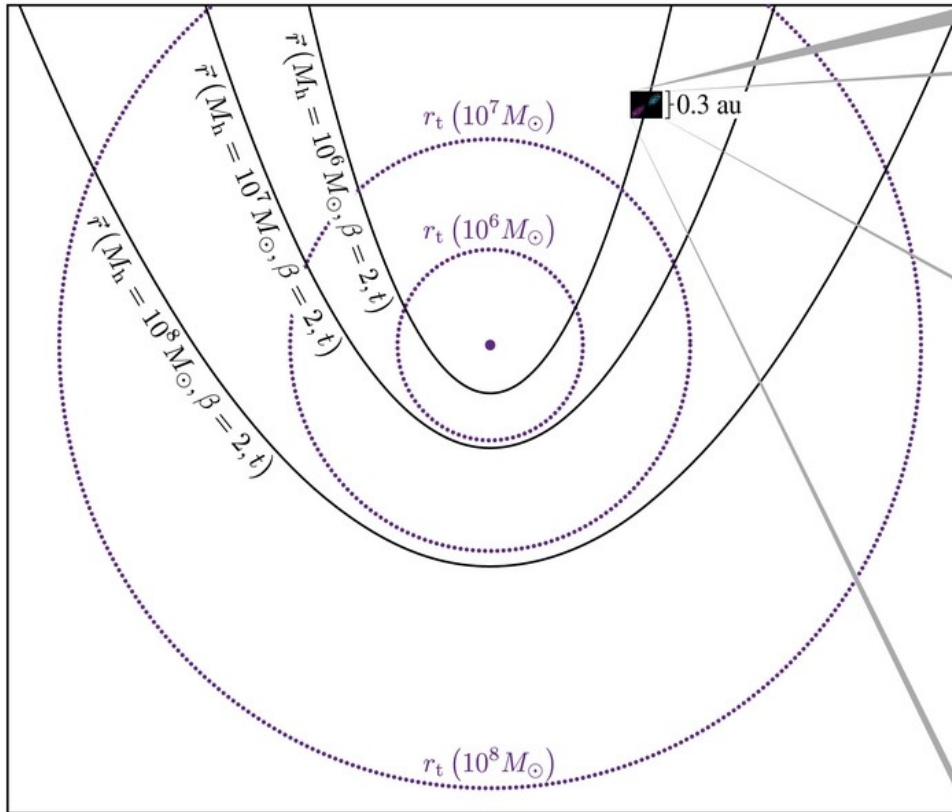
$$M_{crit} \approx 10^8 \left( \frac{R_*}{R_{sun}} \right)^{3/2} \left( \frac{m_*}{m_{sun}} \right)^{-1/2} m_{sun}$$

Per una data massa  $M$  del SMBH,  $R_T$  dipende sensibilmente dalle dimensioni della malcapitata stella





# Metà nel SMBH, metà scagliata via

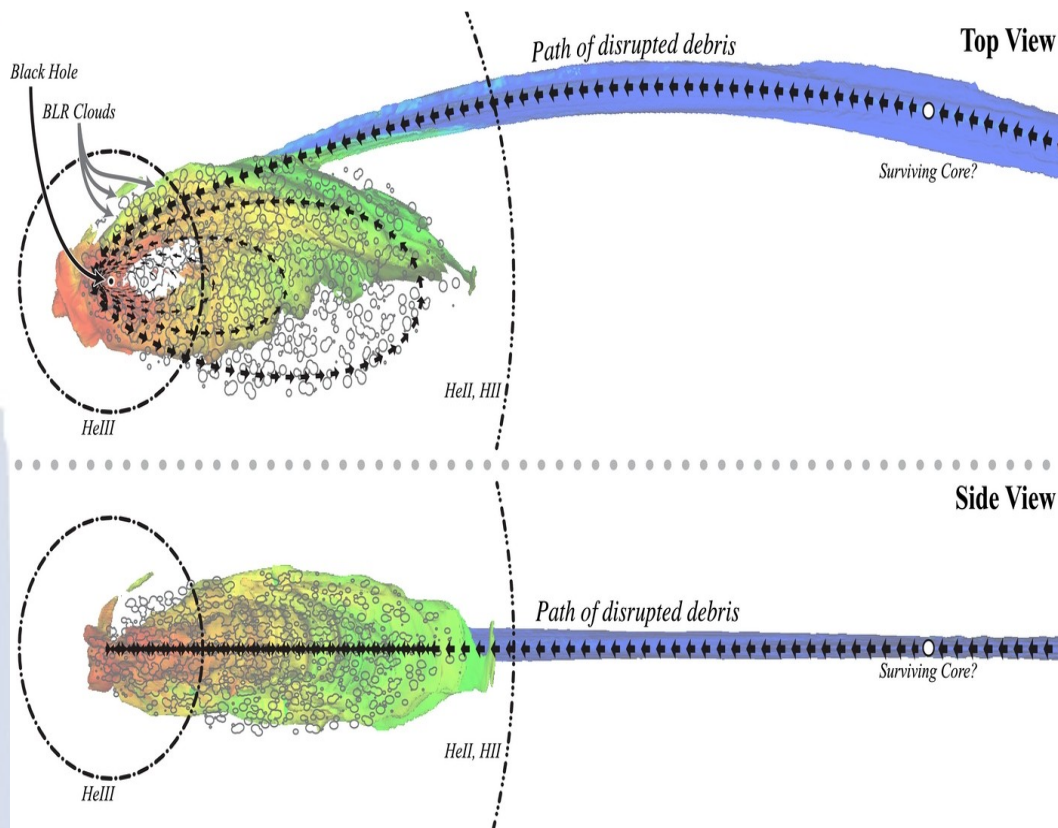


Fattore determinante:

$$\beta = \frac{R_T}{R_p}$$

De Colle+12

# Tasso di accrescimento del gas intrappolato



Spread in grav potential energy

( $R_p$  = periastron distance):

$$\Delta E \approx \pm \frac{GM}{R_p^2} R_* \simeq \frac{GM}{a}$$

where  $a \simeq \frac{R_p^2}{R_*}$

Orbital timescale (3<sup>rd</sup> Kepler's law):

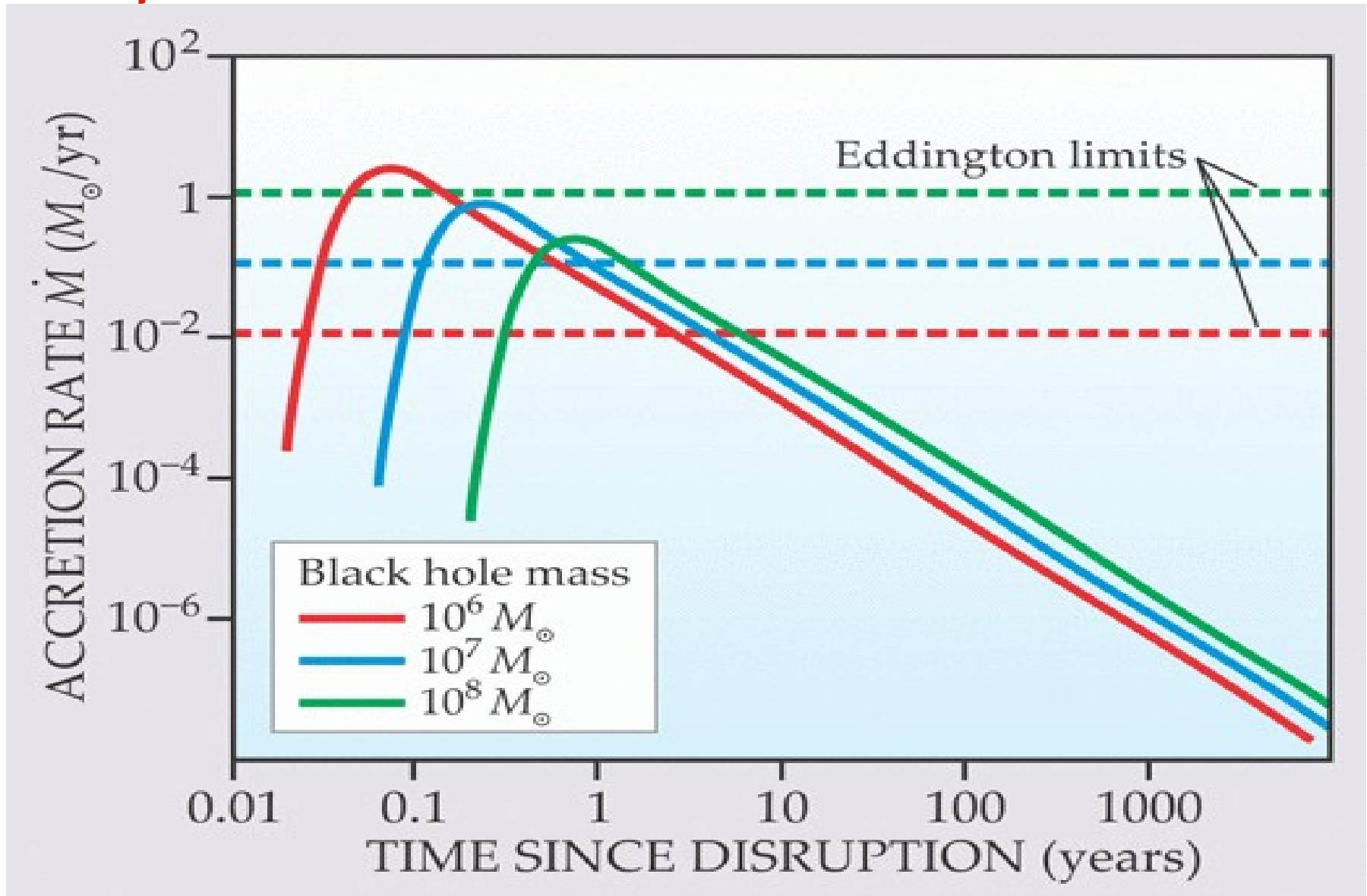
$$t_p \simeq \left( \frac{a^3}{GM} \right)^{1/2} \simeq \left( \frac{R_p^6}{GMR_*^3} \right)^{1/2}$$

$$t_p \simeq \beta^{-3} \left( \frac{R_*^3}{Gm_*} \right)^{1/2} \left( \frac{M}{m_*} \right)^{1/2} \simeq \frac{\beta^{-3}}{\sqrt{G\rho_*}} \left( \frac{M}{m_*} \right)^{1/2} \approx 10^3 \text{ s} \left( \frac{M}{m_*} \right)^{1/2} \beta^{-3} \approx 40 \text{ d}$$

↑  
Sun

$\beta \simeq 1; M/m_* \simeq 4 \times 10^6$

A  $t > t_p$  il flusso decresce nel tempo:  $f \propto t^{-5/3}$



(Rees88; Evans+Kochanek89; Lodato+09)

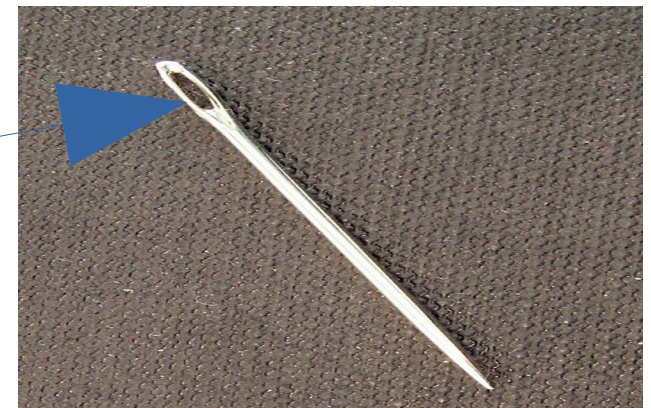
# I TDE: eventi molto rari nell'Universo

- Il raggio di distruzione mareale per una stella di sequenza principale come il Sole è soltanto 1 UA (= distanza Terra-Sole = 150 milioni di km)
- Le stelle che cadono dentro appartengono alla cosiddetta “sfera di influenza del SMBH”, che ha un raggio di circa 1 pc (=3.26 anni-luce)
- Molto + rari delle supernovae:

*1 TDE ogni 100 mila anni per ogni galassia!*



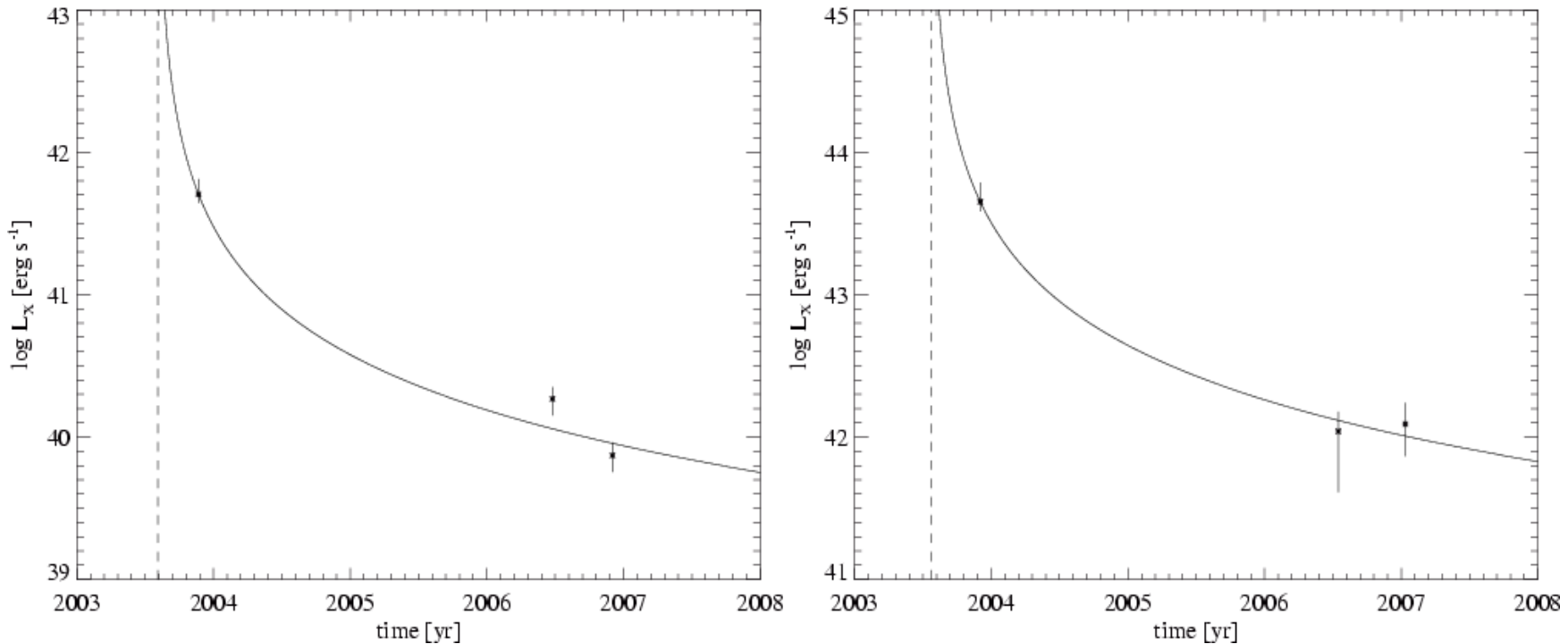
Far passare una stella  
entro il raggio di  
distruzione mareale è tanto  
raro quanto un granello di  
sale attraverso la cruna di  
un ago a 1 Km di  
distanza.



Credits: Guillochon

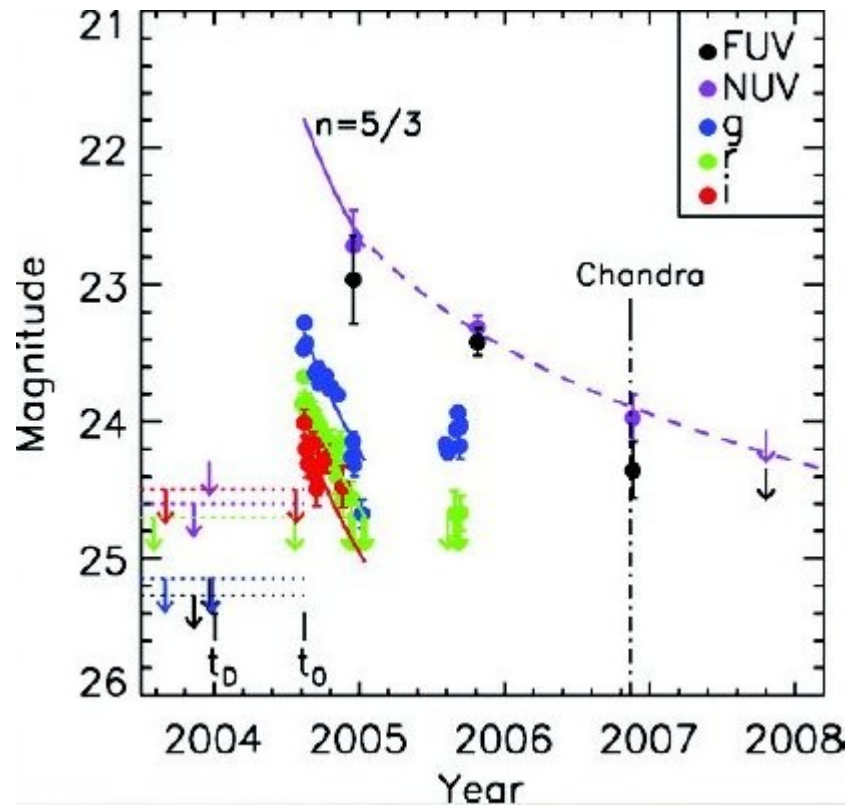
# Primi casi sospetti trovati nei raggi X

Fino al 2011 c'erano solo pochi casi sospetti, trovati da un piccolo aumento e diminuzione dei raggi X provenienti dal centro di alcune galassie. (Komossa+99+04, Esquej+08)

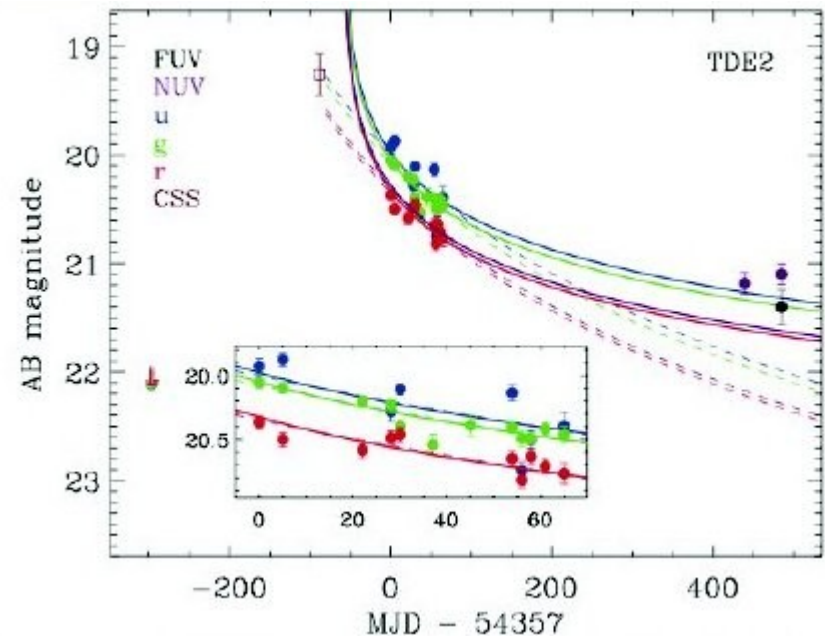


XMM light curves (Esquej+08)

# + qualche caso sospetto nel visibile



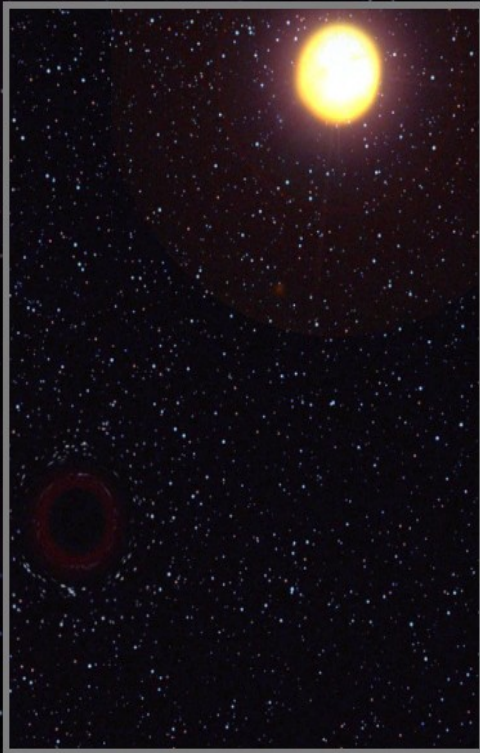
Gezari+09



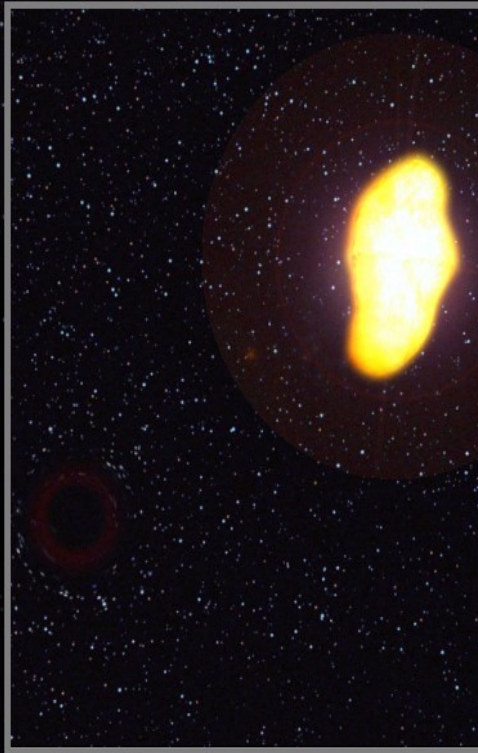
vanVelzen+11

# 28 marzo 2011: stella divorata in diretta

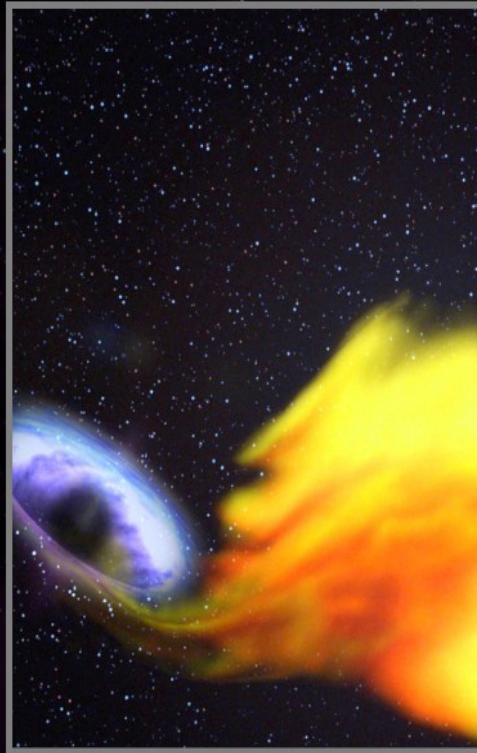
## Swift J1644+57: Onset of a relativistic jet



**1.** A sun-like star on an eccentric orbit plunges toward the supermassive black hole in the heart of a distant galaxy.



**2.** Strong tidal forces near the black hole increasingly distort the star. If the star passes too close, it is ripped apart.



**3.** The part of the star facing the black hole streams toward it and forms an accretion disk. The remainder of the star just expands into space.



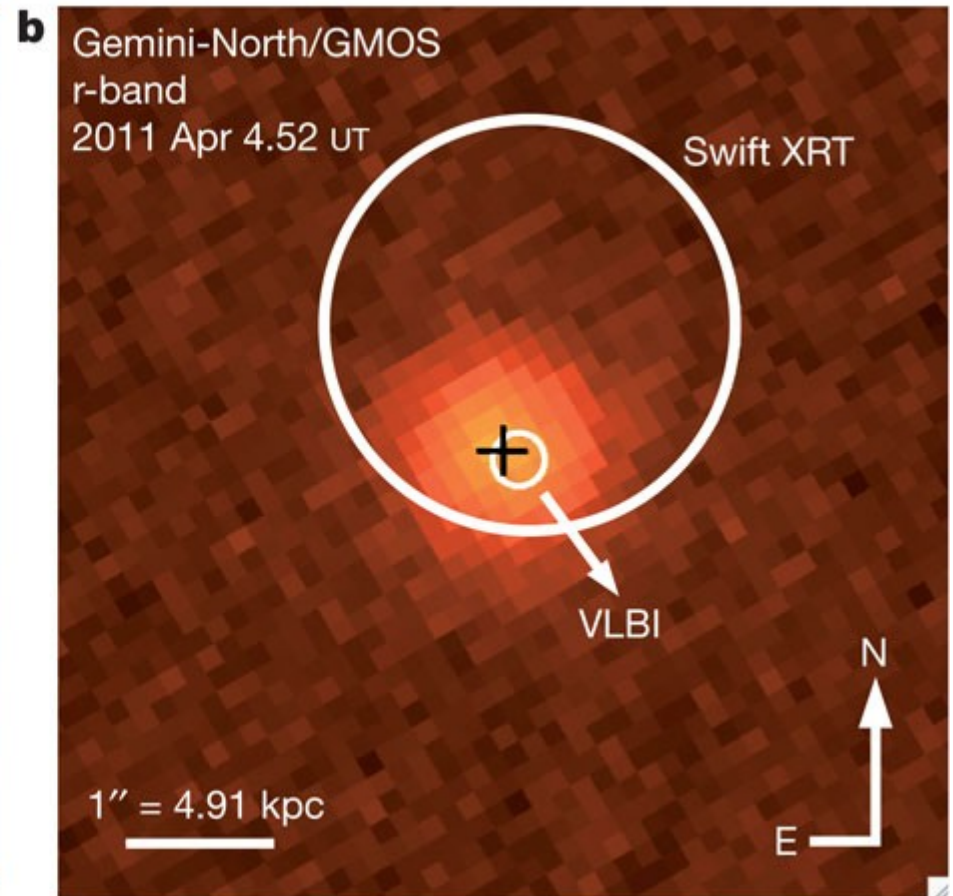
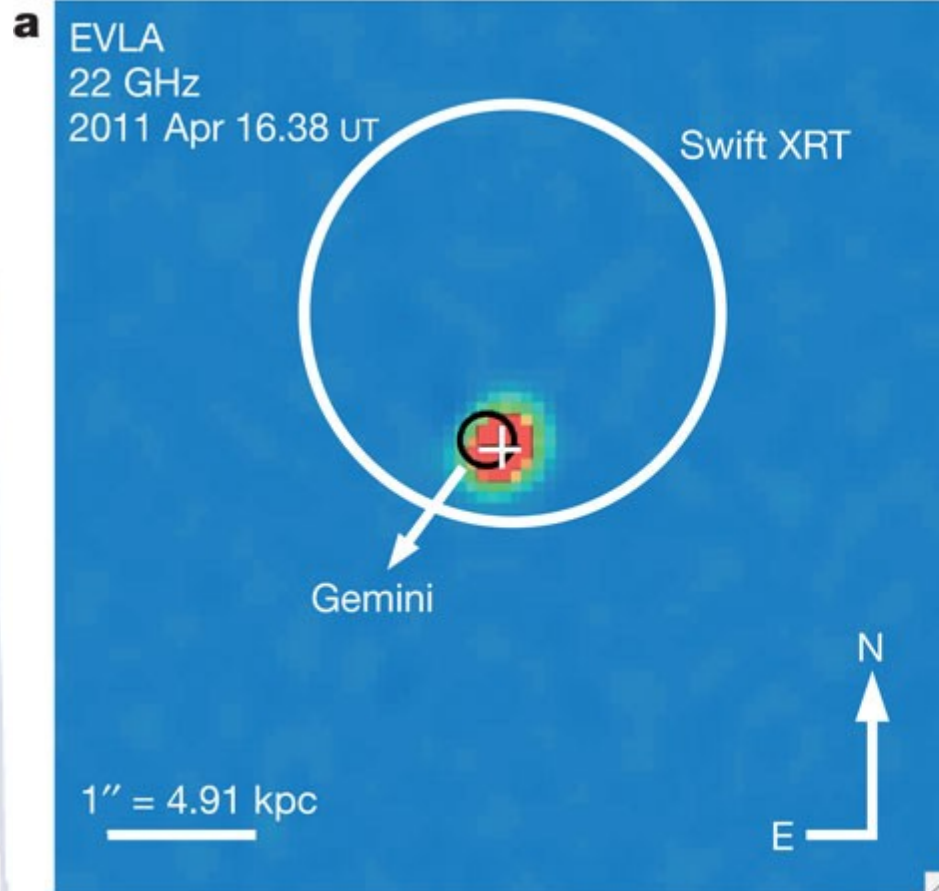
**4.** Near the black hole, magnetic fields power a narrow jet of particles moving near the speed of light. Viewed head-on, the jet is a brilliant X-ray and radio source.

# 28 marzo 2011: stella divorata in diretta





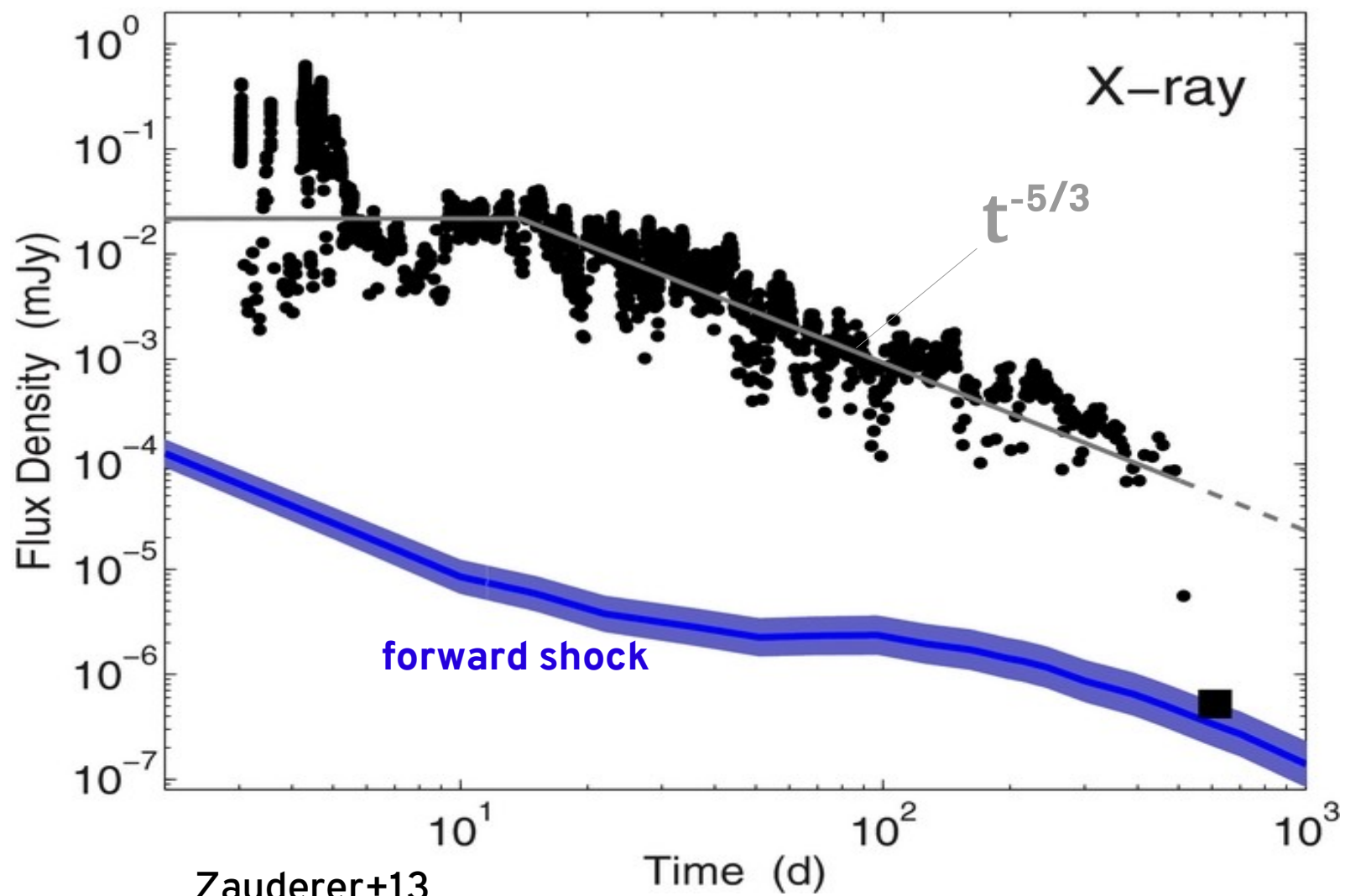
# Sw J1655+57: al centro di una galassia a 6 miliardi di anni-luce da noi



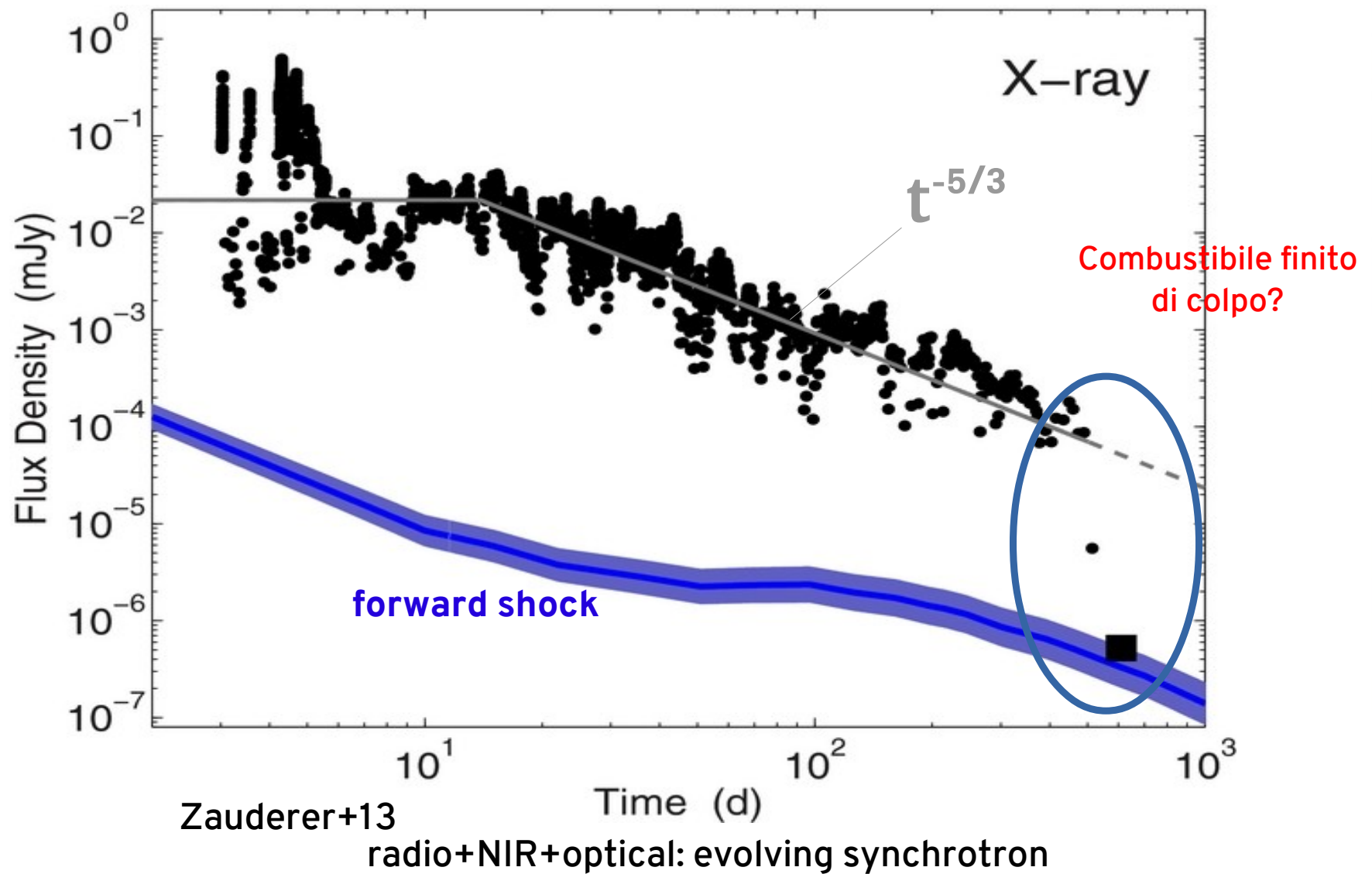
Offset:  $0.5 \pm 0.9$  kpc

Zauderer+11

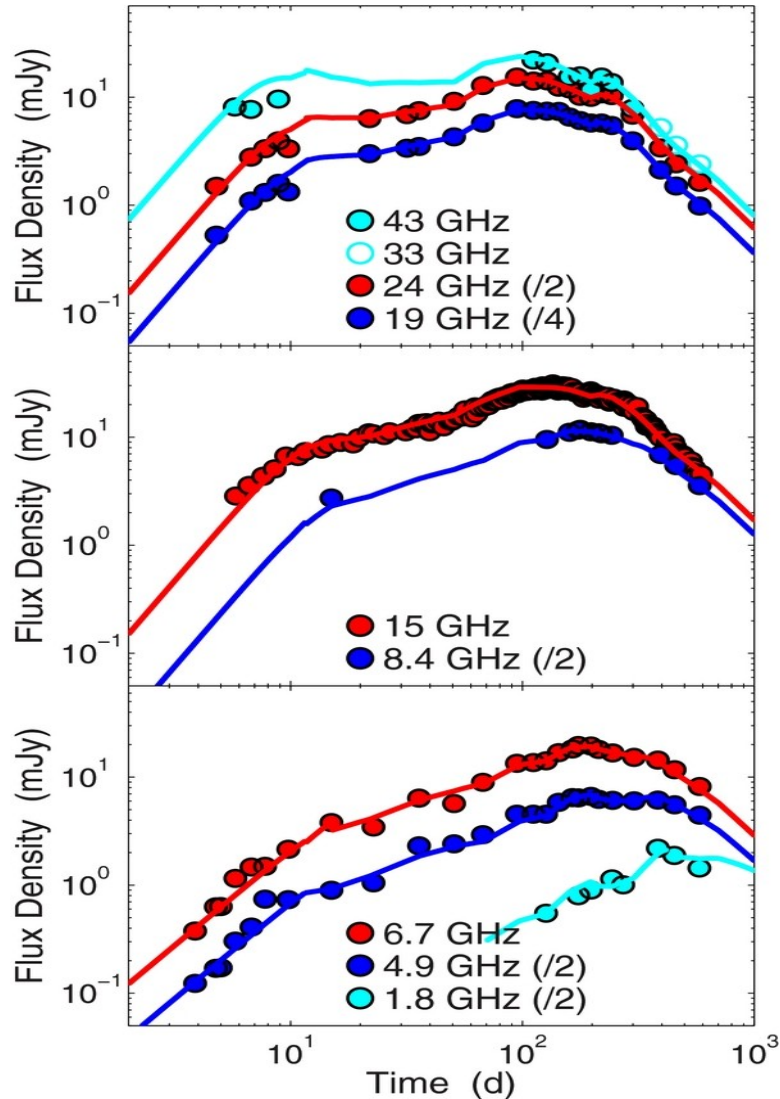
# Sw J1655+57: 2 anni di misure in raggi X



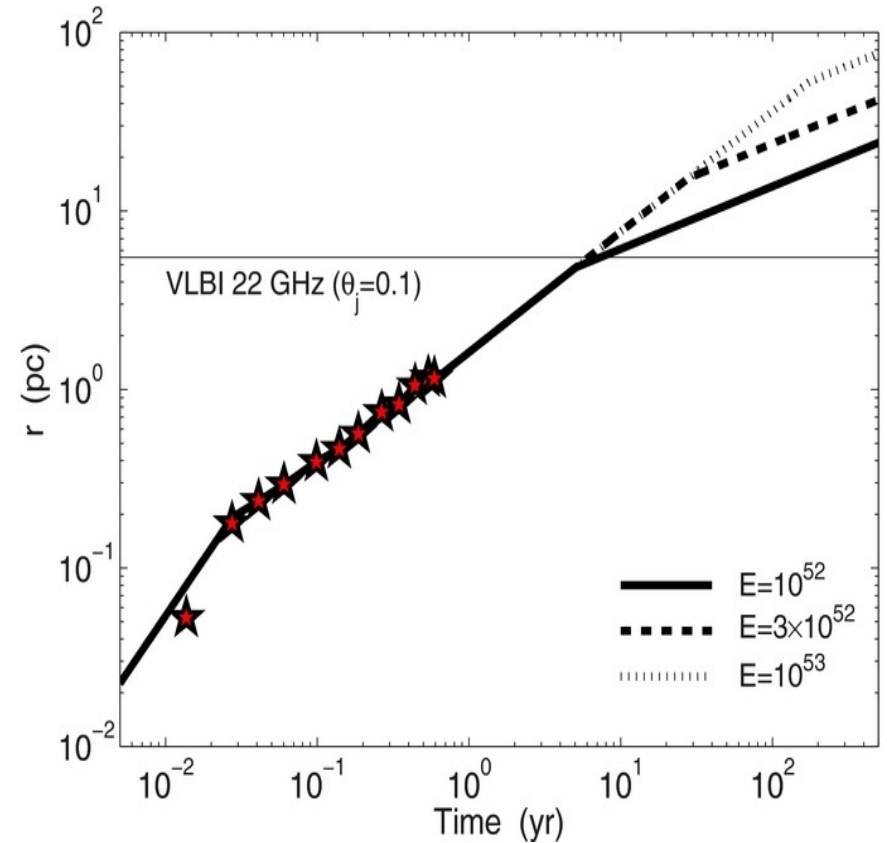
# Sw J1655+57: 2 anni di misure in raggi X



# Sw J1655+57: 2 anni di misure in radio



Zauderer+13

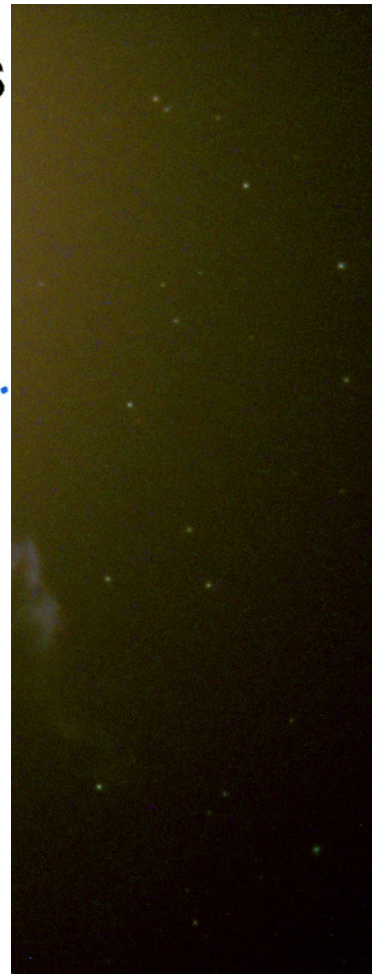
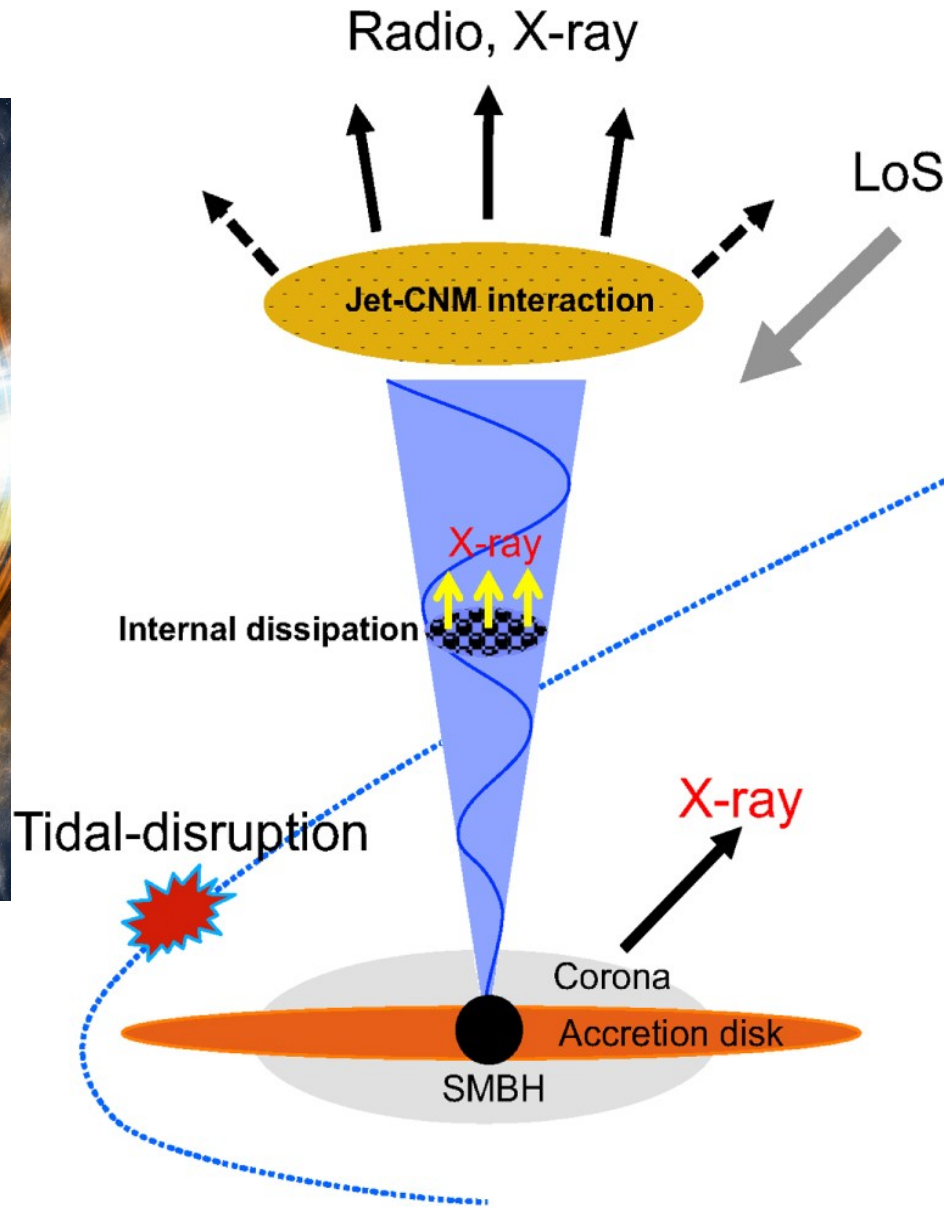
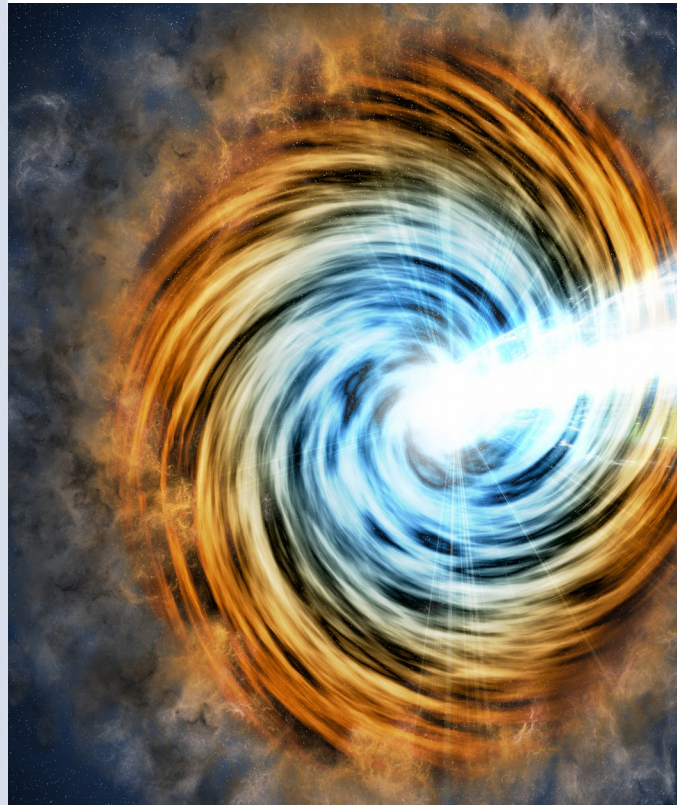


$$E_j \sim 10^{52} \text{ erg} ; M \sim 3 \times 10^6 M_{\odot}$$

$$\theta_j = 0.1 \text{ rad}$$

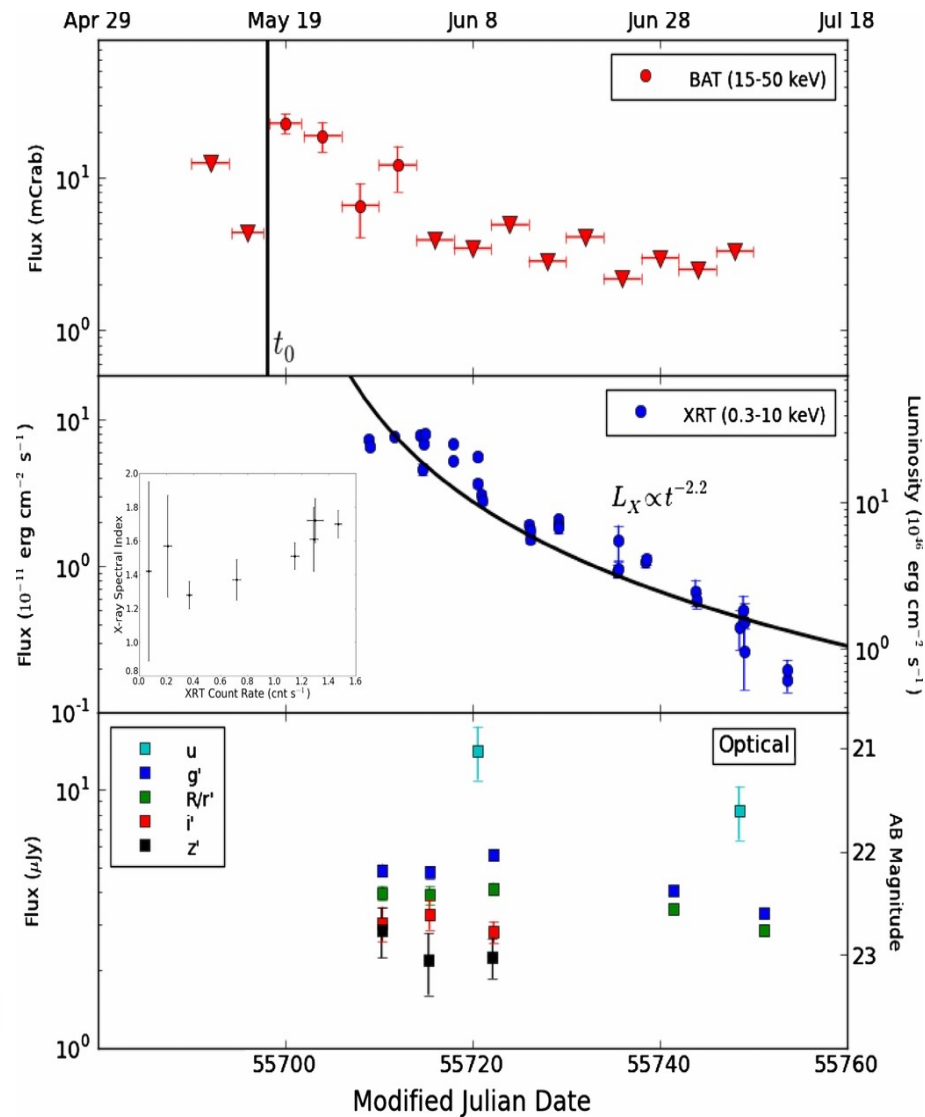
$$\Gamma \sim \text{a few}$$

# Getti: gas accelerato a velocità relativistiche

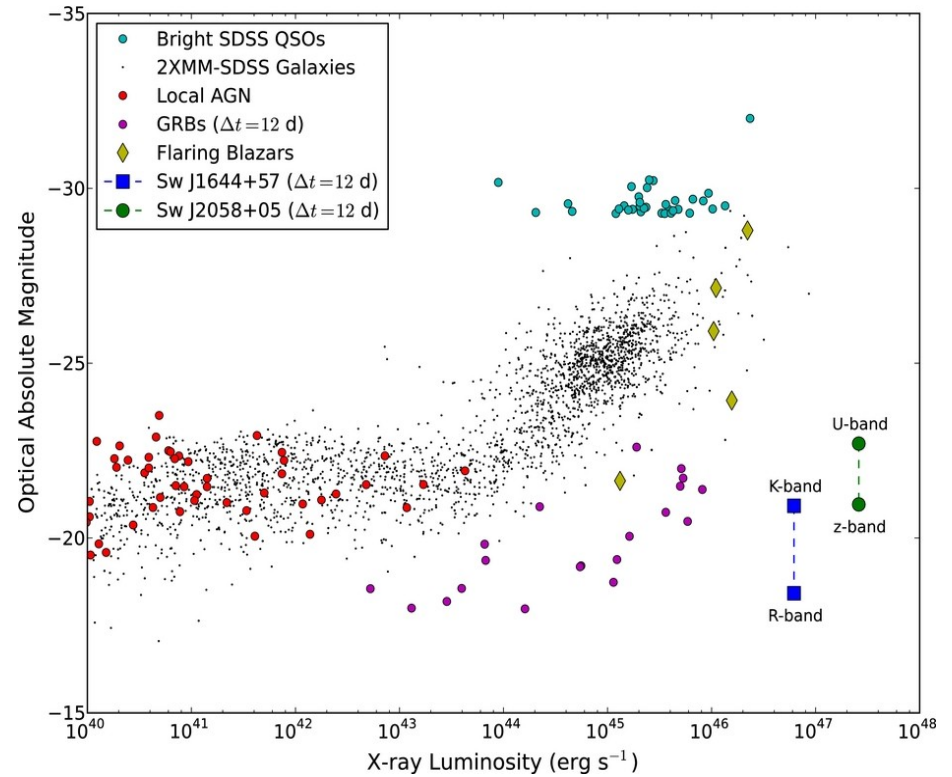


(Lei+16)

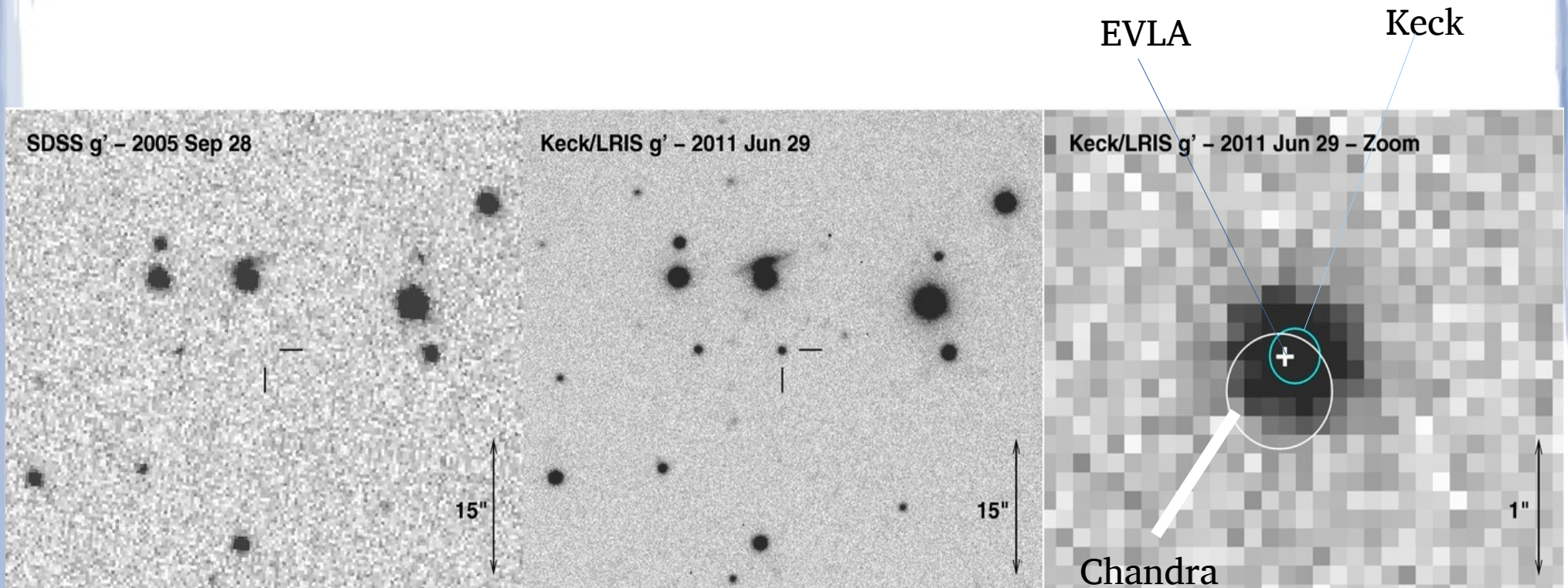
# Sw J2058+05: un altro caso molto sospetto



Cenko+12



# Sw J2058+05: un altro caso molto sospetto

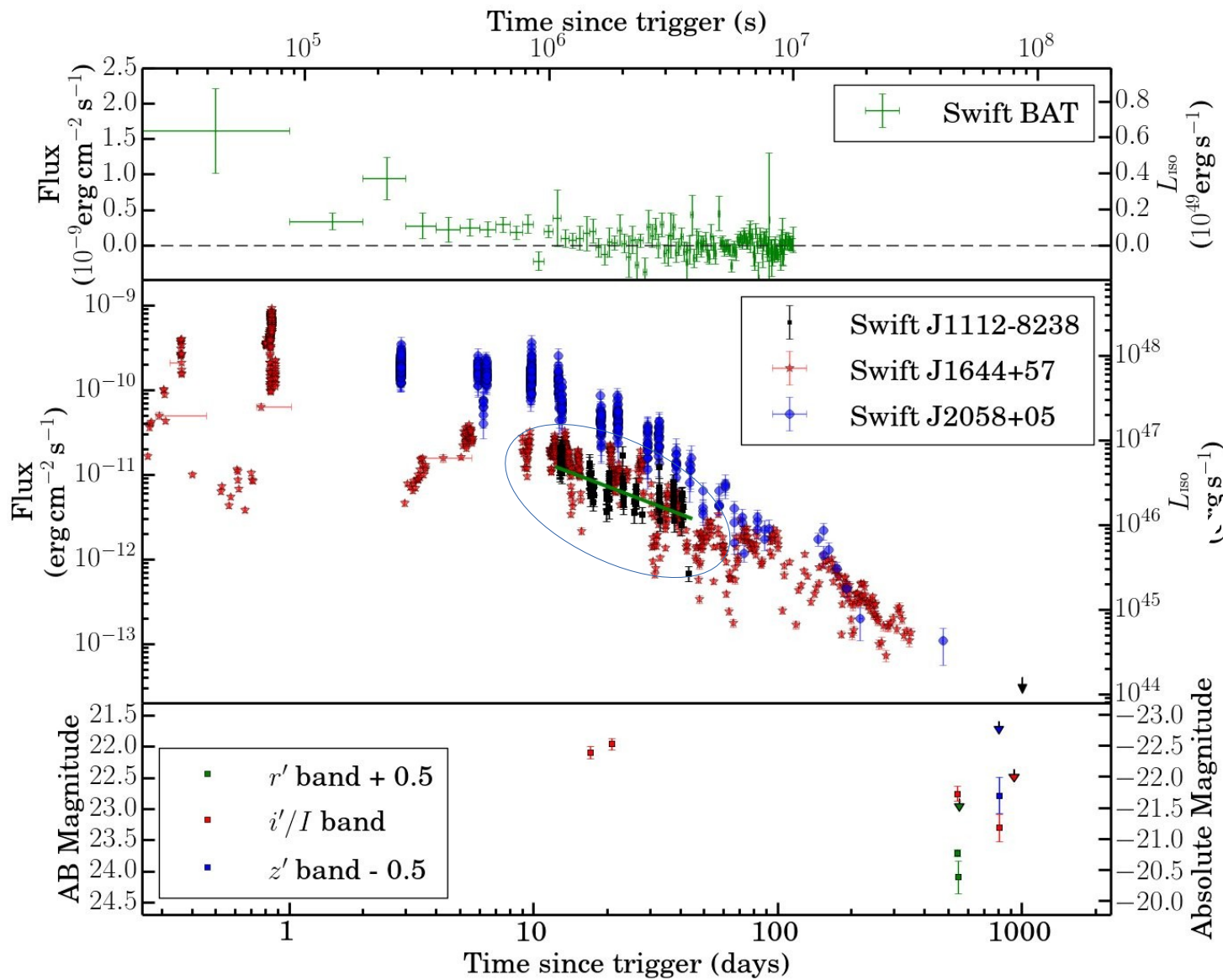


$Z = 1.1853$

Distanza da noi = 27 miliardi di anni-luce

Quando l'Universo aveva 5 miliardi di anni di vita (cfr. i 13.8 attuali)

# Sw J1112.2-8238: un terzo caso molto sospetto



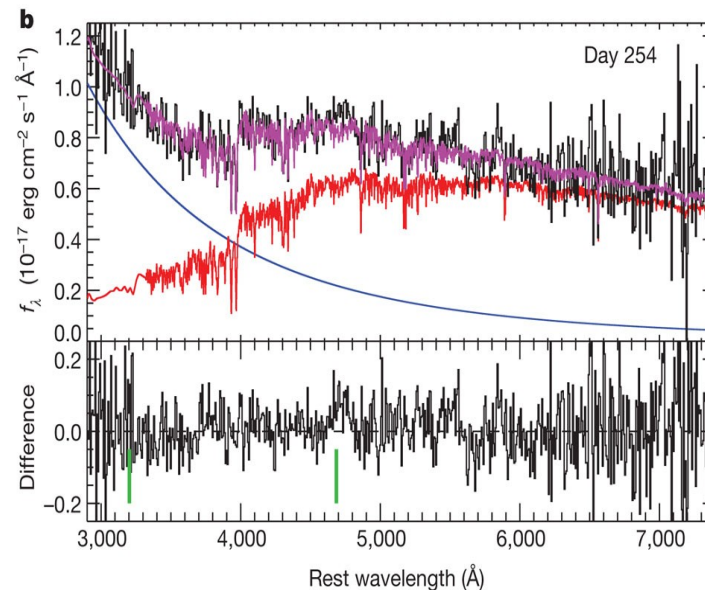
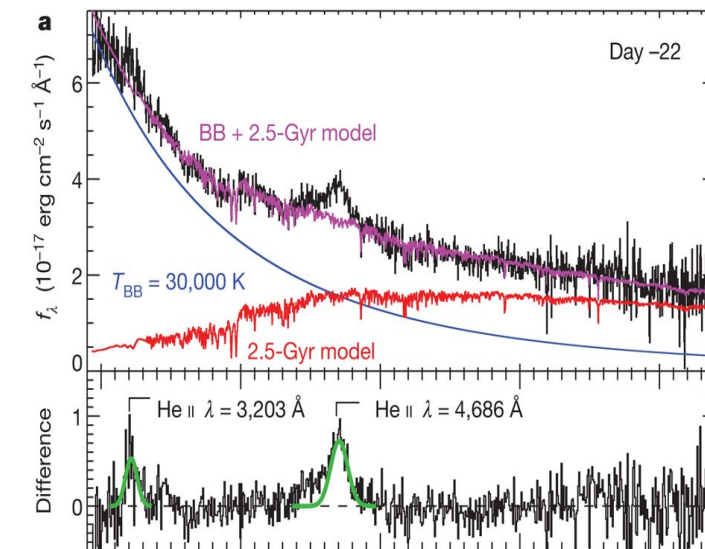
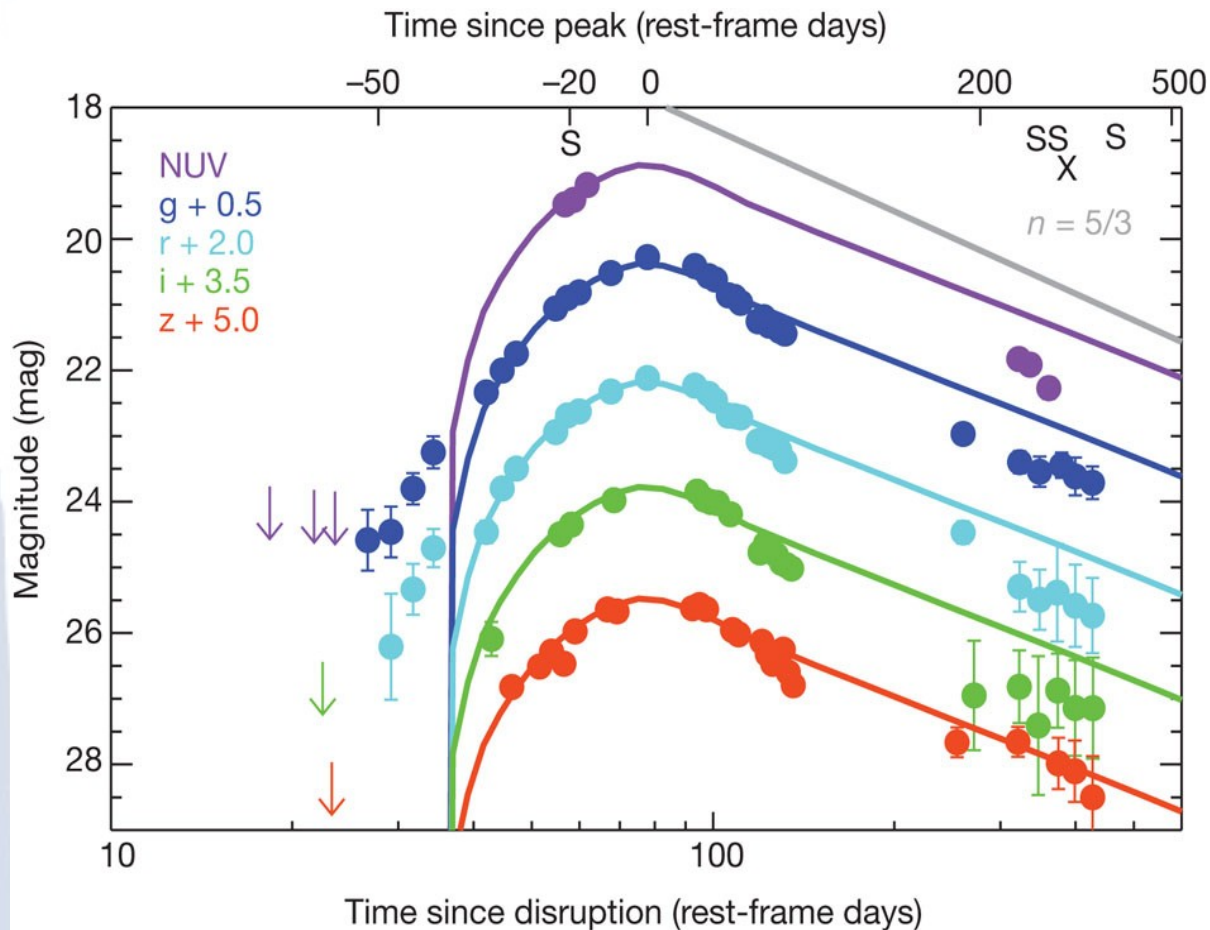
June 2011

Coincident  
with nucleus  
of faint gal @  
 $z = 0.89$

$L_x = 10^{47} \text{ erg/s}$



# Brillamento UV: distruzione di una stella ricoperta di elio



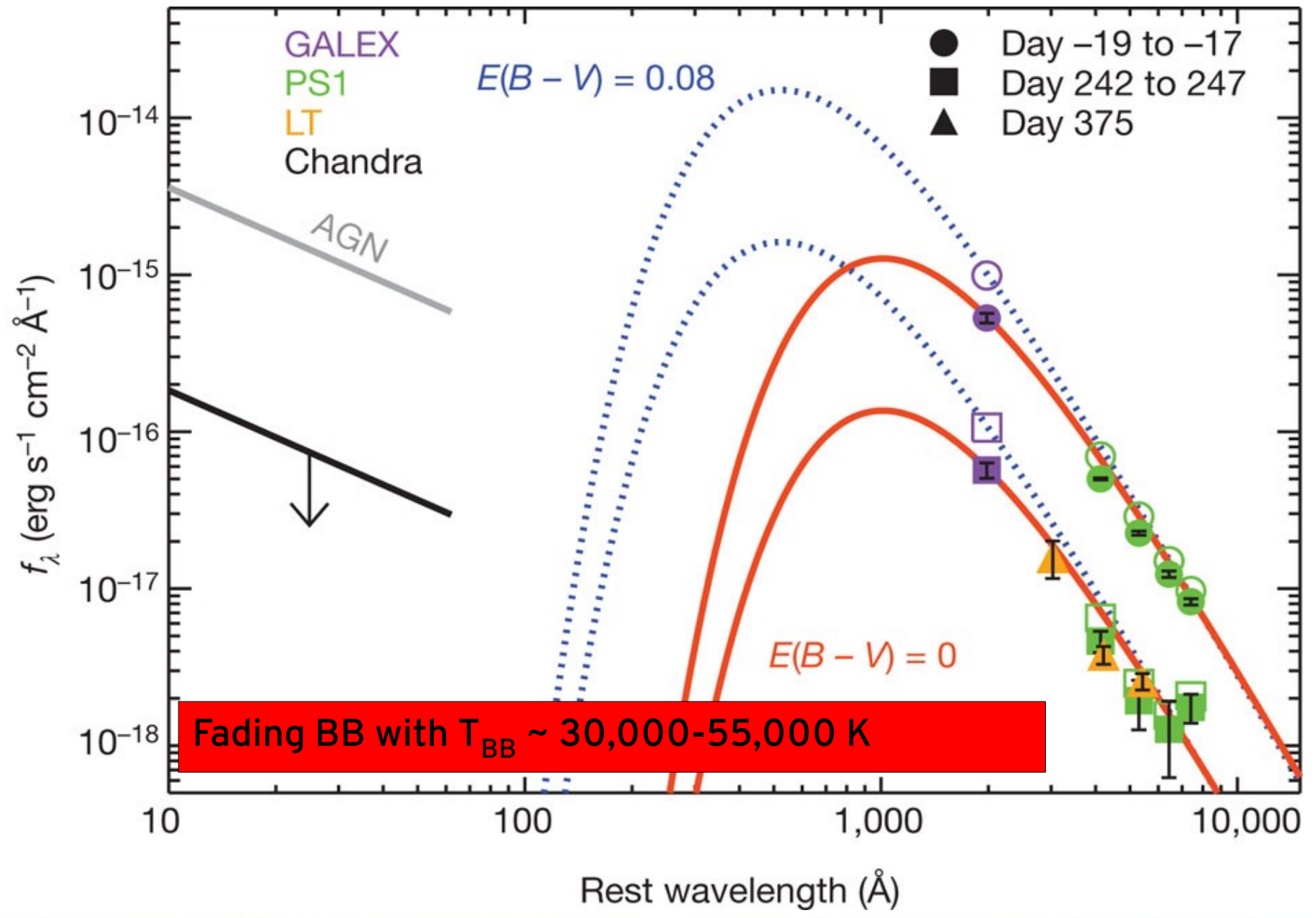
At centre of galaxy with  $M_{\text{stars}} = 3.6 \times 10^9 M_{\odot}$

SMBH:  $M_{\text{stars}} = 4(+4, -2) \times 10^6 M_{\odot}$  (scal rel)

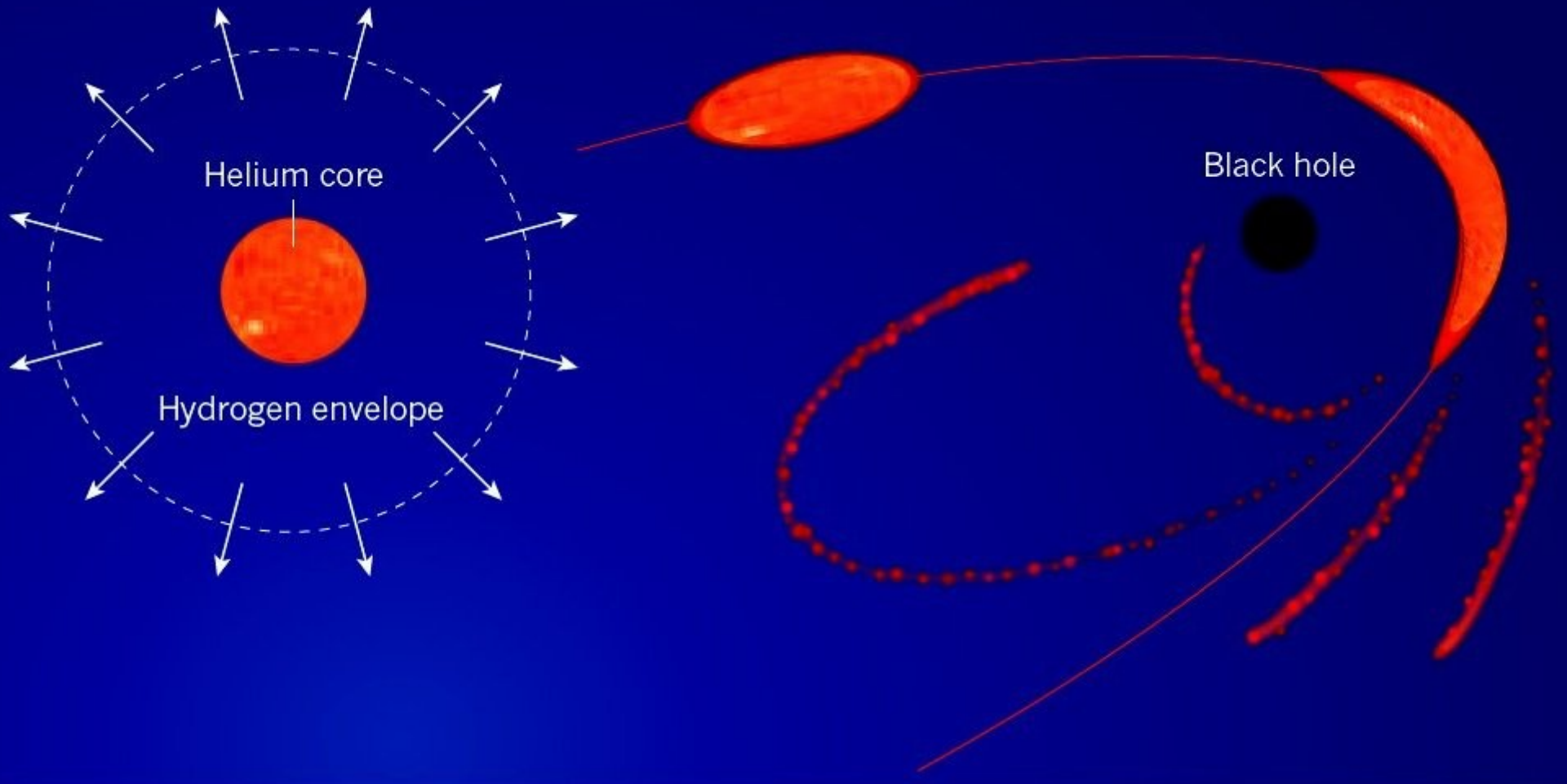
$z = 0.1696$  (LumDist = 816 Mpc)

**PS1-10jh**

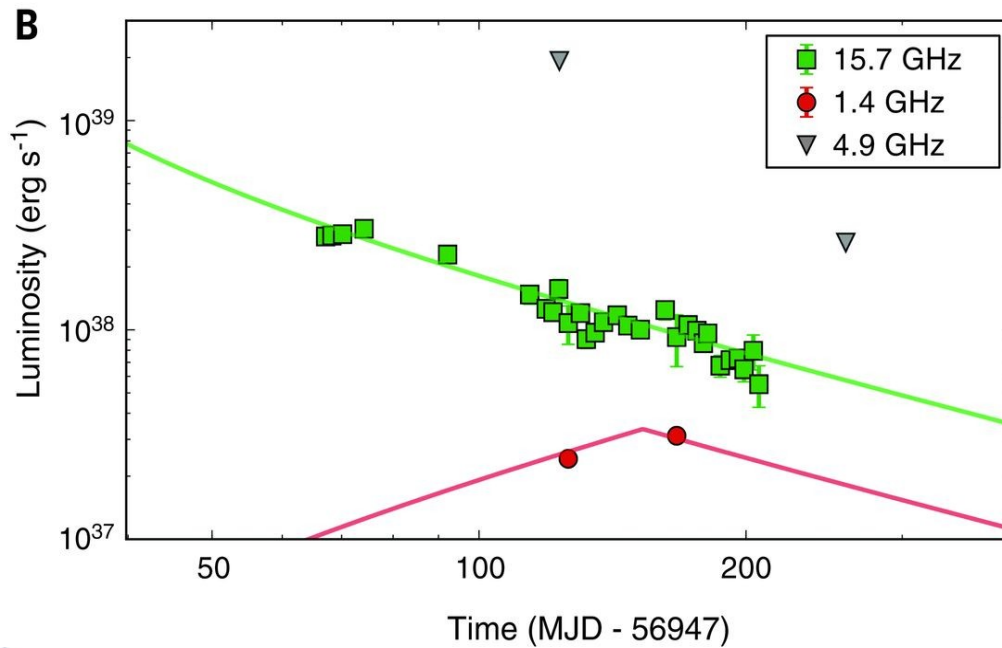
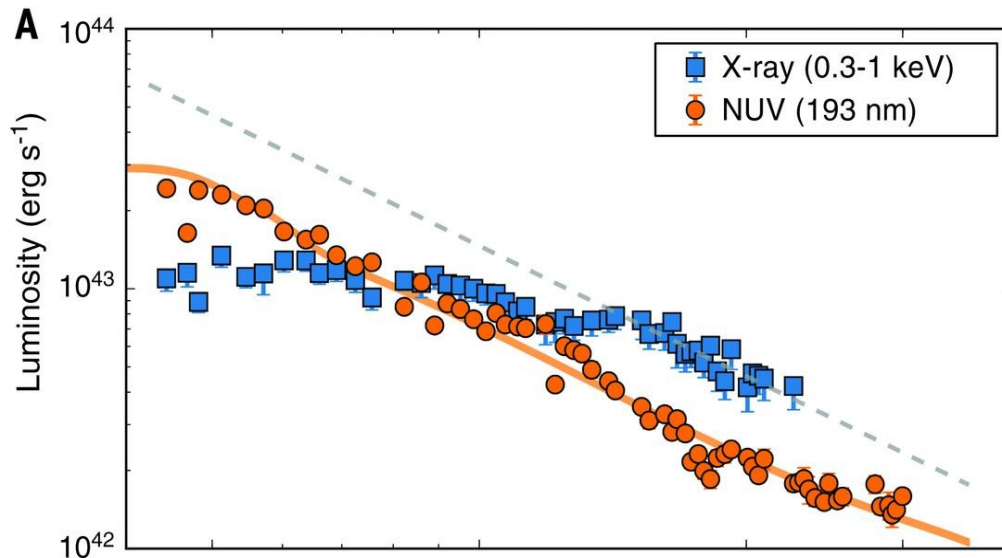
# Brillamento UV: distruzione di una stella ricoperta di elio



## Brillamento UV: distruzione di una stella ricoperta di elio



**ASASSN-14li:  
Un getto radio variabile da un  
TDE brillante in ottico e in  
raggi X**



Van Velzen+16



# ASTROCRASH.NET

THE RESEARCH OF JAMES GUILLOCHON

[HOME](#)
[ABOUT ME](#)
[RESOURCES](#)
[PROJECTS](#)
[BLOG](#)

Google “TDE Catalogue” and...

► [Astrocrash.net](#) » [Resources](#) » Catalogue of Possible Tidal Disruption Events

## CATALOGUE OF POSSIBLE TIDAL DISRUPTION EVENTS

This table is intended to be a "catch-all" list of possible tidal disruption events (TDEs) that have been claimed over the years in the literature, even for events in which the favored interpretation is not a tidal disruption.

The table is a continual work in progress, and likely is missing a few events and may have a few mistakes. Please [e-mail me](#) if you'd like to add any missing events or correct any of the entries, or if you'd like to suggest ways that the catalogue can be improved.

Search:

Name(s)	Host Name(s)	Publications	Instruments	Redshift	Claimed Event Type	Notes
2MASXJ0203	<a href="#">2MASX J02030314-0741514</a>	<a href="#">Esquej et al. 2007*‡</a>	2MASS, XMM-Newton, ROSAT	0.0615	TDE	Star-forming host, possibly pre-TDE AGN
2MASXJ0249	<a href="#">2MASX J02491731-0412521</a>	<a href="#">Esquej et al. 2007*‡</a>	2MASS, XMM-Newton, ROSAT	0.0186	TDE	Star-forming host, possibly pre-TDE AGN
ASASSN-14ae	<a href="#">SDSS J110840.11+340552.2</a>	<a href="#">Holoien et al. 2014*‡</a>	LCOGT 1-m, LG 2-m, Swift	0.0436	TDE	Exponential decay
D1-9	<a href="#">GALEX J022517.0-043258</a>	<a href="#">Gezari et al. 2008*‡</a>	MegaCam (g, r, i, z), GALEX (NUV, FUV), Chandra, XMM-Newton‡, VLT*	0.326	TDE	
D3-13	<a href="#">GALEX J141929.8+525206</a>	<a href="#">Gezari et al. 2006*‡</a> , <a href="#">Gezari et al. 2008</a>	MegaCam (g, r, i, z), GALEX (NUV, FUV), Keck*	0.3698	TDE	
D23H-1	<a href="#">SDSS J233159.53+001714.5</a>	<a href="#">Gezari et al. 2009*‡</a>	GALEX (NUV, FUV)	0.1855	TDE	Star-forming host
Dougie	<a href="#">SDSS J120847.77+430120.1</a>	<a href="#">Vinko et al. 2014*‡</a>	ROTSE, HET	0.191	TDE	1 kpc off-center, super-Eddington, no emission lines.
GRB060218, SN2006ai	<a href="#">SDSS J032139.69+165201.7</a>	<a href="#">Campana et al. 2006*</a> <a href="#">Shcherbakov</a>	Swift (UVOT, XRT)	0.0335	WD + IMBH	

# Cosa impariamo studiando i TDE?

- Demografia dei SMBH di piccola massa, dormienti
- Come i SMBH accrescono la propria massa
- Come si muovono statisticamente le stelle che stanno nelle vicinanze di questi mostri
- Eccellente strumento di verifica di effetti di relatività generale che altrimenti non sarebbero testabili (lo spazio-tempo è molto distorto dalla vicinanza al mostro)
- Come si formano ed evolvono i getti radio che questi mostri producono nel cuore delle galassie che li ospitano.

IMPREVISTI

IMPREVISTI

Fate tre passi indietro (con tanti auguri!)

IMPREVISTI



VIALE  
LUDOVICO

TASSA  
DI LUSSO



# Fast Radio Bursts (FRBs)

unexpected mysterious blasts from past



# Proprietà generali

- A oggi (feb 2016) osservati soltanto 16 eventi
- Tutti alla lunghezza d'onda di 21 cm ( $f=1.4$  GHz)
- Provenienti da tutte le regioni del cielo
- Nessuna ripetizione osservata finora.
- Tipica incertezza sulla direzione: vari primi d'arco
- Flussi: 0.35-30 Jy [1Jy =  $10^{-26}$  W m<sup>-2</sup> Hz<sup>-1</sup>]
- Durate: qualche ms
- Dispersione DM molto + alta di quella galattica

$$DM = 375 - 1629 \text{ pc cm}^{-3}$$

$$DM = \int_0^d n_e dl$$

Event	Telescope	gl [deg]	gb [deg]	FWHM [deg]	DM [cm <sup>-3</sup> pc]	SN	W <sub>obs</sub> [ms]	S <sub>peak,obs</sub> [Jy]	F <sub>obs</sub> [Jy ms]	Ref
<a href="#">FRB010125</a>	parkes	356.641	-20.020	0.25	790(3)	17	9.40 <sup>+0.20</sup> <sub>-0.20</sub>	0.30	2.82	<u>1</u>
<a href="#">FRB010621</a>	parkes	25.433	-4.003	0.25	745(10)		7.00	0.41	2.87	<u>2</u>
<a href="#">FRB010724</a>	parkes	300.653	-41.805	0.25	375	23	5.00	>30.00 <sup>+10.00</sup> <sub>-10.00</sub>	>150.00	<u>3</u>
<a href="#">FRB090625</a>	parkes	226.443	-60.030	0.25	899.55(1)	30	1.92 <sup>+0.83</sup> <sub>-0.77</sub>	1.14 <sup>+0.42</sup> <sub>-0.21</sub>	2.19 <sup>+2.10</sup> <sub>-1.12</sub>	<u>4</u>
<a href="#">FRB110220</a>	parkes	50.828	-54.766	0.25	944.38(5)	49	5.60 <sup>+0.10</sup> <sub>-0.10</sub>	1.30 <sup>+0.00</sup> <sub>-0.00</sub>	7.28 <sup>+0.13</sup> <sub>-0.13</sub>	<u>5</u>
<a href="#">FRB110523</a>	GBT	56.119	-37.819	0.26	623.30(6)	42	1.73 <sup>+0.17</sup> <sub>-0.17</sub>	0.60	1.04	<u>6</u>
<a href="#">FRB110626</a>	parkes	355.861	-41.752	0.25	723.0(3)	11	1.40	0.40	0.56	<u>5</u>
<a href="#">FRB110703</a>	parkes	80.997	-59.019	0.25	1103.6(7)	16	4.30	0.50	2.15	<u>5</u>
<a href="#">FRB120127</a>	parkes	49.287	-66.203	0.25	553.3(3)	11	1.10	0.50	0.55	<u>5</u>
<a href="#">FRB121002</a>	parkes	308.219	-26.264	0.25	1629.18(2)	16	5.44 <sup>+3.50</sup> <sub>-1.20</sub>	0.43 <sup>+0.33</sup> <sub>-0.06</sub>	2.34 <sup>+4.46</sup> <sub>-0.77</sub>	<u>4</u>
<a href="#">FRB121102</a>	arecibo	174.950	-0.225	0.05	557(2)	14	3.00 <sup>+0.50</sup> <sub>-0.50</sub>	0.40 <sup>+0.40</sup> <sub>-0.10</sub>	1.20 <sup>+1.60</sup> <sub>-0.45</sub>	<u>7</u>
<a href="#">FRB130626</a>	parkes	7.450	27.420	0.25	952.4(1)	21	1.98 <sup>+1.20</sup> <sub>-0.44</sub>	0.74 <sup>+0.49</sup> <sub>-0.11</sub>	1.47 <sup>+2.45</sup> <sub>-0.50</sub>	<u>4</u>
<a href="#">FRB130628</a>	parkes	225.955	30.655	0.25	469.88(1)	29	0.00	0.00	0.00	<u>4</u>
<a href="#">FRB130729</a>	parkes	324.787	54.744	0.25	861(2)	14	15.61 <sup>+9.98</sup> <sub>-6.27</sub>	0.22 <sup>+0.17</sup> <sub>-0.05</sub>	3.43 <sup>+6.55</sup> <sub>-1.81</sub>	<u>4</u>
<a href="#">FRB131104</a>	parkes	260.549	-21.925	0.25	779(1)	30	2.08	1.12	2.33	<u>8</u>
<a href="#">FRB140514</a>	parkes	50.841	-54.611	0.25	562.7(6)	16	2.80 <sup>+3.50</sup> <sub>-0.70</sub>	0.47 <sup>+0.11</sup> <sub>-0.08</sub>	1.32 <sup>+2.34</sup> <sub>-0.50</sub>	<u>9</u>

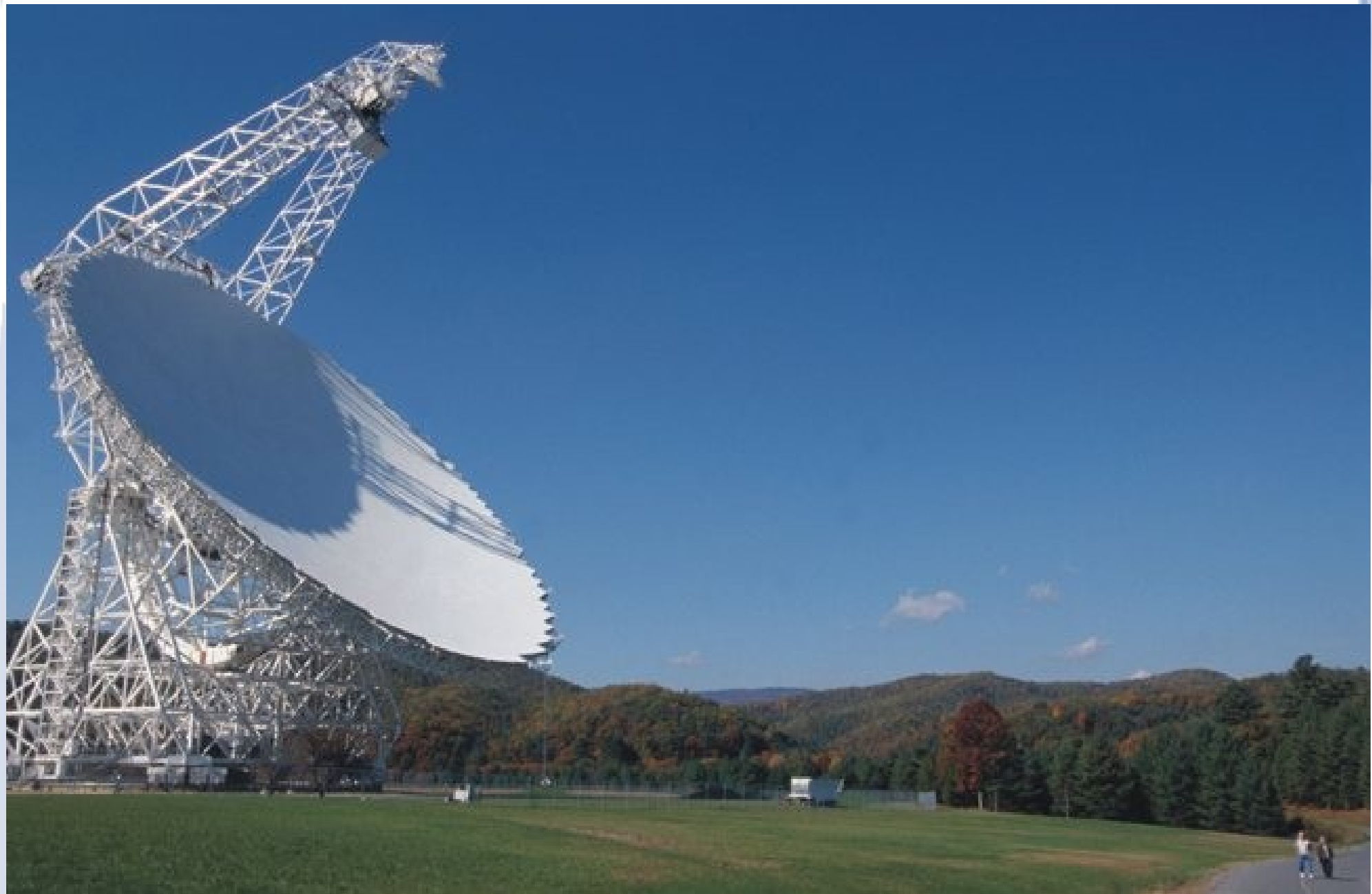
# Quasi tutti osservati col Parkes Radio T.



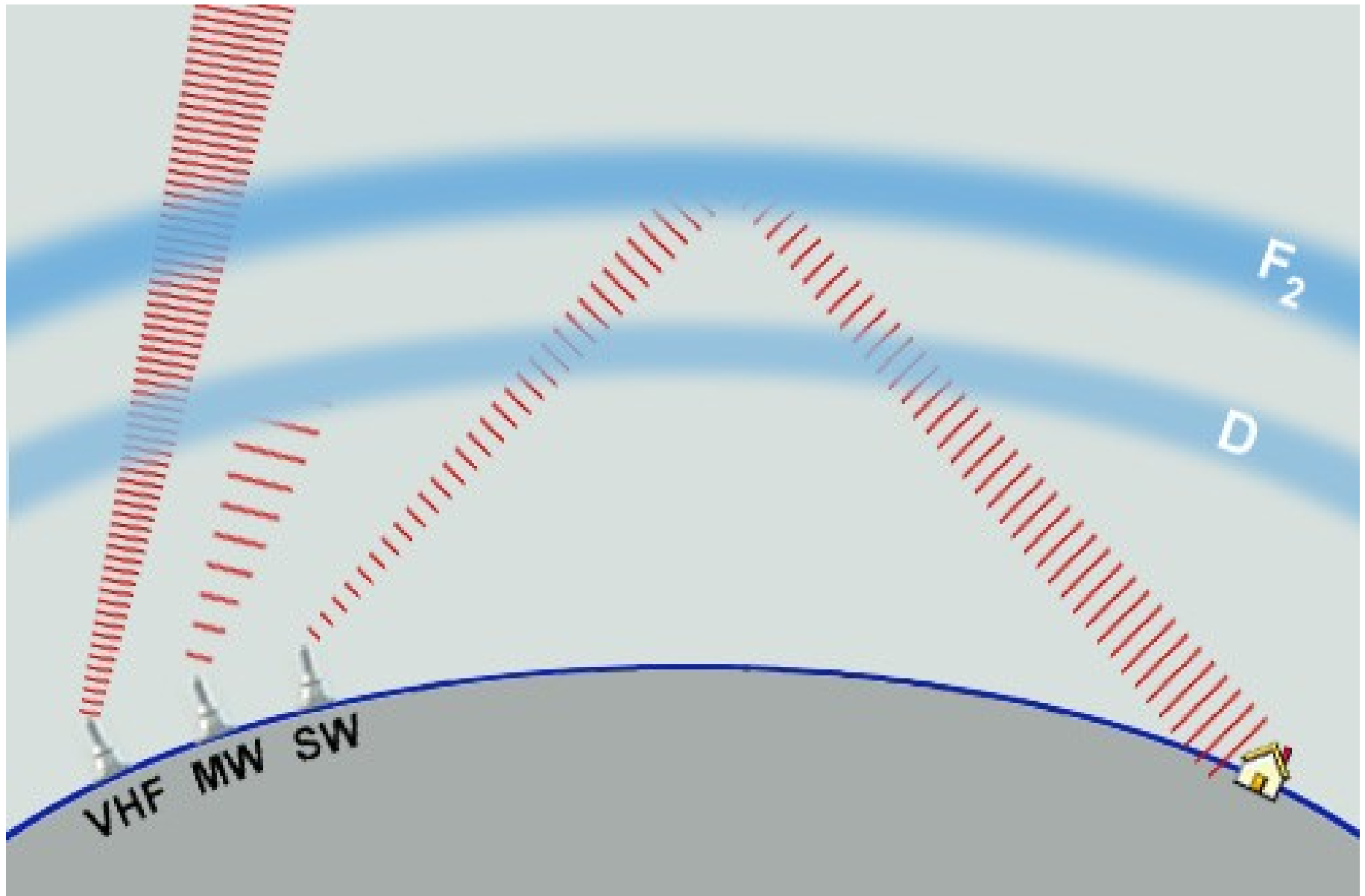
**...tranne 1 con l'Arecibo**



**...e un altro con GBT**



# Onde e.m. attraverso plasma



# Onde e.m. attraverso plasma

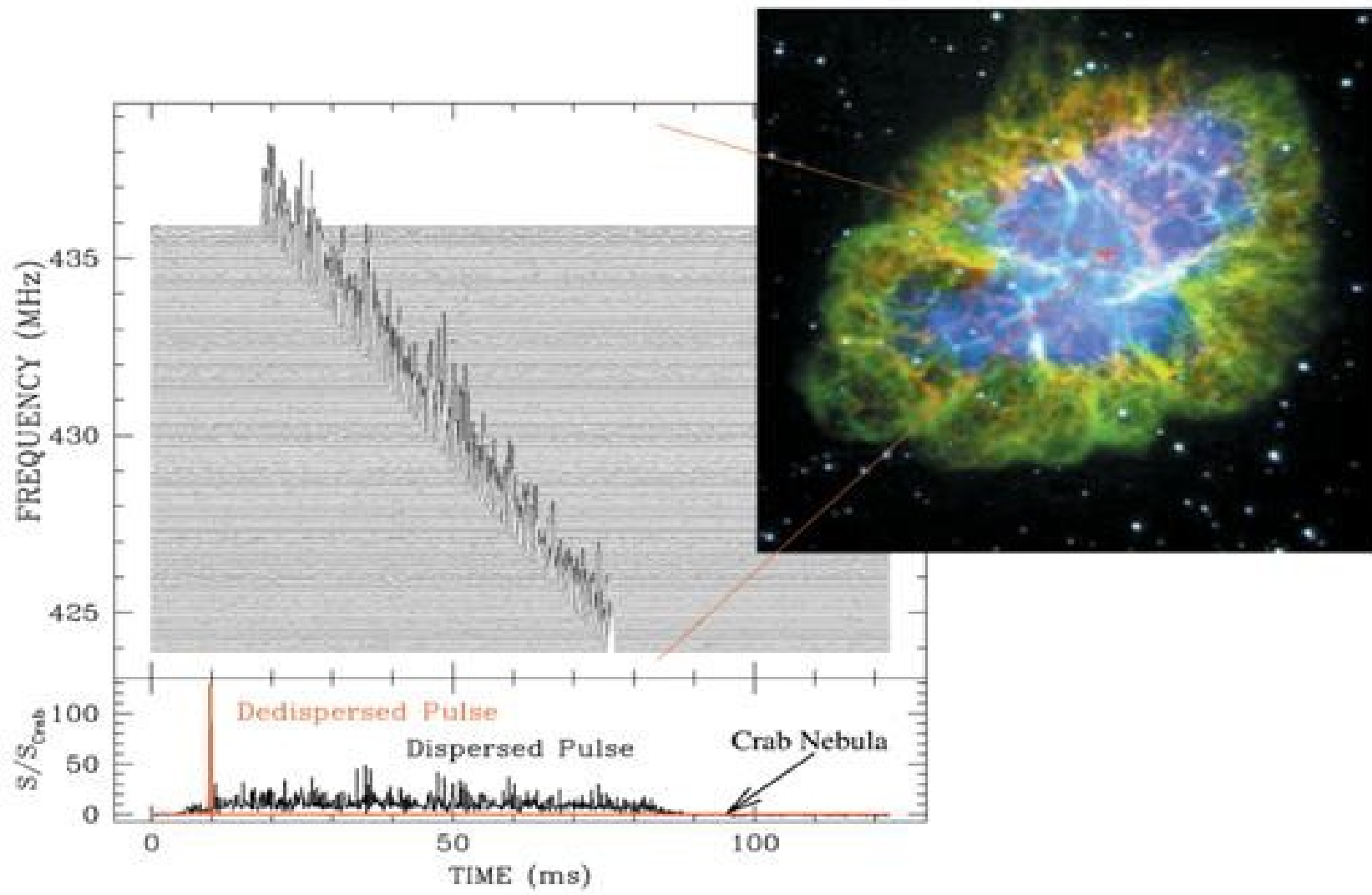
$$\nu_p = \frac{\omega_p}{2\pi} = \sqrt{\frac{ne^2}{\pi m}} = 8.98 \sqrt{n} \text{ kHz} \quad [n] = \text{cm}^{-3}$$

$$n \sim 10^4 \text{ cm}^{-3} \longrightarrow \nu_p \sim 1 \text{ MHz}$$

VHF MW SW



# Dispersion (DM)





# Dispersione

Plasma frequencies in astrophysics are usually around a few kHz, so in the radio band at 100 MHz – 1 GHz the group velocity can be approximately written as

$$v_g = c \sqrt{1 - \left(\frac{\omega_p}{\omega}\right)^2} \simeq c \left[ 1 - \frac{1}{2} \left(\frac{v_p}{v}\right)^2 \right]$$

Suppose a pulse of radio waves is emitted at  $t = 0$  from a pulsar at distance  $l$  from Earth. The arrival time  $t_a$  is then

$$\Delta t_a = \frac{e^2}{2\pi m c} \frac{D}{v^2}$$

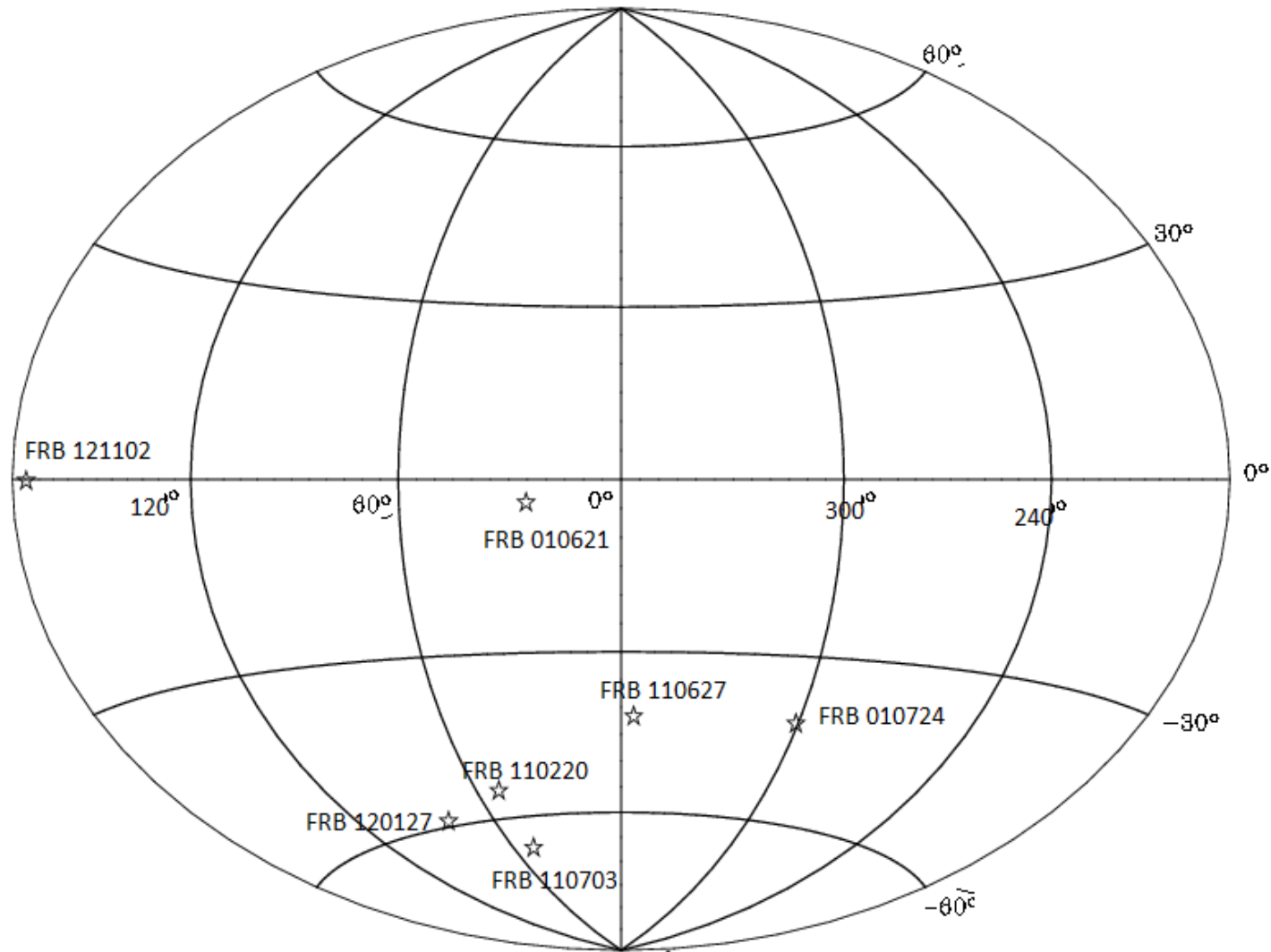
$$D := \int_0^l n dl \quad \text{DISPERSION (or DM)}$$

$$\Delta t_a \simeq \frac{4.15 \times 10^{15}}{v^2} D \quad \text{s}$$

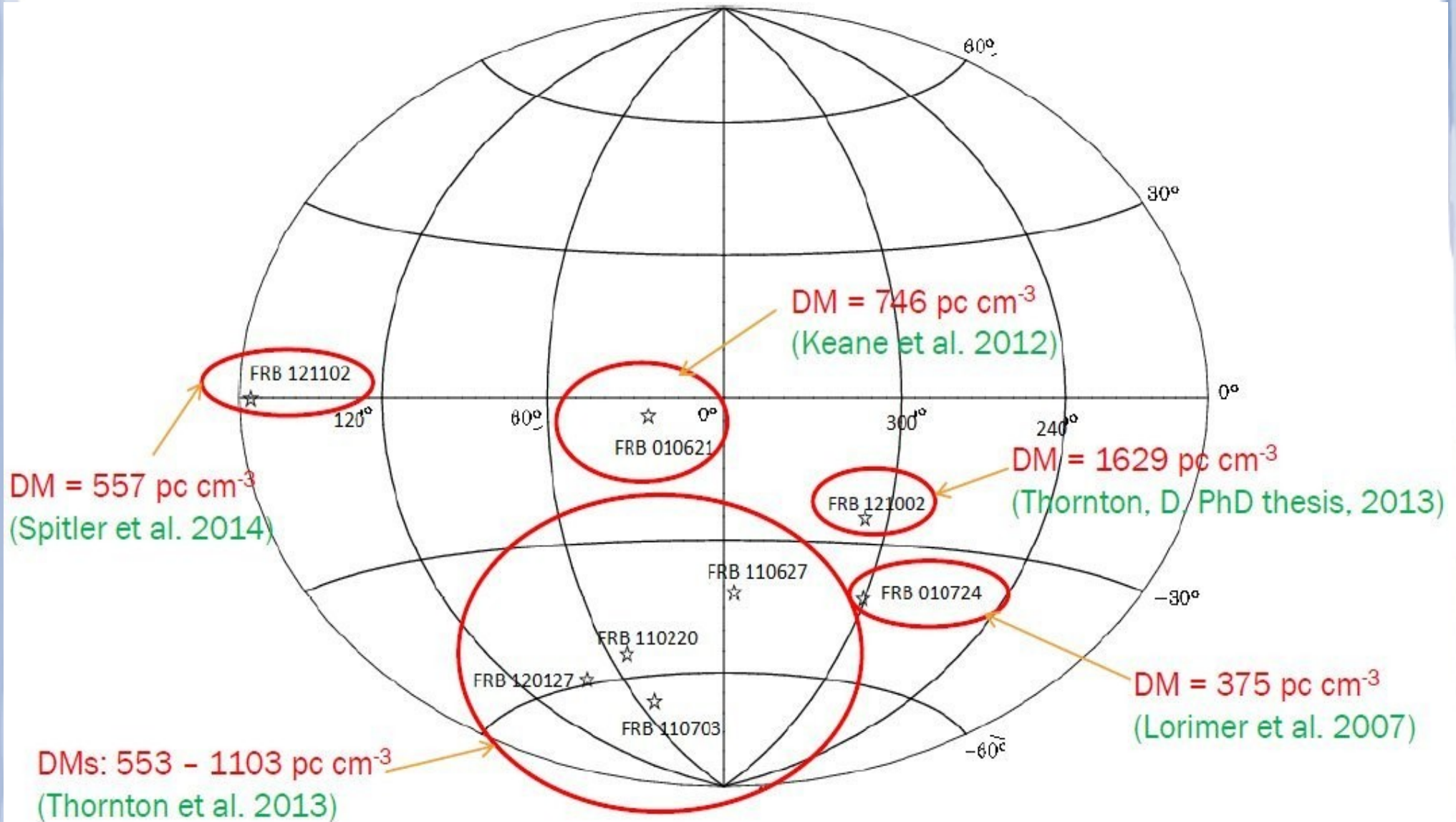
$$[D] = pc \text{ cm}^{-3}$$

$$[v] = \text{Hz}$$

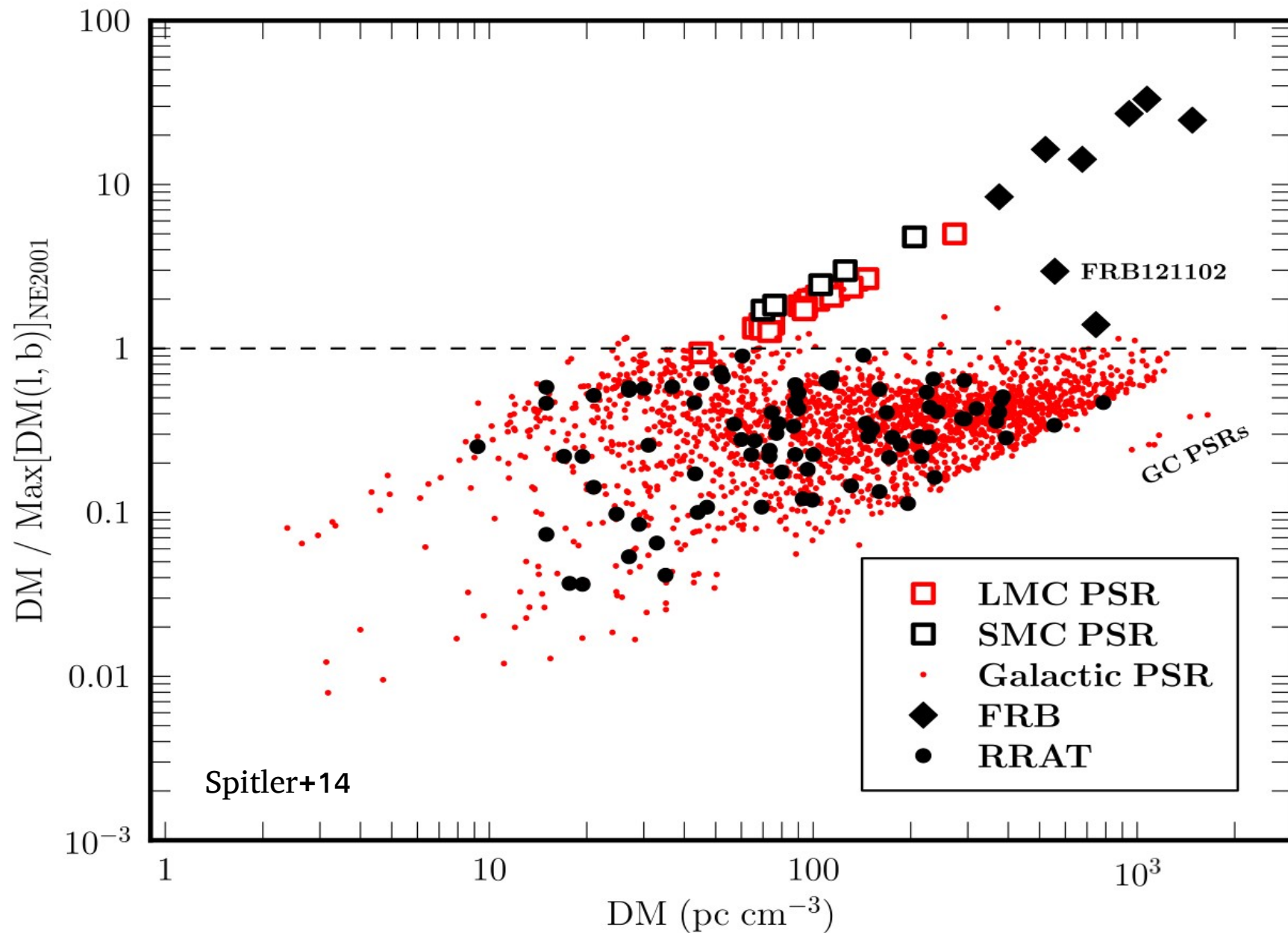
# Distribuzione in coordinate galattiche



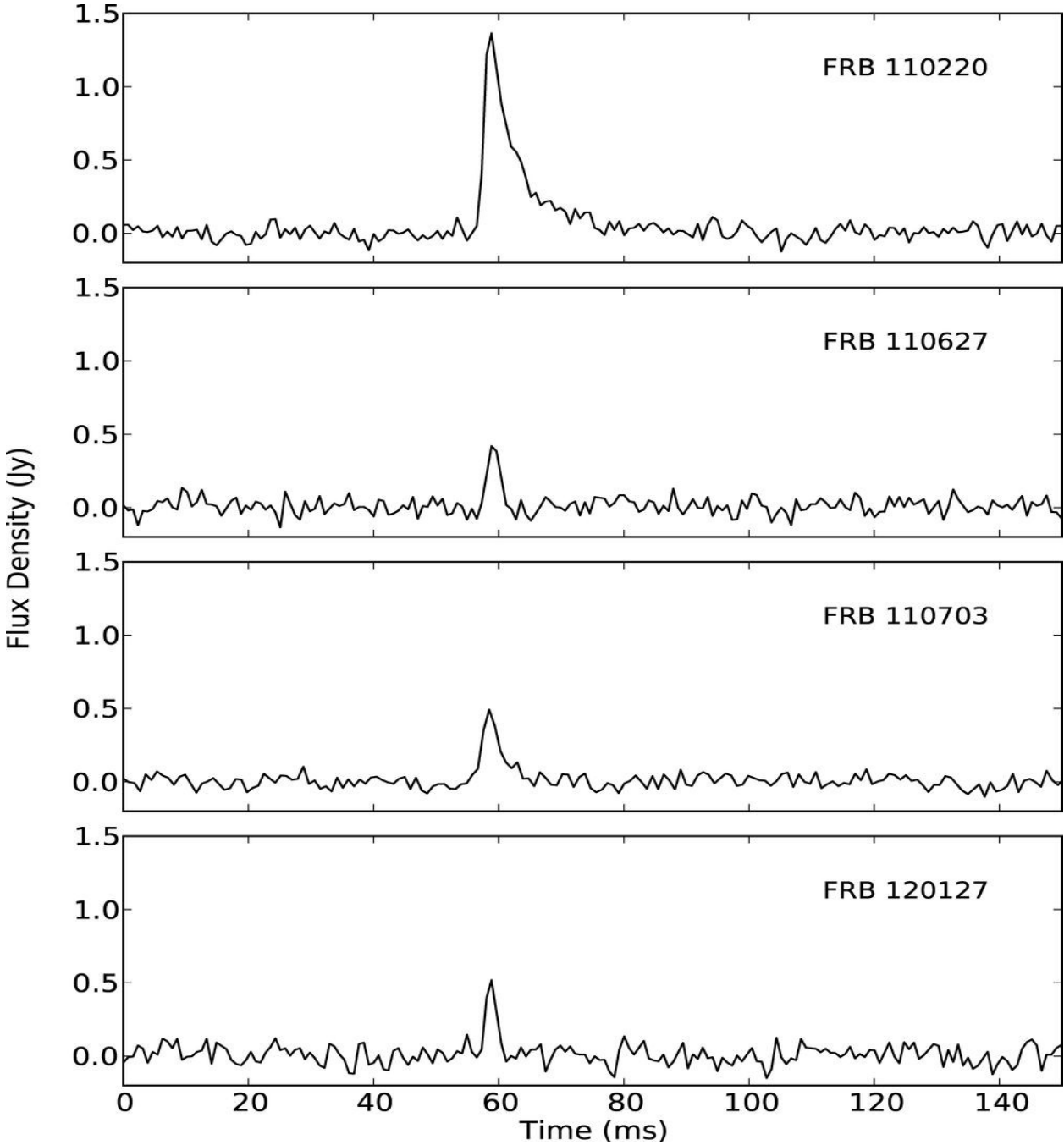
# Distribuzione in coordinate galattiche



# Confronto con la DM galattica

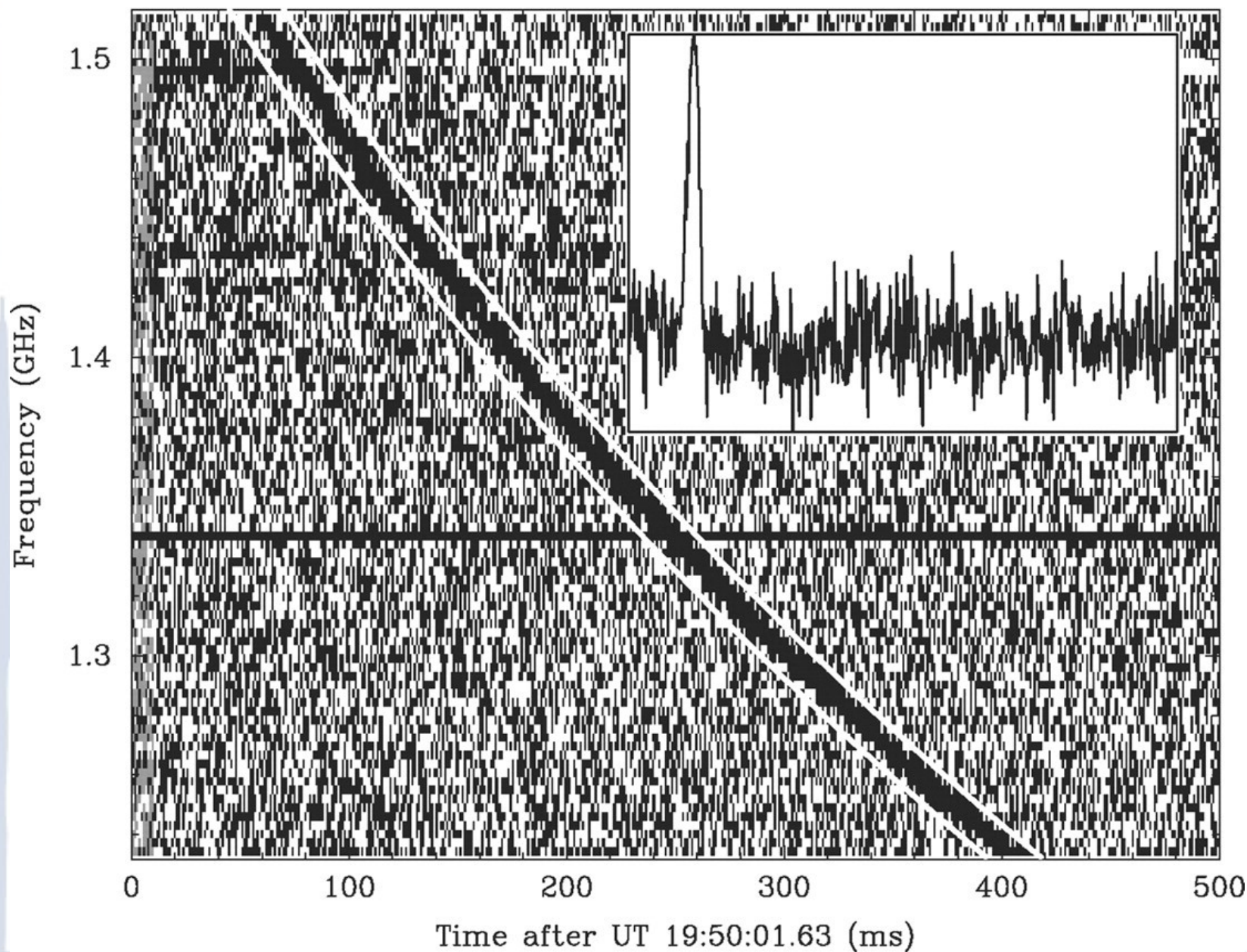


# Profili temporali degli FRB



Thornton+13

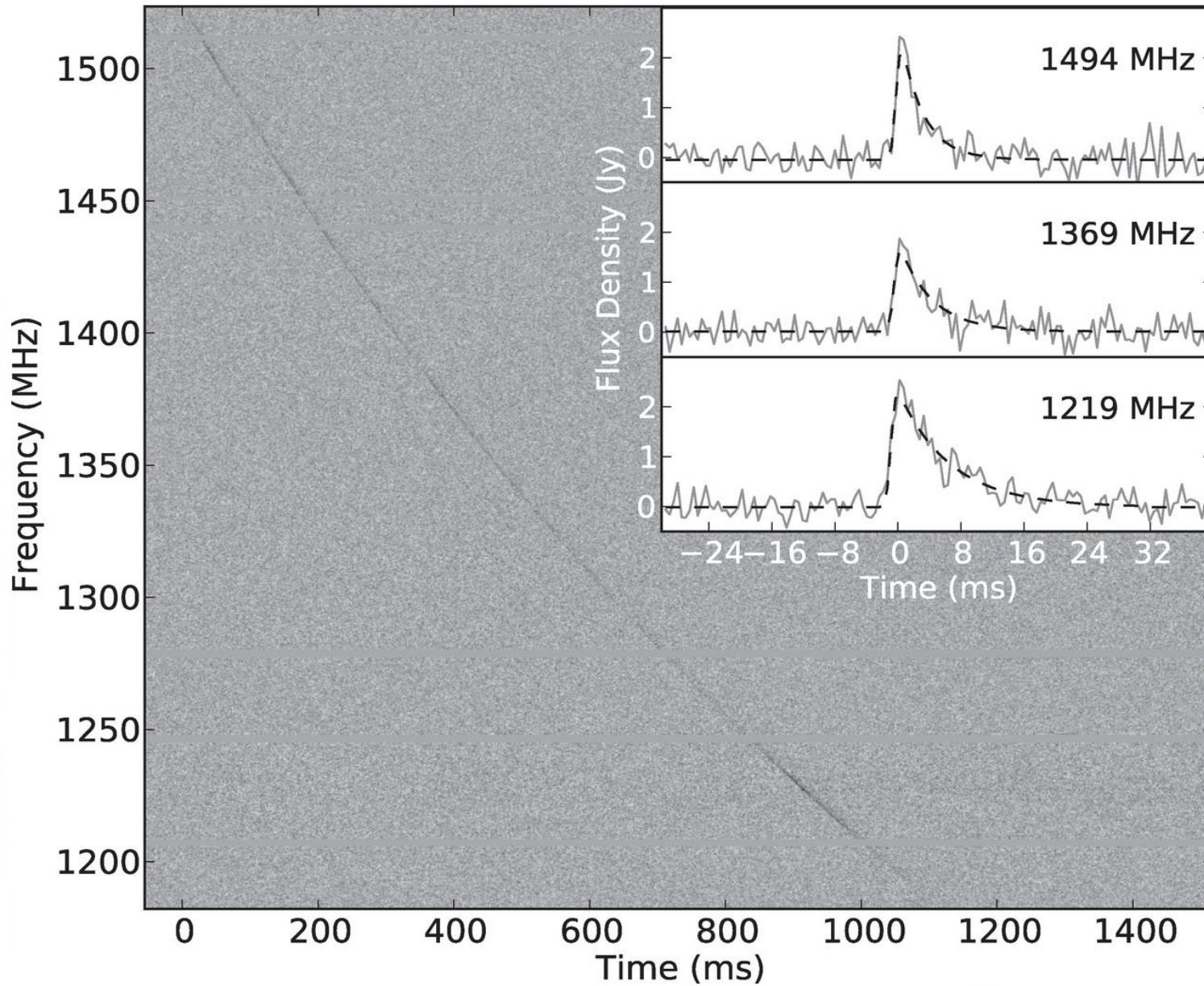
# Spettro dinamico: intensità in funzione della frequenza



FRB010824

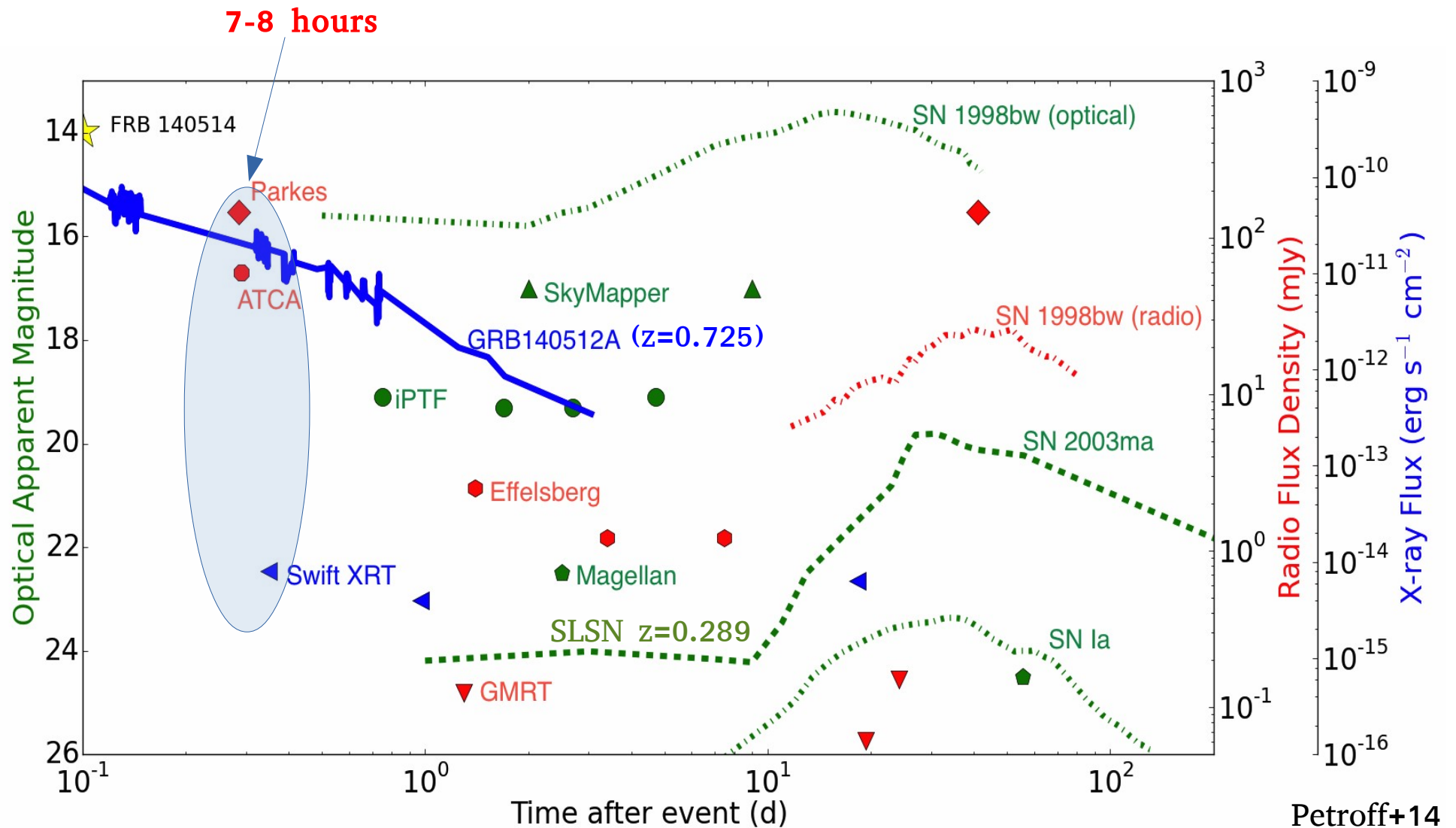
Lorimer+07

# Spettro dinamico: intensità in funzione della frequenza



FRB110220

# FRB 140514: prima volta di una ricerca di controparte ad altre lunghezze d'onda





## Frequenze calcolate di FRB al giorno in tutto il cielo

Survey	Area	$t_{\text{obs}}$	FRBs found	Rate
	(deg <sup>2</sup> )	(s)		(FRBs/day/sky)
HTRU	4078	270	4	$1.2^{+0.2}_{-0.3} \times 10^4$
PALFA	380	268	1	$3.6^{+5.8}_{-0.2} \times 10^4$
PH	3588	265	<1	$4.7^{+9.5}_{-1.0} \times 10^3$

# Interpretazioni proposte: di tutto...

- DM dovuta alle galassie ospiti e al mezzo intergalattico:

- $z \sim 0.5-1$ ,  $L_{p,\text{radio}} \sim 10^{42-43}$  erg/s,  $E \sim 10^{39-40}$  ergs

⇒ Hyperflares from magnetars, collapse of NS to BH, mergers of double NSs or binary WDs, connected with fraction of GRBs  
(Popov&Postnov07,Falcke&Rezzolla14,Totani13,Kashiyama13,Zhang14)

- **Eventi di origine atmosferica?** (Kulkarni+14).

No, Petroff et al (2015) alcuni eventi simili agli FRB furono prodotti dall'apertura prematura della porta di un forno a microonde vicino al Parkes Observatory, ma i FRB sono un'altra cosa.

- **Stelle vicine della nostra Galassia che fanno dei flares?**

(Loeb+14)

- **Impulsi giganti e sporadici di magnetars che si trovano vicino al centro di altre galassie (ma non tra le + lontane)?**

(Pen+Connor 2015)

# **FRB: come ci stiamo attrezzando?**

- Migliorare la statistica (difficili da rivelare!!)
- Molte incertezze finche non se ne misura la distanza
- Se vengono da molto lontano, sono potenziali mezzi di studio per il mezzo intergalattico.
- Molti esperimenti che stanno per diventare operativi o in fase di progetto sono proprio basati sullo studio degli FRBs (FAST, MeerKAT...)
- Un nuovo capitolo dell'evoluzione stellare o di fisica fondamentale?



## Swinburne Pulsar Group

> Home

> Swinburne Pulsar Group > FRBCAT

> Staff & Students

> Research

> SKA

> Instrumentation

> Software

> CAS Home

> FSET Home

### FRB Catalogue

This catalogue contains up to date information for the published population of Fast Radio Bursts (FRBs). This site is maintained by Emily Petroff and Evan Keane and is updated as new sources are published or refined numbers become available. Information for each burst is divided into two categories: intrinsic properties measured using the available data, and derived parameters produced using a model. The intrinsic parameters should be taken as lower limits, as the position within the telescope beam is uncertain. Models used in this analysis are the NE2001 Galactic electron distribution (Cordes & Lazio, 2002), and the Cosmology Calculator (Wright, 2006).

You may use the data presented in this catalogue for publications; however, we ask that you cite the paper, when available (Petroff et al., in prep.) and provide the url (<http://www.astronomy.swin.edu.au/pulsar/frbcats/>).

#### Catalogue Version 1.0

Event	Telescope	gl [deg]	gb [deg]	FWHM [deg]	DM [cm <sup>-3</sup> pc]	SN	W <sub>obs</sub> [ms]	S <sub>peak,obs</sub> [Jy]	F <sub>obs</sub> [Jy ms]	Ref
<a href="#">FRB010125</a>	parkes	356.641	-20.020	0.25	790(3)	17	9.40 <sup>+0.20</sup> <sub>-0.20</sub>	0.30	2.82	<a href="#">1</a>
<a href="#">FRB010621</a>	parkes	25.433	-4.003	0.25	745(10)		7.00	0.41	2.87	<a href="#">2</a>
<a href="#">FRB010724</a>	parkes	300.653	-41.805	0.25	375	23	5.00	>30.00 <sup>+10.00</sup> <sub>-10.00</sub>	>150.00	<a href="#">3</a>
<a href="#">FRB090625</a>	parkes	226.443	-60.030	0.25	899.55(1)	30	1.92 <sup>+0.83</sup> <sub>-0.77</sub>	1.14 <sup>+0.42</sup> <sub>-0.21</sub>	2.19 <sup>+2.10</sup> <sub>-1.12</sub>	<a href="#">4</a>
<a href="#">FRB110220</a>	parkes	50.828	-54.766	0.25	944.38(5)	49	5.60 <sup>+0.10</sup> <sub>-0.10</sub>	1.30 <sup>+0.00</sup> <sub>-0.00</sub>	7.28 <sup>+0.13</sup> <sub>-0.13</sub>	<a href="#">5</a>
<a href="#">FRB110523</a>	GBT	56.119	-37.819	0.26	623.30(6)	42	1.73 <sup>+0.17</sup> <sub>-0.17</sub>	0.60	1.04	<a href="#">6</a>
<a href="#">FRB110626</a>	parkes	355.861	-41.752	0.25	723.0(3)	11	1.40	0.40	0.56	<a href="#">5</a>
<a href="#">FRB110703</a>	parkes	80.997	-59.019	0.25	1103.6(7)	16	4.30	0.50	2.15	<a href="#">5</a>





*That's all Folks!*