Talk for STARS2013

Non-detection in Fermi-LAT observations of magnetars: physical implications

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2013.5

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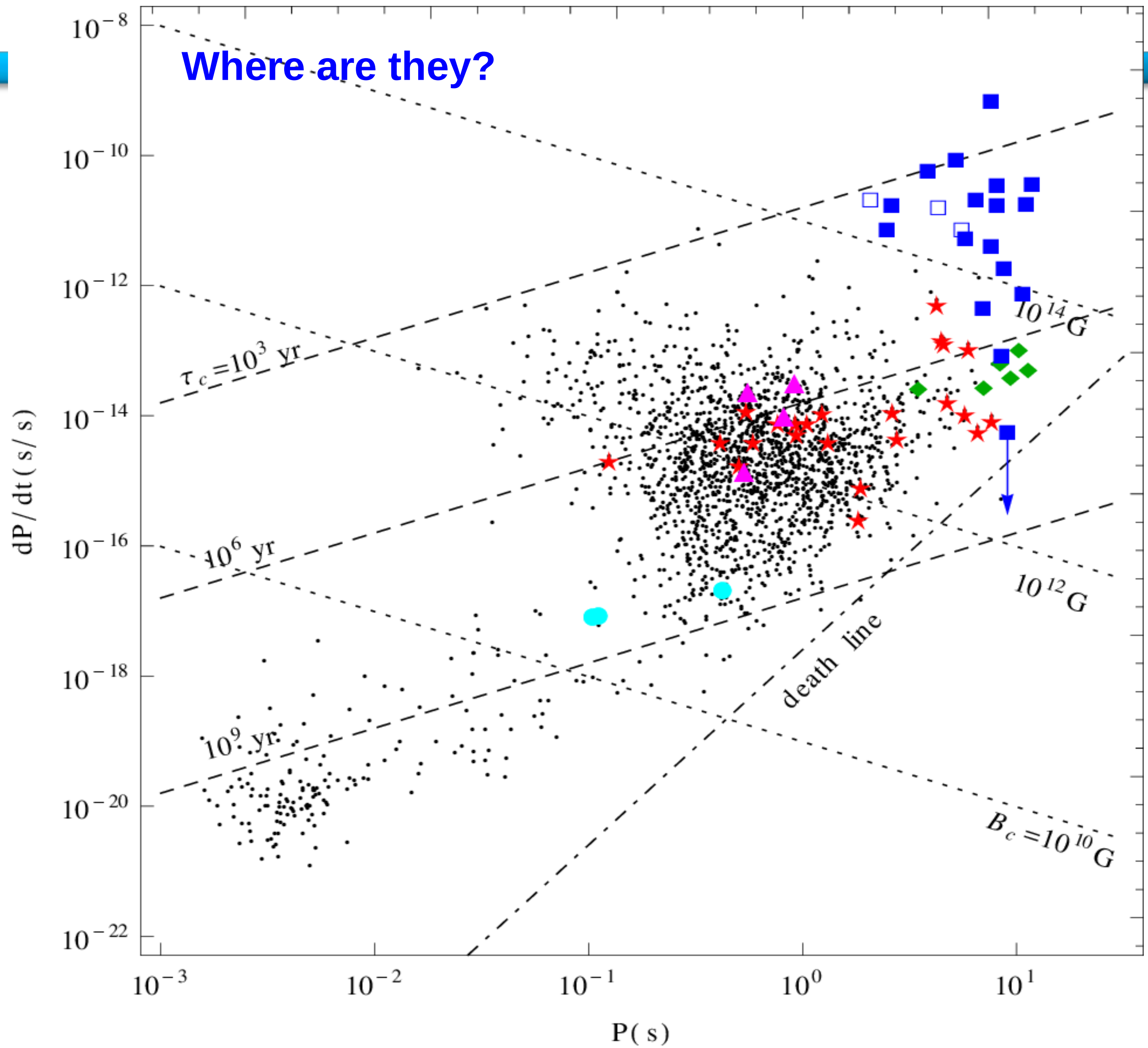

Where are they?
dP/dt(s/s)
P(s)
10^{-8}
10^{-10}
10^{-12}
10^{-14}
10^{-16}
10^{-18}
10^{-20}
10^{-22}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
$\tau_c = 10^3$ yr
10^6 yr
10^9 yr
10^{14}G
10^{12}G
$B_c = 10^{10}$G
death line

What's AXPs & SGRs

- AXPs: anomalous X-ray pulsars
  - Lx>Edot (not necessary!)
  - No binary signature
- SGRs: soft gamma-ray repeaters
  - Soft: typical photon energy is lower
  - Repeater: recurrent bursts

The same class!

Critical magnetic field

- Cyclotron energy = electron rest mass

$$B_q = \frac{m_e^2 c^3}{e\hbar} = 4.4 \times 10^{13}\, G$$

- Microscopic process: QED

Traditional magnetar model (2008)

- Magnetar =
  1. young NS (SNR & MSC)
  2. $B_{dip} > B_{QED} = 4.4\times10^{13}$ G (braking)
  3. $B_{mul} = 10^{14}$ -10^{15} G (burst and super-Eddington luminosity and persistent emission)

→ **Rotation-powered activities in magnetars: High-energy gamma-rays**

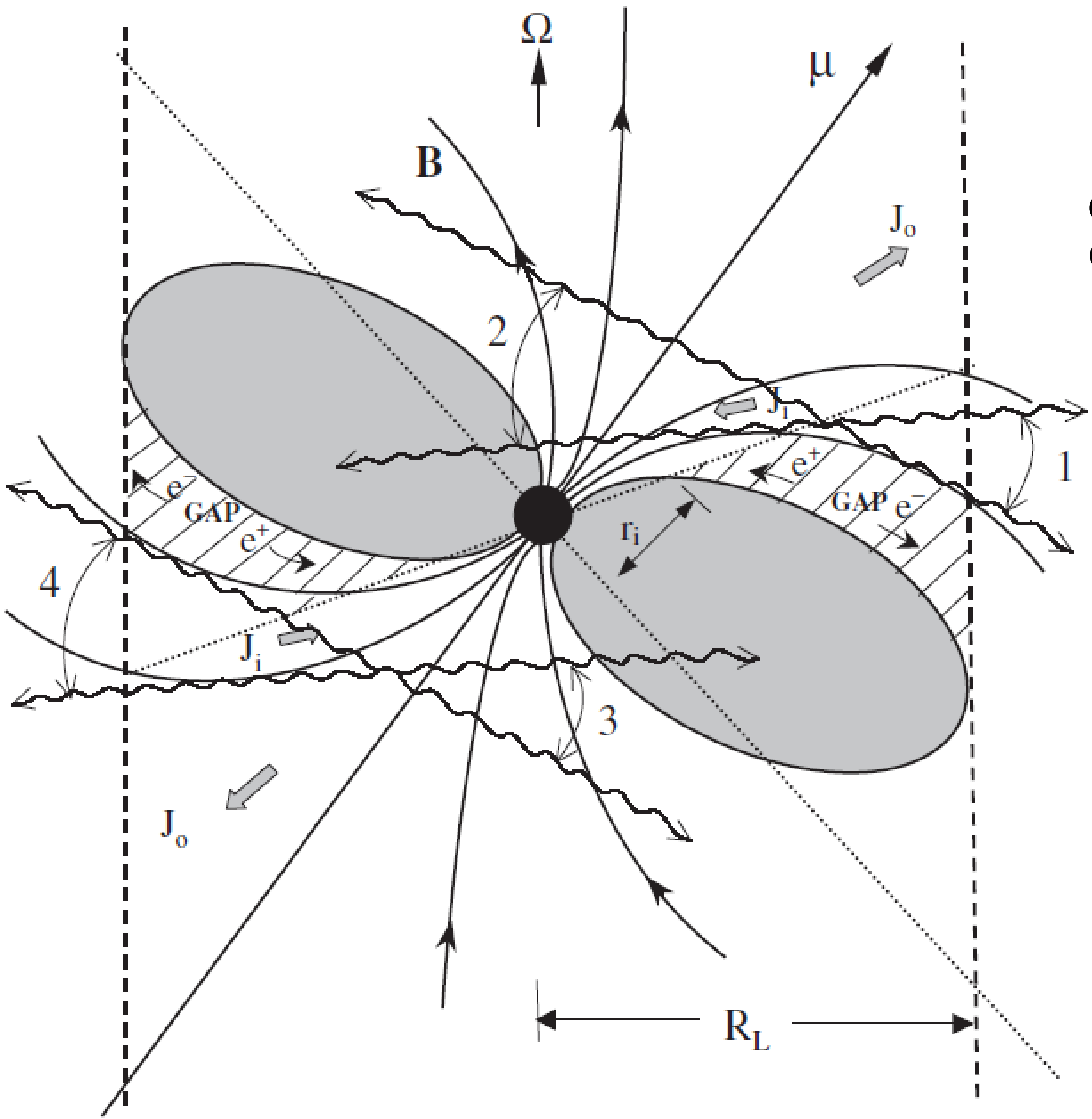
prehistory of magnetars

- 1932: Chadwick, discovery of neuton
- 1932: Landau, celestial objects with nuclear density
- 1934: Baade & Zwicky, NSs born in SNe
- 1939: Oppenheimer & Volkoff, NS structure M_sun, 10 km
- 1967: Hewish & Bell, discovery of (rotation-powered) pulsars
- 1971: Giacconi et al., discovery of accretion-powered X-ray pulsars

A brief history of magnetars

- 1979: giant flare of SGR 0526-66
- 1981: anomalous X-ray pulsars
- 1992: “magnetars”
- 1998: Timing of SGR 1806-20
  giant flare of SGR 1900+14
- 2006-: multiwave era (radio, IR, HX)
- 2010: “low magnetic field” magnetar (B<7.5*10^12 G)

& Fermi obs of magnetars



Outer gap model
Cheng 2009 ApSS

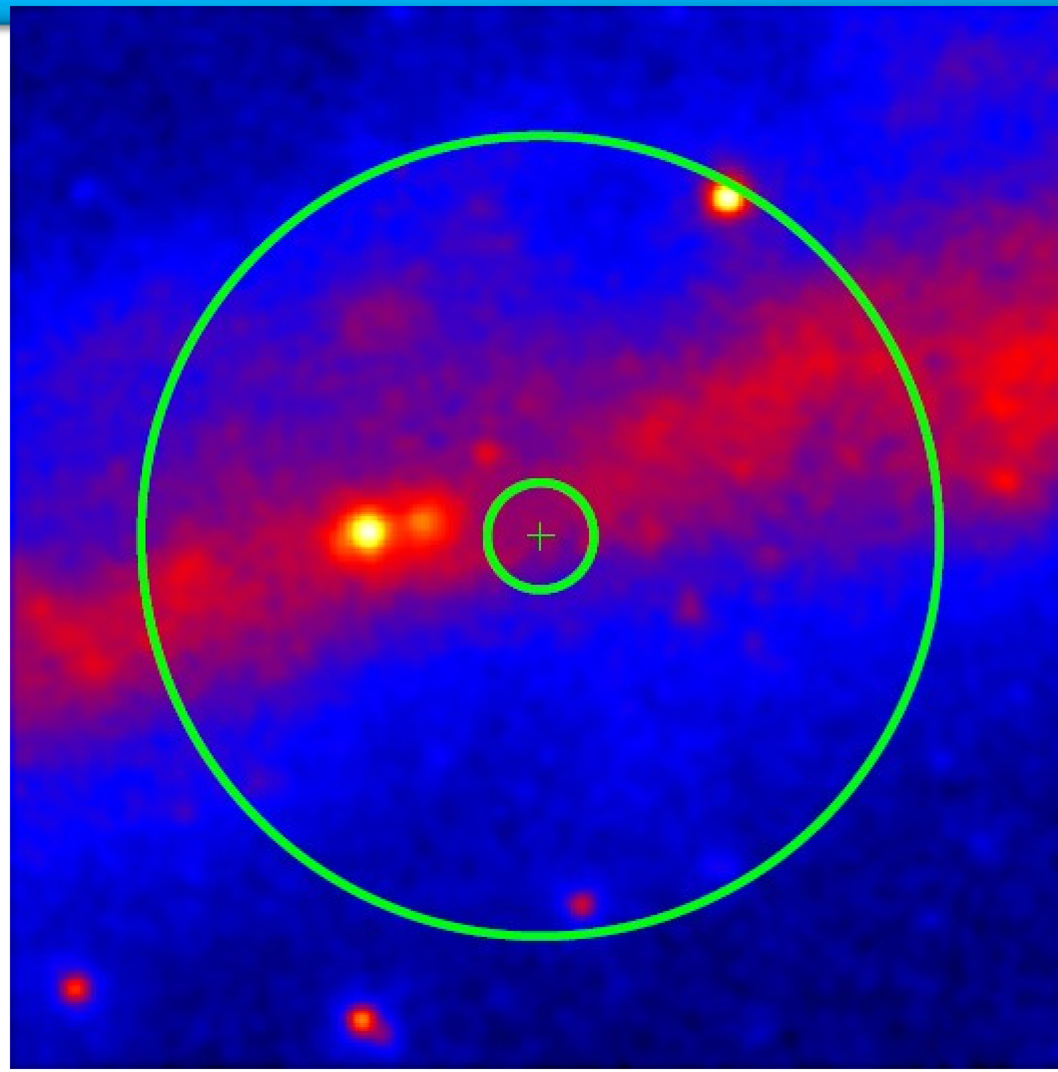
Application to magnetars

1. Cheng & Zhang (2001): 5 AXPs
2. Tong, Song, Xu (2010): comparison with Fermi observation of 4U 0142+61
3. Tong, Song, Xu (2011): all magnetars

Fermi/LAT obs of 4U 0141+61

(Sasmaz Mus & Gogus 2010; Tong, Song & Xu 2010)

- Exposure: 31.7 Ms
- No detection!



Fermi/LAT observation of all magnetars (5 SGRs+8AXPs)

(Fermi-LAT collaboration 2010;
Tong, Song, & Xu 2011)

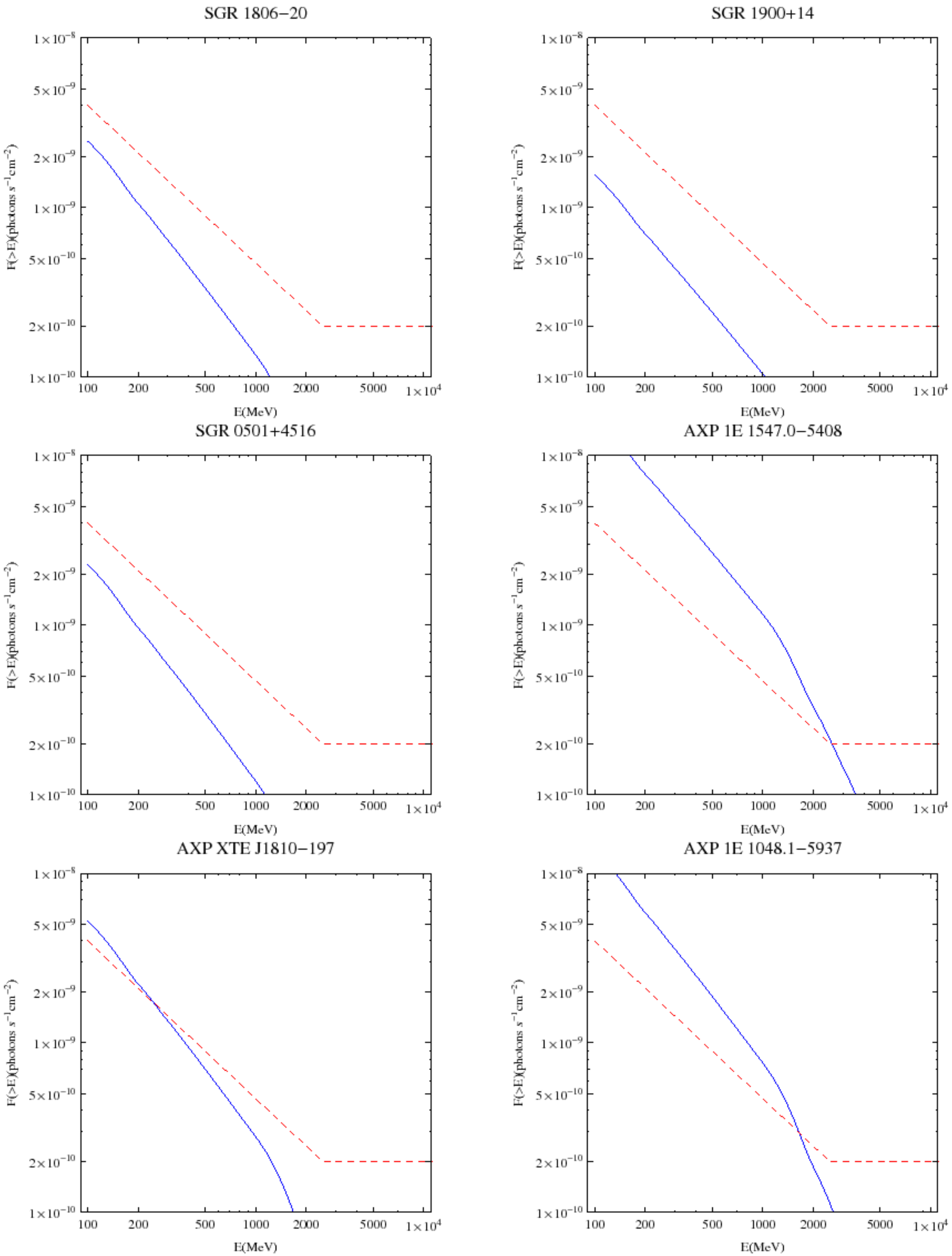
TABLE 1
Fermi-LAT UPPER LIMITS ON MAGNETARS OBTAINED FROM LIKELIHOOD ANALYSIS.

Source	d* kpc	log(B) Gauss	$\log(L_X)^*$ erg s^{-1}	$\log(L_{rot})$ erg s^{-1}	TS	0.1–10 GeV ($\Gamma = 2.5$)	0.1–1 GeV ($\Gamma = 1.5$)	1–10 GeV ($\Gamma = 3.5$)	1FGL srcs within 3°
1E 1048.1−5937	3.0	14.78	34.00	33.90	0.0	<5.3 (12.0)	<3.9 (7.7)	<1.7 (0.7)	7
SGR 1900+14	15	14.81	35.44	34.34	0.0	<0.4 (0.9)	<0.8 (2.0)	<0.6 (0.2)	5
SGR 0418+5729	2.0	<12.70	31.77	<29.47	2.3	<0.4 (0.9)	<0.2 (0.4)	<0.1 (0.04)	2
SGR 1806–20	8.7	15.15	35.21	34.40	2.8	<0.6 (1.4)	<0.5 (0.9)	<0.12 (0.05)	1
4U 0142+614	5.0	14.11	35.32	32.10	3.6	<0.9 (2.0)	<0.5 (0.9)	<0.3 (0.11)	1
1E 1841−045	8.5	14.85	35.34	32.99	7.5	<3.0 (6.0)	<6.3 (13.0)	<2.4 (0.92)	8
XTE J1810–197	4.0	14.46	33.58	33.60	13.1	<5.0 (10.0)	<12.0 (23.0)	<2.0 (0.7)	7
1E 2259+586	3.0	13.76	34.43	31.70	15.6	<1.7 (3.9)	<0.6 (1.0)	<0.63 (0.24)	2
SGR 0501+4516	5.0	14.23	34.77	33.49	16.3	<1.9 (4.3)	<0.6 (1.0)	<0.5 (0.18)	1
1RXS J1708−4009	8.0	14.67	35.27	32.75	32.1	<10.0 (20.0)	<5.0 (9.0)	<9.0 (4.0)	8
CXOU J1647−4552	5.0	14.20	34.41	31.89	33.7	<10.0 (20.0)	<10.0 (20.0)	<19.0 (7.2)	7
SGR 1627–41	11	14.34	33.39	34.63	36.0	<20.0 (50.0)	<20.0 (30.0)	<5.0 (2.0)	8
1E 1547−5408	9.0	14.32	34.16	35.00	36.2	<10.0 (20.0)	<7.9 (16.0)	<2.1 (0.8)	6

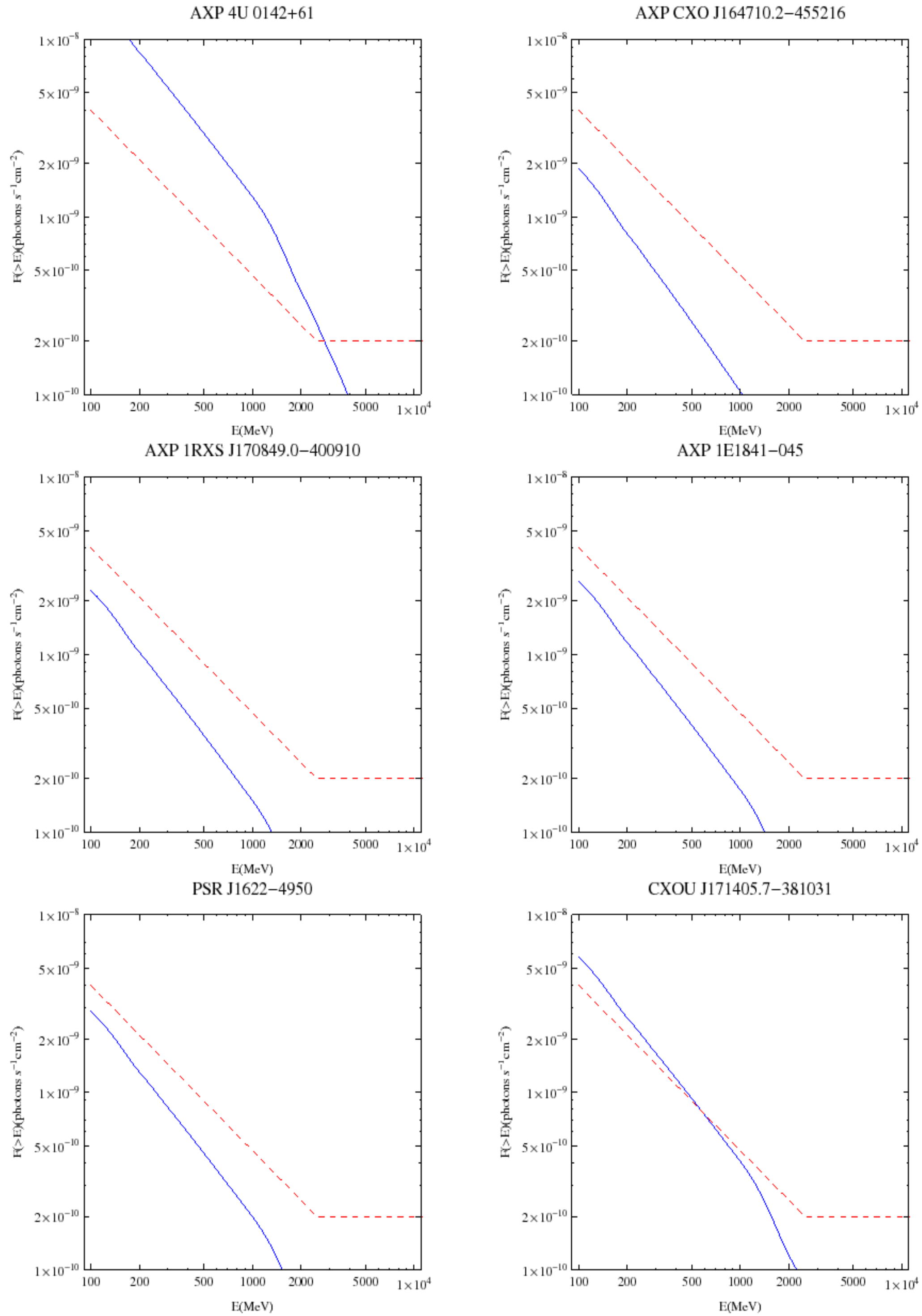
Application to magnetars: 3 SGRs+10 AXPs

1. Closed by gamma-gamma process
2. One source: gamma-ray dead
3. Most sources: too far away to be seen by Fermi-LAT
4. 1E 1547.0-5408, 1E 1048.1-5937, and 4U 0142+61 can be seen by Fermi
5. Fermi upper limits of 4U 0142+61 below its SEDs

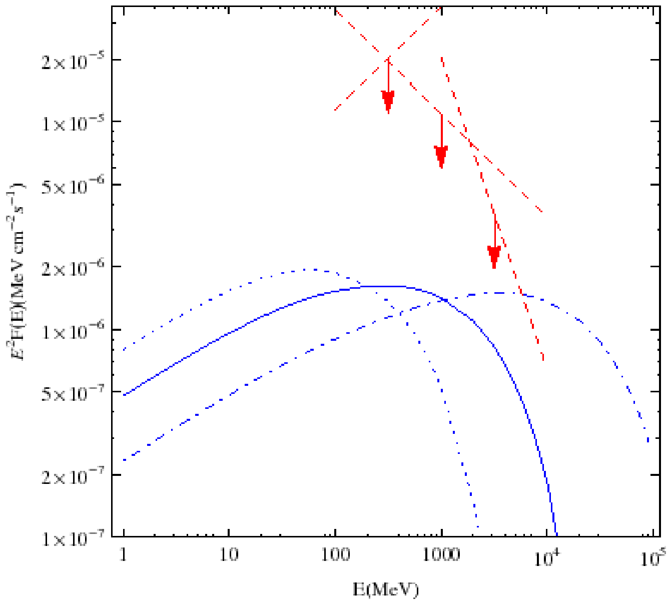
Theoretical SEDs



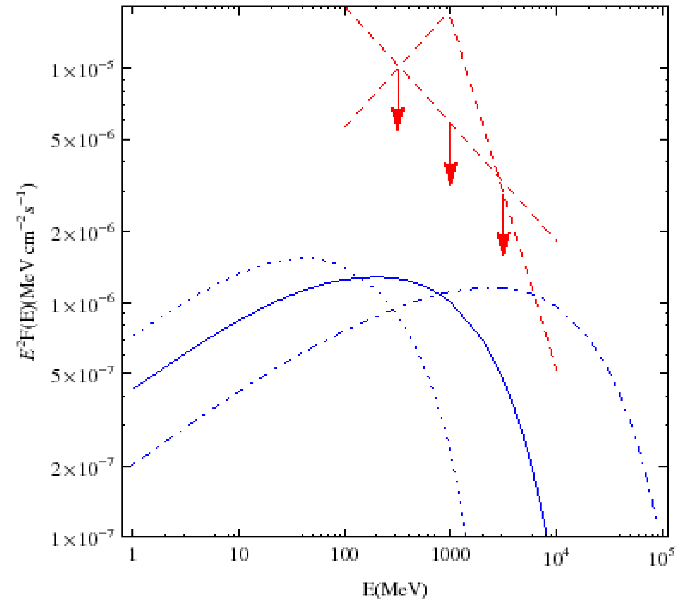
Theoretical SEDs



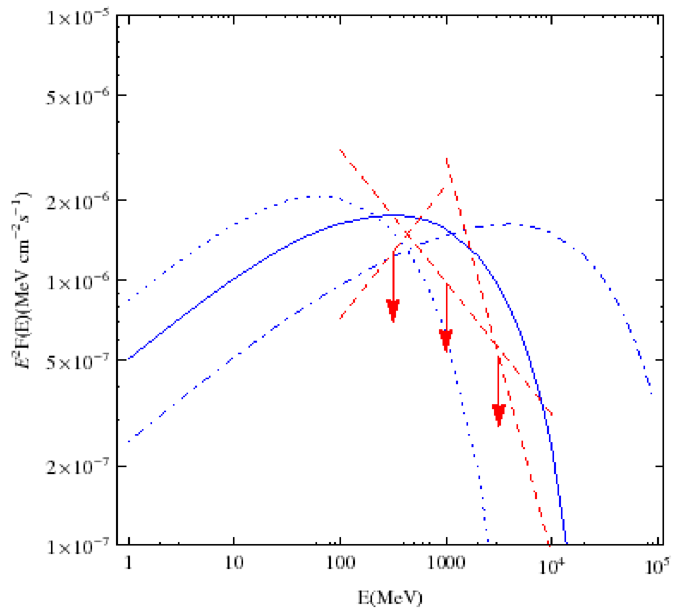
AXP 1E 1547.0−5408



AXP 1E 1048.1−5937



AXP 4U 0142+61



SED vs Fermi upper limits

Summary

- Conflict between outer gap model in the case magnetars and Fermi observation: 1E 1547.0-5408, 1E 1048.1-5937, and 4U 0142+61
- Deeper Fermi-LAT observation needed

Solutions (I)

1. The outer gap model is wrong: unlikely
2. The traditional magnetar model is wrong

Solutions (II)

1. AXPs/SGRs are accretion systems (Tong & Xu 2011)
2. AXPs/SGRs are magnetars: magnetars are wind braking (Tong et al. 2013)
    a) Not so strong a dipole field
    b) Vacuum gaps can not exist

- Using Fermi-LAT obs to distinguish between the accretion model and the magnetar model

Thanks!