Gamma-ray pulsars

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EGRET pulsars

TABLE 1

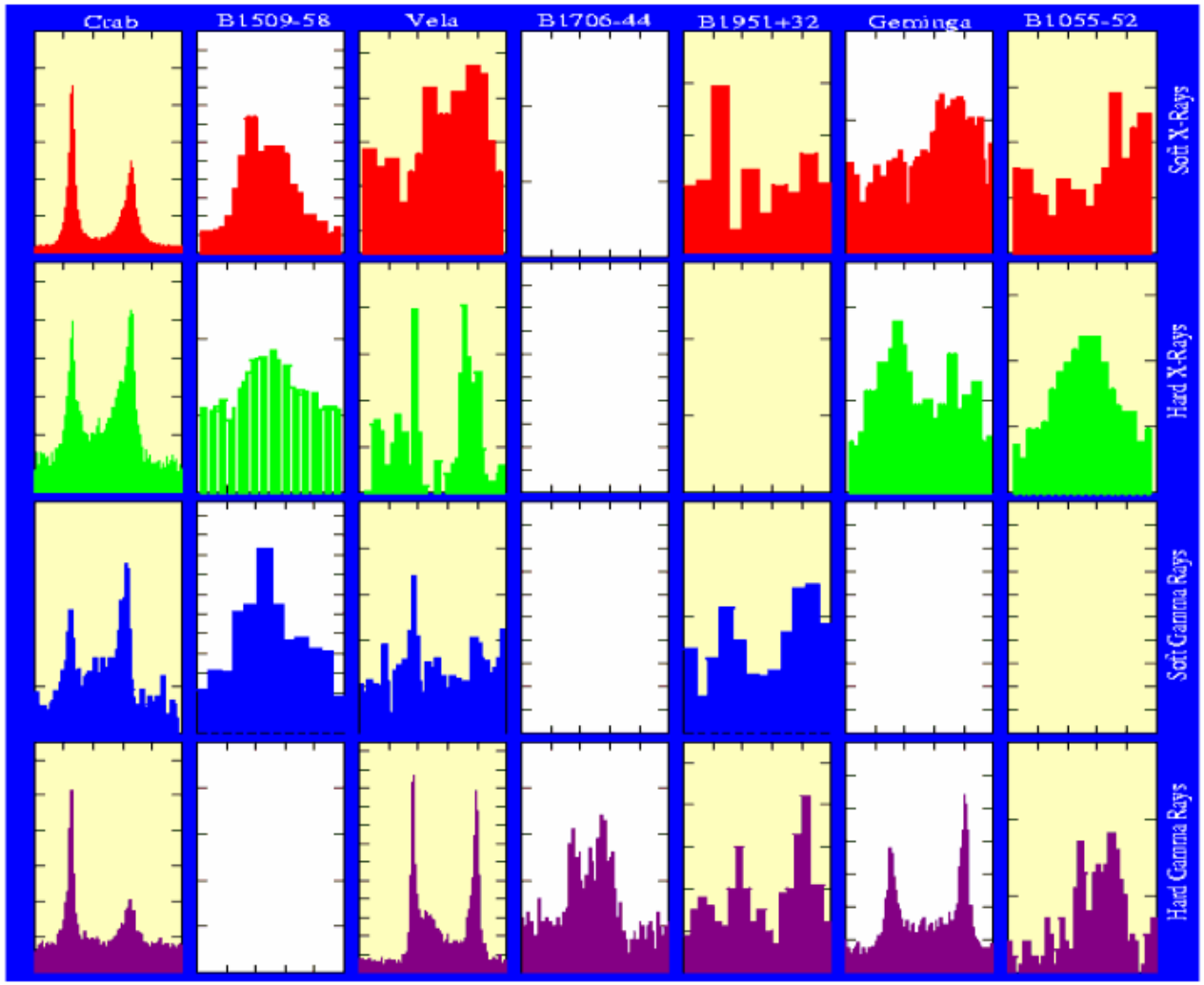
γ-RAY PULSARS DETECTED BY EGRET

Pulsar/3EG Jsource	P (ms)	τ (kyr)	$\dot{E}$ (ergs s^{-1})	d (kpc)	$F_\gamma^{3EG}[\times 10^{-8}]$ (ph cm^{-2} s^{-1})	γ^{3EG}	η (100MeV–10GeV)
Crab/0534–2200	33	1.2	5.0×10^{38}	2.0	226.2±4.7	2.19±0.02	0.01%
Vela/0834–4511	89	12.5	6.3×10^{36}	0.25	834.3±11.2	1.69±0.01	0.08%
B1951+32/ ···	39	100.0	3.7×10^{36}	2.4	···	···	0.3%
B1706–44/1710–4439	102	15.8	3.1×10^{36}	1.8	111.2±6.2	1.86±0.04	1%
Geminga/0633+1751	237	316.2	3.1×10^{34}	0.16	352.9±5.7	1.66±0.01	3%
B1055–52/1058–5234	197	501.1	3.1×10^{34}	0.5/1.5	33.3±3.8	1.94±0.10	2/19%

NOTE.—Pulsar parameters and distances (and η in the case of PSR B1951+32 — this pulsar is not a 3EG source) are taken from Kaspi et al. (2000), excepting PSR B1055–52, for which we also consider a smaller value of distance (Ögelman & Finley 1993; Combi et al. 1997), and Vela (Caraveo et al. 2001 and references therein). $\tau = P/2\dot{P}$, and $\dot{E} = 4\pi^2 I \dot{P}/P^3$, with $I = 10^{45}$ g cm^2. The "P1234" γ-ray fluxes and spectral indices are from the 3EG catalog (Hartman et al. 1999), from which we have computed the η values.

Torres et al. astro-ph/0109228

EGRET light curves



Thompson astro-ph/0101039

Candidate gamma-ray pulsars

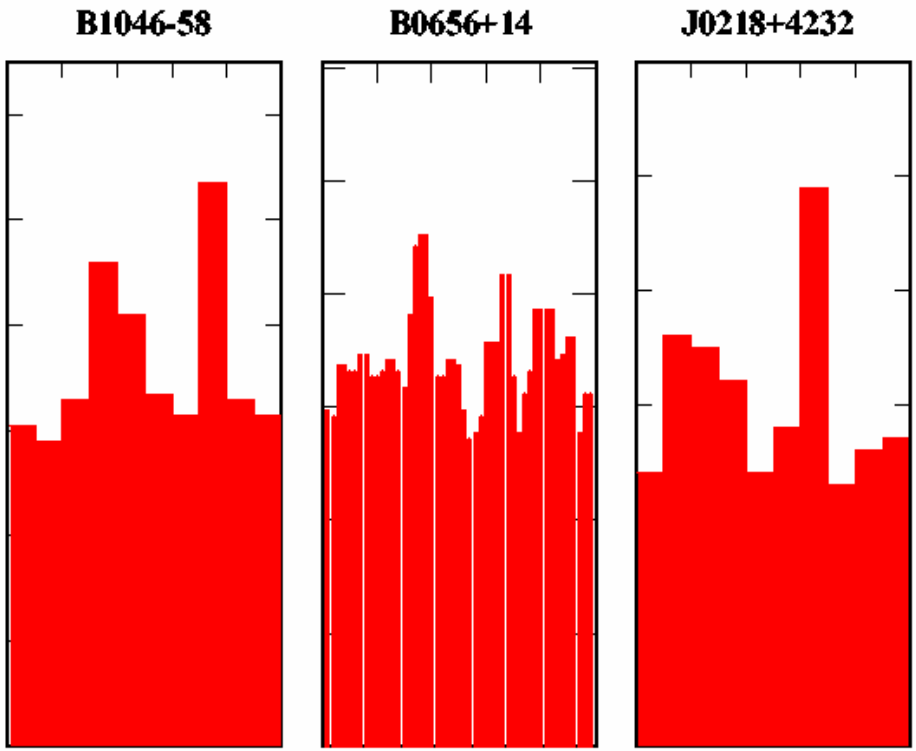


FIGURE 2. Light curves of three candidate gamma-ray pulsars. Each panel shows one full rotation of the neutron star. References: PSR B1046-58: [18]; PSR B0656+14: [19]; PSR J0218+4232 [20].

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Period vs period derivative

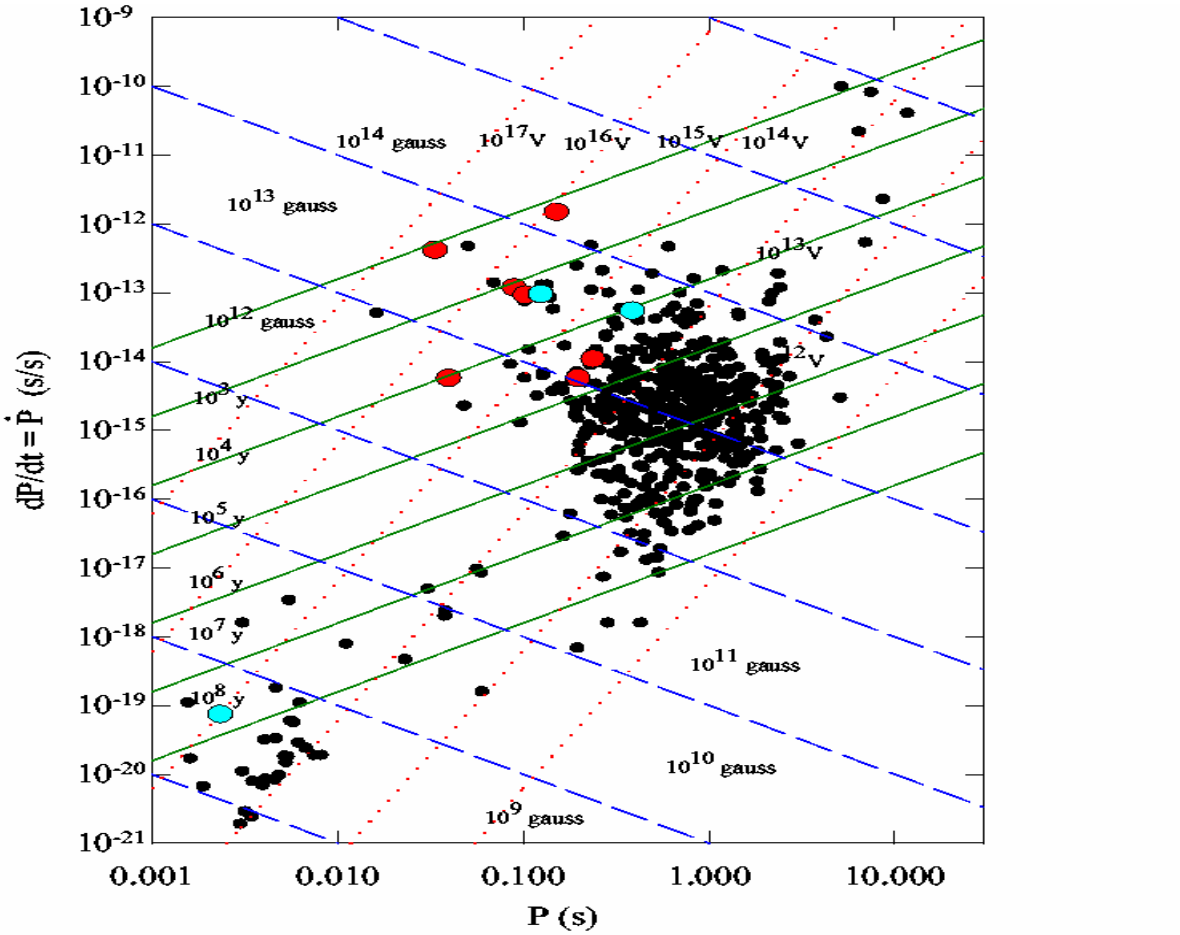

FIGURE 3. Period v. period derivative for a large sample of pulsars. Small dots: no gamma-ray emission. Large dark dots: seven high-confidence gamma-ray pulsars. Large light dots: three lower-confidence gamma-ray pulsars. Solid lines: timing age. Dotted line: open field line voltage. Dashed line: surface magnetic fields.

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Pulsars at high energy

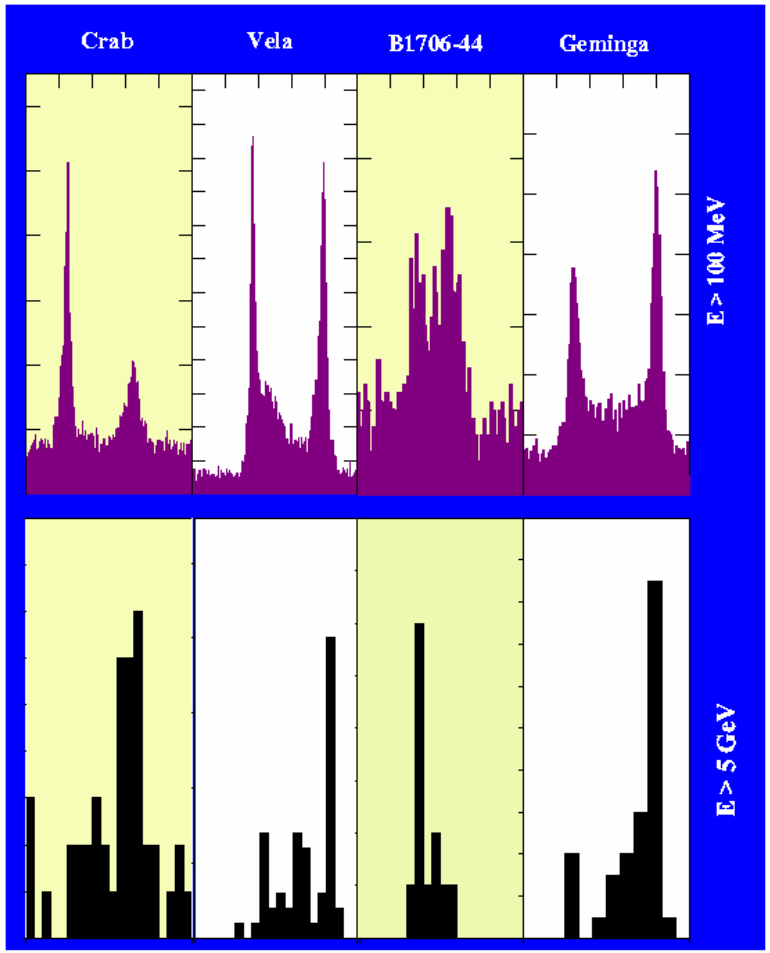

FIGURE 5. Light curves of four gamma-ray pulsars above 100 MeV and above 5 GeV. Each panel shows one full rotation of the neutron star.

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Vela pulsar: predictions

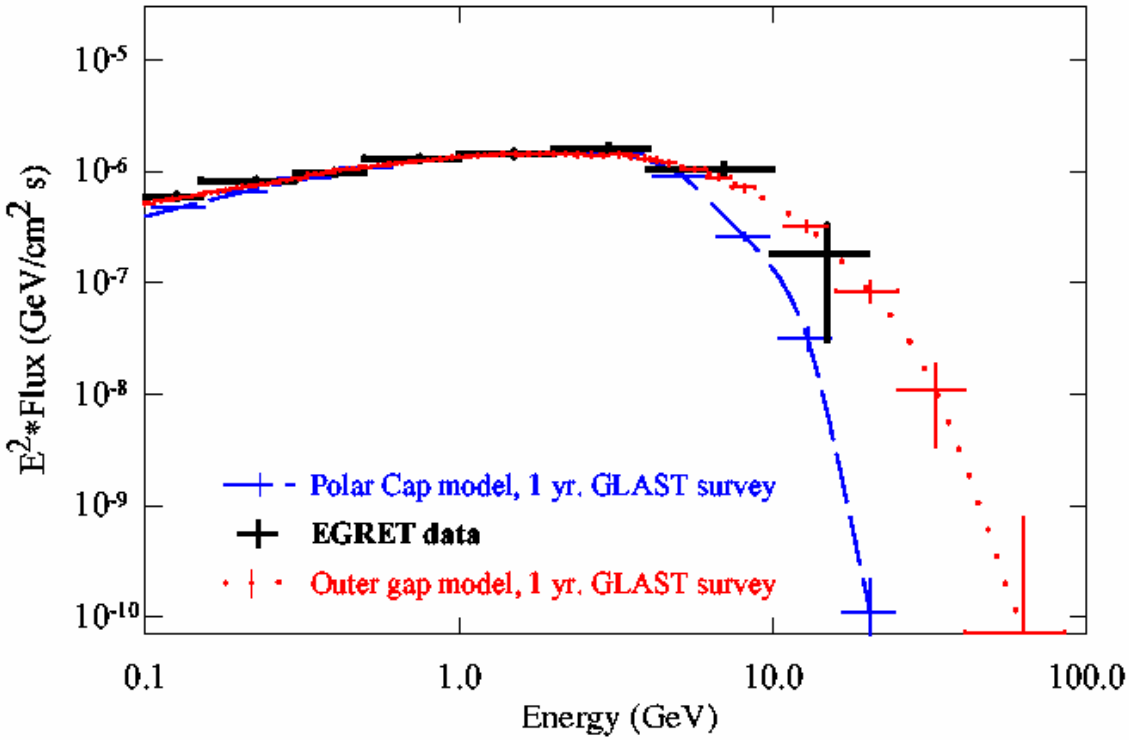

FIGURE 6. High-energy spectrum of the Vela pulsar. Heavy error bars: EGRET data [27]. Dotted line: Outer gap model [25,26]. Dashed line: Polar cap model [23,24]. Error bars shown on the models are those expected from the GLAST mission [28] in a one-year sky survey.

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Pulsar emission models

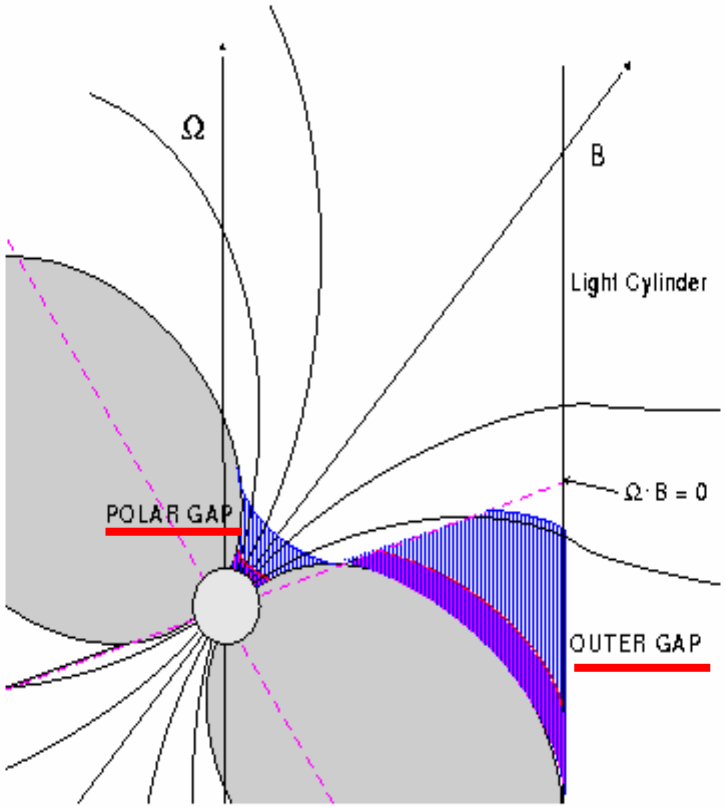

FIGURE 1. Schematic geometry of polar and outer gaps. Dark solid regions are thin gaps of younger pulsars. Hatched regions are thick gaps of older pulsars (see text).

Harding astro-ph/0012268

High-energy cutoff predicted by polar cap models

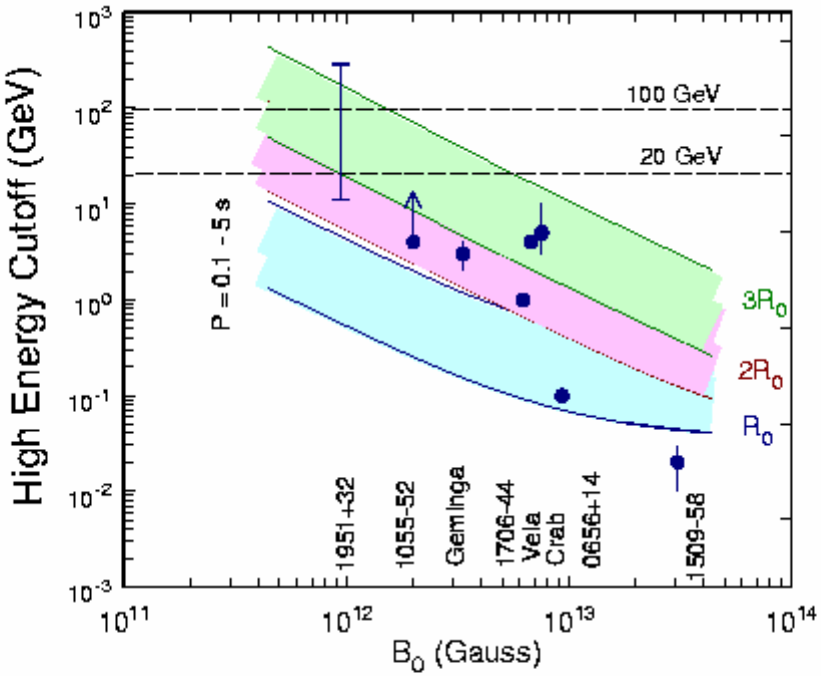

FIGURE 2. Calculated high-energy spectral cutoff energies due to magnetic pair production attenuation vs. surface field strength for a range of periods at different photon emission radii. Also shown are measured turnover energies of detected pulsars.

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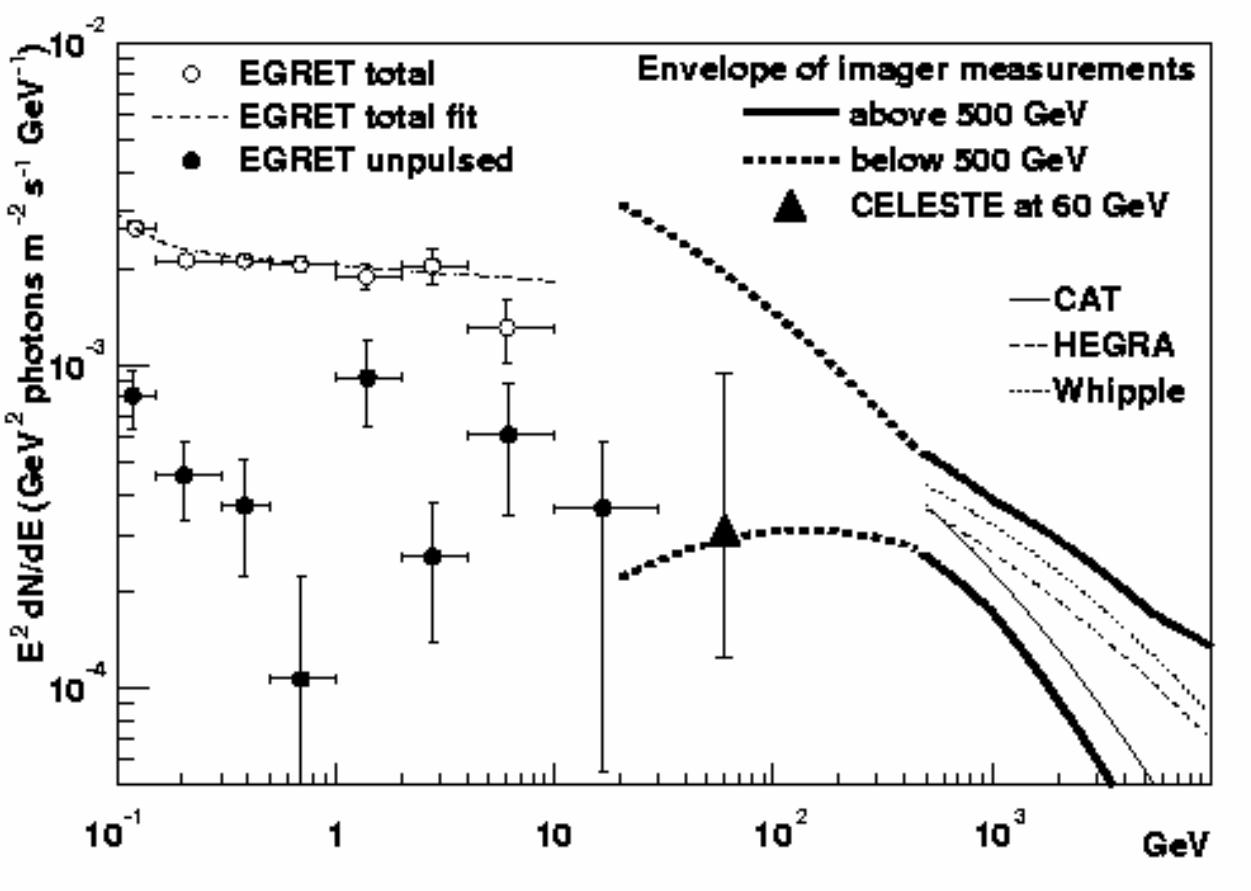
Crab pulsar/nebula (1)



De Naurois et al. astro-ph/0107301

Crab pulsar/nebula (2)

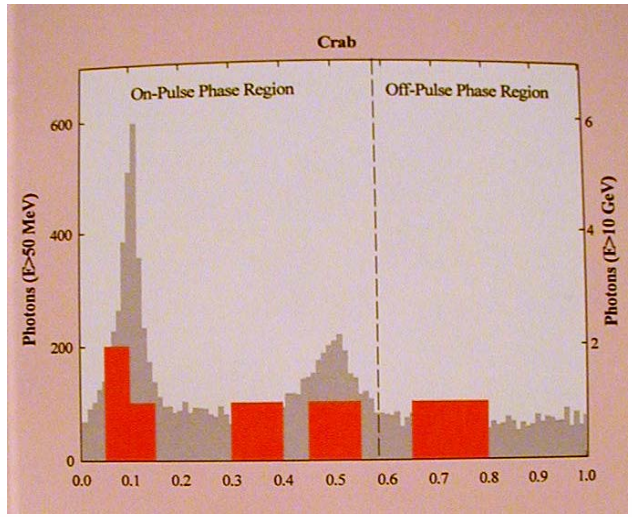


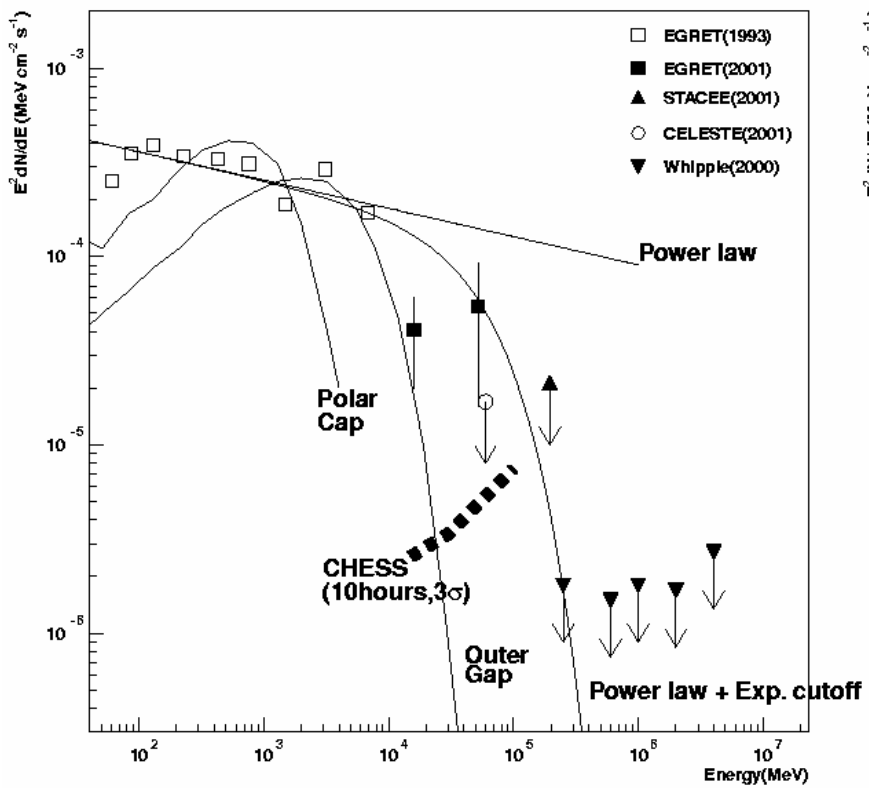
Table 1: List of photons above 10 GeV from the Crab pulsar observed by EGRET. "To psr" means the anglular distance toward the pulsar and VP means the EGRET Viewing Period. Here "pulsed" is defined by $0 <$ phase < 0.6.

JD-2440000	Date	Pulsed (p)	E (GeV)	To psr (deg)	Phase	VP
8371.41209737	04/24/91		29.2	0.112	0.6972	0.2
8420.22591974	06/12/91	p	22.7	0.253	0.3527	2.5
8847.45561746	08/13/92	p	101.3	0.194	0.1000	36.5
8881.07116046	09/16/92	p	117.4	0.223	0.0700	39.0
9330.28419647	12/08/93	p	21.0	0.245	0.0790	310.0
9334.93486661	12/13/93		10.5	0.271	0.7286	310.0
9395.38567745	02/11/94	p	29.6	0.170	0.5219	321.1
9797.70973554	03/21/95	p	12.8	0.262	0.3446	413.0
10321.04196266	08/26/96		14.4	0.293	0.7539	528.0
11312.53385290	05/14/99	p	26.7	0.122	0.4700	-

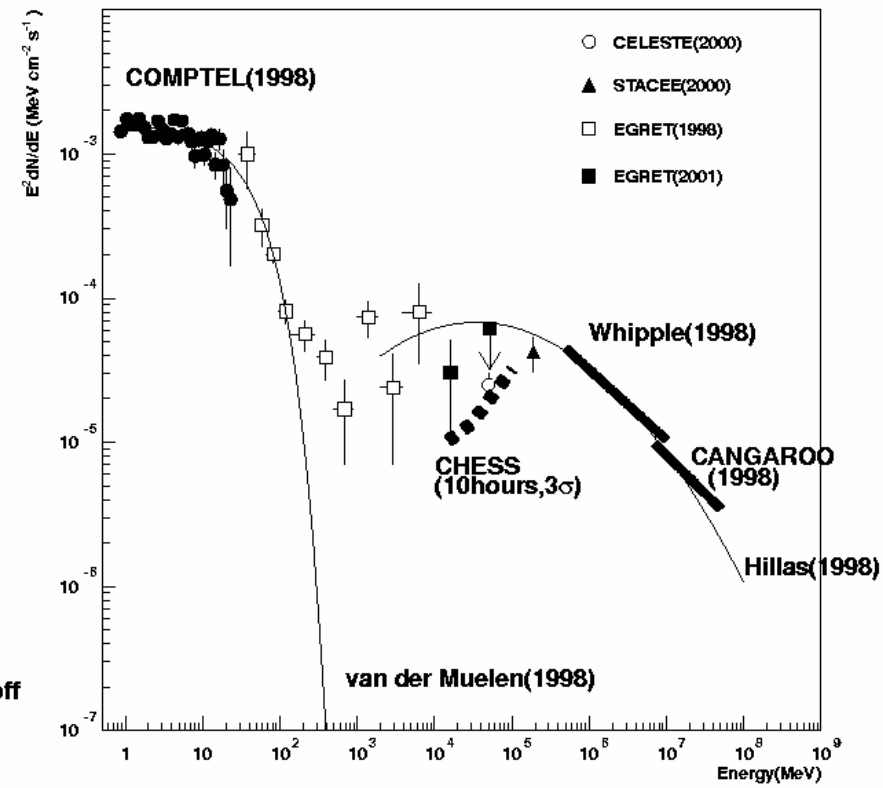
Thompson et al. Gamma2001

Crab pulsar/nebula (3)

Pulsed



Unpulsed



Asahara and Mori 2001

Positional coincidence

POSITIONAL COINCIDENCES BETWEEN UNIDENTIFIED 3EG SOURCES AND PARKES PULSARS

3EG J	Note	I	PSR J	#	SNRs	Ref.	$\dot{E}/d^2$
1013–5915	C, em	1.6	1016–5857	1	G284.3–1.8	Camilo et al. (2001)	2.9×10^{35}
			1013–5934	2			2.0×10^{30}
1014–5705	C, em	1.4	1015–5719	3			3.4×10^{34}
1410–6147	C	1.2	1412–6145	4	G312.4–0.4		1.4×10^{33}
			1413–6141	5			1.6×10^{33}
1420–6038	C	2.1	1420–6048	6		D'Amico et al. (2001)	1.7×10^{35}
1639–4702	C, em	1.9	1637–4642	7	G337.8–0.1; G338.1+0.4; G338.3+0.0		1.9×10^{34}
			1640–4648	8			1.5×10^{32}
			1637–4721	9			3.1×10^{30}
1714–3857	C, em	2.1	1713–3844	10	G348.5+0.0; G348.5+0.1; G347.3–0.5	Butt et al. (2001)	4.0×10^{31}
			1715–3903	11		Butt et al. (2001)	3.0×10^{33}
1837–0423	C	5.4	1838–0453	12	G27.8+0.6		1.2×10^{33}
1837–0606	C, em	2.4	1837–0559	13			6.5×10^{32}
			1837–0604	14		D'Amico et al. (2001)	5.2×10^{34}

NOTE.—A number (#) is assigned to each pair for ease of reference. SNRs contained in Green's (2000) catalog coinciding with the *EGRET* sources are noted (see Torres et al. 2001b). Only in cases #4, 5 and 12 do the pulsars also coincide with the SNRs listed. "C" and "em" refer to the γ-ray sources: source confusion exists and sources are possibly extended or multiple, respectively (Hartman et al. 1999). I is the variability index as in Torres et al. (2001a, c), where $I > 5$ (< 2) represents a source whose flux presents variability levels at least $8\,\sigma$ (less than $2\,\sigma$) above those displayed by confirmed pulsars. Pulsar "spin-down flux" $\dot{E}/d^2$ is in units of ergs s^{-1} kpc^{-2}.

Torres et al. astro-ph/0109228

PSR J1016-5857

P=107ms, 21kyr, Edge of G284.3-1.8

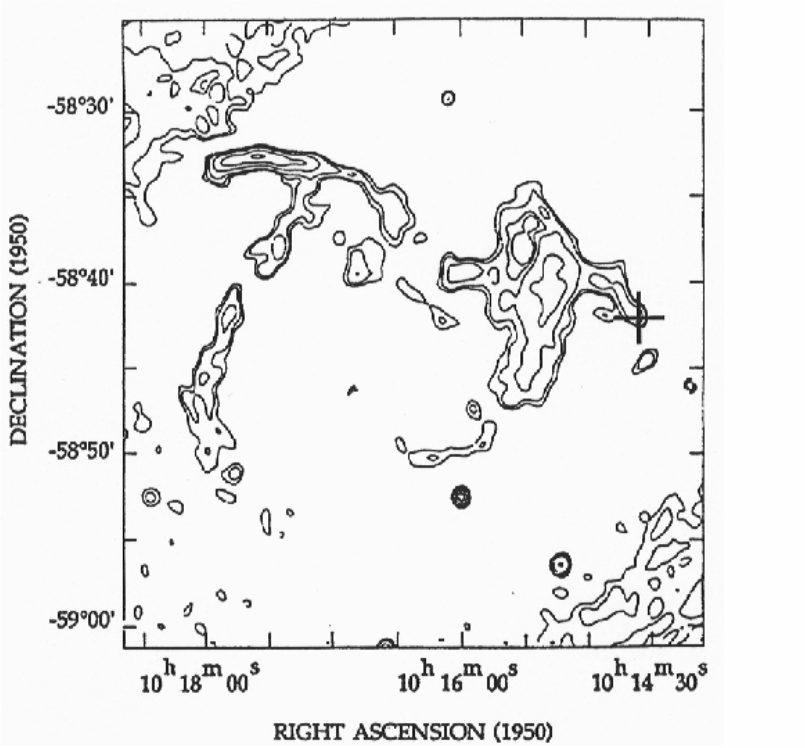


FIG. 2.— MOST radio map at 843 MHz of SNR G284.3–1.8 (Milne et al. 1989), with a spatial resolution of 45″. The position of PSR J1016–5857, known with sub-arcsecond accuracy (Table 1), is indicated with a large cross at the tip of the protuberance on the western edge of the SNR.

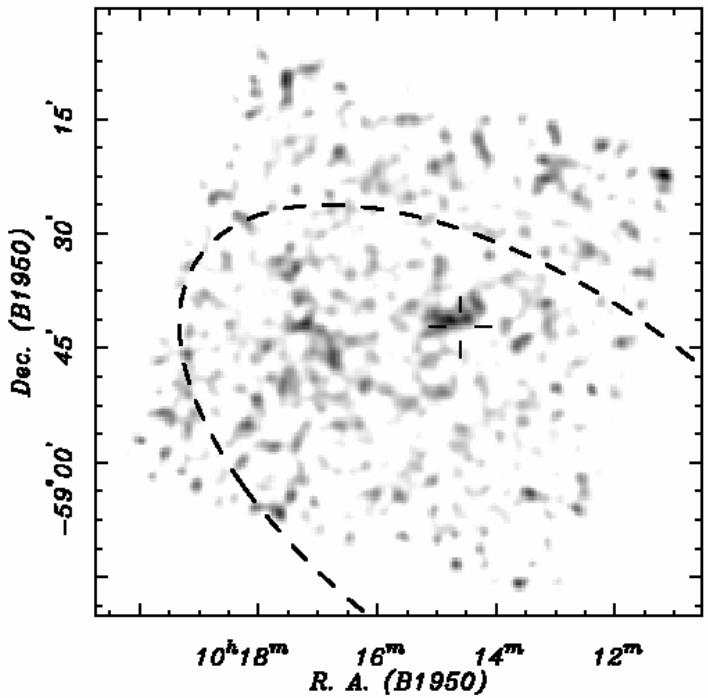


FIG. 3.— *Einstein* IPC observation of the PSR J1016–5857/SNR G284.3–1.8 field: a possibly extended source is detected near the position of the pulsar (cross-hairs; see § 4). The ellipse overlaid represents the approximate 2σ contour of positional uncertainty for the *EGRET* source 3EG J1013–5915 (Hartman et al. 1999; see § 5), which has an effective 2σ uncertainty radius 43′.

Parkes multibeam survey

Camilo et al. astro-ph/0107180

PSR J1420-6048

- P=68ms, 13kyr, 7.7kpc, B=2.4x10^{12}G

PSR J1837-0604

- P=96ms, 34kyr, 6.2kpc , B=2.1x10^{12}G

Parkes multibeam survey

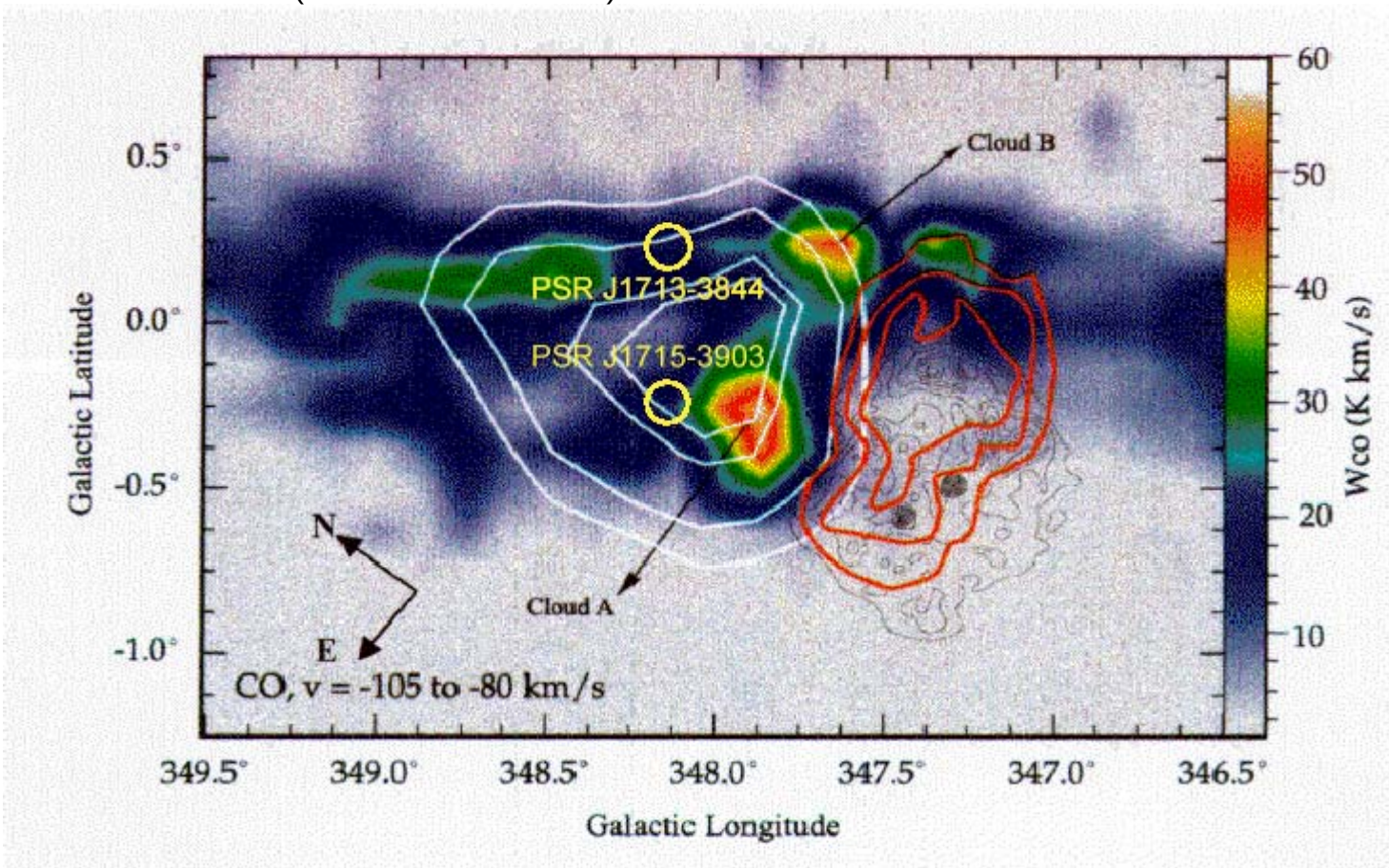
D'Amico et al. ApJ 552, L45 (2001)

3EG J1714-3857

G348.5+0.0; G348.5+0.1; G347.3-0.5

PSR J1713-3944: P=1.60s / PSR J1715-3903: P=278ms, d=4.8kpc; spindown energy too small

Hadron accelerator? (Cloud A? G347.3-0.5?)



Butt et al. astro-ph/0109292

Other candidates

OBSERVATIONAL PARAMETERS FOR THE PULSARS IN THE CANDIDATE ASSOCIATIONS

Case	$\Delta\theta$ [deg]	θ [deg]	(l, b)	d [kpc]	τ [kyr]	P [ms]	$\dot{P}$ [10^{-15}]	$\dot{E}$ [ergs s^{-1}]
#3	0.30	0.67	283.09,−0.58	4.9	38.7	140	57.4	8.2×10^{35}
#4	0.15	0.36	312.32,−0.37	9.3	50.6	315	98.7	1.2×10^{35}
#5	0.28	0.36	312.46,−0.34	11.0	13.5	286	333.4	5.7×10^{35}
#7	0.46	0.56	337.79,+0.31	5.8	41.2	154	59.2	6.4×10^{35}
#12	0.50	0.52	27.07,+0.71	8.2	52.2	381	115.7	8.3×10^{34}

NOTE.—$\Delta\theta$ is the angular distance between the center of the 3EG source and the position of the respective coincident pulsar. θ is the effective 95% confidence level radius of the 3EG source error box (Hartman et al. 1999). Pulsar parameters are taken from the Parkes survey database (see footnote 1), and their distances (d) are estimated from the observed dispersion measure (Taylor & Cordes 1993).

OBSERVED AND COMPUTED γ-RAY EMISSION PARAMETERS FOR NEW CANDIDATE ASSOCIATIONS

Case	F^{3EG} [$\times 10^{-8}$ ph cm^{-2} s^{-1}]	F^{3EG} [ergs cm^{-2} s^{-1}]	γ^{3EG}	$L_{isotropic}$ [ergs s^{-1}]	L_{beamed} [ergs s^{-1}]	η
#3	34.0±6.5	1.90×10^{-10}	2.23±0.20	5.2×10^{35}	4.1×10^{34}	5%
#4	64.2±8.8	4.09×10^{-10}	2.12±0.14	4.1×10^{36}	3.2×10^{35}	270/12%[a]
#5	64.2±8.8	4.09×10^{-10}	2.12±0.14	5.7×10^{36}	4.5×10^{35}	80/3%[a]
#7	53.2±8.7	2.30×10^{-10}	2.50±0.18	9.3×10^{35}	7.4×10^{34}	12%
#12	<19.1	$< 0.70 \times 10^{-10}$	2.71±0.44	$< 5.8 \times 10^{35}$	$< 4.6 \times 10^{34}$	<55%

NOTE.—The EGRET fluxes correspond to the "P1234" values (Hartman et al. 1999). Luminosities, and efficiency values for all pulsars, are given for the distance estimated from the dispersion measure (Table 3).

[a]Second values of efficiency correspond to a distance of 1.9 kpc, one of those estimated for the positionally coincident SNR G312.4–0.4 (see text).

Torres et al. astro-ph/0109228

Pulsar / SNR association (1)

G184.6 -5.8	Crab	plerion Xneb	Pulsar 33msec (10^4GHzbreak)
N157B(LMC)		plerion Xneb	Pulsar 16msec J0537-69
N158A	(in LMC)	Comp. Xneb	Pulsar 50msec 0540-69
G263.9 -3.3	Vela	Comp. Xneb	Pulsar 89msec
G011.2 -0.3	SN~386	Comp. Xneb	Pulsar 65msec J1811-1925
G343.1 -2.7		Comp.	Pulsar 1706-44 102msec
G005.4 -1.2	Milne 56	Comp.??	Pulsar? B1758-24 125msec
G320.4 -1.2	MSH 15-52	Comp. Xneb	Pulsar B1509-58 150msec
G029.7 -0.3	Kes 75	Comp. Xneb	Pulsar 324msec B=5x10^14 semiMagnetar disc+jet
G034.7 -0.4	W44 3C392	Comp. Xneb	Pulsar 1853+01
G069.0 +2.7	CTB80	?	Pulsar 1951+32
G114.3 +0.3		Shell	Pulsar 2334+61
G130.7 +3.1	3C58	plerion Xneb	Pulsar P=65msec B=3.6x10^12G (50GHzbreak)
G292.2 -0.5		ParkesNew	Pulsar J1119-6127
G313.4 +0.2		ParkesNew	Pulsar J1420-6043
G312.4 -0.4		ParkesNew	Pulsar J1413-6141
G352.2 +0.1		ParkesNew	Pulsar J1726-3530
G334.1 -0.2		ParkesNew	Pulsar J1632-4813
G111.7 -2.1	Cas A, 3C461	Shell	QuietNS 12ms?
G260,4 -3.4	Puppis A	Shell	QuietNS 75msNo!

S. Shibata
18-SEP-01

S. Shibata, private comm.

Pulsar / SNR association (2)

G296.5 +10.0	PKS1209-51/52	Shell	QuietNS 424ms
G117.7 +0.6		Shell	QuietNS 24ms
G332.4 -0.4	RCW 103	Shell	QuietNS? (var in X)+run away pulsar 69msec(but
G078.2 +2.1	gamma Cyg	Shell	QuietNS
G010.0 -0.3??		plerion	SGR 1806+20 7.47sec
G042.8 +0.6		Shell	SGR 1900+41 5.15sec in bursts
N49(LMC)		Shell	SGR 0526-66 5.16sec
G337.0 -0.1		Shell	SGR 1627-41 6.41sec
G027.4 +0.0	Kes 73	Shell	AXP 11.7sec
G029.6 +0.1		Shell	AXP AXJ1845-0258 6.97sec
G109.1 -1.0	CTB~109	Comp.	AXP 7sec
G028.8 +1.5			AXP 1838.4-0301
?			AXP 1E1048.1-5937 6.5sec
?			AXP RXSJ1708-40 11sec
?			AXP 4U0142+61 8.69sec
G039.7 -2.0	W50	Shell(ears)	SS433 jets binary
G309.2 -0.6		Shell(ears)	Xpnt.(ATCA J134649-625235)
G000.9 +0.1		Comp.	
G021.5 -0.9		plerion Xneb.	(30GHzbreak)
G027.8 +0.6		plerion	(<10GHzbreak)
G074.9 +1.2	CTB 87	plerion	(10GHzbreak) Xnebula
G119.5 +10.2	CTA 1	Comp.Xneb	gamma?
G292.0 +1.8	MSH~11-54	Comp.	
G327.1 -1.1		Comp.	Xpnt.source+nebula
G065.7 +1.2		Comp.	Xnebula
G291.0 -0.1		Comp.	Xnebula
G321.9 -0.3			Cir X-1 jets binary run away
G189.1 +3.0	IC443,3C157	Shell	Xnebula
G039.2 -0.3	3C396	Shell	Xnebula

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Gamma-ray pulsar observability

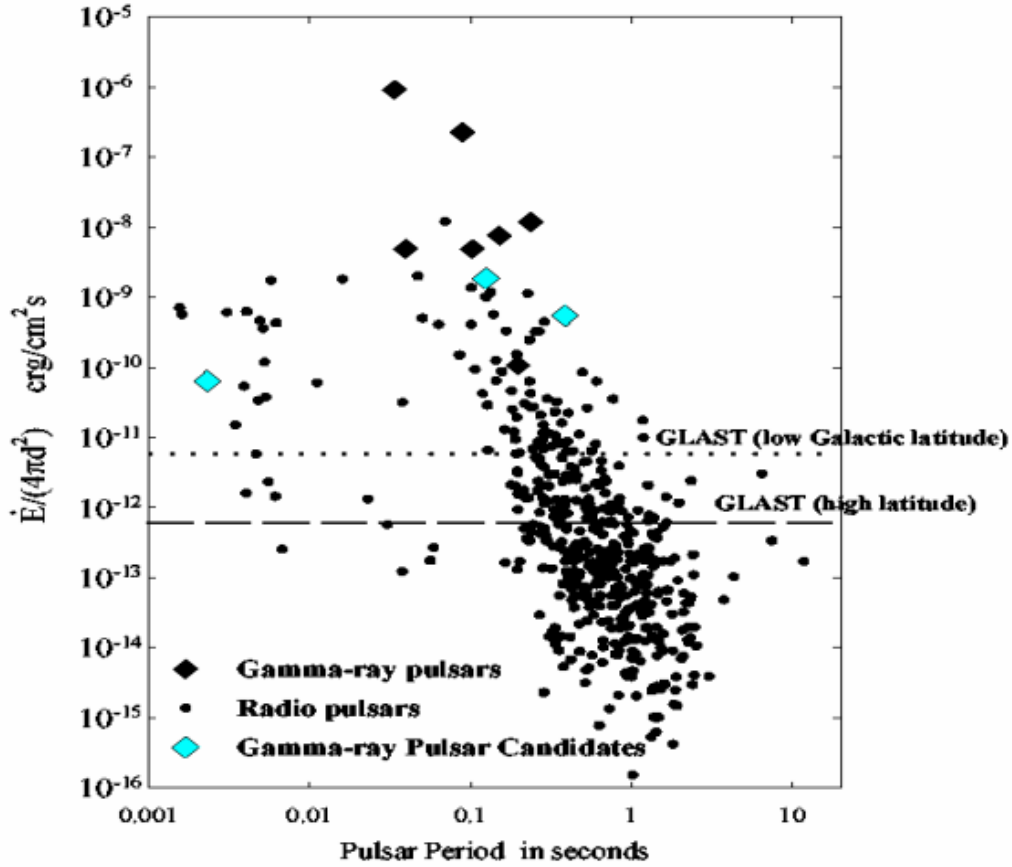

FIGURE 7. Gamma-ray pulsar observability, as measured by the spin-down energy seen at earth.

Thompson astro-ph/0101039