Pulsar timing for GLAST with the Nançay Radio telescope

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GLAST Pulsar timing at Nançay

1. Brief reminder: what we need and how we get it
2. Introduction to the Nançay Radio telescope:
   a) The instrument and its capabilities
   b) Why GLAST<==> Nançay is symbiotic
3. Initial trials and results
4. Where we go from here:
   a) Long-term tracking of known gamma ray pulsar candidates
   b) Deep radio searches for new gamma pulsar candidates

What we need, where we get it

- With the Science Tools, to see if your gammas are pulsed, use *gtpulsarDb* to get timing parameters from the D4 database (and *getephcomp* to see what's there).
- The ephemerides from our young and noisy pulsars get stale fast. The fainter pulsars take years to give enough photons.
- (*gtpsearch* allows some period fudge for a given epoch. *gtpphase* has a free parameter to fudge absolute phase. But to sum photons over many epochs, absolute radio phase may make the difference for a good Nσ/Ntrials.)
- So: we need to fill the database with ephemerides, *and* we'll need to keep re-filling it regularly. As often as monthly is not unreasonable for some pulsars, and "a few times per year" is reasonable/necessary for many.
- Thorsett's various slides (in appendix of this talk): Jodrell Arecibo Parkes GBT willing and able. Also oversubscribed! Long term follow-up for 2nd-string candidates could be challenging.
- This talk: Nançay is an excellent resource for GLAST.

2nd largest in the world (200m x 35 m)

Only Arecibo (300m) is bigger

<2 hours south of Paris (near Orléans)

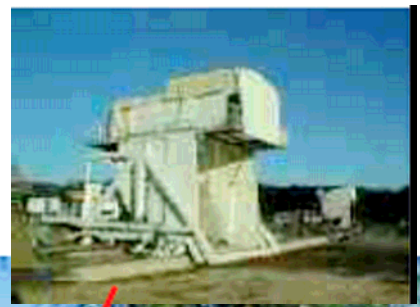
Introduction to Nançay

- It is a *meridian* telescope : sources visible ~1 hour per day, at transit.
- South mirror fixed (300 m x 35 m), north mirror tilts (200m x 40m), little trolley car (shown below) moves to focus. (94 m diameter equivalent)
- Covers $-40^o < \delta < 60^o$ (best for $-30^o < \delta < 40^o$)
- Lobe is 21' north-south x 4' east-west (at 21 cm ~ 1400 MHz)
- 2.5 M$ refurbishing 5 years ago, big pulsar improvements 2 years ago
- Some performance details in a galaxy survey paper,

  G. Theureau et al, A&A 430 373-383 (2005)

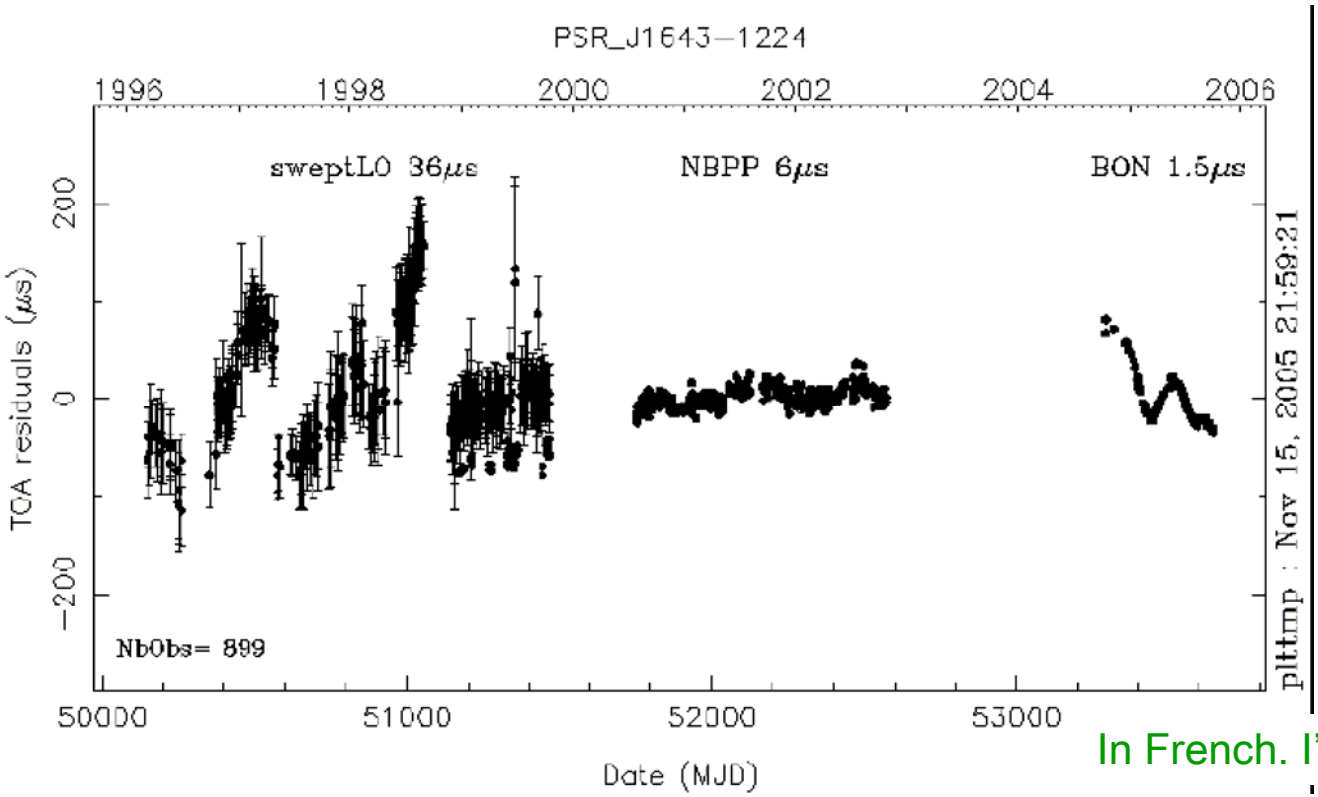
http://www.obs-nancay.fr/

http://klun.obs-nancay.fr/pulsar.html



Timing Performance…

- One of the keys to Nançay's pulsar performance is their de-dispersion hardware, called BON = Berkeley-Orléans-Nançay. Ismael (who dat? See following slides) made it with D. Becker while on sabbatical at Cal.
- Want nitty-gritty details? See Ismael's workshop talk
  http://lpce.cnrs-orleans.fr/~pulsar/PSRworkshop/Talks/I.Cognard.pdf

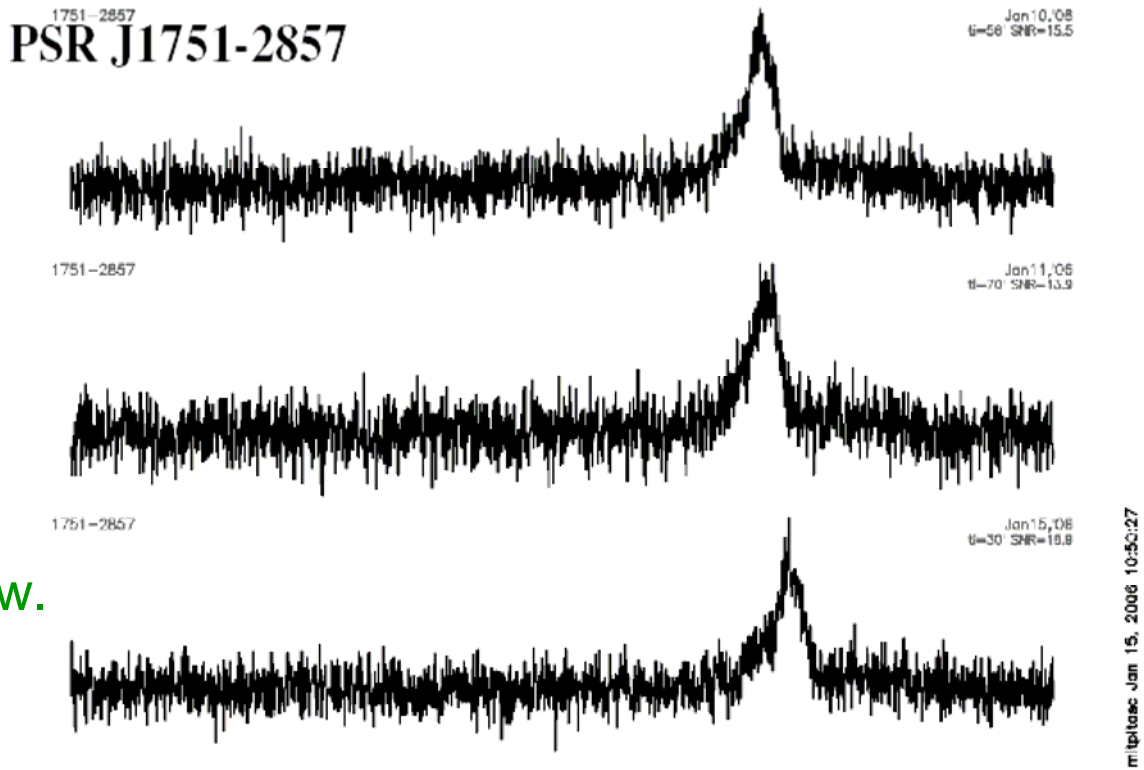


In French. I'll help you parse if you ask.

Sensitivity…

- I asked Dave & Roger for advice. Roger said, timing at 50 uJy is key.
- Ismael had J1751-2857 with 60 +/- 20 uJy in current list
- Popped right out in less than an hour, three nights in a row.

A 60 μJy ms pulsar



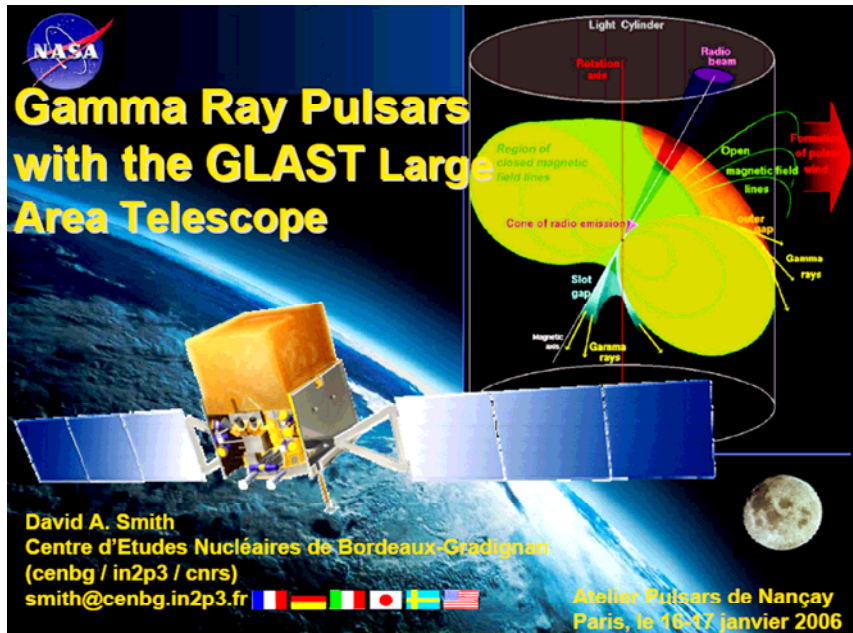
Observation du pulsar PSR J1751-2857
P=3.915ms, DM=42.8pc.cm^{-3}
S_{1400} ~ 60(20) μJy (Stairs et al. astro-ph/0506188)

We need them, and they need us ("symbiosis")

- 50% of the telescope time is for pulsars, handled by two guys (!), named Ismael Cognard and Gilles Theureau.
- Program questioned by national authorities. So they organised a workshop… Successful. A few distinct communities in France, long-term visible program.

  http://lpce.cnrs-orleans.fr/~pulsar/PSRworkshop/pulsar_index.html

- For them, a long-term, high scientific return collaboration with GLAST is just what the doctor ordered.
- Here's the 1st slide from my talk =>



Some initial tests & results

- When Roger said “key issue is 50 μJy” he suggested J2229+6114 (see e.g. astro-ph/0112518 by Dave & Seth & Pat & Olaf)
- Ismael made an attempt, and didn’t see it.
  - High declination = bad optics? (naw…)
  - Foreground supernova 3C58 radio noise? (don’t think so…)
  - Not used to young, noisy pulsars and the importance of fresh n’ up to date timing parameters?
  - Most likely the latter. We’ll come back to this point…

Towards a long term program (1 of 3)

- On Feb 9th I went to Orléans to work with Ismael & Gilles. Beforehand, asked Roger for examples of pulsar he thinks well-suited for Nançay+GLAST.
- Roger's suggestion: some tough nuts that are exciting and motivating, *and* some more standard ones to offload the other radio telescopes.
- Roger's list, next slide.

Roger's test pulsars

From rwr@astro.Stanford.EDU Tue Jan 31 20:00:23 2006

To: D.A. Smith <smith@cenbg.in2p3.fr> Subject: some glast pulsars

Hi David -- as requested, here are a few pulsars that you can discuss in your upcoming meeting with Ismael. I will describe some of my thinking in ranking things on the 21st. But here are 10 PSR worth discussing, all above DEC -35. Note -- many of these are presently being timed, although it is not clear that the timing is adequate or will continue during GLAST. You might want to avoid competing in the Arecibo DEC range (0-38), as well:

Ridiclously difficult, but important:

Name	~S_1.4(mJy)	
J1833-1034	0.08767	0.07
J1930+1852	0.004619	0.06
J2021+3651	0.0001662	0.1
J1946+2611	5.776e-05	0.06
Not so hard, but likely interesting		
J1747-2958	0.008501	0.25
J2229+6114	0.00108	0.25
J1815-1738	0.0002536	0.25
J1913+0832	0.0001506	0.6
J1734-3333	0.000144	0.5
J1735-3258	4.161e-05	0.46

- Discovered last year. 62 ms, both Edot/d² and B_{LC} greater than for e.g. 1951+32
- Roger ranks by this variable, and gave us two radio intensity groups. See his talk to learn about the mystery variable.
- Discovered in '95, no published timing since (no publications, period!).
- Serious fun -- galactic center, 3EG and HESS TeV sources nearby, big Edot/d² , called the "Mouse". Bow shock visible in Xrays.
- And so forth and so on…

Anyway, something to discuss, although certainly not an exhaustive list. Let me know what Ismael thinks... -- Roger

A learning curve

- Included in Ismael's first tries was J1747-2958, 98.8 ms at 250 uJy. Shoulda been easy, but no hint of a signal.
- He used timing parameters from ATNF reference , from 2002 discovery: "Heartbeat of the Mouse in G359.23-0.82", Ap J Lett 579 25-28
- We looked it up in Simbad and found stuff 2 years younger, significantly different. "The Mouse that Soared", Ap J 616:383-402 (2004) Ismael loaded fresh parameters into the de-dispersor and waited from the source to come back around the earth.
- He had to go out of town… waiting for news…
- In Roger's list, another one that Ismael looked at and saw a hint of a signal. Again, found fresher parameters in the literature.
- Others only very old in the literature, e.g. J1946+2611 was discovered in 1996 and then apparently never published again.
- Ismael to contact Camillo Fernandez at Parkes for unpublished results.

Towards a long term program (2 of 3)

- Nançay guys willing to take on ~30 pulsars for us…
- I've begun an application form. After these informal tests, start becoming more official.
- Want this machine to be humming quietly by mid-2007.

RADIOTELESCOPE DE NANCAY - FORT

OBSERVING TIME REQUEST / DEMANDE DE TEMPS

semester 2006b : July 1st 2006 to December 30th 2006

Année : 2006a

N° :

Reçu le :

(do not fill this field / ne pas remplir ce champ)

IMPORTANT: Fill ALL relevant items in boxes below / remplir TOUS les champs concernés !

DEADLINE / DATE LIMITE : April 18th 2005, 12h UT

SEND TO / ENVOYER À (10 copies) :

Mrs Nicole HALLET, GEPI, Observatoire de Paris, F- 92195 Meudon Cedex, FRANCE.

Fax : +33 1 45 07 79 39 Phone n° : +33 1 45 07 75 98 E-mail : Nicole.Hallet@obspm.fr

PUBLIC TITLE / titre public : Long term timing of young, noisy pulsars preparatory to pulsed gamma ray searches with the GLAST satellite

ABSTRACT / resume : When GLAST is launched in late 2007, the sensitivity of the Large Area Telescope (« LAT ») to ~GeV gamma rays will be roughly 25 times greater than it was for EGRET on the Compton Gamma Ray Observatory, flown from 1991 to 2000. The angular resolution will also be significantly better than for EGRET, allowing improved source localization. On this basis, GLAST could detect over a hundred gamma ray pulsars, as compared to the fewer than 10 presently known. However, these pulsed detections require excellent radio timing over long periods, because the photon rates from the fainter pulsars will be very low: GLAST sees the whole sky every two orbits (3 hours) but even one of the brightest pulsars, the Crab, only gives one photon every 16 seconds (on average) when in the field of view. Furthermore, pulsars likely to emit detectable gamma ray fluxes are mainly young pulsars suffering substantial timing noise and glitches. Hence, for radio ephemerides to be valid over months and years requires repeated radio measurements (as often as monthly for some, and a few to several times per year for others).

The purpose of the present request is to establish a pilot program prior to requesting long-term timing for GLAST. We aim to establish the performance of the Nançay telescope for this particular class of pulsars, by making a series of measurements of known gamma pulsar candidates. The published timing parameters for these pulsars are often out of date and do not allow detection as simply as for older, more stable pulsars. We will thus be acquiring timing parameters from other radio telescopes in order to establish the first pulsed detections of these objects at Nançay. On the basis of these first results we will define a longer list of gamma candidates for which we will request observation time in the future.

Assuming the success of this initial program, we aim to build towards a "key program" consisting of the long-term timing of about 30 pulsars. We aim to have this program in place by mid-2007, and would hope to continue the program during the 5 to 10 years of the GLAST mission.

ASKING FOR KEY PROGRAMME STATUS ? / Demande de statut de programme clé ? :	X No	O Yes (starting date, if already given)

Key programme status is intended for applications demanding large amounts of time or long term monitoring. Successful applicants will be subject to fast release of the results by the means of publications or public databases. This status is given for two years, and a progress report is demanded every semester. / Les programmes clés sont prévus pour des demandes très importantes en temps de télescope, ainsi que pour des suivis à long terme. Les bénéficiaires de ce statut seront soumis à des conditions de publication rapide dans des journaux scientifiques ou bien sous forme de base de données. La durée du statut est de deux ans, et un rapport d'avancement est demandé chaque semestre.

PART OF A PhD THESIS ? / fait partie d'une thèse de Doctorat ? :	X No	O Yes (date ?)
FUTURE REQUESTS PLANNED ? / demandes ultérieures prévues ? :	O No	X Yes
PREVIOUS RELATED REQUEST ? / demande(s) antérieure(s) liée(s)? :	X No	O Yes (date(s) ?)
OTHER PREVIOUS REQUEST ? / autre(s) demande(s) antérieure(s) ? :	*X No*	*O Yes (date(s) ?)*

OBSERVING TIME UTILIZATION / REPARTITION DU TEMPS DE TELESCOPE :

	Sidereal time	0h	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h
Number of hours	00-19 mn												
	20-39 mn												
	40-59 mn												
	Sidereal	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h

Towards a long term program (3 of 3)

- Roger believes radio guys will work out GLAST pulsar sharing amongst themselves, with oversight from him and Dave.
- ThorsettMultiwaveObs.pdf (June 2005) lists “advisory group”. Could Ismael be included?

Pulsar advisory group

- Group established to plan observing strategy and make recommendations to mission for needed support or special coordination requirements
- Current membership:
  - Dick Manchester, Matthew Bailes (Parkes)
  - Andrew Lyne (Jodrell)
  - Don Backer (ATA)
  - David Nice (Green Bank, EGRET experience)
  - Roger Romani (theory)
  - Maura McLaughlin (population modeling)
  - Dave Thompson (GLAST)

Discovering unknown pulsars

- GLAST and HESS will find galactic point sources that don't correspond to known objects. I learned that deep pulsar searches are far from complete -- lots of places in the sky have not had deep pulsar searches -- motivating!
- We and HESS will want deep searches… (VERITAS? Talk to me if you want…)
- Ismael & Gilles are *not* the guys: their de-dispersor needs an input period. About 1 CD-rom per minute of raw data goes to the bit dump, only results get stored.
- Another guy, Emmanuel Davoust (see workshop program) does pulsar searches. He does surveys. We and HESS maybe try to re-direct him?
- Yves Gallant is a pulsar theorist/observationalist working on HESS in Montpellier (same lab as Fred Piron & Eric Nuss). He aspires to Nançay follow-up of HESS unidentifieds. Perhaps he could help us get this program going. Nice when HESS and GLAST unidentifieds overlap…

Various & Sundry

- Where is AGILE getting its radio ephemerides? Cooperation?
- Some overlap with measurements at other radio telescopes is healthy.
- Oldtimers know Nançay for long term timing of a few stable pulsars. This was true. But since the upgrades they can and want to do more.

AGILE will be launched by the PSLV rocket from the Sriharikota base in India (Madras, Chennai). Launch date: March 10, 2006?

Conclusions

- A French 100-meter class radio telescope with modern pulsar electronics is eager to work with GLAST to time faint, young, and noisy pulsars over our mission lifetime.
- Goal is to keep the D4 database well-stocked with fresh products.
- Exploratory measurements have begun. We're ramping up.
- Nançay could handle ~30 pulsars routinely. A mix of tough, exciting ones and more mundane ones has been suggested.
- Deep searches for new pulsars around unidentified gamma sources not covered by the present effort. A parallel task could be initiated (Not clear *at all* that Nançay is the right place…)

Appendix

Extra slides,

including a smattering taken from 3 talks

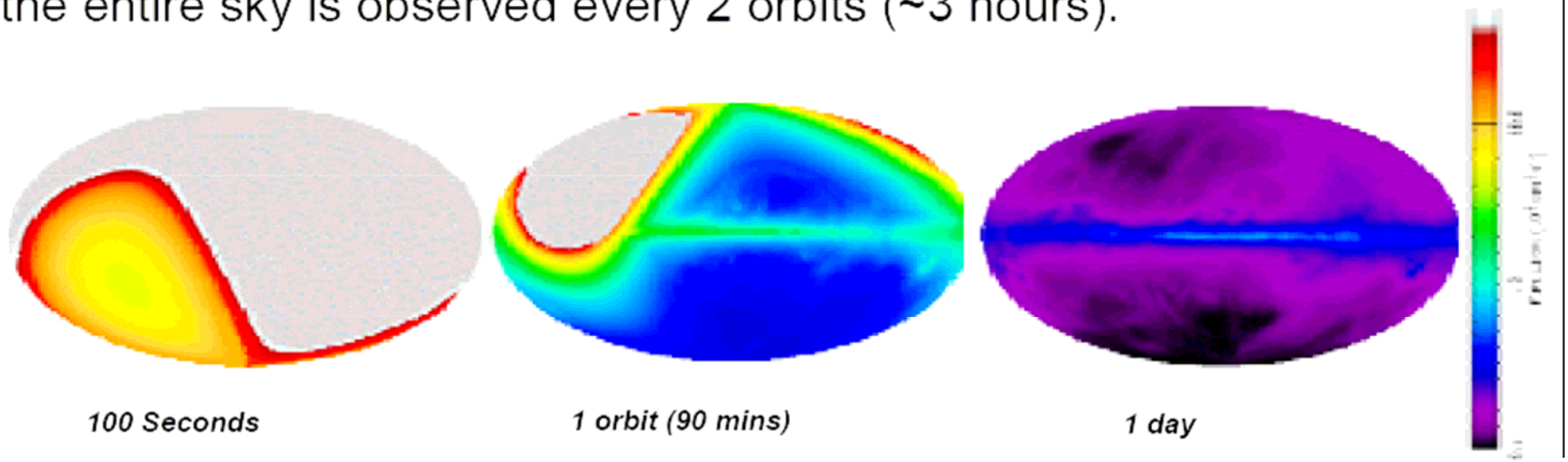
By Steve Thorsett

Cartographie céleste continue

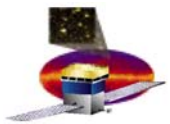
GLAST ne “pointera” qu’exceptionellement, donc photons pulsés à tout moments.

Field of View and Transient Monitoring

The field of view of the LAT is huge, ~20% of the sky at any instant, and can cover up to 75% of the sky every orbit. In scanning mode the the entire sky is observed every 2 orbits (~3 hours).



100 Seconds *1 orbit (90 mins)* *1 day*



Candidats pour une émission pulsée au GeV

Pulsar	P s	τ yr	$\dot{E}$ erg s^{-1}	F_E erg $cm^{-2}s^{-1}$	d kpc	L_{HE} erg s^{-1}	η
Crab	0.033	1300	4.5×10^{38}	1.3×10^{-8}	2.0	5.0×10^{35}	0.001
B1509−58	0.150	1500	1.8×10^{37}	8.8×10^{-10}	4.4	1.6×10^{35}	0.009
Vela	0.089	11,000	7.0×10^{36}	9.9×10^{-9}	0.5	2.4×10^{34}	0.003
B1706−44	0.102	17,000	3.4×10^{36}	1.3×10^{-9}	2.4	6.9×10^{34}	0.020
B1046−58	0.124	20,000	2.0×10^{36}	2.5×10^{-10}	3.0	2.1×10^{34}	0.011
B1951+32	0.040	110,000	3.7×10^{36}	4.3×10^{-10}	2.5	2.5×10^{34}	0.007
Geminga	0.237	340,000	3.3×10^{34}	3.9×10^{-9}	0.16	9.6×10^{32}	0.029
B1055−52	0.197	530,000	3.0×10^{34}	2.9×10^{-10}	1.5	6.2×10^{33}	0.20

EGRET pulsars

If ranked by $\dot{E} / d^2$ (spin-down flux at Earth), these pulsars are numbers 1, 2, 3, 4, 5, 6, 9, and 24. (Number 7 is a nearby millisecond pulsar, and 8 is a recently discovered pulsar.)

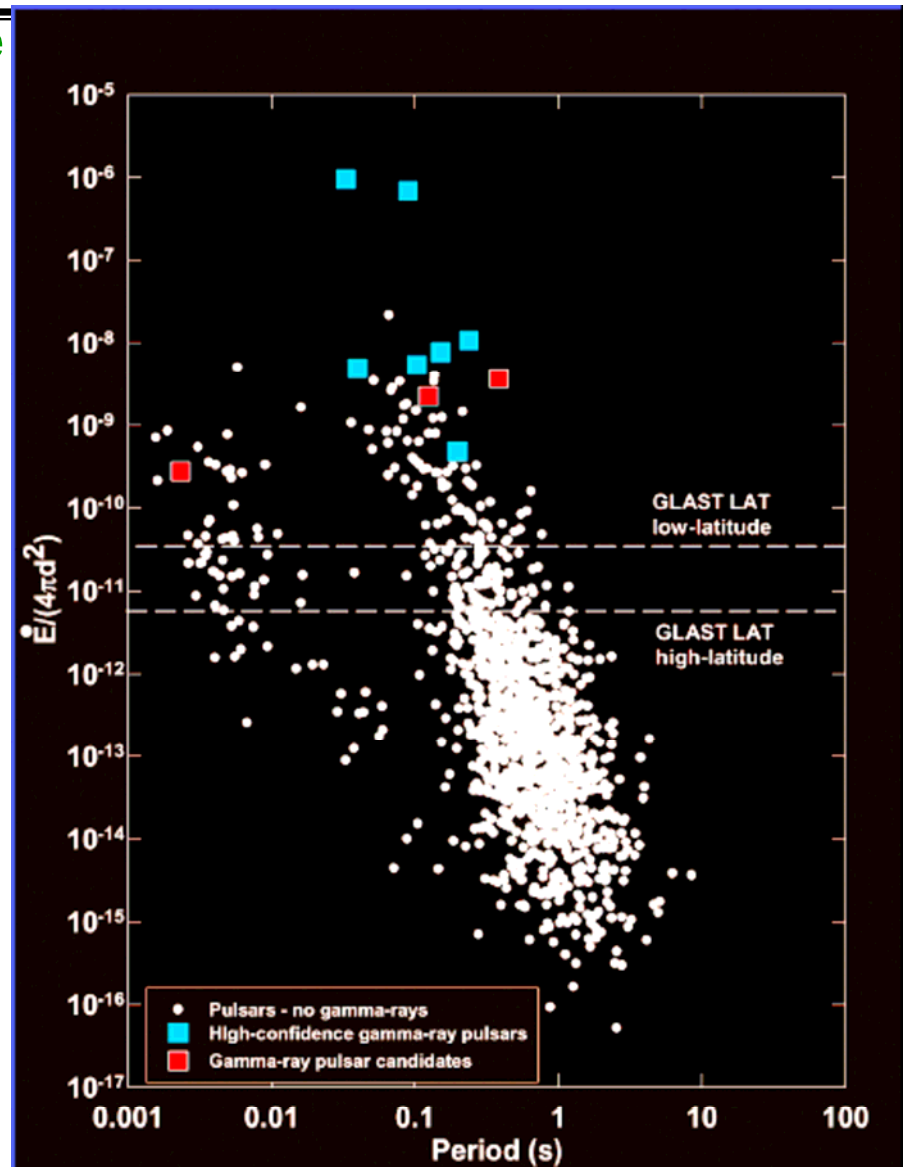
Pourquoi 24? “d” pas toujours fiable… (‘1055)

Clearly, **spin-down flux at Earth is an excellent proxy for gamma-ray luminosity**.

Pulsars proches, jeunes, sujets à glitches

- 600 pulsars radios connus à l'époque d'EGRET, ~1600 attendus d'ici le lancement de GLAST.

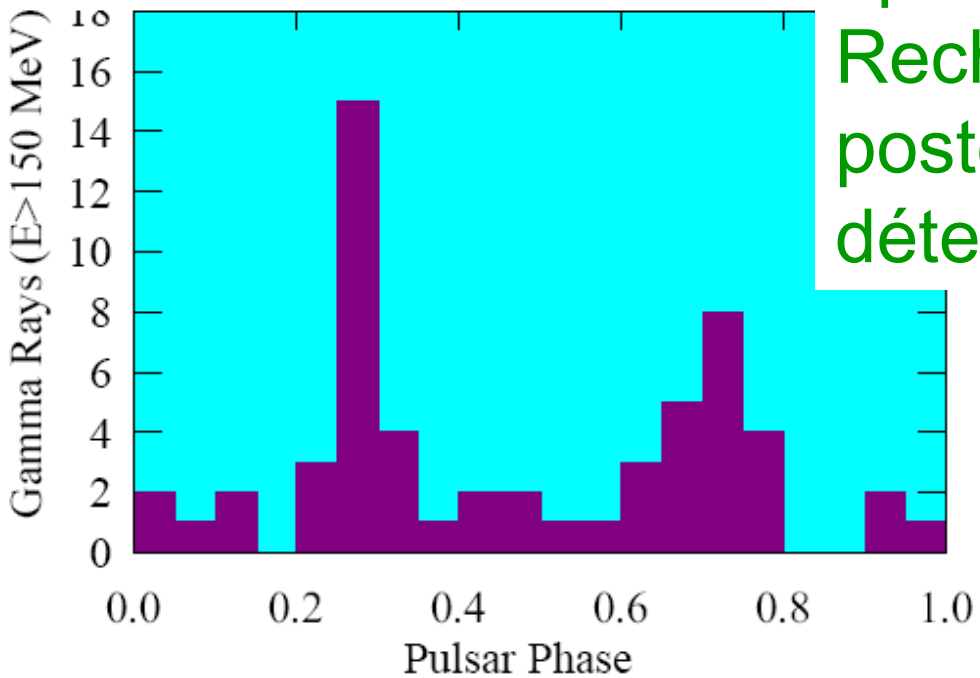
- POINT CLEF: Il faudra bien les 10 ans de données pour les plus faibles, donc un suivi soutenu de datation.



Exemple de faible stats et de datation perimée

Thompson, Digel, Nolan & Reimer

astro-ph/0112518



Pulsar découvert après EGRET, Recherche a posteriori, pas de détection.

Figure 1. Possible EGRET light curve for PSR J2229+6114 in Viewing Period 34, based on a search of periods and period derivatives consistent with the later radio measurements.

Pellizoni et al (AGILE) 2004 (1 of 2)

Table 1. Preliminary sample of the ranking list of radio-pulsars expected to have gamma-ray fluxes near AGILE sensitivity (see text). This sample includes 14 radio-pulsars coincident with selected unidentified EGRET sources, some of which have marginal pulsed detections. F_{min} and F_{max} represent the expected gamma-ray flux ranges of the sources in the hypothesis that the gamma-ray beams intersect the line of sight.

PSR Name	Gal. Long. deg	Gal. Lat. deg	P s	$\dot{P}$ 10^{-15} s/s	D kpc	$\dot{E}$ log erg/s	$F_{\rm min}$*	$F_{\rm max}$*	3EG coinc.
J1932+1059	47.38	-3.88	0.227	1.16	0.17	33.59	109	986	
J0659+1414#	201.11	8.26	0.385	55.01	0.76	34.58	16	151	
J2043+2740	70.61	-9.15	0.096	1.26	1.13	34.75	9	83	
J1908+0734	41.58	-0.27	0.212	0.82	0.58	33.53	8	76	
J1048-5832#	287.42	0.58	0.124	96.32	2.98	36.30	8	71	3EG J1048-5840
J0205+6449	130.72	3.08	0.066	193.93	7.54	37.43	4	41	
J1856+0113#	34.56	-0.50	0.267	208.41	2.78	35.63	4	38	3EG J1856+0114
J1913+1011	44.48	-0.17	0.036	3.37	4.48	36.46	4	37	
J1549-4848	330.49	4.30	0.288	14.11	1.54	34.37	3	28	
J1718-3825	348.95	-0.43	0.075	13.22	4.24	36.10	3	27	3EG J1714-3857
J1730-3350	354.13	0.09	0.139	85.10	4.24	36.09	3	27	
J1705-1906	3.19	13.03	0.299	4.14	1.18	33.79	2	25	
J1420-6048	313.54	0.23	0.068	83.17	7.69	37.02	2	24	
J0358+5413#	148.19	0.81	0.156	4.40	2.07	34.66	2	22	
J1509-5850	319.97	-0.62	0.089	9.17	3.81	35.71	2	22	
J1739-3023	358.09	0.34	0.114	11.40	3.41	35.48	2	21	
J1835-1106	21.22	-1.51	0.166	20.61	3.09	35.25	2	19	
J1530-5327	325.33	2.35	0.279	4.68	1.46	33.93	2	19	
J1302-6350#	304.18	-0							
J2337+6151	114.28	0.							

"#" -- low significance pulsed Egret detection

Pellizoni et al (AGILE) 2004 (2 of 2)

Table 1. Preliminary sample of the ranking list of radio-pulsars expected to have gamma-ray fluxes near AGILE sensitivity (see text). This sample includes 14 radio-pulsars coincident with selected unidentified EGRET sources, some of which have marginal pulsed detections. F_{min} and F_{max} represent the expected gamma-ray flux ranges of the sources in the hypothesis that the gamma-ray beams intersect the line of sight.

J1837-0604	25.96	0.26	0.096	45.17	6.19	36.30	1	16	3EG J1837-0606
J2229+6114#	106.65	2.95	0.052	78.27	12.00	37.35	1	14	3EG J2227+6122
J1105-6107	290.49	-0.85	0.063	15.83	7.07	36.39	1	14	3EG J1102-6103
J1740-3015	358.29	0.24	0.607	465.87	3.28	34.92	1	11	3EG J1744-3011
J1637-4642	337.79	0.31	0.154	59.20	5.77	35.81	1	10	3EG J1639-4702
J1745-3040	358.55	-0.96	0.367	10.66	2.08	33.93	1	9	3EG J1744-3011
J1016-5857	284.08	-1.88	0.107	80.62	9.31	36.41	0	8	3EG J1013-5915
J1757-2421	5.31	0.02	0.234	13.00	3.50	34.60	0	7	3EG J1800-2338
J1853+0056	34.02	-0.04	0.276	21.39	3.82	34.61	0	6	3EG J1856+0114
J1715-3903	348.10	-0.32	0.278	37.69	4.80	34.84	0	5	3EG J1714-3857
J0614+2229	188.79	2.39	0.335	59.63	4.72	34.80	0	5	3EG J0617+2238

"#" -- low significance pulsed Egret detection

AGILE (un mini-GLAST italien) sera lancé prochainement, avec une performance EGRET-like.

dixit Cognard : 31 des candidats dans cet article détectables à Nançay

(dec>-40° et >0.2 mJy @ 1400 MHz)
(la liste étant le classement en Edot/d²)

PROSPECTS FOR HIGH ENERGY STUDIES OF PULSARS WITH THE AGILE GAMMA-RAY TELESCOPE

A. Pellizzoni[1], A. Chen[1,2], M. Conti[1], A. Giuliani[1,2], S. Mereghetti[1], M. Tavani[1], S. Vercellone[1]

Prédictions polar cap à 50 GeV

Date: Wed, 22 May 2002 13:47:02 -0400 (EDT)
From: Alice Harding <harding@twinkie.gsfc.nasa.gov>
To: D.A. Smith <smith@cenbg.in2p3.fr>
Subject: MS pulsars
Hi David,
I know it has been a long time since I promised to get you a list of pulsars to observe with Celeste, but other things just seemed to get in the way ... Anyway, I did a crude estimate of expected flux at 50 GeV for the ms pulsars in the ATNF catalog. In the polar cap model, ms pulsars are the only sources which are expected to have detectable emission above 30 GeV. More of the details are in my paper that was just accepted and is on astro-ph/0205077. In ms pulsars, the electric field is unscreened by pairs, so the particles accelerate to the curvature radiation reaction limit and radiate a very hard spectrum (photon index -2/3) out to energies of 20-100 GeV, depending on pulsar parameters. IF the flux is high enough, you might see it. So my list of the top candidates based on a rank ordering in flux*E^2 at 50 GeV is

J0437-4715 J1744-1134 J2124-3358 J0030+0451 J1959+2048
J1300+1240 J1024-0719 J0034-0534 J1012+5307

Several of these, J0437-4715, J2124-3358 and J0030+0451 are X-ray pulsars. Just about all of these are nearby sources, less than a kpc.
I hope you will be able to hunt for a few of these and let me know if you need any more info.
Best Regards, Alice

Les pulsars optiques

THE ASTROPHYSICAL JOURNAL, 547:967–972, 2001 February 1

(Cette article est une excellente introduction au sujet.)

IMPLICATIONS OF THE OPTICAL OBSERVATIONS OF ISOLATED NEUTRON STARS

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Seulement 5 connus…

TABLE 1

MAIN CHARACTERISTICS OF OPTICAL PULSARS

	NAME	D (kpc)	P (ms)	$\dot{P}$ (10^{-14} s s^{-1})	log AGE (yr)	B_S (log G)	B_{LC} (log G)	OPTICAL LUMINOSITY (μcrab) Integrated	OPTICAL LUMINOSITY (μcrab) Peak	SPECTRAL INDEX AT 4500 Å	CUTOFF (Å)
γ	Crab	2	33	42	3.09	12.6	6.1	10^6	10^6	−0.11	15000(?)
γ	Vela	0.5	89	11	4.11	12.5	4.8	27	21	0.2	6500(?)
	PSR 0545−69	49	50	40	3.20	12.7	5.7	1.1×10^6	1.4×10^5	0.2	>7000
	PSR 0656+14	0.25(?)	385	1.2	5.50	12.7	3.0	1.8	0.3	1.3	>8000
γ	PSR 0633+17	0.16	237	1.2	4.99	12.2	3.2	0.3	0.1	1.9	>8000

– geminga

Des candidats:

TABLE 3

PREDICTED LUMINOSITY OF X- AND γ-RAY–EMITTING PULSARS

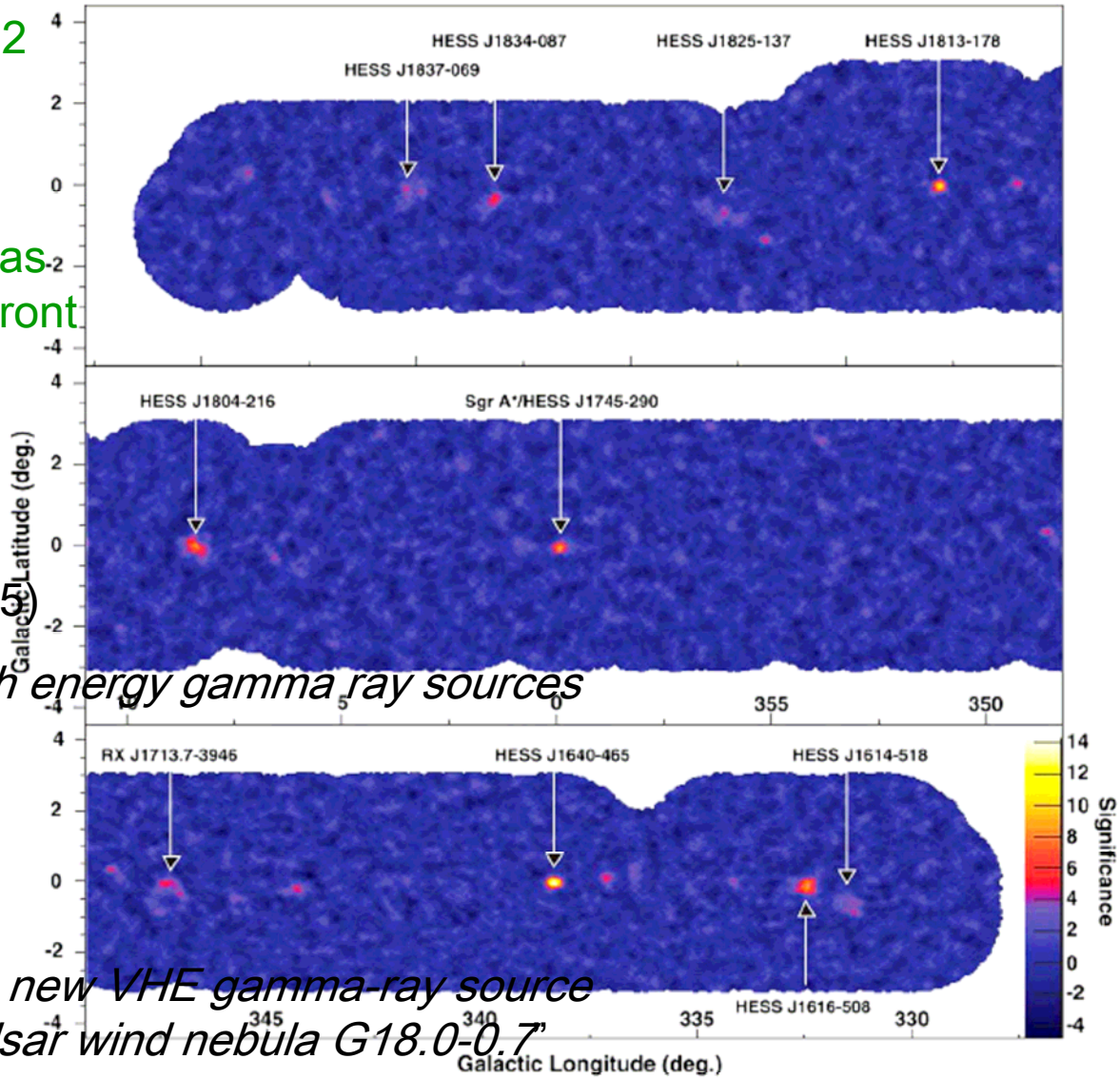
	Name	D (kpc)	P (ms)	$\dot{P}$ (10^{-14} s s^{-1})	B_S (log G)	B_{LC} (log G)	Duty Cycle	Predicted Luminosity (μcrab)
γ	PSR 1055−52	1.5	197	0.6	12.03	3.11	0.2	0.01
γ	PSR 1706−44	1.8	102	9.3	12.49	4.42	0.14	35
γ	PSR 1951+32	2.5	40	0.6	11.69	4.86	0.08	670
	PSR 1821−24(M28)	5.1	3	1.1^{-4}	9.3	5.8	0.1	$0.3–1 \times 10^6$
	PSR J2322+2057	0.78	4.8	7.0^{-7}	8.3	4.2	0.3(?)	8
	1E 1841−045	7	11770	4700	≈15	−2	0.5?	$\ll 10^{-10}$

NOTE.—The duty cycle has been estimated from γ-ray observations. Also included are the nearby millisecond pulsar PSR J2322+2057 (Nice et al. 1993) and the anomalous X-ray pulsar 1E 1841−045 (Vasisht & Gotthelf 1997).

HESS est formidable!!

Sol ~~vous l'a dit…~~ ~~le réseau~~ de 4 « imageurs Tcherenkov » de 12 mètres fonctionne *très bien* en Nambibie depuis plus d'un an.

Il est en train de découvrir un tas d'objets galactiques qui mériteront un follow-up Nançay et/ou GLAST.



Science 307, 1938-1942 (2005)

"*A new population of very high energy gamma ray sources in the Milky Way*"

A&A 442, L25-L29 (2005)

"*A possible association of the new VHE gamma-ray source HESS J1825-137 with the pulsar wind nebula G18.0-0.7*"

The "easy" parts

- Judging from EGRET, we expect radio groups will compete for directed searches of candidate pulsars from *GLAST:* most important telescopes will be Arecibo, GBT, Parkes and perhaps Jodrell
- Distance scale is a challenging problem, but
  - Cordes and group have been working on new dispersion model (NE2001)
  - Our group has been doing very large scale VLBA parallax survey (better than 0.1 mas means better than 10% at 1 kpc)
  - Both will be done before *GLAST* flies

The hard parts

- Two key pulsar advances in *GLAST* era:
  - Improved sensitivity of *GLAST* itself
    - EGRET saw primarily the youngest, relatively nearby pulsars
    - *GLAST* will see an older, more distant population
    - Existing surveys are less complete, and possible targets are much larger in number
  - Substantial increase in known pulsar population
    - Parkes Multibeam Survey
      - ~700 new pulsars, many young
    - Arecibo drift surveys
      - Scores of pulsars, biased towards older population & millisecond pulsars
    - Factor of ~3 more pulsars known than when EGRET flew

Follow-up

- All new pulsars must be timed to determine p-dot, E-dot, and detect binary motion
- It takes about a year of observations to separate position from p-dot
- It is roughly 2.6 hours/pulsar, or ~2600 hours!
- This doesn't include longer term monitoring
- So far, time allocation committee has not been very generous with follow-up time

GLAST verra 1 gamma du Crabe par 500 rotations = 16 secondes

Contemporaneous radio timing...

- ...is needed to allow gamma-ray photons to be folded synchronously
- ...was relatively easy when targeting only the brightest pulsars for EGRET
- ...is very hard when the number of potentially interesting sources is much higher
- Must be carried out on the very biggest radio telescopes (Arecibo, GBT, Parkes, Jodrell) in the vast majority of cases

Thorsett n'exclu pas Nançay de cette liste…

Lessons from EGRET

- Major timing programs were set up for CGRO:
  - We studied about 100 pulsars at Green Bank (140ft and a small dedicated telescope, neither available any longer)
  - About 280 were studied at Jodrell
  - Parkes also did regular timing (unknown number)
  - Several special cases observed daily (Crab, Vela, ...)
- Very hard work:
  - Most pulsar observers were involved in the early 1990s
  - All major telescopes were involved
  - Lots of observing time was required

Status for *GLAST*

- Good news is Jodrell: currently timing about 500 pulsars regularly
- Parkes has been doing follow-up on PMB-discovered pulsars and others
- US facilities (GBT, Arecibo) heavily oversubscribed
- Other options still uncertain (e.g., Allen Telescope Array)
- Bottom lines:
  - It will be relatively straightforward to time a comparable set as was done for EGRET
  - This is a much smaller fraction of "interesting" sources

Une occasion pour Nançay

1. Nançay n'a pas forcement vocation de faire concurrence aux usines à éphémérides. En revanche GLAST saura avaler tout ce qui nous voudrions lui proposer.
2. Le gros besoin d'un suivi soutenu me semble être une belle opportunité pour Nançay: on pourra étudier en profondeur un petit nombre d'objets qui nous intéressent particulièrement.
3. On serait heureux de travailler avec des pulsaristes sur un assortiment délectable de pulsars gamma, et de candidats, dont d'éventuels « gemingas ».

The remaining challenge: timing

- Goal: fold time-tagged *GLAST* photons at pulsar period
- Obstacle: pulsar period varies
  - deterministically because of spin-down, binary motion, and observatory motion
  - unpredictably because of "timing noise" and discrete "glitches"
- Plan:
  - monitor radio pulsars over *GLAST* life
  - provide mean parameters and piecewise polynomial fit to pulsar phase (collectively, an "ephemeris")