Pulsars in DC 2: behind the scenes...

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DC 2 Closeout Meeting
(NASA GSFC, May 31-June 2, 2006)

3 months ago,
in a $\gamma$-ray galaxy far, far away...
From Alice’s talk you’ve seen the physics behind the pulsars in DC2.

Now you will see how they have been processed and put into the simulations

- The PulsarSpectrum simulator;
- The PulsarSimTools suite;
- Creating a simulated pulsar population;
- Summary of DC2 pulsar populations;
- The case of EGRET pulsars and 3EG coincident;
- A new gamma-ray pulsar class: the MSP
- Some FAQ about DC2 pulsars…
- DC2 and pulsar simulations: what are next steps?
PulsarSpectrum is a detailed pulsar simulator of gamma-ray emission from pulsars. An upgraded version has been used for simulating pulsars in the DC2.

**Main features:**
- The default model simulates lightcurves and spectra according to the observed $\gamma$ ray pulsars;
- Simulations of barycentric effects due to motion of GLAST and Earth, and gravitational time delays.
- Takes into account period variations with time;
- Interfacing with Gleam;
- Simulated pulsar data are also formatted in an output file that can be converted to D4 format.
The simulation of the lightcurves

The model used in DC2 was a phenomenological one

Lightcurves can be random generated or read from a profile

- Random curves (Lorentz peaks);
- Existing TimeProfiles are useful for simulating known pulsars (here in DC2...)

All these are examples, not the EGRET pulsars in DC2
The simulation of spectra

We choose this analytical spectral shape:
(Nel and De Jager, 1995):

\[
\frac{dN_\gamma}{dE} = K \left( \frac{E}{E_n} \right)^{-g} \exp \left( \frac{-E}{E_0} \right)^{-b}
\]

✓ Description of the high energy cutoff;
✓ Parameters are obtained from fits on the known $\gamma$ ray pulsars (e.g. ref. N, DJ95, and DJ 2003);
✓ Flux normalisation based on 3rd EGRET catalog (ph/cm$^2$/s, E>100MeV);

Example for Vela-like PSR
F(E>100) $\sim$ 9*10$^{-6}$ ph/cm$^2$/s,
$E_n$=1GeV, $E_0$=8GeV;
$g$=1.62

Different scenarios

Data fit

06/02/2C
Input data for pulsar simulations

- **PulsarSpectrum** can be used to simulate set of pulsars (*simulated population*)
- A set of parameters for each pulsar is needed and it is stored in 2 input files

**DataList ASCII file:**
contains ephemerides, and other *model-independent* parameters

**XML source file:**
contains position and *model-dependent* parameters, e.g. spectral parameters

Pulsar name

PulsarSpectrum

DC2 Skymodel

06/02/2006
The Pulsar Simulation Tools

• A suite of ancillary c++ classes and ROOT macros for generating pulsar population data to be used by PulsarSpectrum

• Available under /users/razzano/PulsarSimTools (currently v0r3). (Better documentation must be added)

Principal PulsarSim Tools:

• Population synthetizer: Generate a pulsar population in a phenomenological way using ATNF Radio pulsar catalog and simple theoretical model (up to now only the basic Polar Cap). Not used in the DC2 generation;

• Ephemerides generator: Create ephemerides and validity ranges using ATFN ephemerides distribution or random;

• TH2DMaker: create a 2D ROOT histogram that describe the pulsar (was not implemented at the DC2 simulation stage);

• PulsarSetsViewer: plot pulsar population data (see plots in this talk);

• PulsarFormatter: From population data create input files to PulsarSpectrum;
Pulsars for DC2: the recipe

• An original list of pulsars, e.g. those proposed by Alice Harding + EGRET;
• This contains pulsar position, flux and some spectral parameters (except from exponential cutoff index);
• We need to complete the information by synthetizing other parameters, like epoch and ephemerides validity range;
The DC2 pulsar population contains 6 sub-populations

- EGRET pulsars;
- 3EG-coincident pulsars;
- “Normal” pulsars with and without Radio-counterparts;
- Millisecond pulsars with and without Radio-counterparts;

• We define as **Radio-Quiet (RQ)** pulsars that does not have a radio counterpart visible because of low radio flux or geometry. We call the others **Radio-Loud (RL)**

• Each RL has an entry in the D4 e.g. PSR_JHHMMpDDMM. The RQ have a code DC2_JHHMMpMMDD (now available in a D4-format)
Identikit of a DC2 pulsar

• For every pulsar in DC2 a correspondant “ID card” has been produced by Seth Digel

• These ID contains info about main properties of simulated pulsar

• Ephemerides validity range was chosen to contain the 55 days for most pulsars (but not for all…)

• These are available on the Web
The major arcana: EGRET pulsars (I)

- The lightcurves come directly from the EGRET papers;
- Spectra are obtained by gamma-ray fits (see e.g. De Jager 1995)
For weakest EGRET pulsars we keep the original binning. No further interpolations.
The 3EG coincident pulsars

We included 39 simulated pulsars within 3EG error boxes. Each of them was simulated with **Slot Gap emission model**
The normal pulsars (I)

Radio-Loud: 37 pulsars

Radio-Quiet: 103 pulsars
The normal pulsars (II)

- The spectral model is the Slot Gap;
- We choose a super-exponential cutoff index $b$ ranging from 1.8 to 2.2;
- RQ are generally more far away, the flux distribution is expected to be shifted;
- We select pulsars with flux $> 10^{-9}$ ph/cm$^2$/s;

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The millisecond pulsars(I)

Radio-Loud:
17 MSP

Radio-Quiet:
212 MSP
The millisecond pulsars (II)

Spectral model with exponential index fixed to 1
(according to model by A. Harding)

We increased some fluxes to be sure that users will detect at least some MSP
The brightest RL MSPs

These should have been the first MSP detected in DC2, here are their IDs

- **Razzano/Harding DC2 Pulsar: PSR_J0904m5008**
  - Class: Msec RL
  - Flux (>100 MeV): 1.26E-06 cm$^{-2}$ s$^{-1}$
  - Flux (>10 GeV): 3.36E-07 cm$^{-2}$ s$^{-1}$

- **Razzano/Harding DC2 Pulsar: PSR_J0717m1235**
  - Class: Msec RL
  - Flux (>100 MeV): 5.93E-07 cm$^{-2}$ s$^{-1}$
  - Flux (>10 GeV): 1.35E-07 cm$^{-2}$ s$^{-1}$

- **Razzano/Harding DC2 Pulsar: PSR_J1735m5757**
  - Class: Msec RL
  - Flux (>100 MeV): 3.37E-07 cm$^{-2}$ s$^{-1}$
  - Flux (>10 GeV): 6.62E-08 cm$^{-2}$ s$^{-1}$

Actually very near Vela, disturbed analysis of Vela-Jr....

...sorry about that....
The brightest RQ pulsars

• For pulsar blind searches checks, here are the brightest RQ pulsars in the DC2 sky
• Detailed data can be found in the HTML tables

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<th>Name</th>
<th>F&gt;100MeV</th>
<th>FREQ/PER</th>
<th>P/F0</th>
<th>Pdot/F1</th>
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Where to find the truth data

All the data used for the pulsars in DC2 are now available at:

www-glast.slac.stanford.edu/software/DataChallenges/DC2/SkyModel/simulated_data.htm

Here you can find:

• Data for each pulsar;
• Pulsar “Id cards” (lightcurves and spectra)
• Pulsar database for all pulsars (RL and RQ)

Check the results of our analysis...have fun with that!
Some pulsars FAQ...

Q: The J1631m4813 phase curve show a peak. It is normal? (A.Caliandro)
A: Yes, it comes from the model, since it represents a very narrow emission profile, and there is also binning effects

Q: Several pulsar have wide peaks. Physics, or messy ephemerides? E.G. J1735-5757 (D.Smith)
A: Yes, they are, single and broad pulses. It is from the model of ms pulsar adopted. In addition, since it is a MSP, timing effects can be very important.

I will try to give an answer...
Q: Fierro light curves (i.e. templates for simulations) are shifted with respect to the reconstructed phase curve. Strange shift… (D. Smith)

A: Yes, but they are ok since we include these shifts by hand. In the D4 there is a column named TOAXBARY_INT and TOAXBARY_FRAC. It represent the time where a particular point of the lightcurve occur. In real life one can define for example one peak, but in simulations we decided to use the start of the TimeProfile. Then, if TOAXBARY is the same of TEPOCH it means that the reconstructed photons are not shifted, otherwise they are, as in EGRET pulsars.

Congratulations to David & Bordeaux people because they notice that. This means that EGRET pulsars have been looked carefully and with reference to the literature
DC2 pulsars: a group picture...

Credits: Seth Digel

06/02/2006

M. Razzano - DC II Closeout Meeting
Conclusions...from DC2 to the future...

- What we’ve learned after DC2 from the point of view of simulations?
- The DC2 was an excellent opportunity to test simulator and the pulsar simulation chain (Model→FT1 data files);
- Apart from PulsarSpectrum, a suite of additional tools have been developed and tested for simulating large number of pulsars (total=414 pulsars);
- Simulations under more “extreme” conditions have been tested (long observation time, big number of sources, multiple runs, etc...). We faced some problems and we solved after some troubles;
- PulsarSpectrum need to be upgraded to better support longer observation times (refine decimal precision in variables);
- PulsarSpectrum need two major upgrades: phase-dependent spectra and binary demodulation (under development)
- Refine input data (e.g. more detailed lightcurves for EGRET pulsars);
- Lots of important issues identified→now its time to be ready for longer and more detailed observation simulations