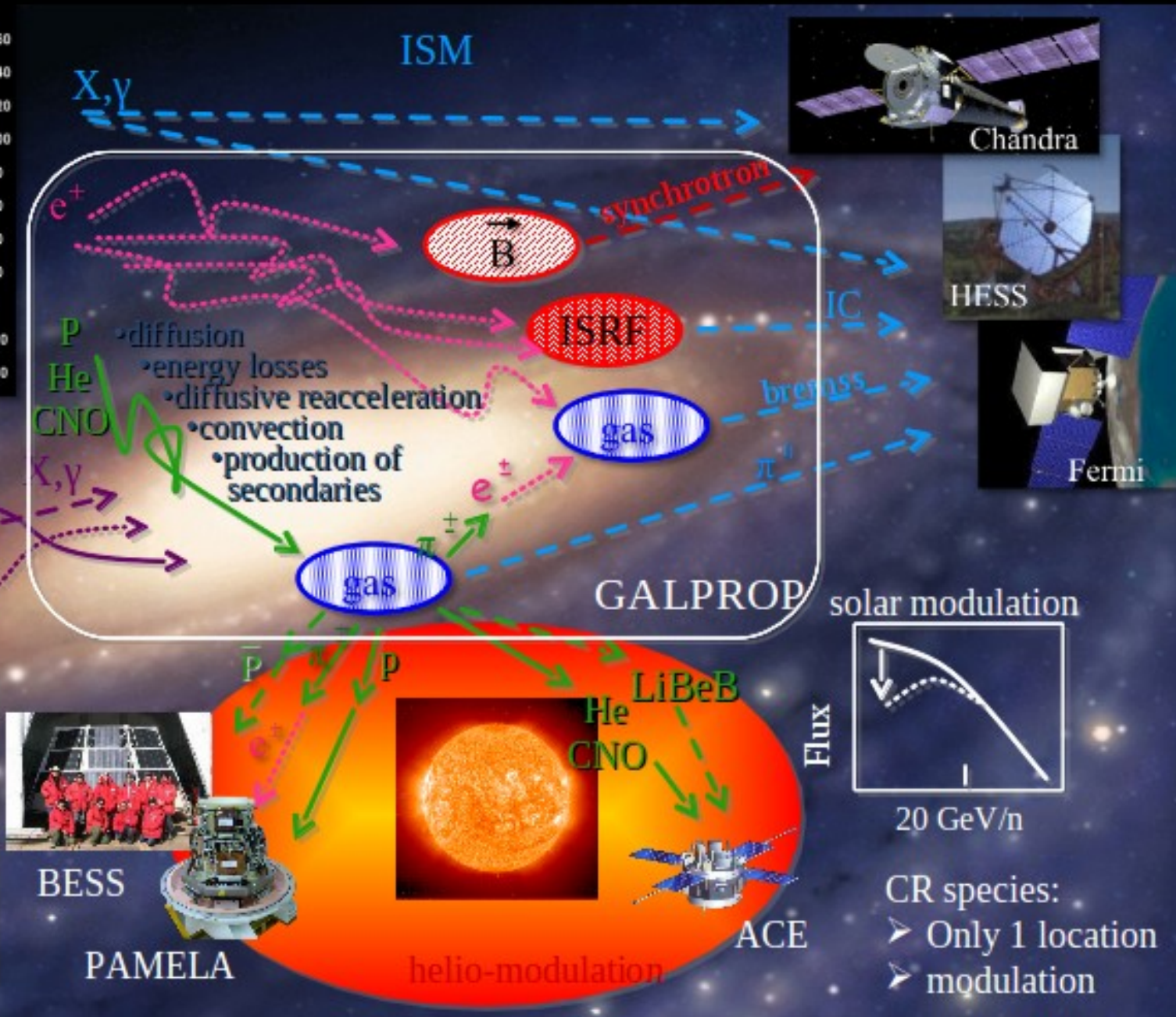
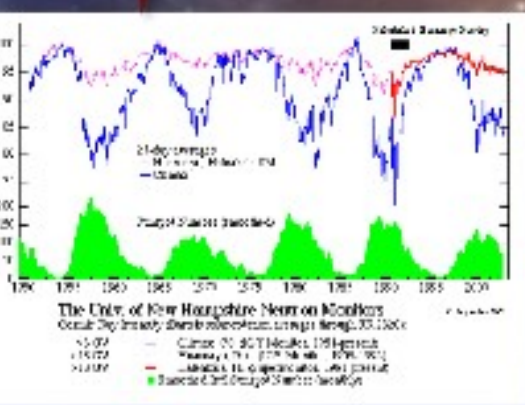
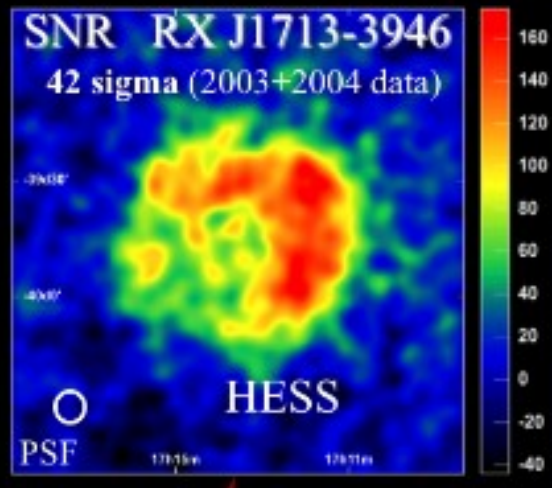


# Calculations in GALPROP WebRun and applications for the analysis of the Fermi-LAT data



Fermi Summer School 2012  
Lewes, Delaware

# CRs in the Interstellar Medium





# Components of GALPROP

- ◇ Detailed gas distribution from HI and CO gas surveys (energy losses from ionization, bremsstrahlung; secondary production;  $\gamma$ -rays from  $\pi^0$ -decay, bremsstrahlung)
- ◇ Interstellar radiation field in 2D and 3D (inverse Compton losses/ $\gamma$ -rays for  $e^\pm$ )
- ◇ Models of the Galactic magnetic field
- ◇ Nuclear & particle production cross sections + the reaction network (cross section database + LANL nuclear codes + phenomenological codes)
- ◇ Propagation modes: Diffusion, diffusive acceleration, convection
- ◇ Numerically solves transport equations for all cosmic ray species (stable + long-lived isotopes + pbars + leptons  $\sim 90$  equations) in 2D or 3D
- ◇ State-of-the-art propagation code, a de facto standard in astrophysics of cosmic rays and diffuse gamma rays (Strong & IVM and GALPROP team 1998-2012)



# CRs and Diffuse Galactic Emissions (gamma-rays, synchrotron)

## ◇ Origin and propagation of CRs

- ✦ Nature and distribution of CR sources
- ✦ Abundances of primary species
- ✦ Production of secondary species
- ✦ Propagation modes and their relationship to magnetic turbulence in the ISM

## ◇ Interstellar Medium (gas species)

- ✦ Distribution of HI, H<sub>2</sub>, HII gas
- ✦ Nature of X<sub>CO</sub> relation in Galaxy
- ✦ Distribution and intensity of interstellar radiation field and formation of H<sub>2</sub>
- ✦ Physics of HI

## ◇ Foreground against which sources are detected

- ✦ Point sources: limitation on sensitivity
- ✦ Extended sources: disentanglement
- ◇ Indirect dark matter detection
  - ✦ Predicted  $\gamma$ -ray/CR signals
  - ✦ Relies on accurate treatment of standard astrophysical sources
- ◇ Foreground for isotropic diffuse background
  - ✦ Whatever its nature
- ◇ Synchrotron foreground
  - ✦ WMAP & PLANCK

# GALPROP WebRun

- GALPROP WebRun is a service that allows to run GALPROP online
- No local installation of the code or related libraries is necessary; only a web browser is required
- Available at **<http://galprop.stanford.edu/webrun>**
- Calculations are performed on a 192-cores computing cluster at Stanford University, using the most recent GALPROP v54.1
- The service is free and open to the community  
Registration is required.

The purpose of this talk is to demonstrate how to use the GALPROP WebRun to produce physically motivated diffuse emission maps for the subsequent analysis of the Fermi-LAT data

See also the lecture by Seth Digel on the diffuse gamma-ray emission



# Configuring GALPROP via WebRun

The screenshot shows the GALPROP WebRun interface in a browser window. The URL is <http://galprop.stanford.edu/webrun/>. The page features a navigation menu with links for CODE, WEBRUN, FORUM, RESOURCES, PUBLICATIONS, CONTACTS, and BUGS?. A search bar and a 'Logout [ avladim ]' link are also present. The main content area is titled 'Common Parameters' and includes a table with the following data:

Name	Value	Description
Title	Plain diffusion mod	Descriptive title used to identify the run.
n_spatial_dimensions	2	Specifies whether 2 or 3 spatial dimensions.

Below this is the 'Energetic and Spatial Grids' section with another table:

Name	Value	Description
r_min	00.0	Minimum galactocentric radius (R) for 2D case, in kpc. Ignored for 3D.
r_max	20.00	Maximum galactocentric radius (R) for 2D case, in kpc. Ignored for 3D.
dr	1.0	Cell size in galactocentric radius (R) for 2D case, in kpc.
z_min	-4.0	Minimum height for 2D and 3D case, in kpc.
z_max	+4.0	Maximum height for 2D and 3D case, in kpc.
dz	0.1	Cell size in z for 2D and 3D case, in kpc

The 'CR Propagation' section contains a third table:

Name	Value	Description
D0_xx	2.2e28	The spatial diffusion coefficient divided by beta=v/c at rigidity D_rigid_br. The value at other rigidities is determined via the formula $D = \beta D_{0xx} (\rho / D_{rigid\_br})^{D_g}$ , where $D_g = D_{g\_1}$ for rigidity less than $D_{rigid\_br}$ , and $D_g = D_{g\_2}$ for rigidity greater than $D_{rigid\_br}$ .
D_rigid_br	3.0e3	Rigidity for D0_xx formula, and also break point in case $D_{g\_1} \neq D_{g\_2}$ .
D_g_1	0.	Diffusion coefficient index below reference rigidity. See formula for D0_xx. Kolmogorov turbulence corresponds to a value 1/3.
D_g_2	0.60	Diffusion coefficient index below reference rigidity. See formula for D0_xx. Kolmogorov turbulence corresponds to a value 1/3.

On the left side, there is a sidebar with 'WebRun Help', 'Configure & Submit', 'Monitor Queue', and 'Download Results'. A note at the bottom left says 'Please remember to cite GALPROP'.

Interactive interface for parameter entry.  
Parameters are validated to avoid misconfigured runs.


# Gamma-ray emission

- Click on the panel “Emission”
- Put “gamma\_rays=1”
- Put “skymap\_format=1”

skymap\_format=1 means that you will obtain the mapcube for Fermi Science Tools in the output



# Panel "Emission" in the WebRun



[galprop.stanford.edu](http://galprop.stanford.edu)  
 studies of cosmic rays and galactic diffuse gamma-ray emission

CODE
WEBRUN
FORUM
RESOURCES
PUBLICATIONS
CONTACTS
BUGS?

Logout [ phdmityr ]

**GALPROP version: 54**  
click to change

**WebRun Help**

Configure & Submit

Help: Configure & Submit

First-time User Mode

Advanced User Mode

Show fixed parameters

Show inactive parameters

Show validation rules

Batch Runs

Monitor Queue

Download Results

Exchange Runs

Please remember to  
[cite GALPROP](#)

Enter the desired GALPROP v. 54 parameters and click 'Submit' at **the bottom of the form** ↓

Common	Grids	Propagation	Gas	Sources	Emission	Abundances
Name	Value	Description				
gamma_rays	1	Indicates whether to compute diffuse Galactic gamma-ray skymaps and emissivities. (0: do not compute gamma rays, 1: compute total gamma rays, 2: compute HI, H2 skymaps separately) See <a href="#">manual</a> .				
pi0_decay	3	Indicate whether to include pi0-decay in the calculation of gamma ray emission. 0: no pion decay, 1: standard formalism ( <a href="#">Moskalenko &amp; Strong (1998)</a> ), 2: <a href="#">Blattnig et al. (2000)</a> , 3: <a href="#">Kamae et al. (2006)</a>				
IC_isotropic	1	Indicates whether to compute isotropic inverse compton (IC) emission. 0: no IC computation, 1 to compute total emission, 2 to store components separately.				
IC_anisotropic	0	Indicates whether to compute anisotropic inverse compton (IC) emission (0: no, 1: yes).				
bremss	1	Indicates whether to compute bremsstrahlung (0: no, 1: yes).				
E_gamma_min	100	Minimum gamma-ray energy (MeV) for diffuse gamma-ray maps.				
E_gamma_max	1.0e6	Maximum gamma-ray energy (MeV) for diffuse gamma-ray maps.				
E_gamma_factor	1.5	The ratio between successive gamma-ray energy grid points (i.e., ratio of high to low end of photon energy bins for calculations and output).				
ISRF_factors	1.0,1.0,1.0	Scaling factors for inverse Compton from separate components: optical, FIR and CMB. Normally should be 1.0.				
synchrotron	0	Indicates whether to compute synchrotron skymaps (0: no, 1: yes). Requires primary_electrons=1.				
long_min	0	Minimum galactic longitude for gamma-ray intensity skymaps (degrees). In ver. 54, the first longitude bin spans [long_min ... long_min+d_long]. Only used when Skymap_format <= 2.				
long_max	360	Maximum galactic longitude for gamma-ray intensity skymaps (degrees). In ver. 54, the last longitude bin spans [long_max-d_long ... long_max]. Only used when Skymap_format <= 2.				
lat_min	-90	Minimum galactic latitude for gamma-ray intensity skymaps (degrees). In ver. 54, the first latitude bin spans [lat_min ... lat_min+d_lat]. Only used when Skymap_format <= 2.				
lat_max	+90	Maximum galactic latitude for gamma-ray intensity skymaps (degrees). In ver. 54, the last latitude bin spans [lat_max-d_lat ... lat_max]. Only used when Skymap_format <= 2.				
d_long	1.0	Binsize in longitude for gamma-ray intensity skymaps (degrees). Only used when Skymap_format <= 2.				
d_lat	1.0	Binsize in latitude for gamma-ray intensity skymaps (degrees). Only used when Skymap_format <= 2.				
skymap_format	1	Skymap fitsfile format: 0=old format (see <a href="#">manual</a> ), 1=mapcube for <a href="#">Fermi Science Tools</a> , 2=hnhh 3=HFAI Pix				

# galdef file = the text file that defines the parameters for the Galprop calculation

## **Good to go!**

The parameters you requested are appropriate for the GALPROP ver. 54 calculation.

A GALDEF configuration file with your parameters has been generated.

**Click the 'Add Job to Queue' button to add this job to your run queue on the the GALPROP server.**

After that you will be taken to the Monitor, where you can observe the progress of your calculation or manage your queue.

## Configuration Viewer

phdmity's run #000p (GALPROP v.54, completed):

Download

View Log

Quick Plots

Import

Delete

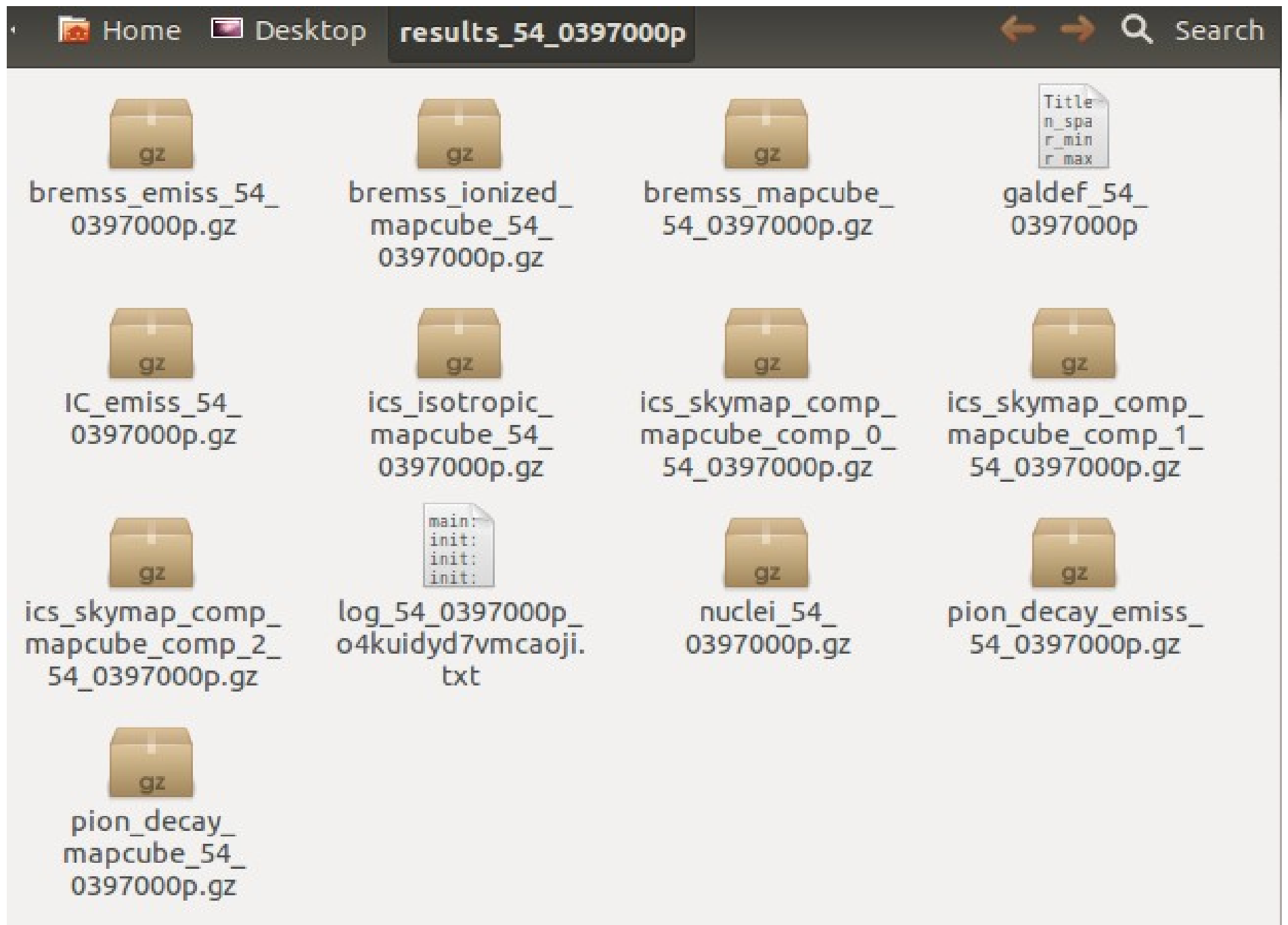
Submitted on (YYYY/MM/DD): 2012/06/03 at 19:55:53 PDT  
Launched on (YYYY/MM/DD): 2012/06/03 at 19:55:55 PDT  
Finished on (YYYY/MM/DD): 2012/06/03 at 20:05:39 PDT  
Exit Status: success

Calculation parameters (may be re-used by clicking 'Import' above):

```
Title = Untitled WebRun calculation
n_spatial_dimensions = 2
  r_min = 0.0
  r_max = 25.0
  dr = 1.0
  z_min = -04.0
  z_max = +04.0
  dz = 0.2
  x_min = -20.0
  x_max = +20.0
  dx = 1.0
  y_min = -20.0
  y_max = +20.0
  dy = 1.0
p_Ekin_grid = Ekin
  p_min = 1000
  p_max = 4000
  p_factor = 1.3
  Ekin_min = 1.0e1
  Ekin_max = 1.0e8
  Ekin_factor = 1.3
  gamma_rays = 1
  pi0_decay = 3
  IC_isotropic = 1
  IC_anisotropic = 0
  bremss = 1
integration_mode = 0
  E_gamma_min = 100
  E_gamma_max = 1.0e6
  E_gamma_factor = 1.5
  ISRF_factors = 1.0,1.0,1.0
```



# MAPCUBE files produced with GALPROP



# How to run the GALPROP WebRun using the galdef files

**GALPROP version: 54**  
click to change

Enter the desired GALPROP v. 54 parameters and click

**Common**   **Grids**   **Propagation**   **Gas**

Import configuration from:

### Common Parameters

Name	Value	
Title	Untitled WebRun	Descriptive title used to identify
n_spatial_dimensions	2	Specifies whether 2 or 3 spatial
timestep_print	10000	The full cosmic-ray density array needed for normal runs, and set to eliminate unnecessary output. Use
timestep_diagnostics	10000	Diagnostics to evaluate the quality normally only occasionally as specified. For normal runs, set this parameter for debugging.
control_diagnostics	0	Controls the amount of detail in (should become large at end of for explanation of output.
network_iterations	2	Number of iterations of the entire important; use 1 if a ~10 percent used to confirm convergence. More (12) may require more than 10 ite
output_gcr_full	0	Set to 0 to output spectra of all output of spectra (all z).
verbose	0	Controls level of output. -1: error 1 through 10: levels of debuggin

### Energetic and Spatial Grids

Name	Value	
r_min	0.0	Minimum galactocentric radius (l

**WebRun Help**

**Configure & Submit**

Help: Configure & Submit

First-time User Mode

**Advanced User Mode**

- Show fixed parameters
- Show inactive parameters
- Show validation rules

**Batch Runs**

**Monitor Queue**

**Download Results**

**Exchange Runs**

Submit an archive with galdef files for GALPROP v. 54 for a batch of runs

Upload an archive with galdef files for your new batch run:

Browse...

Upload

More Info

**Note:** Processing time is proportional to the number of galdef files in the archive.

## **Fermi-LAT Observations of the Diffuse $\gamma$ -Ray Emission: Implications for Cosmic Rays and the Interstellar Medium by Ackermann et al. 2012, ApJ, 750, 3**

The parameter files of the GALPROP models used in this paper are available in the supplementary material to this paper available in the online journal. These give a precise definition of the models used which can be reproduced as required.

**<http://galprop.stanford.edu/PaperIISuppMaterial/>**



How to include MapCube files in a xml source model before performing likelihood analysis of the Fermi-LAT data

```
<source name="SOURCE_NAME" type="DiffuseSource">  
<spectrum type="ConstantValue">  
<parameter free="1" max="10.0" min="0.0" name="Value"  
scale="1.0" value="1.0"/>  
</spectrum>  
<spatialModel file="MAPCUBE.fits" type="MapCubeFunction">  
<parameter free="0" max="1000.0" min="0.001"  
name="Normalization" scale="1.0" value="1.0"/>  
</spatialModel>  
</source>
```

If you use the GALPROP WebRun, please acknowledge by citing the GALPROP webpage and GALPROP publications

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