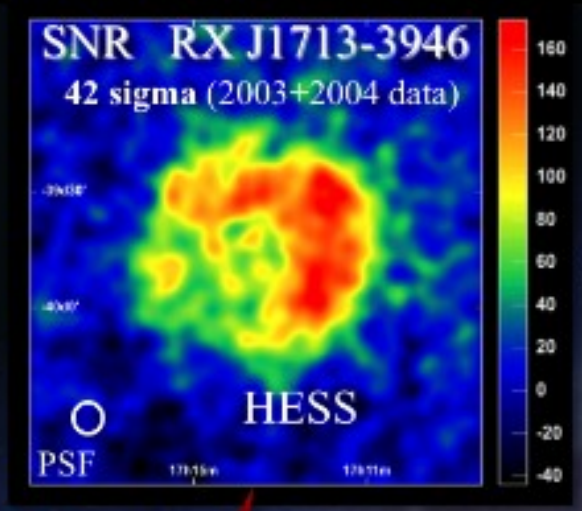
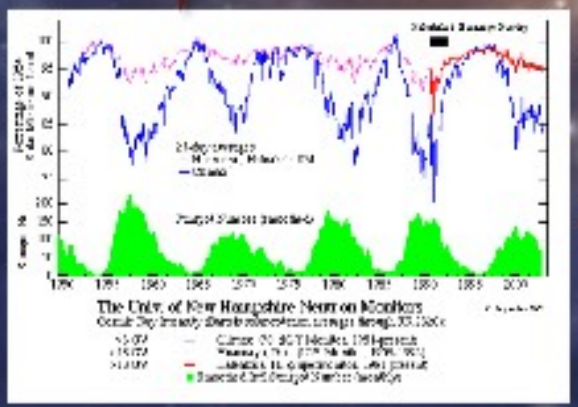
Calculations in GALPROP WebRun and applications for the analysis of the Fermi-LAT data

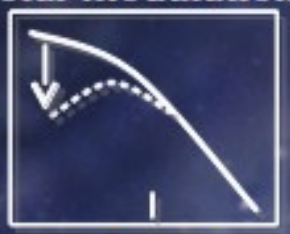
Fermi Summer School 2012

Lewes, Delaware

CRs in the Interstellar Medium







ISM

X,γ

synchrotron

IC

brems

$\vec{B}$

ISRF

gas

gas

e+

P
He
CNO

•diffusion
•energy losses
•diffusive reacceleration
•convection
•production of secondaries

X,γ

P, $\bar{P}$

e±

π±

WIMP annihil.

GALPROP

$\bar{P}$

P

e±

LiBeB

He
CNO

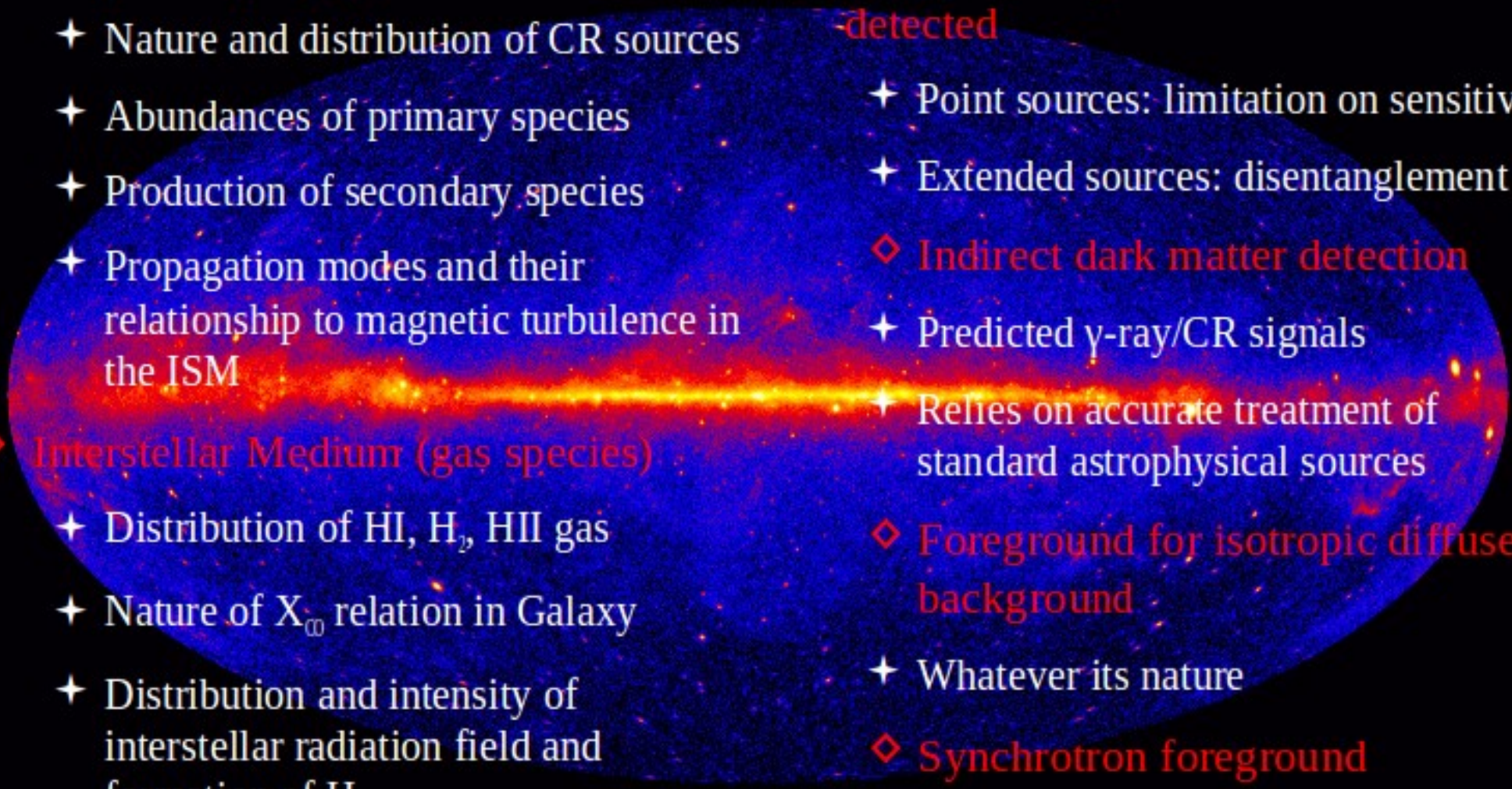
helio-modulation

CR species:
- Only 1 location
- modulation

Components of GALPROP

- Detailed gas distribution from HI and CO gas surveys (energy losses from ionization, bremsstrahlung; secondary production; γ-rays from π^0-decay, bremsstrahlung)
- Interstellar radiation field in 2D and 3D (inverse Compton losses/γ-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 ~ 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_2, HII gas
  - Nature of X_{CO} relation in Galaxy
  - Distribution and intensity of interstellar radiation field and formation of H_2
  - Physics of HI
- Foreground against which sources are detected
  - Point sources: limitation on sensitivity
  - Extended sources: disentanglement
- Indirect dark matter detection
  - Predicted γ-ray/CR signals
  - Relies on accurate treatment of standard astrophysical sources
- Foreground for isotropic diffuse background
  - Whatever its nature
- Synchrotron foreground
  - WMAP & PLANCK

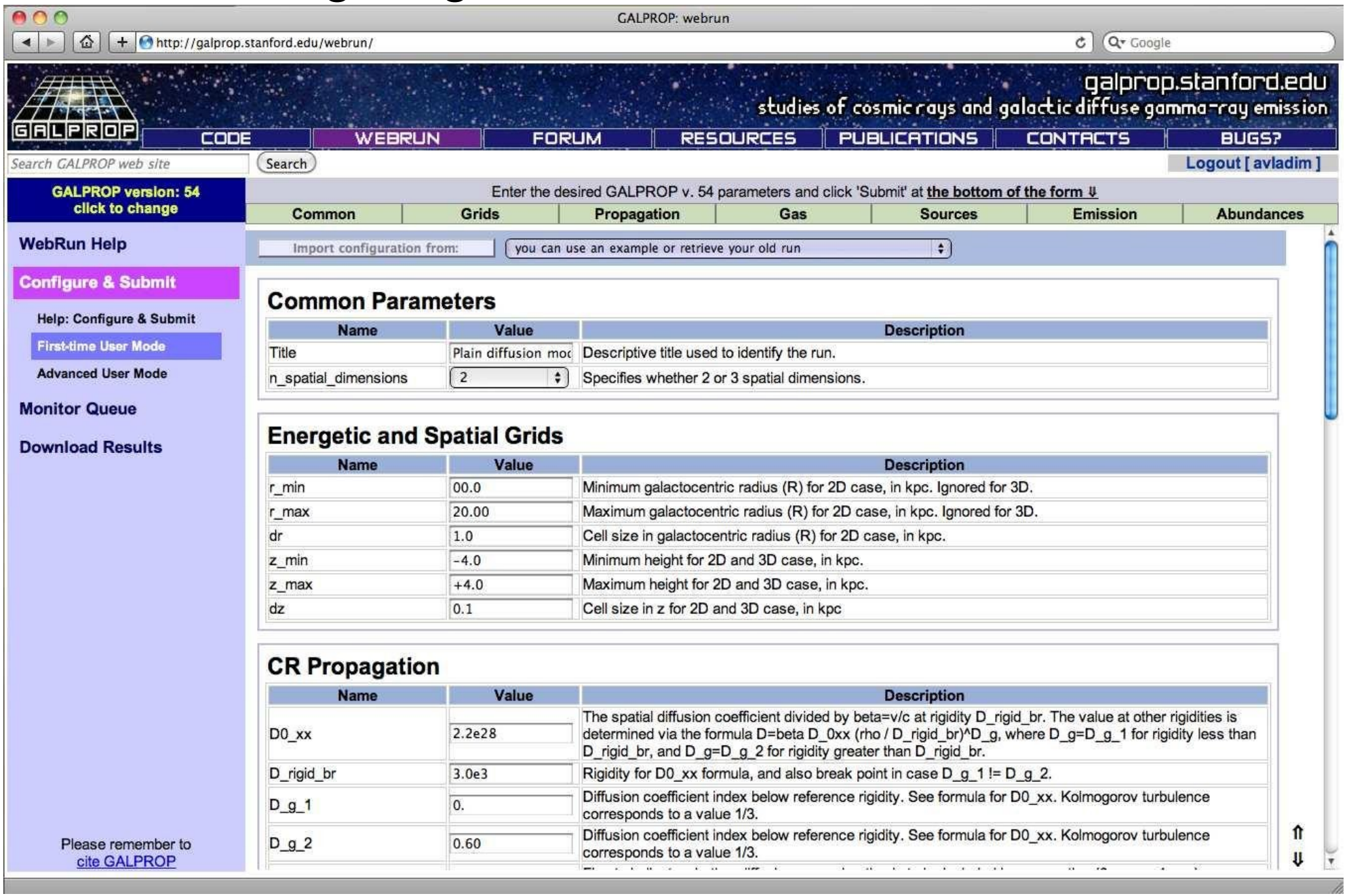
GALPROP WebRun

- 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



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

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 manual.
pi0_decay	3	Indicate whether to include pi0-decay in the calculation of gamma ray emission. 0: no pion decay, 1: standard formalism (Moskalenko & Strong (1998)), 2: Blattnig et al. (2000), 3: Kamae et al. (2006)
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 manual), 1=mapcube for Fermi Science Tools, 2=both, 3=HEALPix

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

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

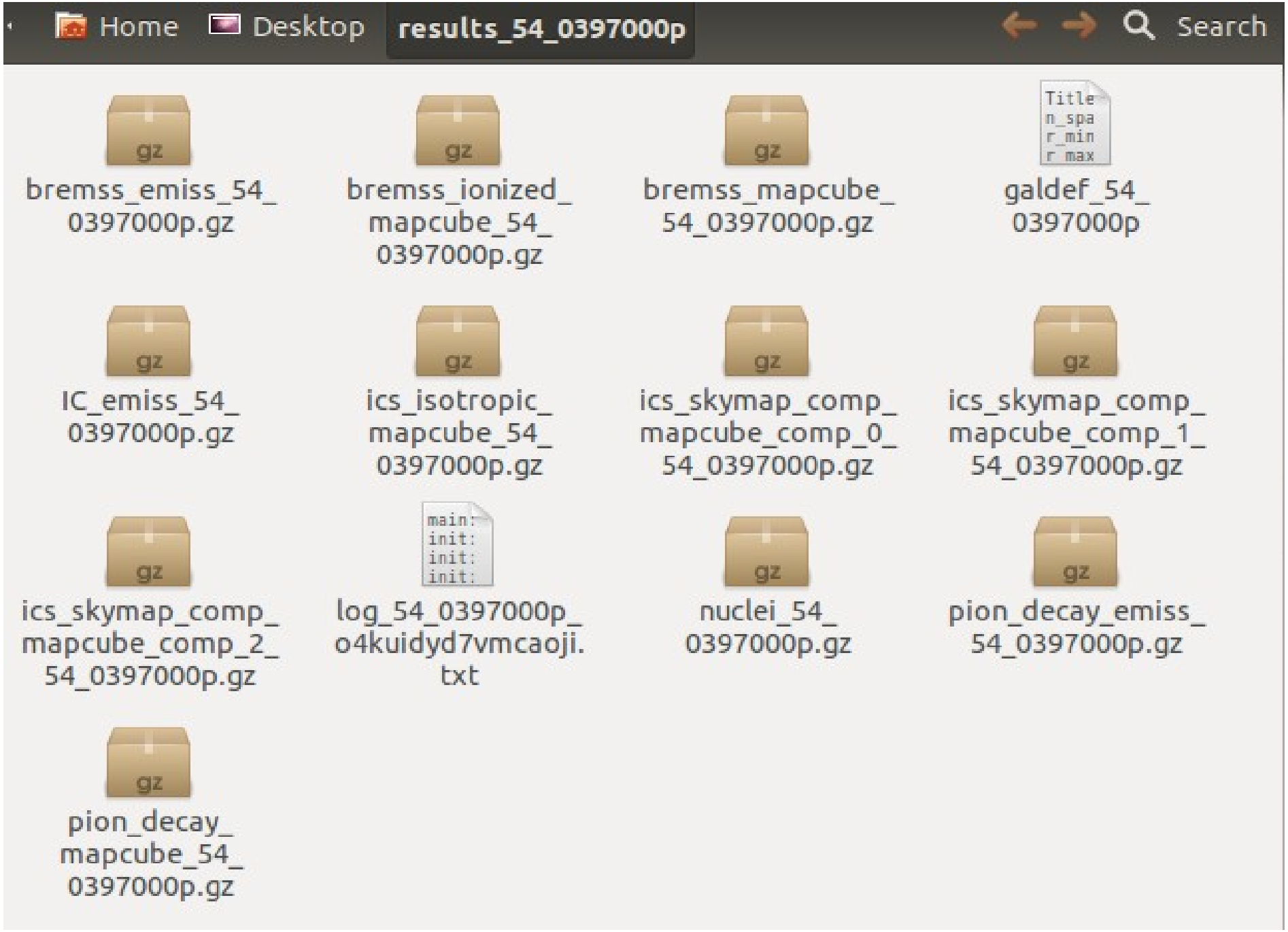
Download | View Log | Quick Plots | Import | Delete

```
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
```

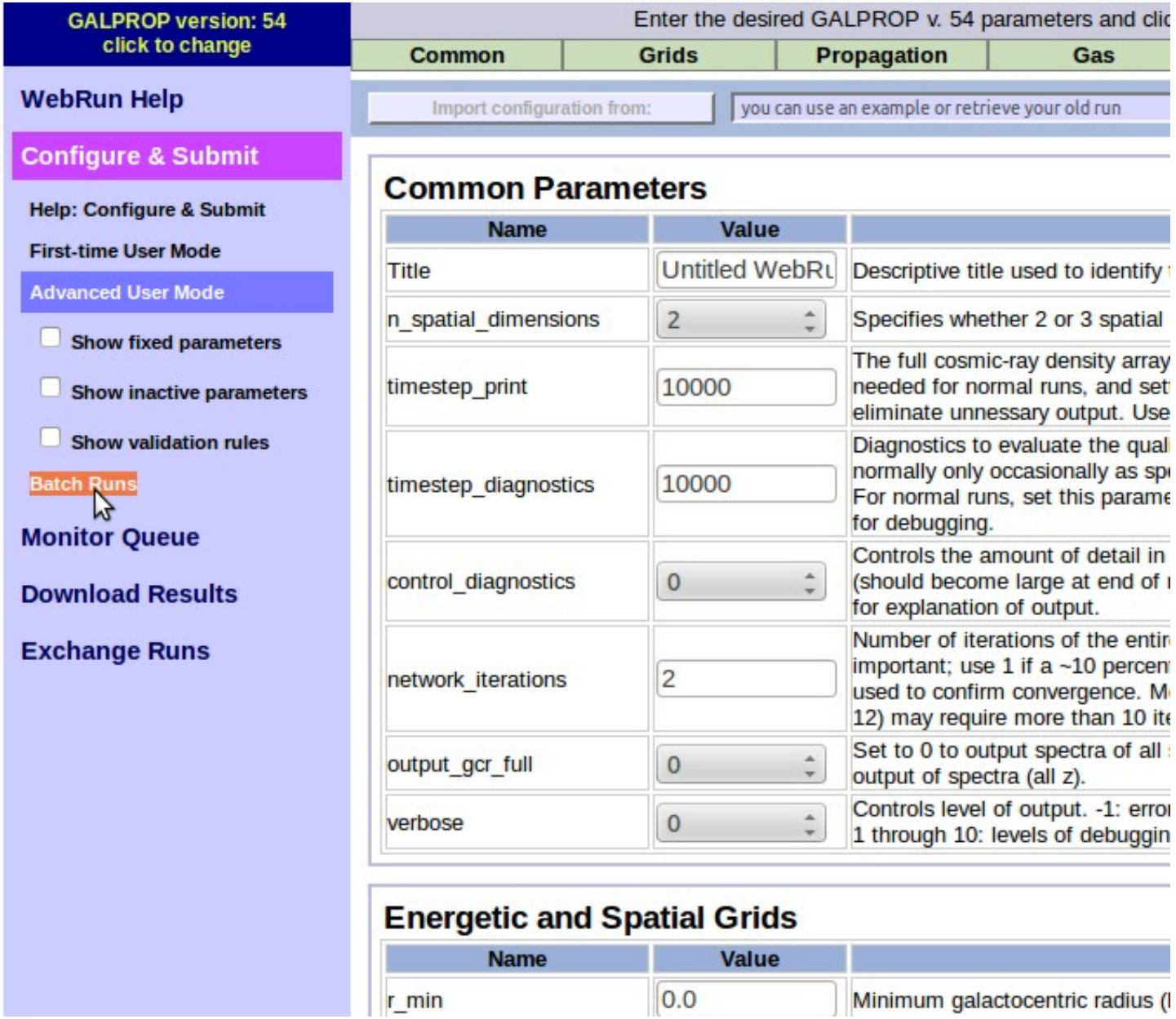
Calculation parameters (may be re-used by clicking 'Import' above):

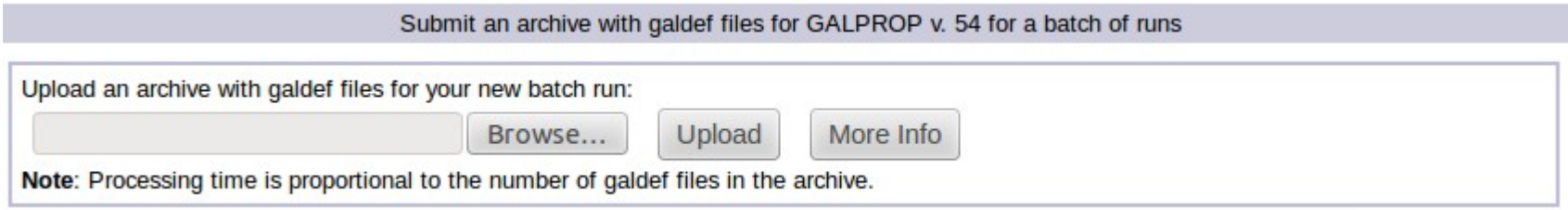
```
                Title = Untitled WebRun calculation
n_spatial_dimensions = 2
               r_min = 0.0
               r_max = 25.0
                  dr = 1.0
               z_min = -04.0
               z_max = +04.0
                  dz = 0.2
               x_min = -20.0
               x_max = +20.0
                  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





Fermi-LAT Observations of the Diffuse γ-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

GALPROP team:

Seth Digel
Guðlaugur Jóhannesson
Igor Moskalenko
Elena Orlando
Troy Porter
Andrew Strong
Andrey Vladimirov

http://galprop.stanford.edu/contact.php