THE AGILE GAMMA-RAY LEGACY ARCHIVE AND THE EASY AGILE-LV3 WEB TOOL

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on behalf of C. Pittori, F. Verrecchia

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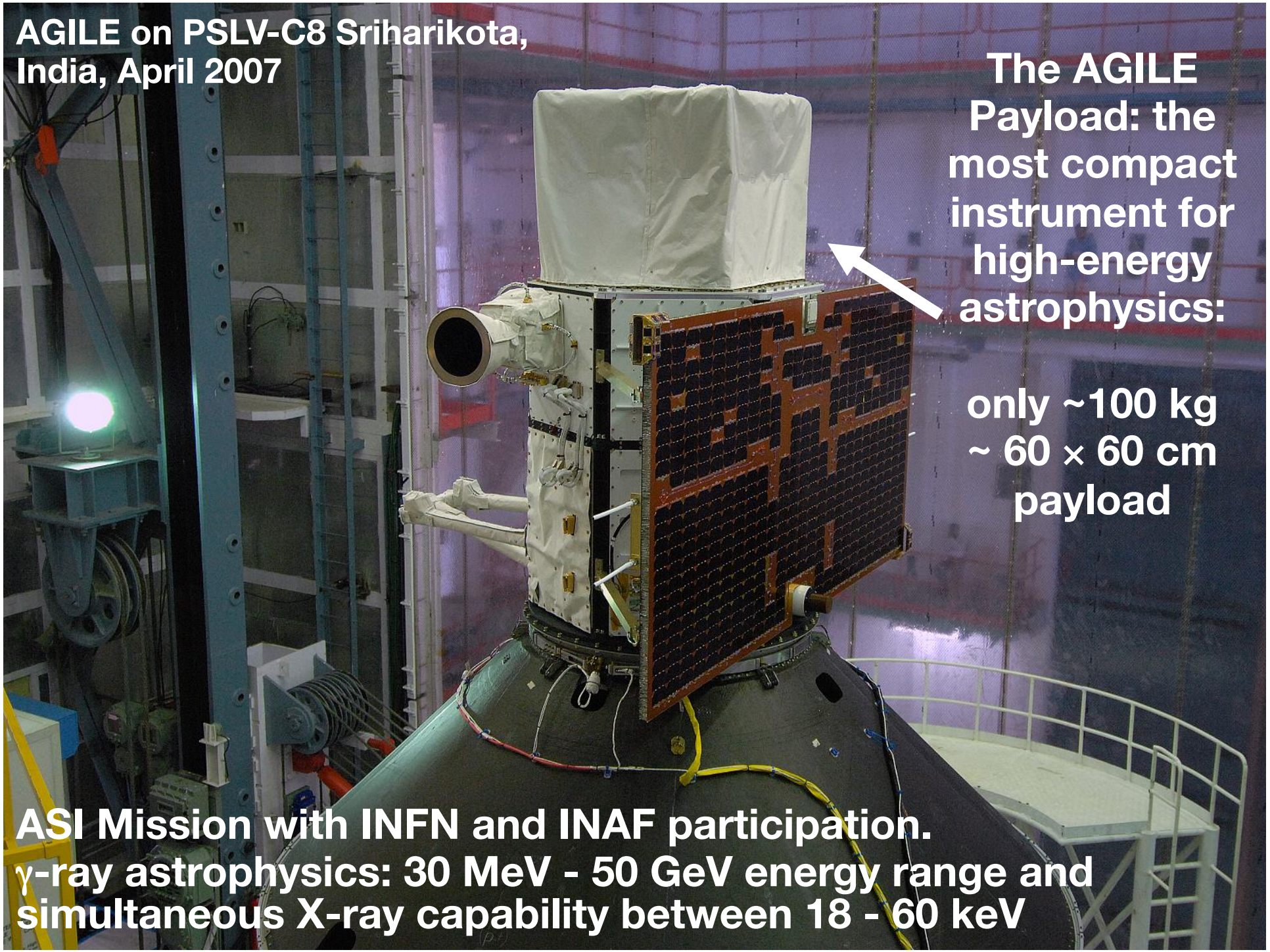
INAF - Astr. Obs. of Rome

OUTLINE

- The AGILE gamma-ray mission
- The AGILE gamma-ray data analysis
- The online interactive analysis tool and the AGILE-LV3 archive
- Summary and conclusions

THE AGILE GAMMA-RAY MISSION


AGILE on PSLV-C8 Sriharikota,
India, April 2007
The AGILE Payload: the most compact instrument for high-energy astrophysics:
only ~100 kg
~ 60 × 60 cm payload
ASI Mission with INFN and INAF participation.
γ-ray astrophysics: 30 MeV - 50 GeV energy range and simultaneous X-ray capability between 18 - 60 keV

GRID performances:

A_eff = 300-350 cm^2 @ 100 MeV (~500 cm^2 above 400 MeV)

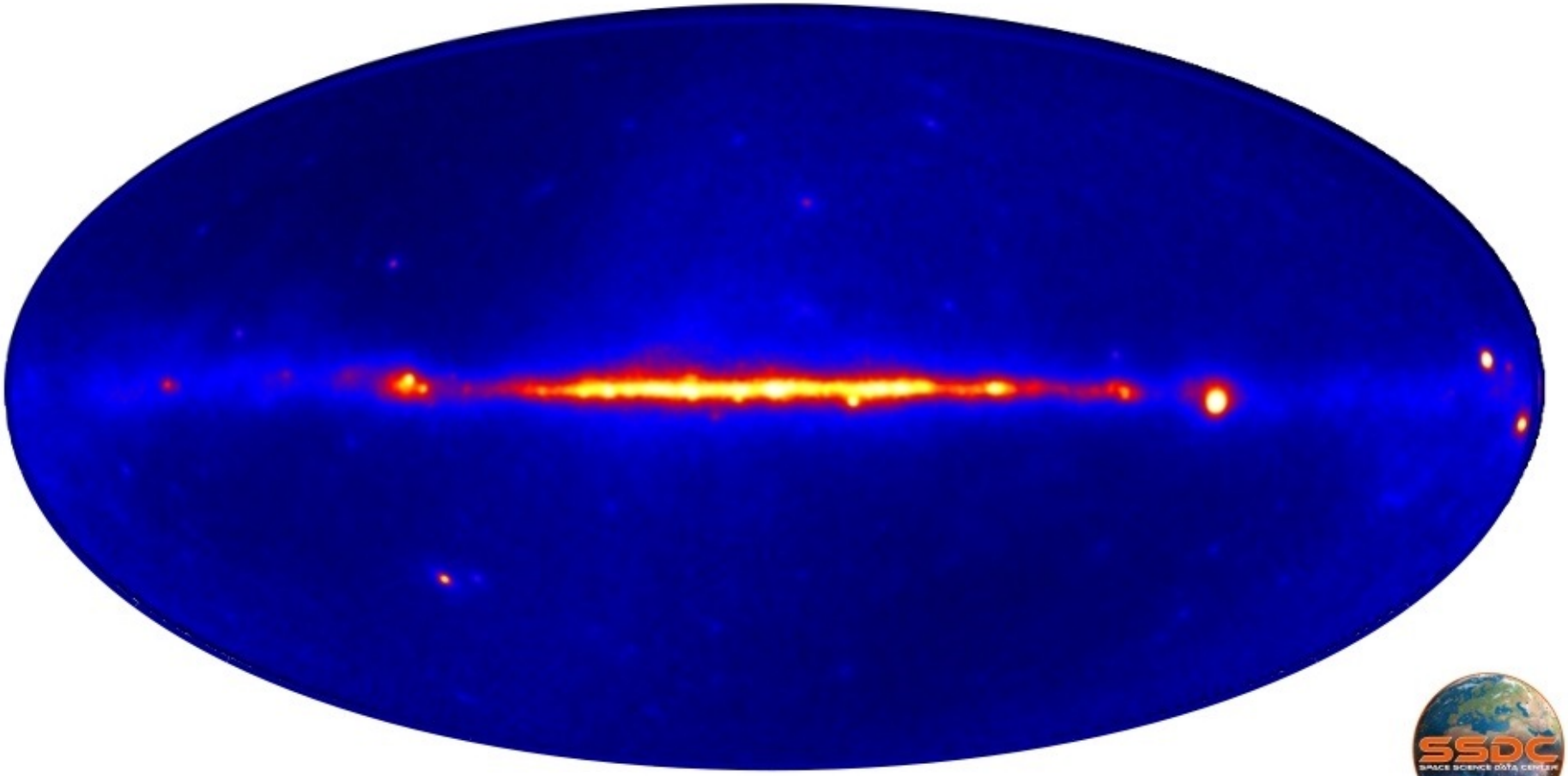
Angular Res. (68% cont.radius) = 3.5° @100 MeV (1.2° @ 400 MeV)

TWO "LIFES" OF AGILE

	AGILE-POINT	AGILE-SPIN
time period	Jul.07 – Oct.09	Nov. 2009 - today
attitude	fixed	variable (spinning ~ 1°/sec)
sky coverage	1/5	~ 70-80 %
1-day exposure (≤ 30 deg off-axis, @ 100 MeV)	~ 2×10^7 (cm^2 sec)	$(0.5\text{-}1) \times 10^7$ (cm^2 sec)

2-day Flux sensitivity in spinning (E>100 MeV, @5σ): 2÷4 x 10^{-6} ph cm^{-2} s^{-1}
1-yr Flux sensitivity in spinning (E>100 MeV, @5σ): 1÷8 x 10^{-7} ph cm^{-2} s^{-1}

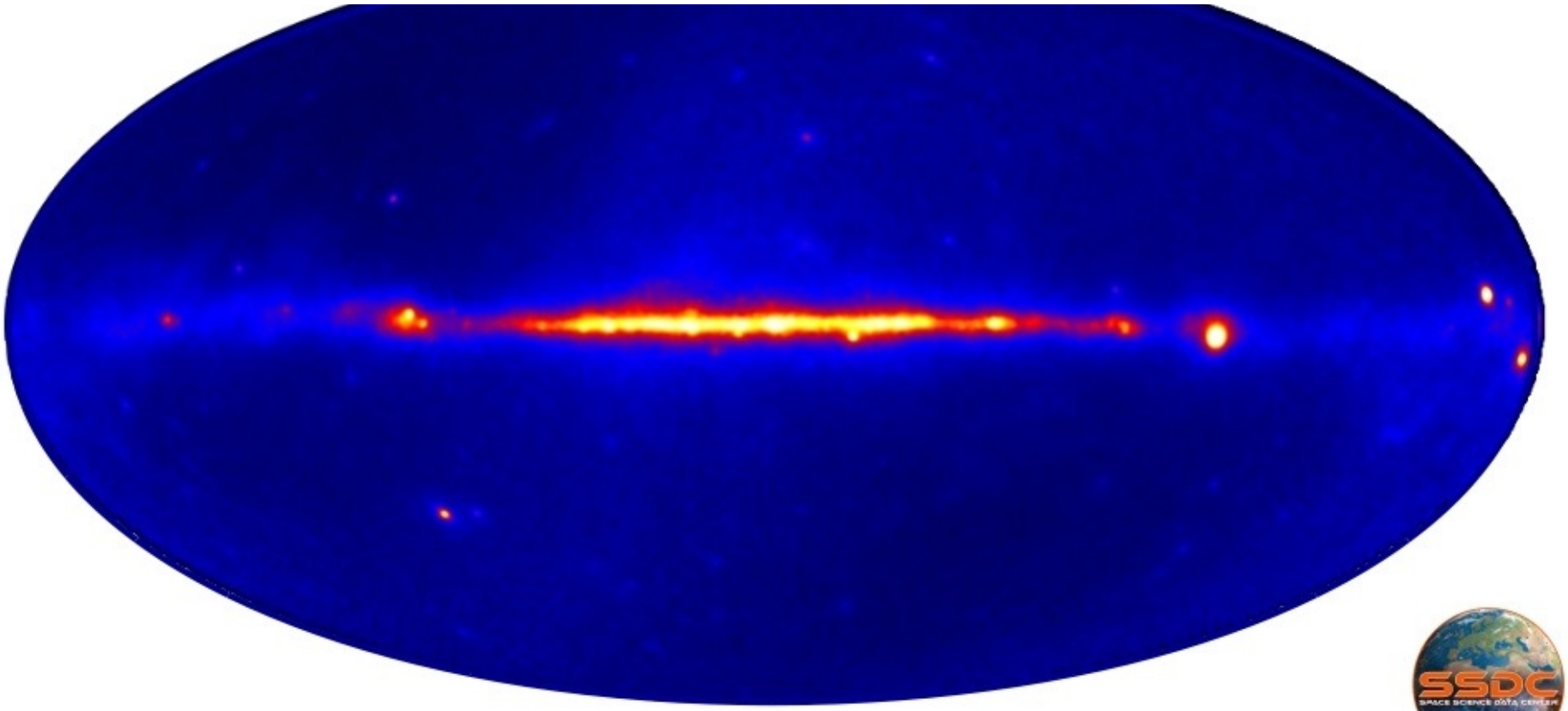
THE AGILE GAMMA-RAY SKY (E>100 MEV)



AGILE INTENSITY MAP ABOVE 100 MeV (up to Sept. 2017)

THE AGILE GAMMA-RAY SKY (E>100 MEV)

MORE THAN 11 YEAR OPERATING IN ORBIT!



AGILE INTENSITY MAP ABOVE 100 MeV (up to Sept. 2017)

THE AGILE DATA CENTER (ADC)

- The **AGILE Data Center (ADC)** hosted at the SSDC is in charge of all the activities related to the archiving and analysis of the AGILE data:

From the raw scientific telemetry (Level-0):

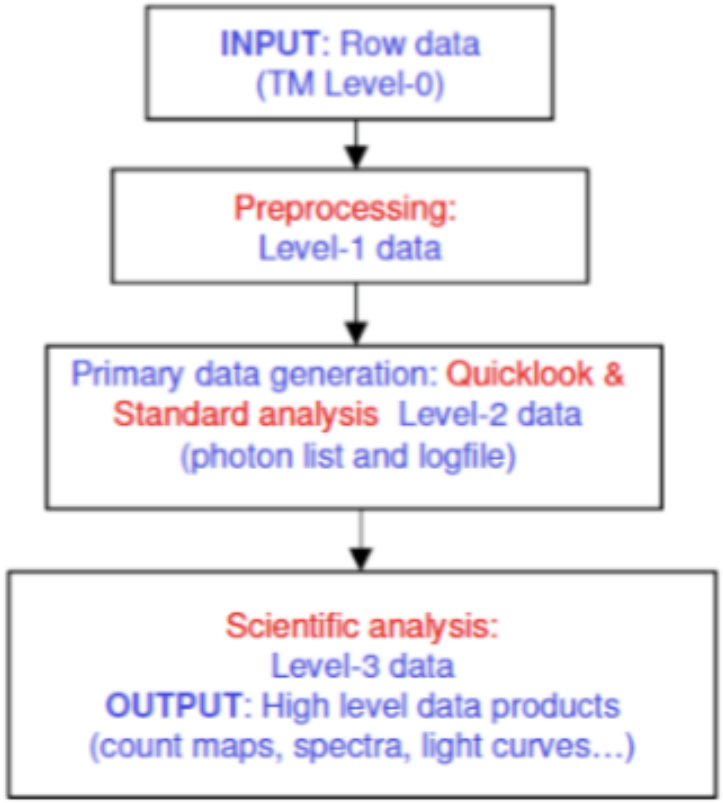
✓ Pre-processing → Level-1 data

✓ Quick Look analysis (transient detection) and Standard analysis → Level-2 data (photon list + auxiliary information)

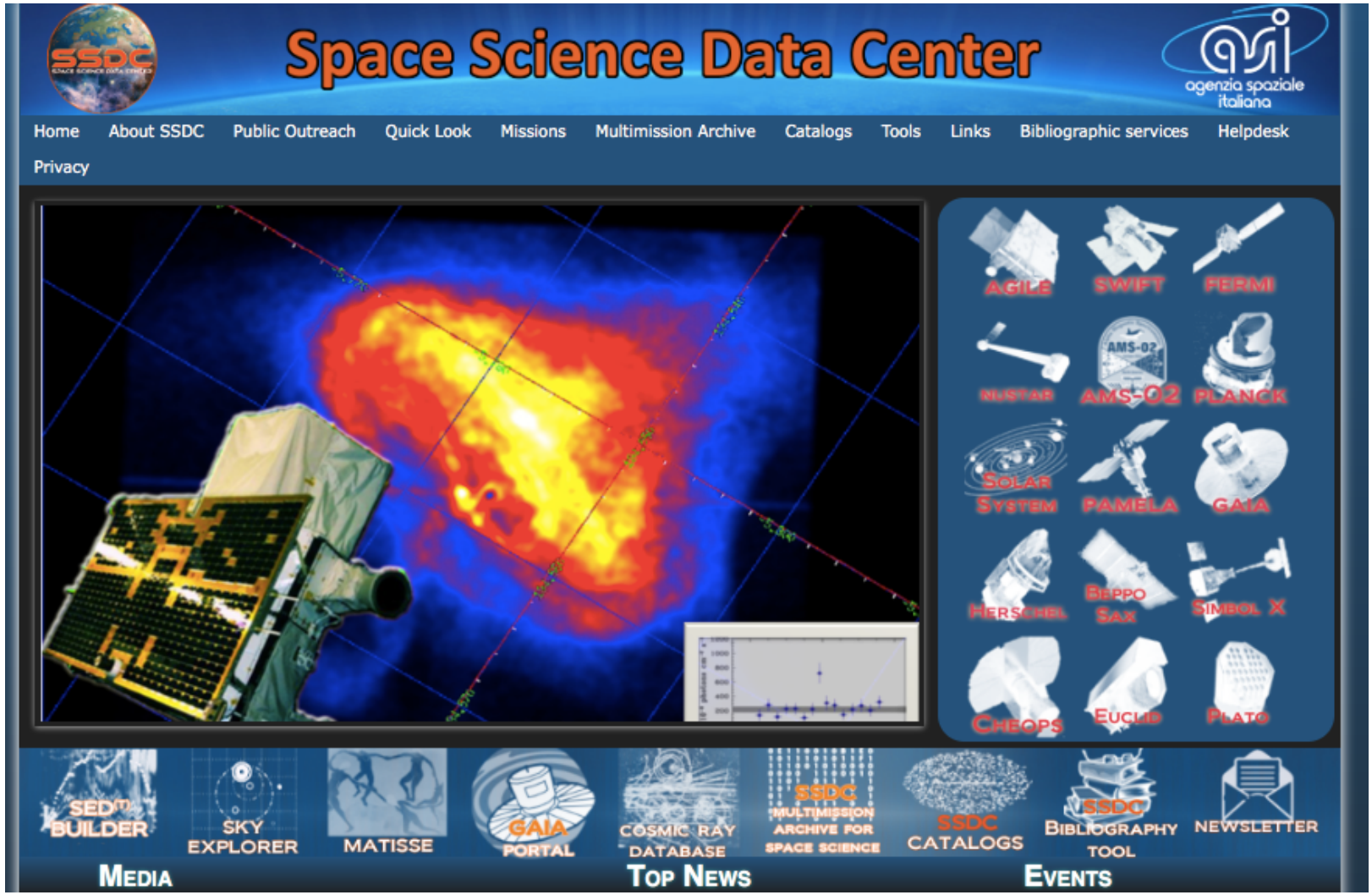
✓ Archiving and distributing all L2 data + official AGILE analysis s/w and calibrations (IRFs)

✓ Server of high-level data products (general AGILE catalogues, see Verrecchia's Talk.)

AGILE data flow



THE SSDC WEB PORTAL



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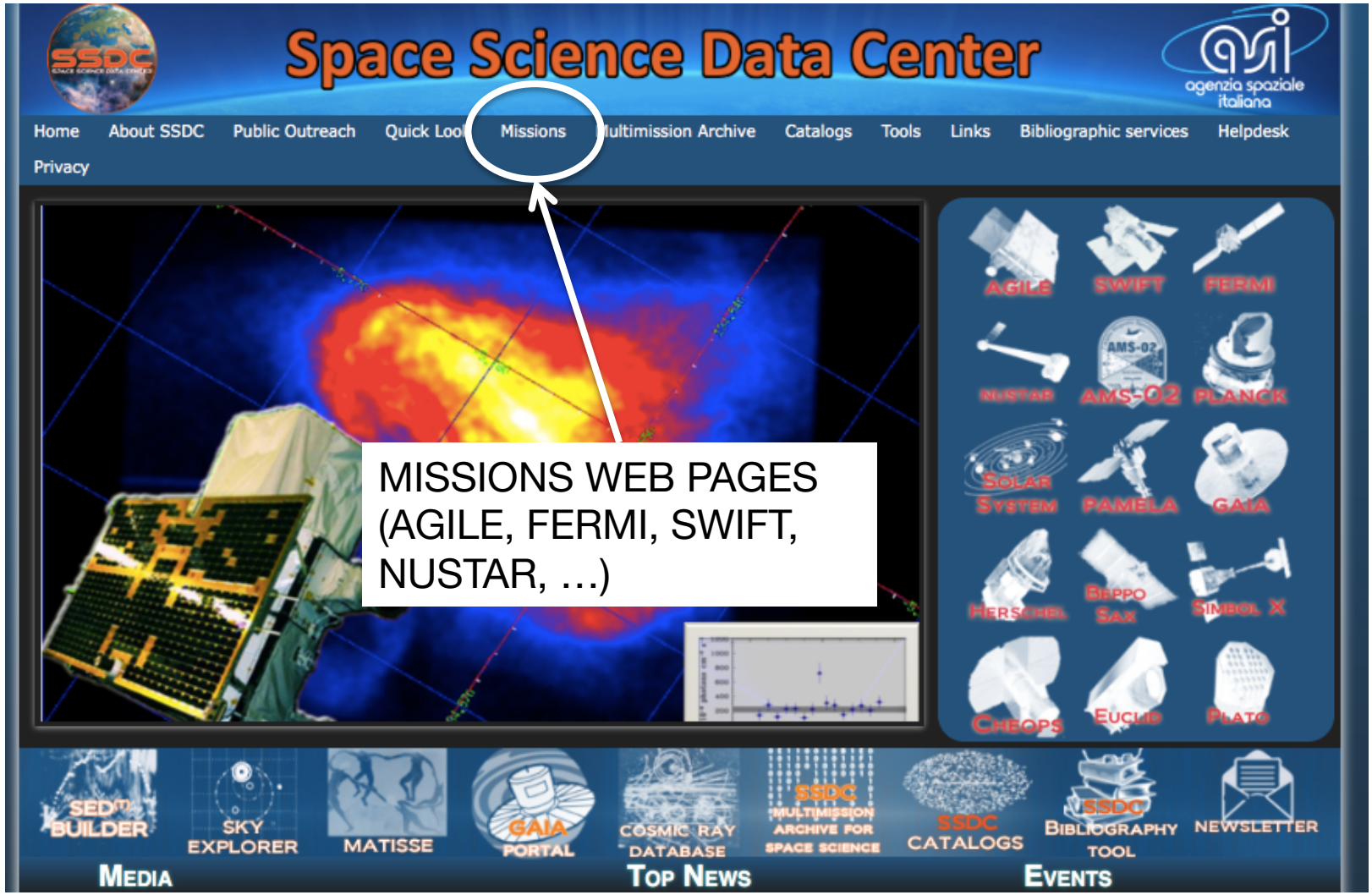


THE AGILE GAMMA-RAY DATA ANALYSIS

THE AGILE MULTI-SOURCE ANALYSIS

- Based on the Maximum Likelihood (ML) algorithm developed by EGRET (Mattox et. al (1998), Chen et al. (2010)).

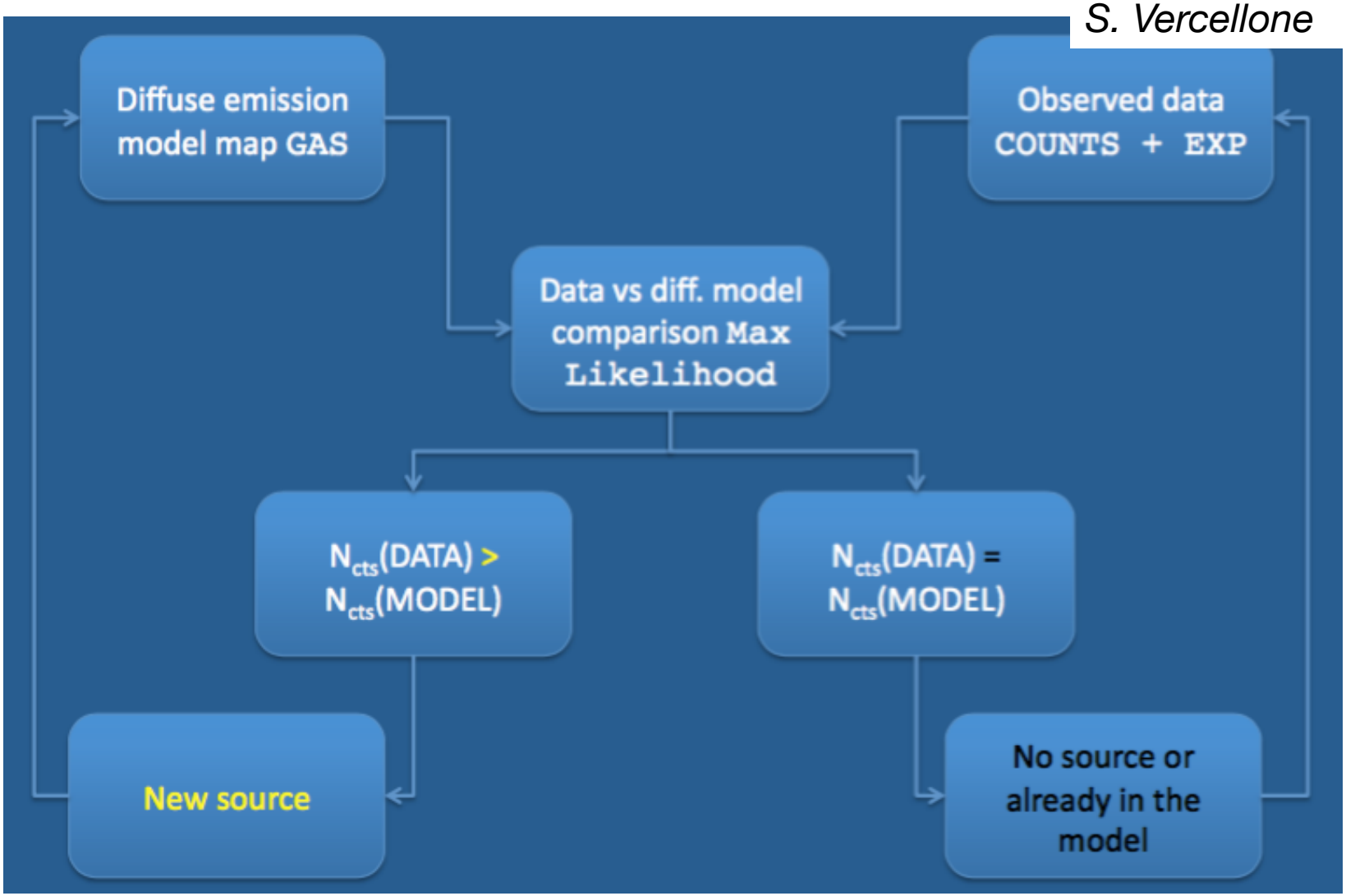
- Basic input to the AGILE analysis:
  - LV2 data: photons list (EVT) and logfiles (LOG) (HK, attitude, ratemeters info, …) in FITS file format.

- Count, exposure and background FITS maps, centered at the location of interest (within an energy (E>100 MeV) and time interval), are then produced from the LV2 data using the tasks of the AGILE s/w.

- The ML method: testing the *Null* hypothesis (only signal from background) against the *True* hypothesis (gamma-ray source at the input position).

AGILE S/W FUNCTIONAL SCHEME

S. Vercellone



AGILE S/W FUNCTIONAL SCHEME

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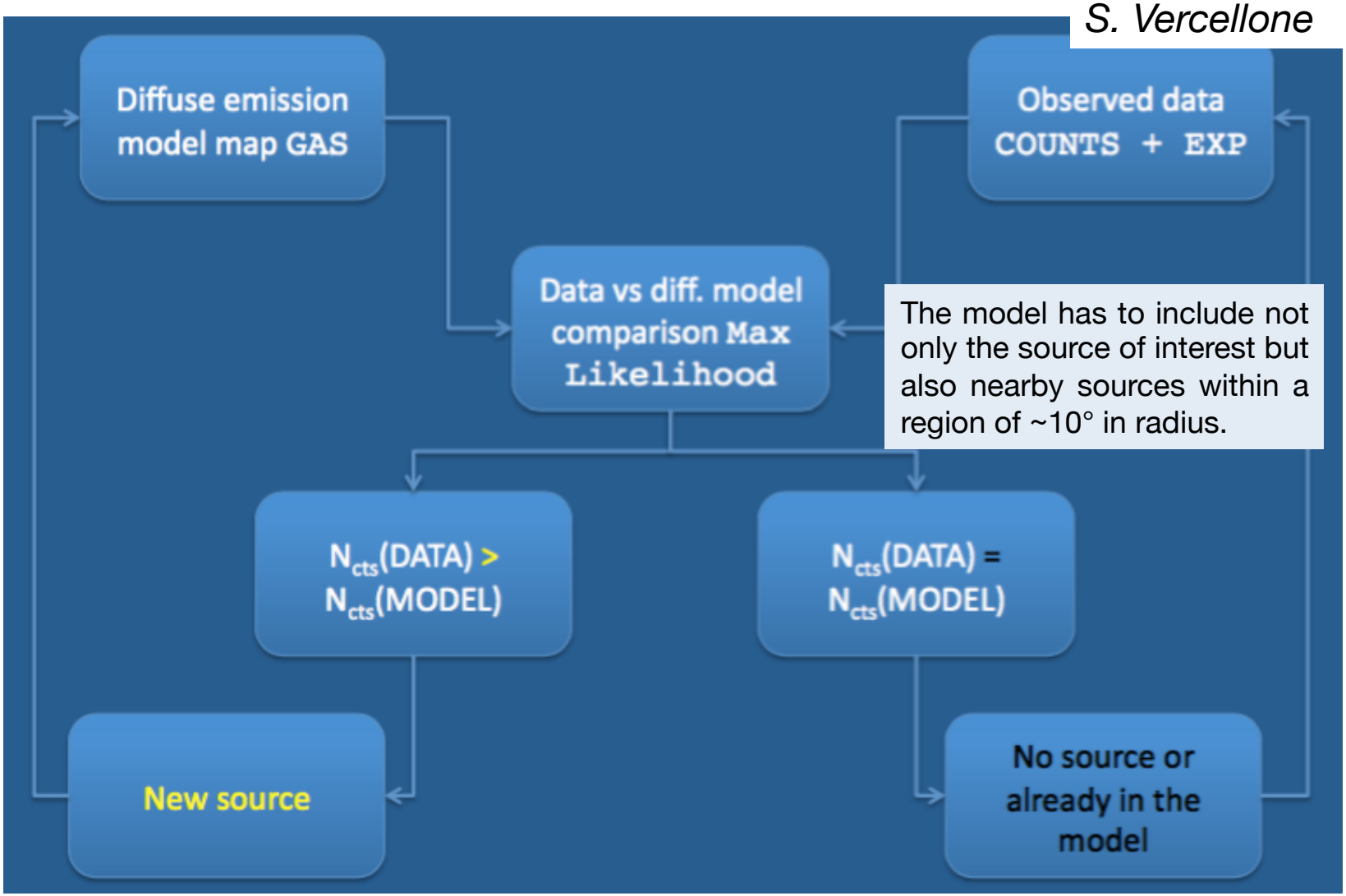
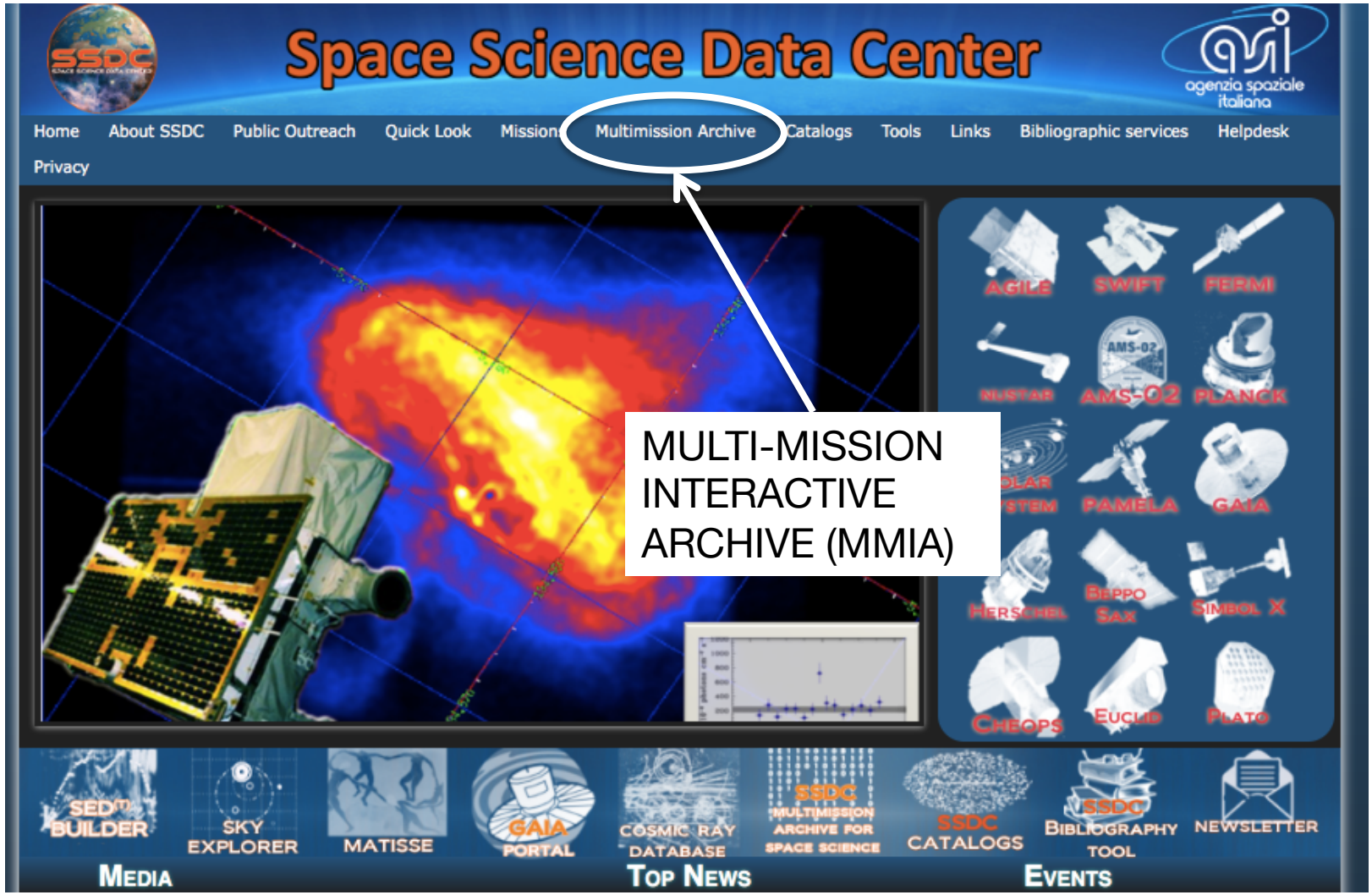


ACCESS TO AGILE DATA AND S/W



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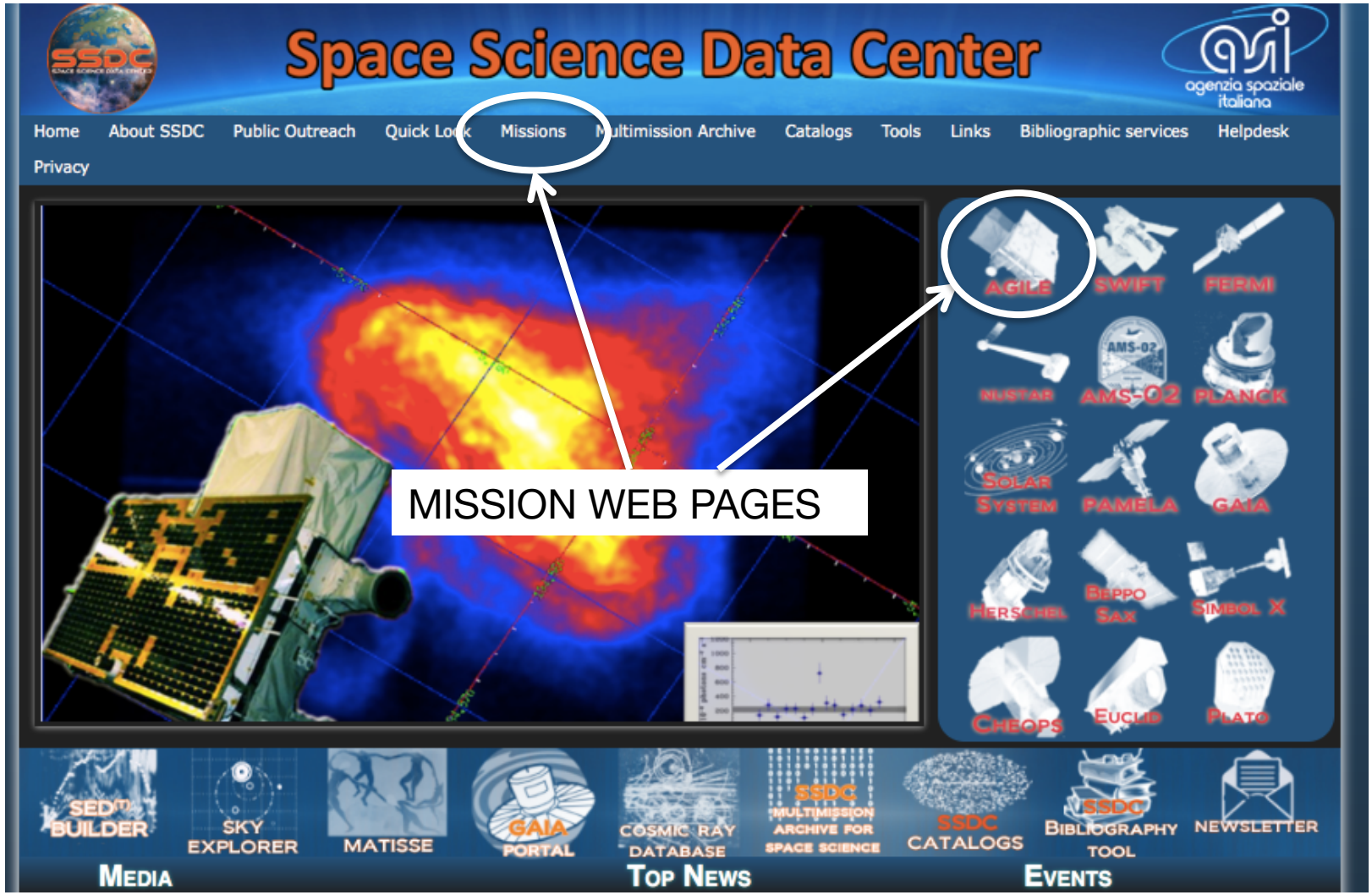

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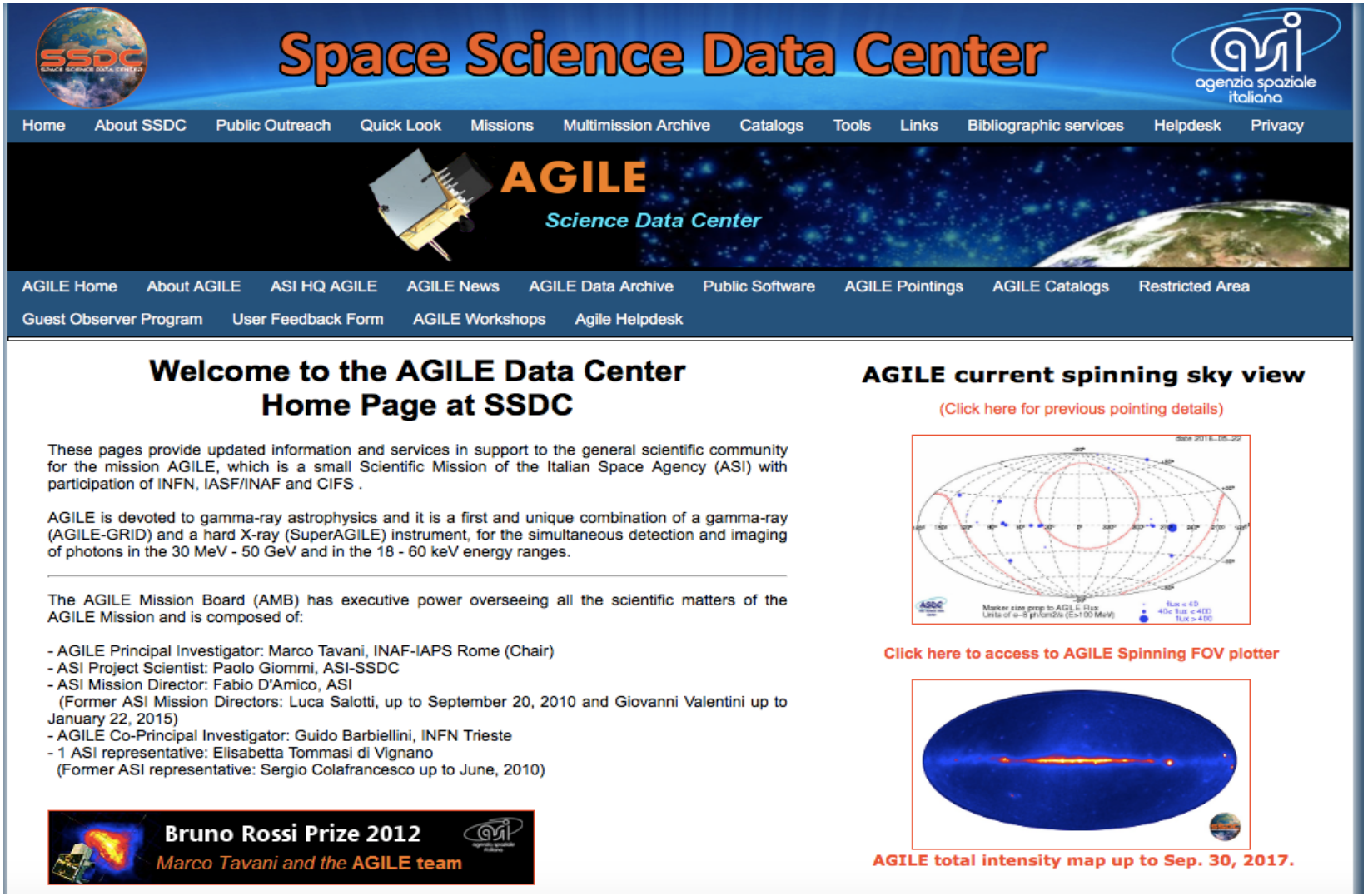


THE AGILE ONLINE INTERACTIVE ANALYSIS TOOL

WHY AN ONLINE ANALYSIS TOOL?

- AGILE gamma-ray data analysis above 100 MeV is an event-by-event analysis that requires many steps and it can be **time-consuming** (expecially in case of deep studies or generation of light-curves over long time intervals).

- The **generation of the exposure maps** is the task requiring more computation time (few hours to generate a 6-month expmap on a PC with medium capability).

- Downloading of LV2 data can also requires enough locally data space, especially for LOG files (~2 GB per 15 days of AGILE observations).

- Users from the astronomical community might want to have a quick and robust result to be inserted in their MWL papers without performing the full AGILE data analysis.

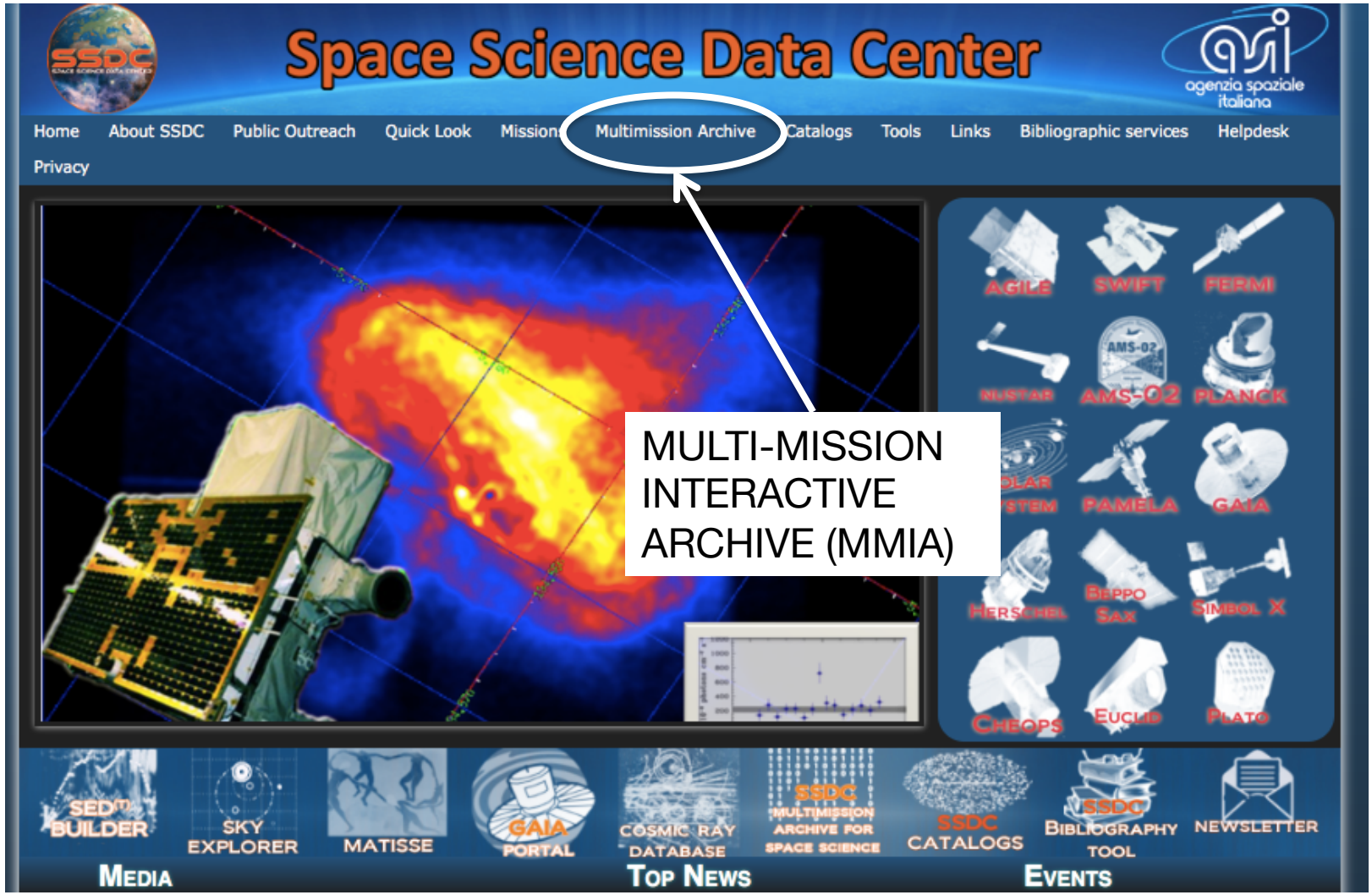
THE AGILE ONLINE ANALYSIS

- The ADC @ SSDC provides then an online interactive AGILE data analysis tool.

- The tool is a web interface for official interactive on-line Maximum Likelihood analysis on AGILE data. **It does neither require any locally installed s/w or calibrations nor LV2 data retrieval!**

- The tool provides the estimate of flux and significance of a source in the selected period, taking into account all other known gamma-ray sources in the region, the diffuse gamma-ray background and other sources of background (such as the Earth albedo).

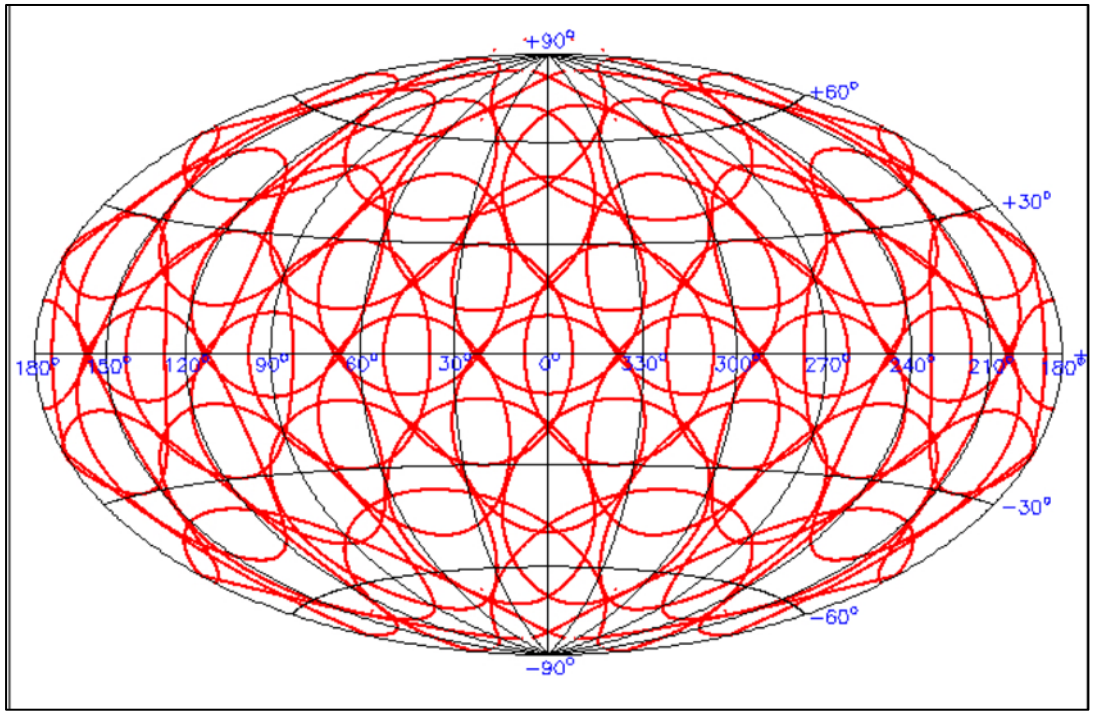
ACCESS TO THE TOOL



ACCESS TO THE TOOL

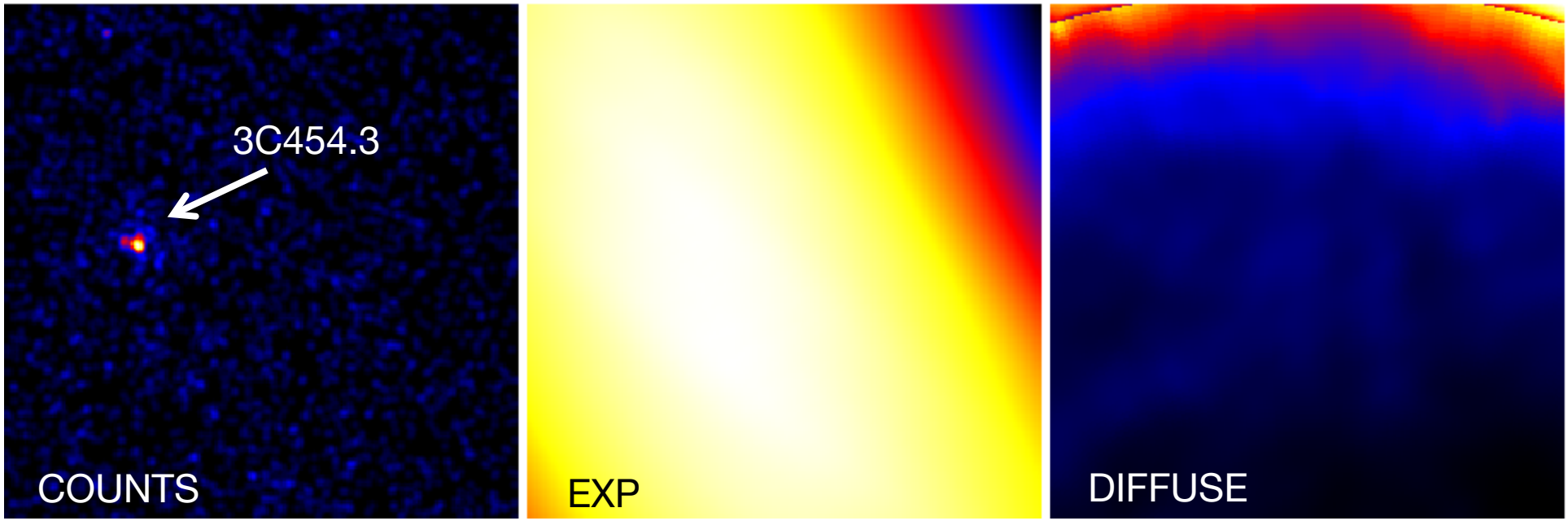
THE AGILE LEVEL-3 (LV3) ARCHIVE

- The basic blocks of the AGILE online interactive analysis is the **AGILE Level-3 archive**, composed by counts, exposure, and diffuse gamma-ray background FITS maps generated on predefined sky positions (48 centers/rings).
- Each LV3 map covers 1 day of integration, starting from the beginning of the mission until the last published AGILE-LV2 (photon list and LOG) data.



THE AGILE LEVEL-3 (LV3) ARCHIVE

- The 1-day LV3 FITS maps are then merged to form an archive of different time integrations: **2, 7 and 28 days ➔** possibility to perform variability studies on different time-intervals, over long timescales, within a few minutes.
- The map parameters (binning, maximum off-axis angle, cut on Earth albedo, …) are chosen to guarantee the most robust analysis results.



AGILE-LV3 MERGED MAPS ON THE 7-DAY INTERVAL 9-16/12/2009. CENTER @ l,b=(67, -41) deg

INPUT QUERY TO THE LV3 ARCHIVE

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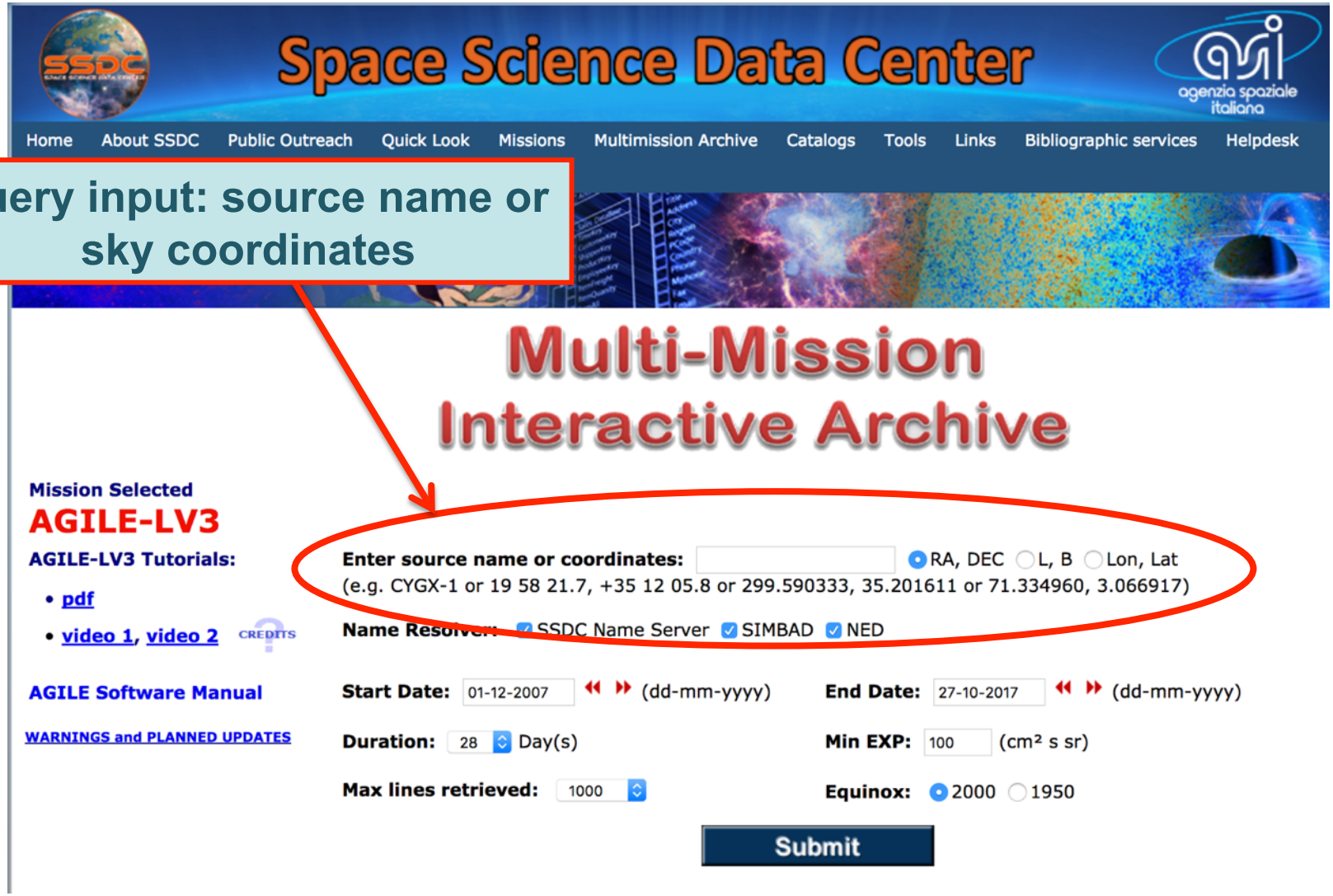

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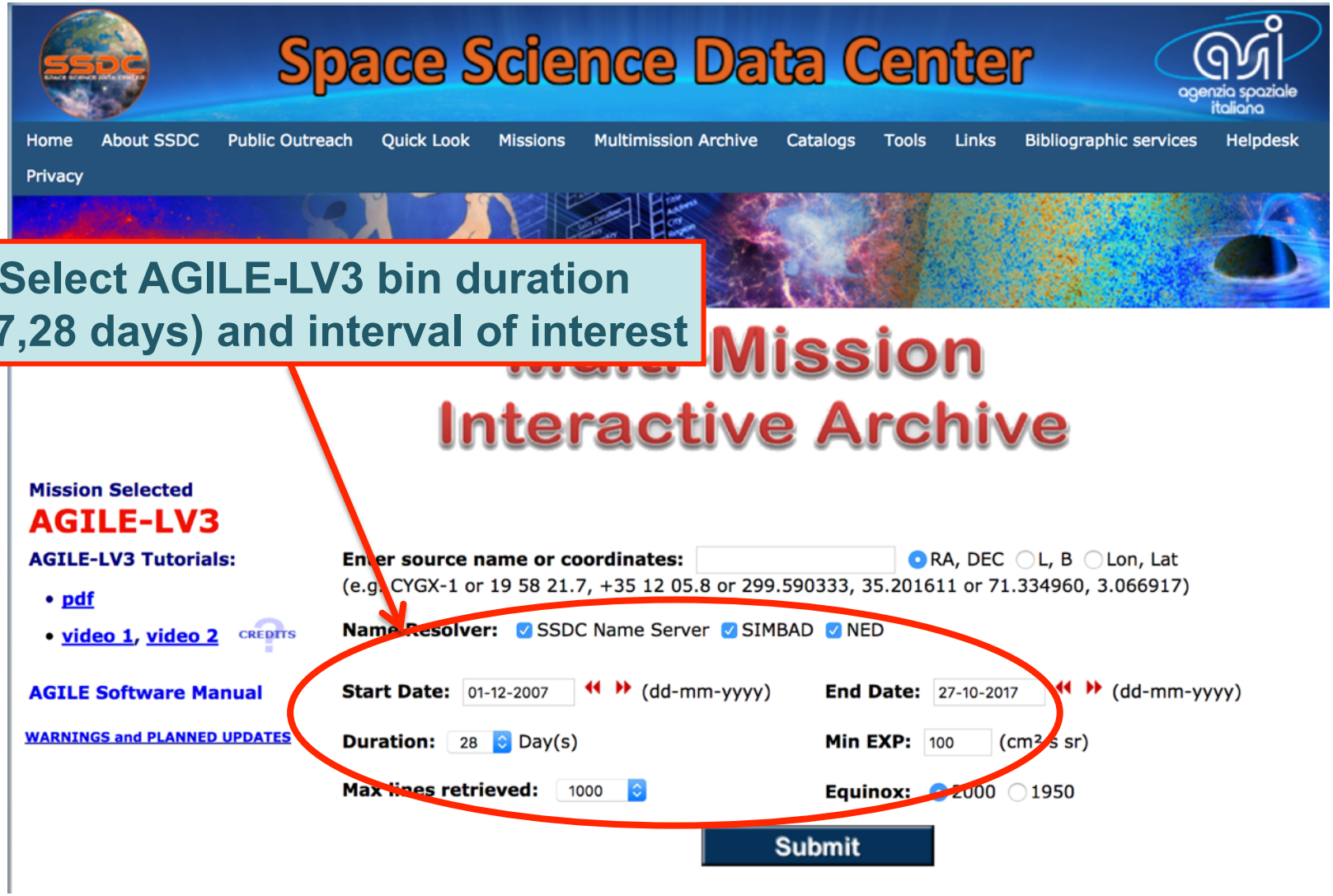

EXAMPLE OF ONLINE ANALYSIS

AGILE-LV3 Data

Query results for: 3c454.3(SSDC)

Details: query by **COORDINATE** & **TIME** with **RA** = 343.490417; **DEC** = 16.148056; **L** = 86.110748; **B** = -38.183841; **Lon** = 351.367785; **Lat** = 21.330631; **EQUINOX** = 2000; **RADIUS** = 30 degree
01-09-2009; **End date** = 17-11-2011; **Duration** = 28 day(s); **Min EXP** = 100 cm² s sr; sort by **START DATE**; max lines retrieved 1000;

Modify AGILE-LV3 query parameters

Make Light Curve: LC likelihood

Export Current view of Table in: Latex format | FITS format | Raw text format | CSV text format | Browse table

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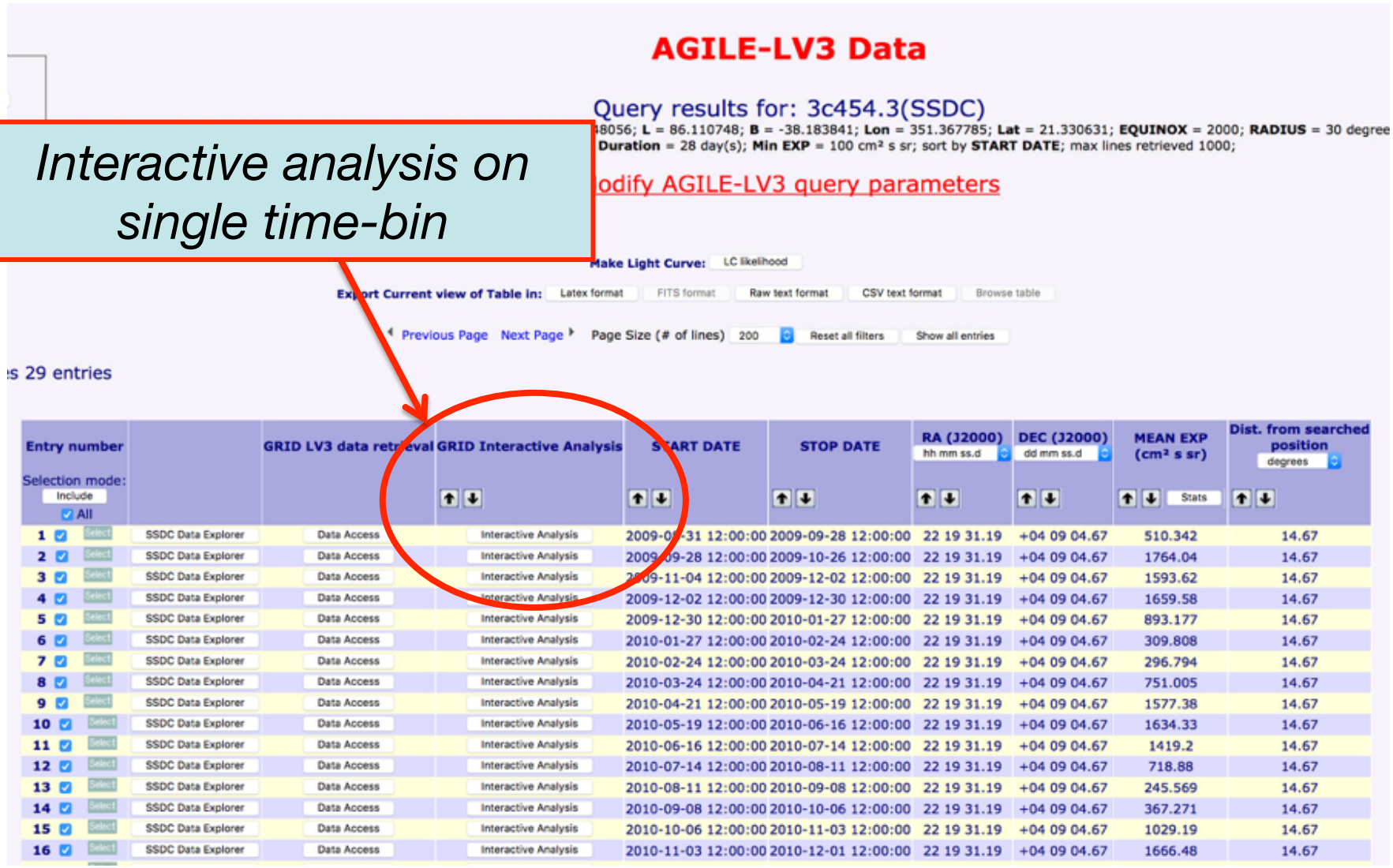
s 29 entries

Entry number Selection mode: Include, All		GRID LV3 data retrieval	GRID Interactive Analysis	START DATE	STOP DATE	RA (J2000) hh mm ss.d	DEC (J2000) dd mm ss.d	MEAN EXP (cm² s sr) Stats	Dist. from searched position degrees
1	SSDC Data Explorer	Data Access	Interactive Analysis	2009-08-31 12:00:00	2009-09-28 12:00:00	22 19 31.19	+04 09 04.67	510.342	14.67
2	SSDC Data Explorer	Data Access	Interactive Analysis	2009-09-28 12:00:00	2009-10-26 12:00:00	22 19 31.19	+04 09 04.67	1764.04	14.67
3	SSDC Data Explorer	Data Access	Interactive Analysis	2009-11-04 12:00:00	2009-12-02 12:00:00	22 19 31.19	+04 09 04.67	1593.62	14.67
4	SSDC Data Explorer	Data Access	Interactive Analysis	2009-12-02 12:00:00	2009-12-30 12:00:00	22 19 31.19	+04 09 04.67	1659.58	14.67
5	SSDC Data Explorer	Data Access	Interactive Analysis	2009-12-30 12:00:00	2010-01-27 12:00:00	22 19 31.19	+04 09 04.67	893.177	14.67
6	SSDC Data Explorer	Data Access	Interactive Analysis	2010-01-27 12:00:00	2010-02-24 12:00:00	22 19 31.19	+04 09 04.67	309.808	14.67
7	SSDC Data Explorer	Data Access	Interactive Analysis	2010-02-24 12:00:00	2010-03-24 12:00:00	22 19 31.19	+04 09 04.67	296.794	14.67
8	SSDC Data Explorer	Data Access	Interactive Analysis	2010-03-24 12:00:00	2010-04-21 12:00:00	22 19 31.19	+04 09 04.67	751.005	14.67
9	SSDC Data Explorer	Data Access	Interactive Analysis	2010-04-21 12:00:00	2010-05-19 12:00:00	22 19 31.19	+04 09 04.67	1577.38	14.67
10	SSDC Data Explorer	Data Access	Interactive Analysis	2010-05-19 12:00:00	2010-06-16 12:00:00	22 19 31.19	+04 09 04.67	1634.33	14.67
11	SSDC Data Explorer	Data Access	Interactive Analysis	2010-06-16 12:00:00	2010-07-14 12:00:00	22 19 31.19	+04 09 04.67	1419.2	14.67
12	SSDC Data Explorer	Data Access	Interactive Analysis	2010-07-14 12:00:00	2010-08-11 12:00:00	22 19 31.19	+04 09 04.67	718.88	14.67
13	SSDC Data Explorer	Data Access	Interactive Analysis	2010-08-11 12:00:00	2010-09-08 12:00:00	22 19 31.19	+04 09 04.67	245.569	14.67
14	SSDC Data Explorer	Data Access	Interactive Analysis	2010-09-08 12:00:00	2010-10-06 12:00:00	22 19 31.19	+04 09 04.67	367.271	14.67
15	SSDC Data Explorer	Data Access	Interactive Analysis	2010-10-06 12:00:00	2010-11-03 12:00:00	22 19 31.19	+04 09 04.67	1029.19	14.67
16	SSDC Data Explorer	Data Access	Interactive Analysis	2010-11-03 12:00:00	2010-12-01 12:00:00	22 19 31.19	+04 09 04.67	1666.48	14.67

EXAMPLE OF ONLINE ANALYSIS

Interactive analysis on single time-bin



AGILE-LV3 Data

Query results for: 3c454.3(SSDC)

48056; **L** = 86.110748; **B** = -38.183841; **Lon** = 351.367785; **Lat** = 21.330631; **EQUINOX** = 2000; **RADIUS** = 30 degree
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odify AGILE-LV3 query parameters

Make Light Curve: LC likelihood

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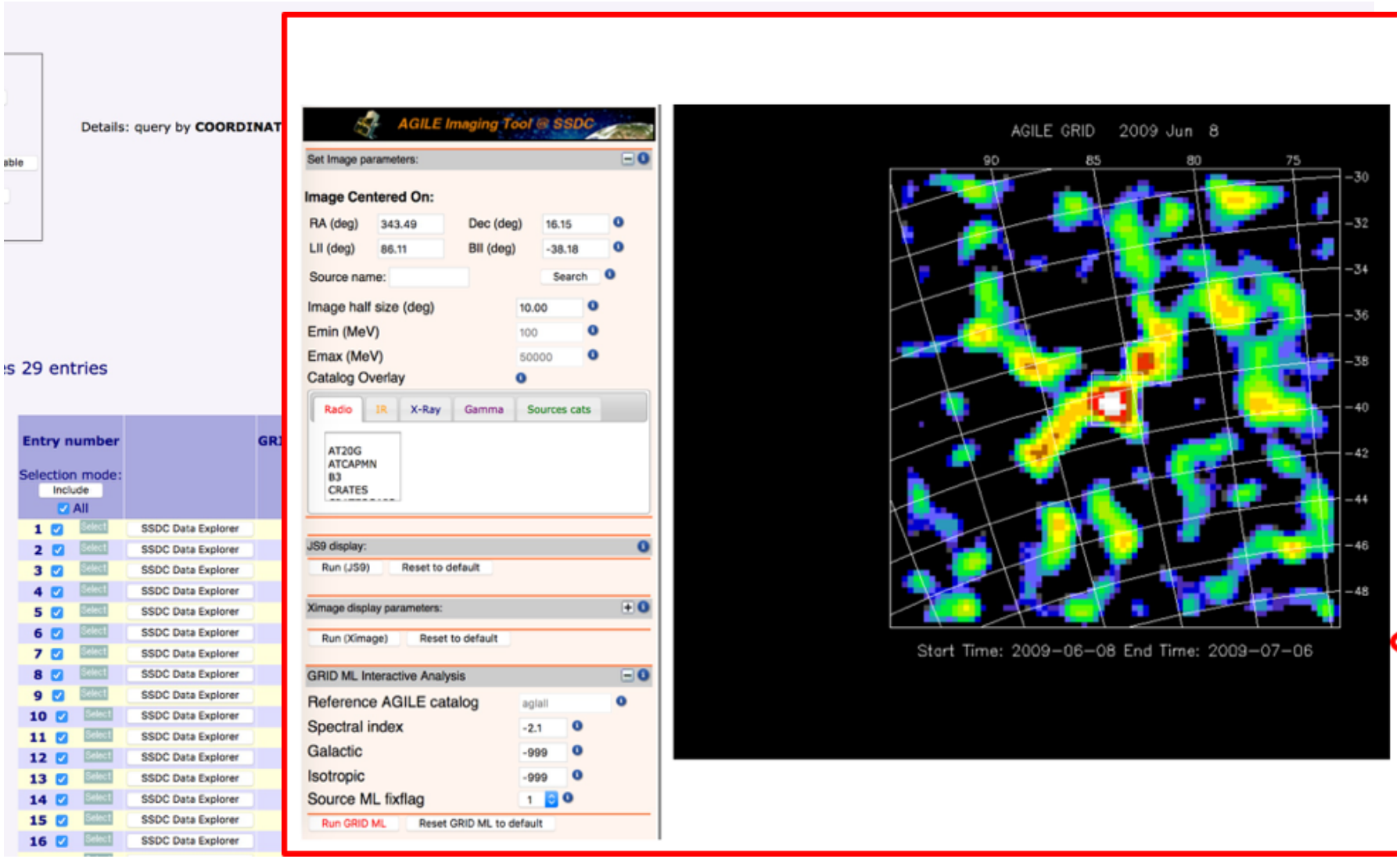
EXAMPLE OF ONLINE ANALYSIS



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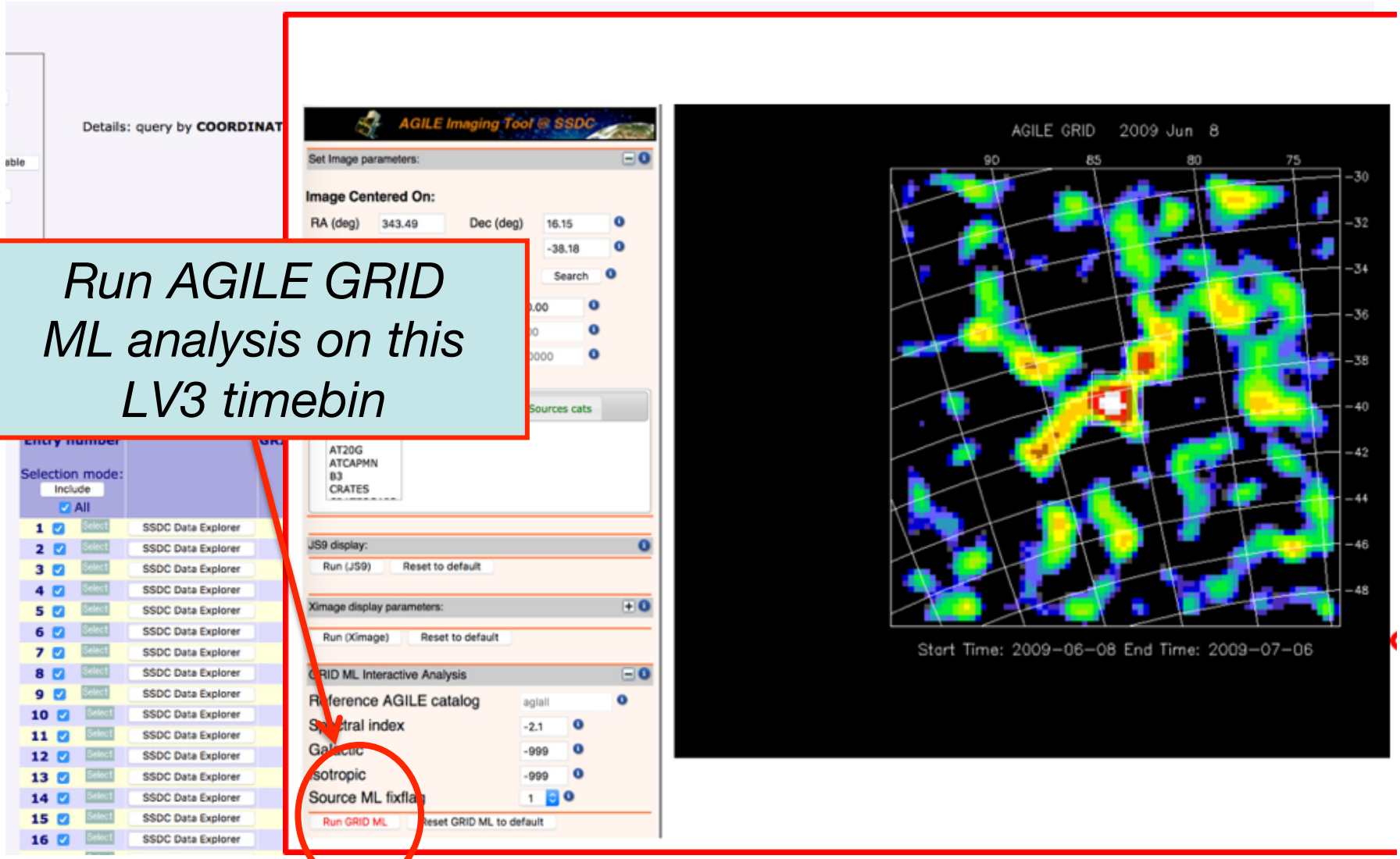
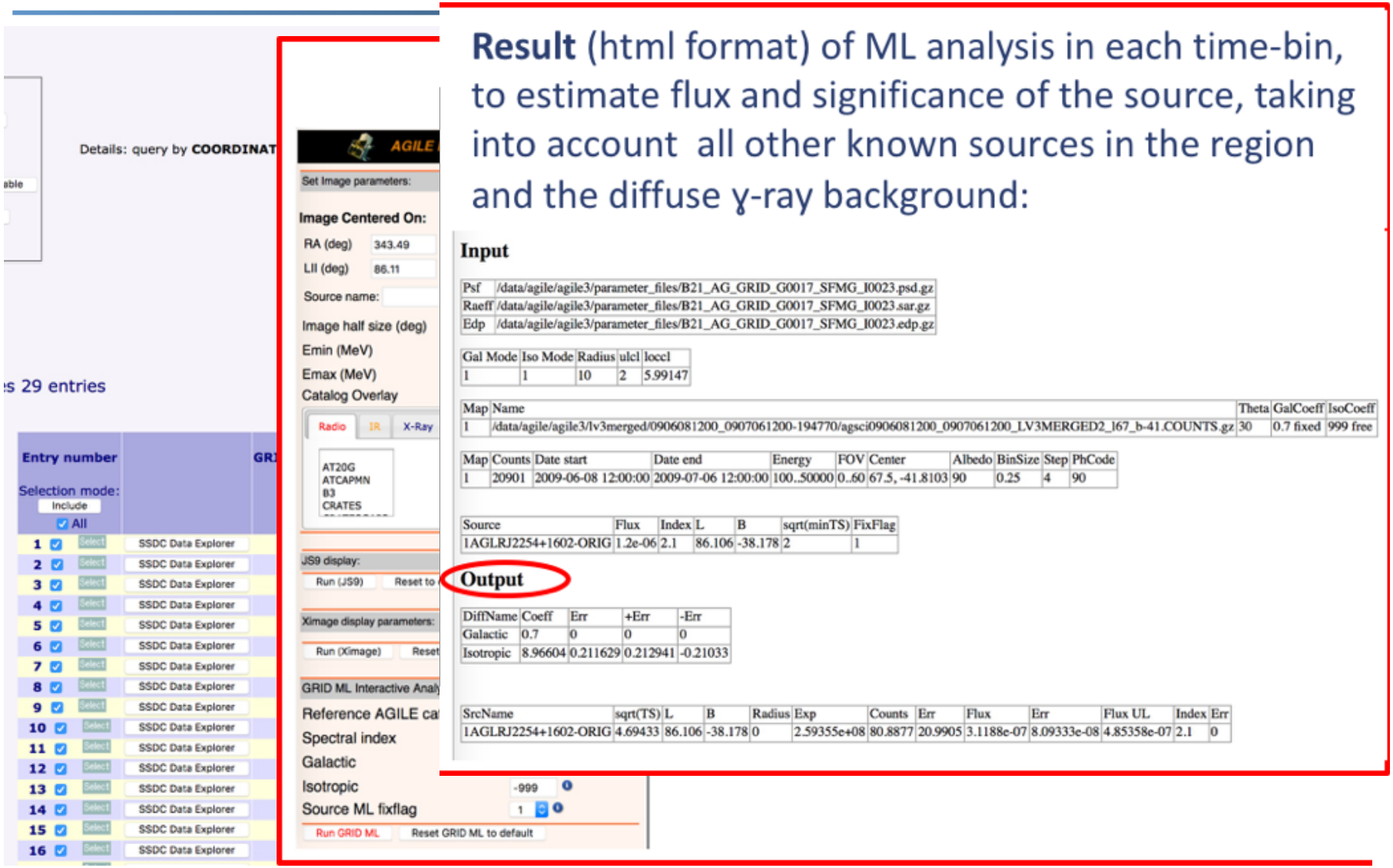


Run AGILE GRID ML analysis on this LV3 timebin

EXAMPLE OF ONLINE ANALYSIS



Result (html format) of ML analysis in each time-bin, to estimate flux and significance of the source, taking into account all other known sources in the region and the diffuse γ-ray background:

Input

Psf	/data/agile/agile3/parameter_files/B21_AG_GRID_G0017_SFMG_I0023.psd.gz
Raeff	/data/agile/agile3/parameter_files/B21_AG_GRID_G0017_SFMG_I0023.sar.gz
Edp	/data/agile/agile3/parameter_files/B21_AG_GRID_G0017_SFMG_I0023.edp.gz

Gal Mode	Iso Mode	Radius	ulcl	loccl
1	1	10	2	5.99147

Map	Name	Theta	GalCoeff	IsoCoeff
1	/data/agile/agile3/lv3merged/0906081200_0907061200-194770/agsci0906081200_0907061200_LV3MERGED2_I67_b-41.COUNTS.gz	30	0.7 fixed	999 free

Map	Counts	Date start	Date end	Energy	FOV	Center	Albedo	BinSize	Step	PhCode
1	20901	2009-06-08 12:00:00	2009-07-06 12:00:00	100..50000	0..60	67.5, -41.8103	90	0.25	4	90

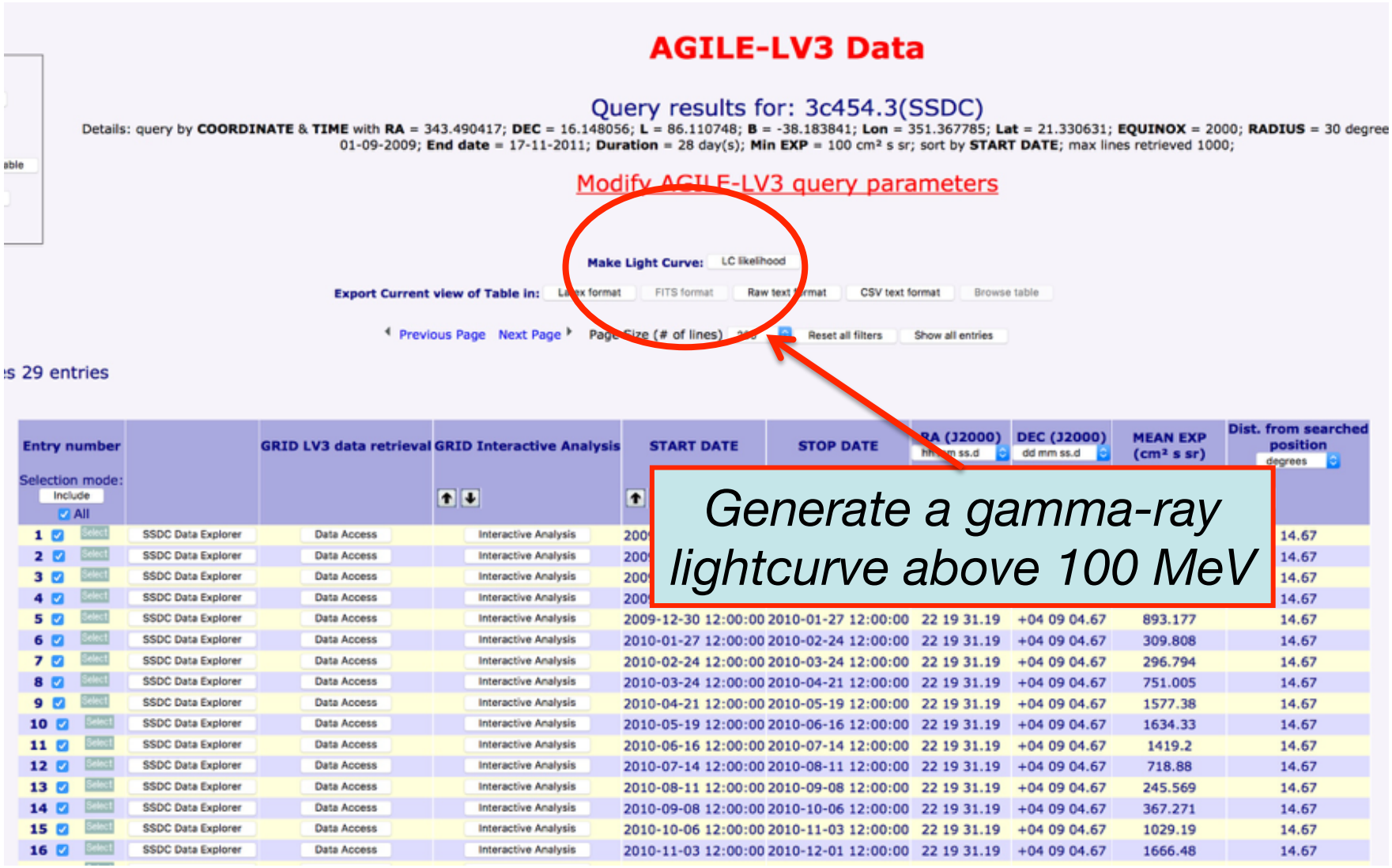
Source	Flux	Index	L	B	sqrt(minTS)	FixFlag
1AGLRJ2254+1602-ORIG	1.2e-06	2.1	86.106	-38.178	2	1

Output

DiffName	Coeff	Err	+Err	-Err
Galactic	0.7	0	0	0
Isotropic	8.96604	0.211629	0.212941	-0.21033

SrcName	sqrt(TS)	L	B	Radius	Exp	Counts	Err	Flux	Err	Flux UL	Index	Err
1AGLRJ2254+1602-ORIG	4.69433	86.106	-38.178	0	2.59355e+08	80.8877	20.9905	3.1188e-07	8.09333e-08	4.85358e-07	2.1	0

EXAMPLE OF ONLINE ANALYSIS: LC



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01-09-2009; **End date** = 17-11-2011; **Duration** = 28 day(s); **Min EXP** = 100 cm² s sr; sort by **START DATE**; max lines retrieved 1000;

Modify AGILE-LV3 query parameters

Make Light Curve: LC likelihood

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s 29 entries

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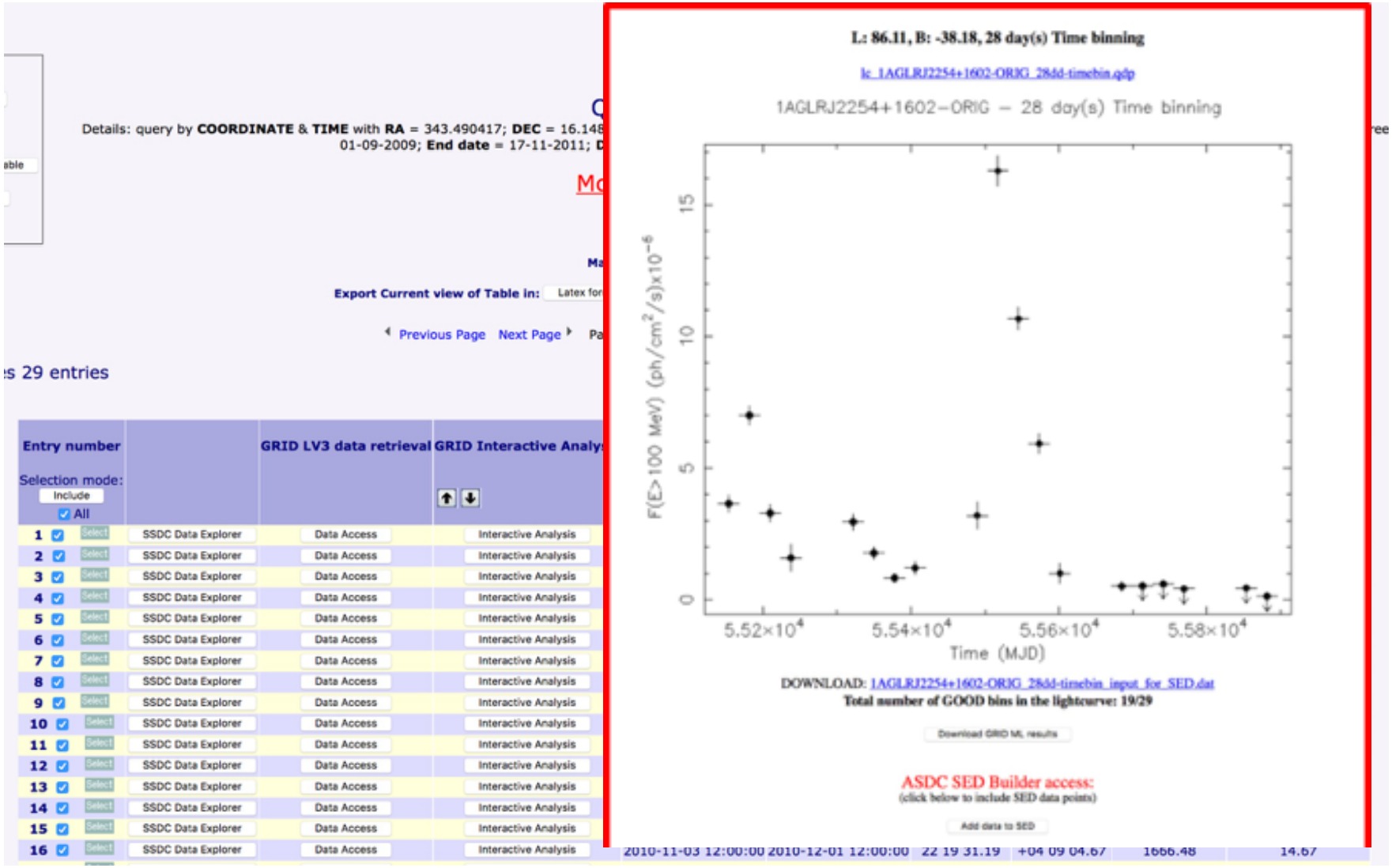
Selection mode: Include, All									
1	SSDC Data Explorer	Data Access	Interactive Analysis	200					14.67
2	SSDC Data Explorer	Data Access	Interactive Analysis	200					14.67
3	SSDC Data Explorer	Data Access	Interactive Analysis	200					14.67
4	SSDC Data Explorer	Data Access	Interactive Analysis	200					14.67
5	SSDC Data Explorer	Data Access	Interactive Analysis	2009-12-30 12:00:00	2010-01-27 12:00:00	22 19 31.19	+04 09 04.67	893.177	14.67
6	SSDC Data Explorer	Data Access	Interactive Analysis	2010-01-27 12:00:00	2010-02-24 12:00:00	22 19 31.19	+04 09 04.67	309.808	14.67
7	SSDC Data Explorer	Data Access	Interactive Analysis	2010-02-24 12:00:00	2010-03-24 12:00:00	22 19 31.19	+04 09 04.67	296.794	14.67
8	SSDC Data Explorer	Data Access	Interactive Analysis	2010-03-24 12:00:00	2010-04-21 12:00:00	22 19 31.19	+04 09 04.67	751.005	14.67
9	SSDC Data Explorer	Data Access	Interactive Analysis	2010-04-21 12:00:00	2010-05-19 12:00:00	22 19 31.19	+04 09 04.67	1577.38	14.67
10	SSDC Data Explorer	Data Access	Interactive Analysis	2010-05-19 12:00:00	2010-06-16 12:00:00	22 19 31.19	+04 09 04.67	1634.33	14.67
11	SSDC Data Explorer	Data Access	Interactive Analysis	2010-06-16 12:00:00	2010-07-14 12:00:00	22 19 31.19	+04 09 04.67	1419.2	14.67
12	SSDC Data Explorer	Data Access	Interactive Analysis	2010-07-14 12:00:00	2010-08-11 12:00:00	22 19 31.19	+04 09 04.67	718.88	14.67
13	SSDC Data Explorer	Data Access	Interactive Analysis	2010-08-11 12:00:00	2010-09-08 12:00:00	22 19 31.19	+04 09 04.67	245.569	14.67
14	SSDC Data Explorer	Data Access	Interactive Analysis	2010-09-08 12:00:00	2010-10-06 12:00:00	22 19 31.19	+04 09 04.67	367.271	14.67
15	SSDC Data Explorer	Data Access	Interactive Analysis	2010-10-06 12:00:00	2010-11-03 12:00:00	22 19 31.19	+04 09 04.67	1029.19	14.67
16	SSDC Data Explorer	Data Access	Interactive Analysis	2010-11-03 12:00:00	2010-12-01 12:00:00	22 19 31.19	+04 09 04.67	1666.48	14.67

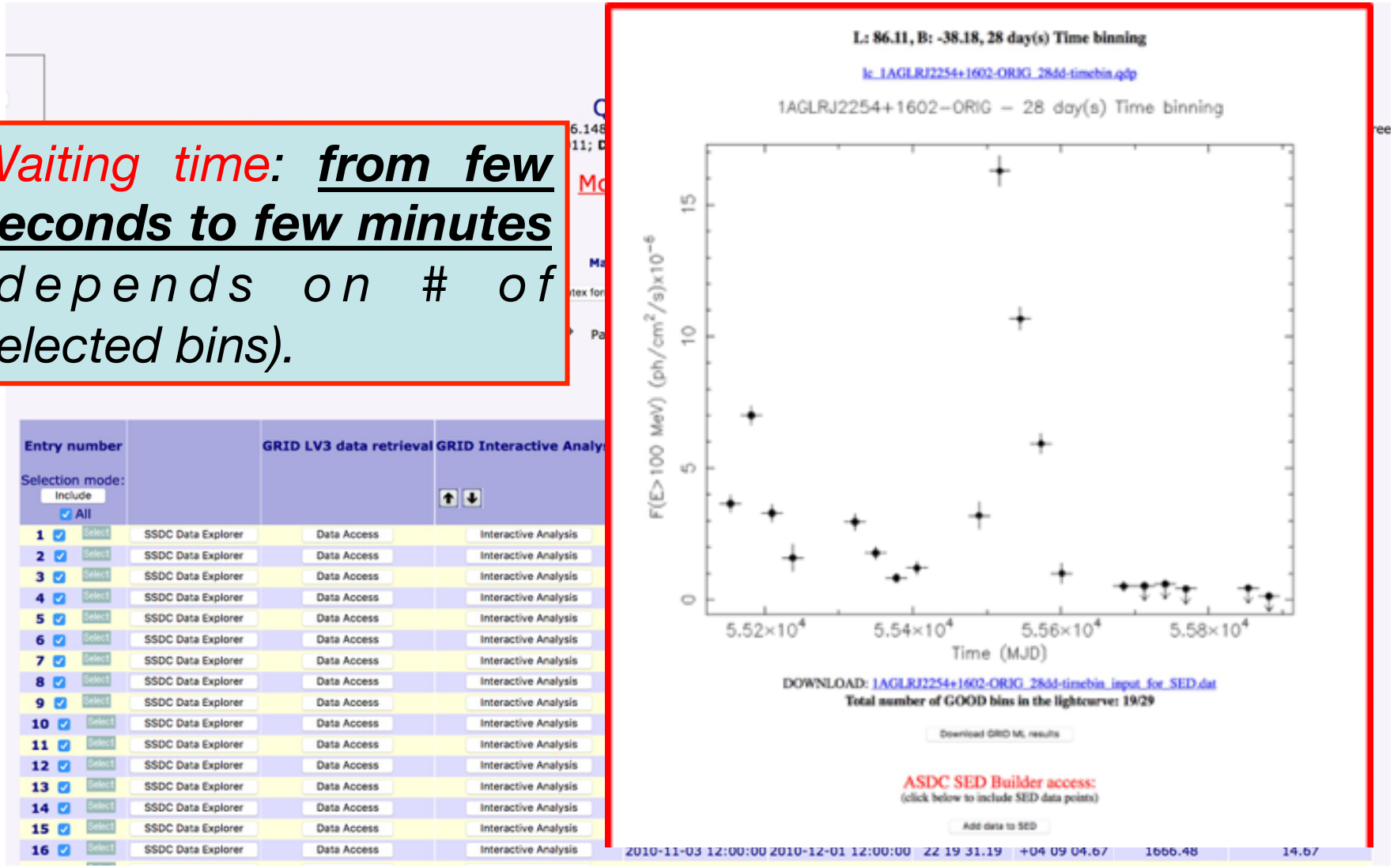
Generate a gamma-ray lightcurve above 100 MeV

EXAMPLE OF ONLINE ANALYSIS: LC

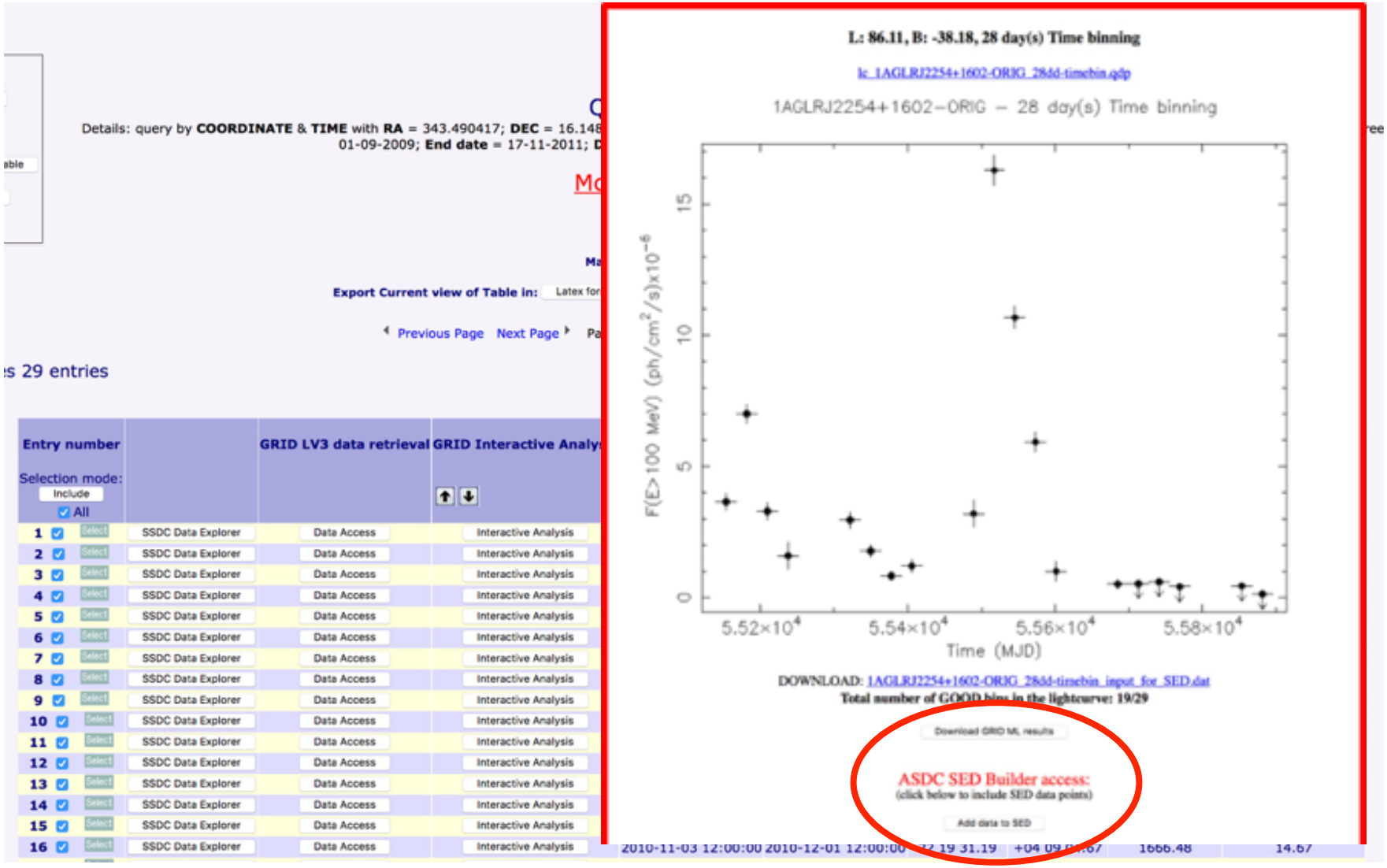


EXAMPLE OF ONLINE ANALYSIS: LC

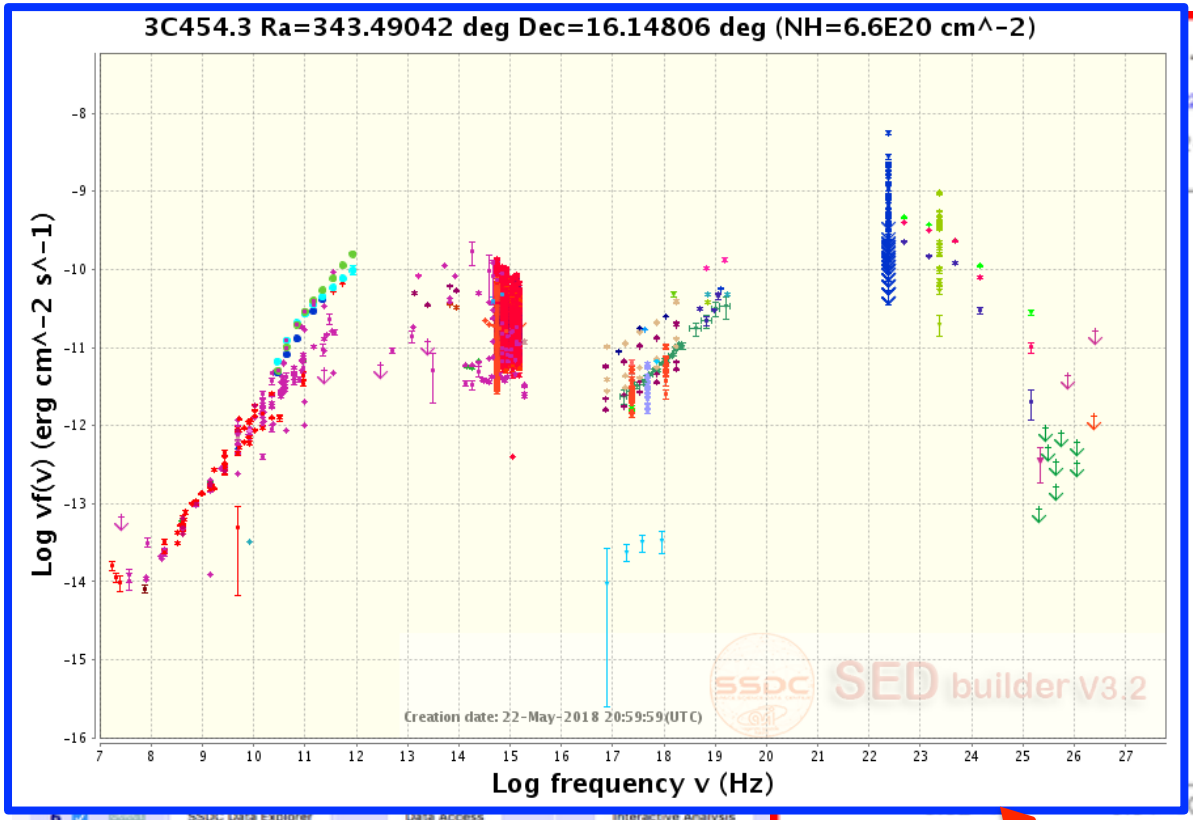
Waiting time: ***from few seconds to few minutes*** *(depends on # of selected bins).*



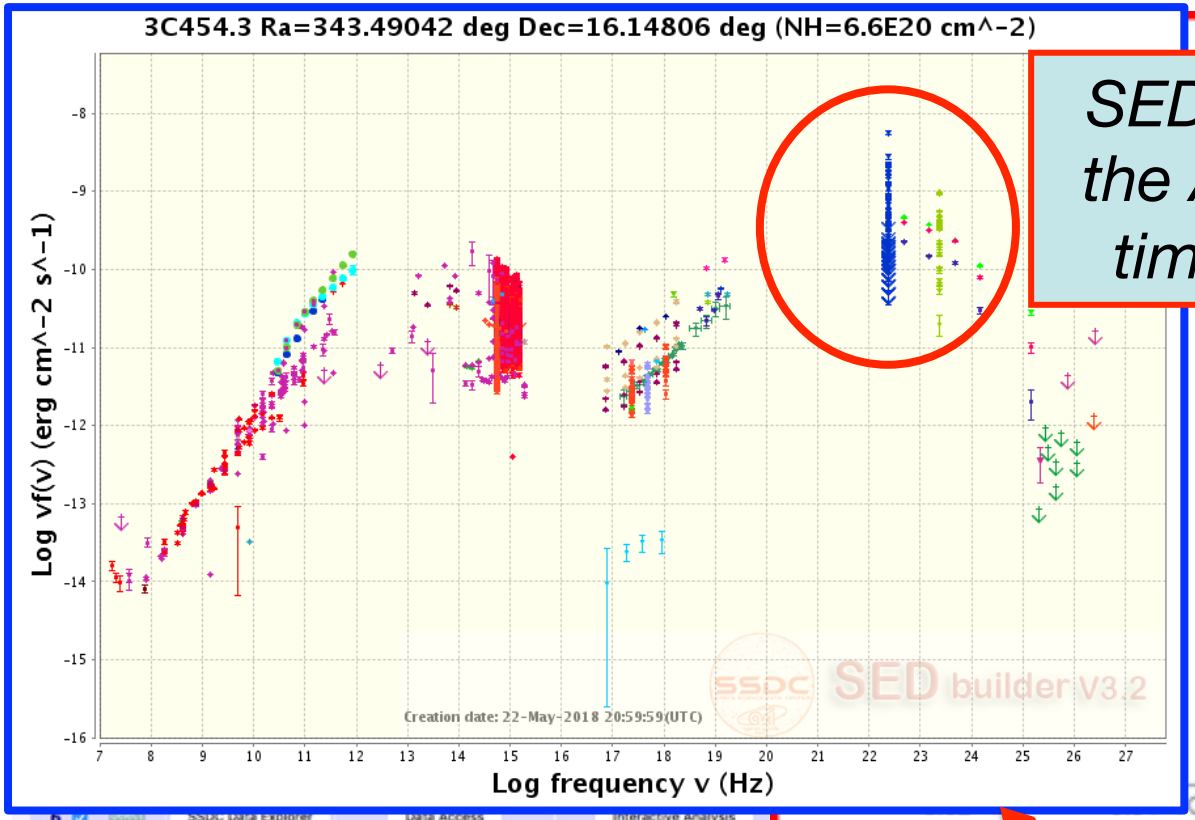
EXAMPLE OF ONLINE ANALYSIS: LC



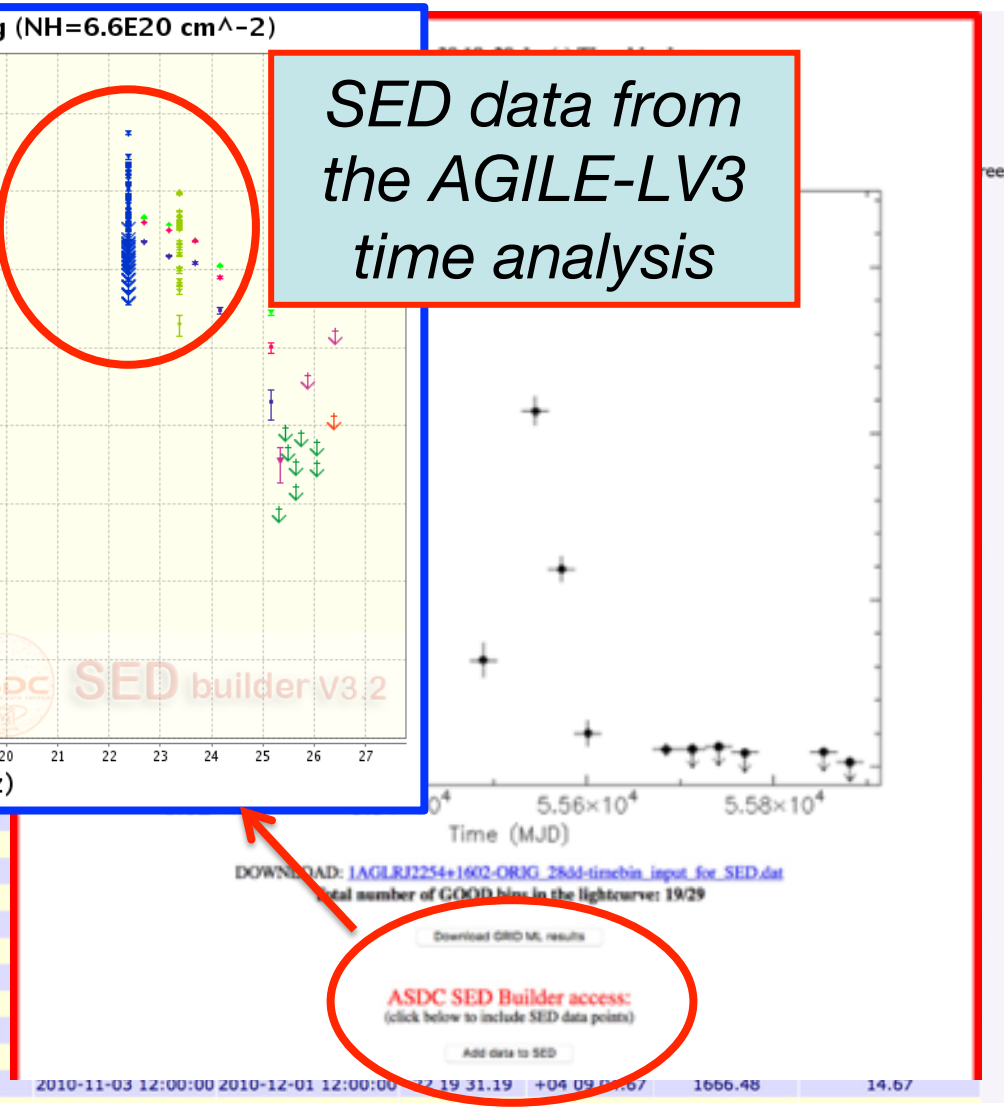
EXAMPLE OF ONLINE ANALYSIS: LC



EXAMPLE OF ONLINE ANALYSIS: LC



SED data from the AGILE-LV3 time analysis



HIDDEN TREASURES IN THE AGILE-LV3 ARCHIVE

- The AGILE-LV3 archive (and the online analysis tool) have been already used by the AGILE Team in a several papers, i.e.:
  - ✓ MWL paper on PKS 1510-089 (AGILE Coll., A&A 569, 2014)
  - ✓ AGILE paper on 3C 279 (Pittori et al., ApJ 856, 2017)
- The possibility to perform variability studies in a few minutes over the whole AGILE lifetime has been also used in recent papers on multi-messenger studies of IceCube neutrino events (Lucarelli et al., ApJ 846, 2017).
- By downloading the LV3 maps, it is also possible to produce very deep map over any desired sky location.

SUMMARY AND OUTLOOK

- The AGILE gamma-ray online and interactive analysis tool is a service of the AGILE data center, providing quick and robust AGILE data analysis using the official AGILE s/w and calibrations.
- No need to download any data (photon lists/logfiles) and s/w installation.
- The online analysis is based on the AGILE Level-3 archive of pre-computed counts, exp and background FITS maps, produced by the ADC.

SUMMARY AND OUTLOOK

- Future AGILE-LV3 Tool planned improvements (work in progress):
  - ✓ updated list of known AGILE sources with the publication of new AGILE catalogues (2AGL (see next talk by F. Verrecchia));
  - ✓ updated scientific s/w and calibrations;
  - ✓ updated AGILE diffuse background model in the Galactic Center region.

WARNINGS: for sources located in crowded regions of the Galactic plane and in the region of 5x5 degrees around the Galactic Center the interactive AGILE-LV3 online analysis might not be reliable at the moment.

STAY TUNED!

http://www.ssdc.asi.it/mmia/index.php?mission=agilelv3mmia

BACKUP SLIDES