AGILE Mission and AGN Studies

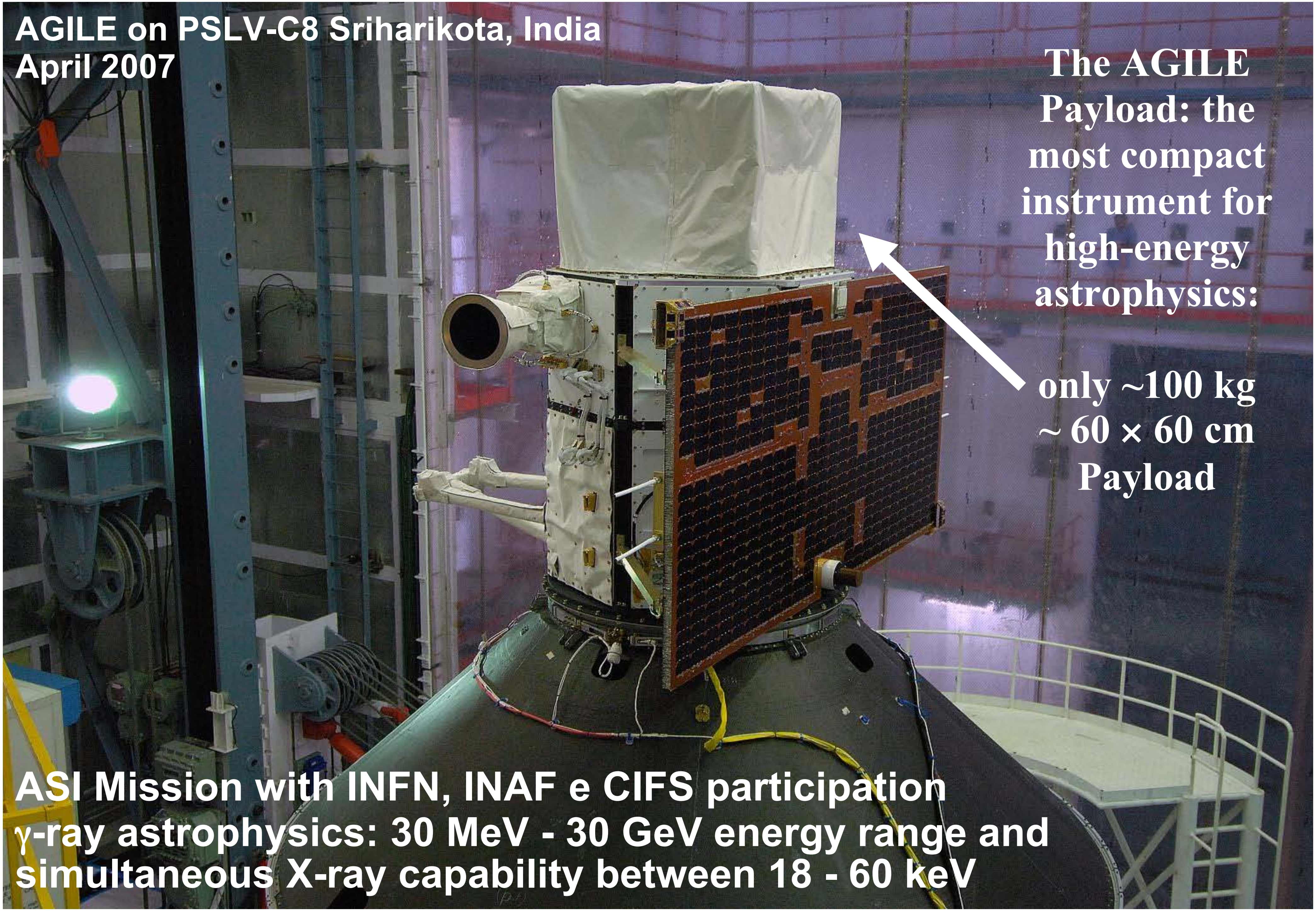
C. Pittori, F. Lucarelli and F. Verrecchia

on behalf of the AGILE Collaboration,

AGN WG and GASP-WEBT

MAGIC AGN MEETING 2013

ASDC, Feb 13, 2013


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, INAF e CIFS participation
γ-ray astrophysics: 30 MeV - 30 GeV energy range and
simultaneous X-ray capability between 18 - 60 keV

AGILE: inside the cube…

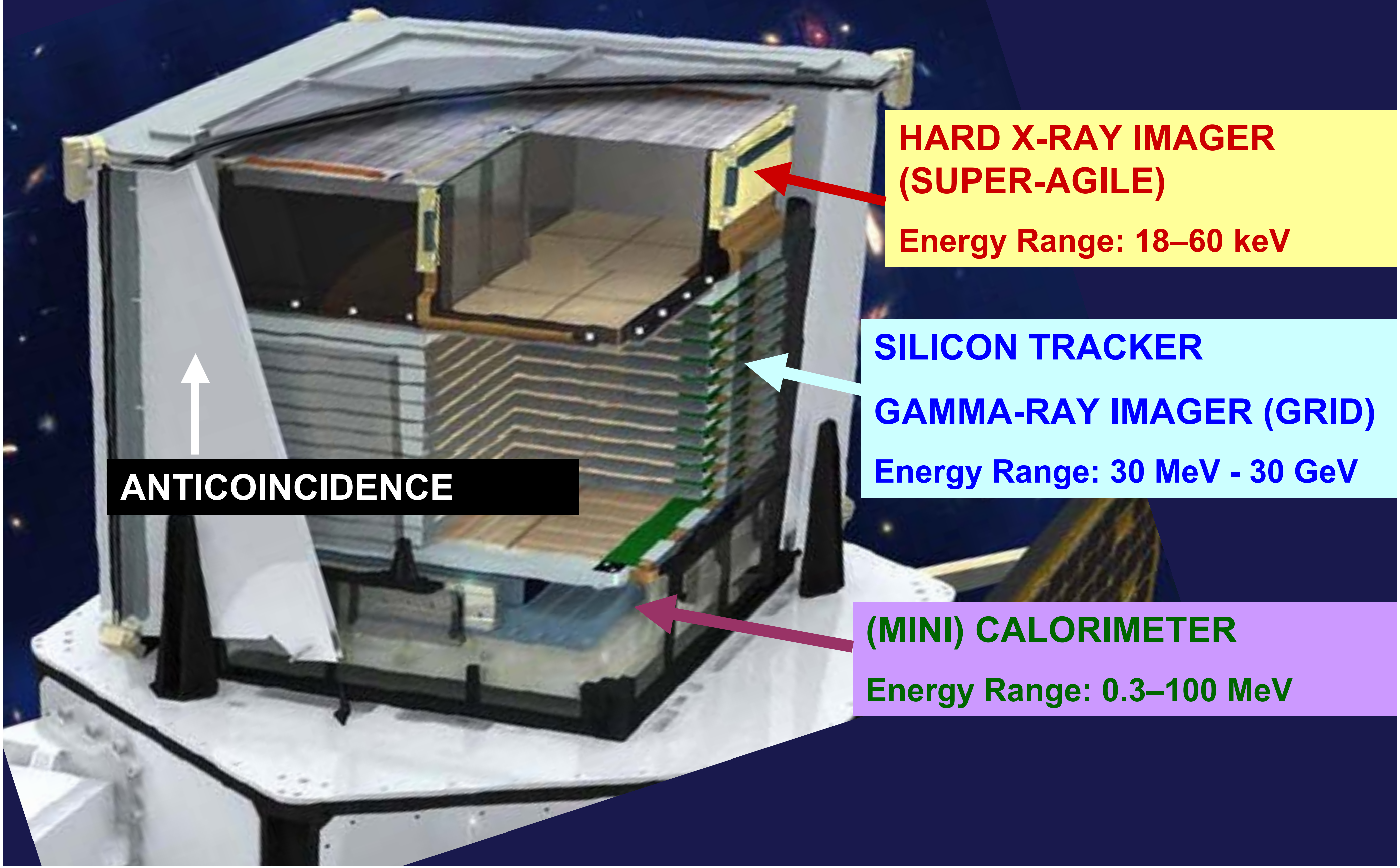
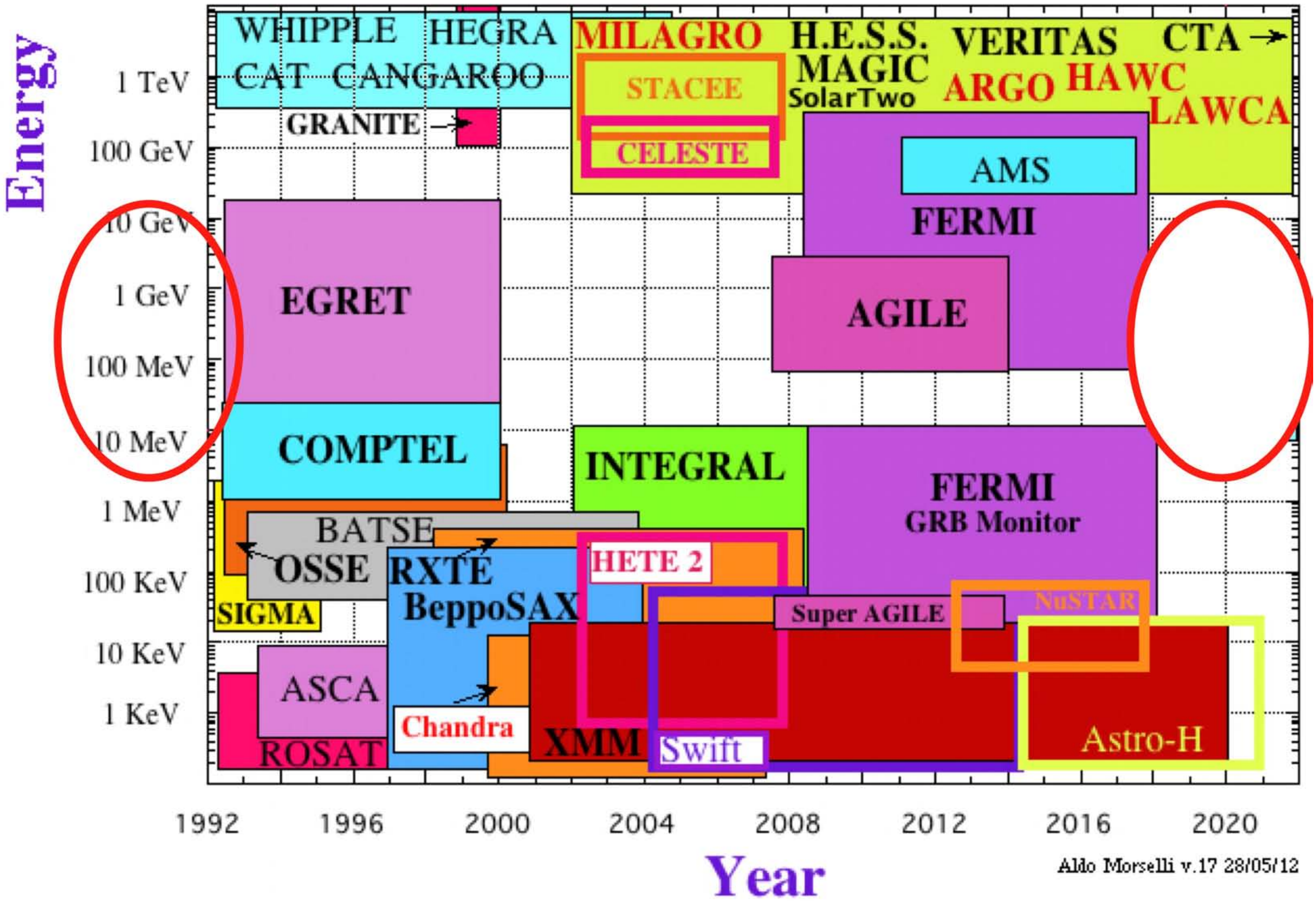
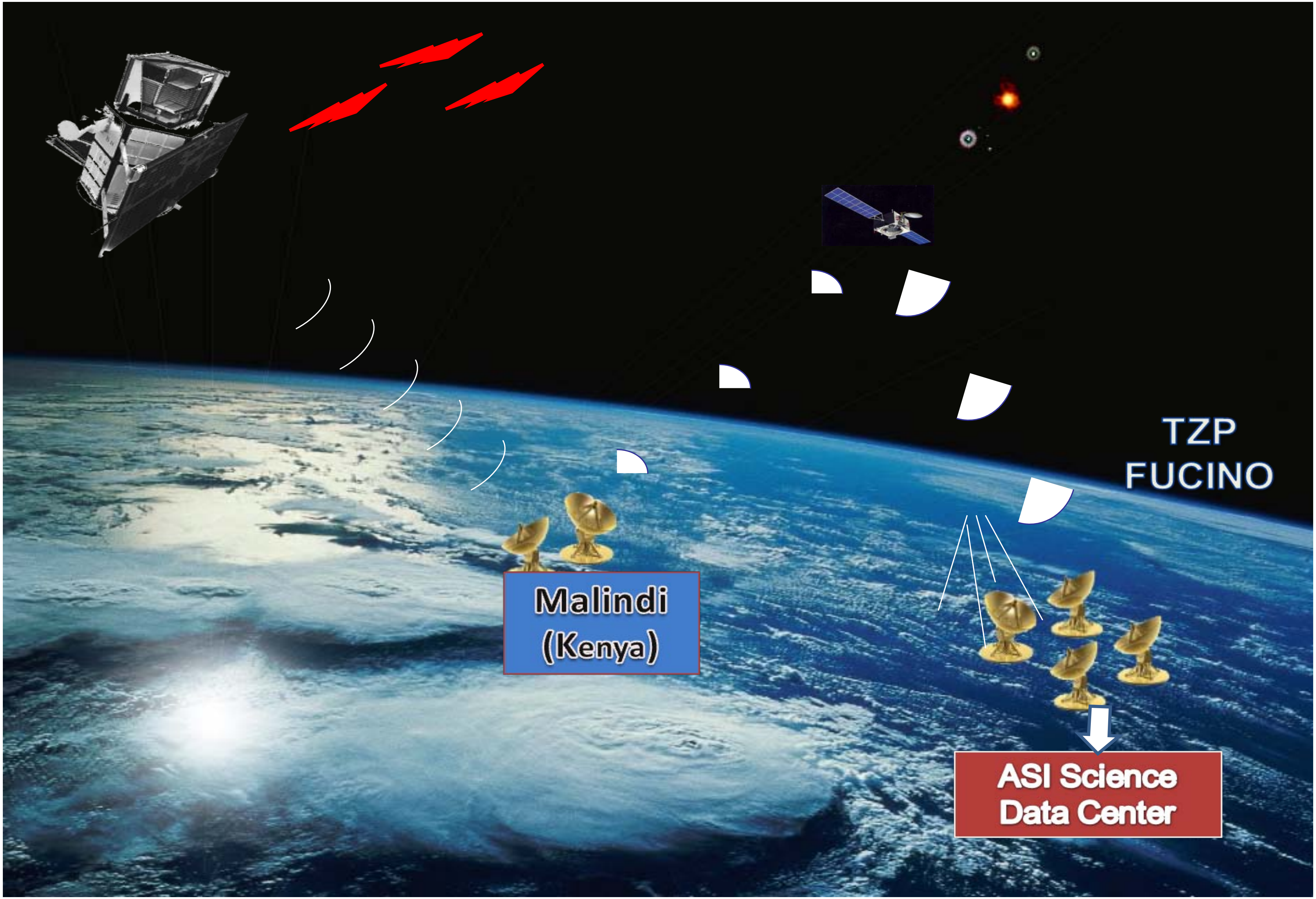


Table 3: AGILE Scientific Performance

Gamma-ray Imaging Detector (GRID)		
Energy Range	30 MeV – 50 GeV	
Field of view	~ 3 sr	
Sensitivity at 100 MeV (ph cm^{-2} s^{-1} MeV^{-1})	6×10^{-9}	(5σ in 10^6 s)
Sensitivity at 1 GeV (ph cm^{-2} s^{-1} MeV^{-1})	4×10^{-11}	(5σ in 10^6 s)
Angular Resolution at 1 GeV	36 arcmin	(68% cont. radius)
Source Location Accuracy	$\sim$5–20 arcmin	S/N$\sim$10
Energy Resolution	$\Delta E/E\sim1$	at 300 MeV
Absolute Time Resolution	$\sim 1\ \mu s$	
Deadtime	$\sim 200\ \mu s$	
Hard X–ray Imaging Detector (Super-AGILE)		
Energy Range	10 – 40 keV	
Field of view	$107^\circ\times68^\circ$	FW at Zero Sens.
Sensitivity (at 15 keV)	$\sim$5 mCrab	(5σ in 1 day)
Angular Resolution (pixel size)	$\sim$ 6 arcmin	
Source Location Accuracy	$\sim$2-3 arcmin	S/N$\sim$10
Energy Resolution	$\Delta E<4$ keV	
Absolute Time Resolution	$\sim 4\ \mu s$	
Deadtime (for each of the 16 readout units)	$\sim 4\ \mu s$	
Mini-Calorimeter		
Energy Range	0.3 – 200 MeV	
Energy Resolution	$\sim$1 MeV	above 1 MeV
Absolute Time Resolution	$\sim 3\ \mu s$	
Deadtime (for each of the 30 CsI bars)	$\sim 20\ \mu s$	

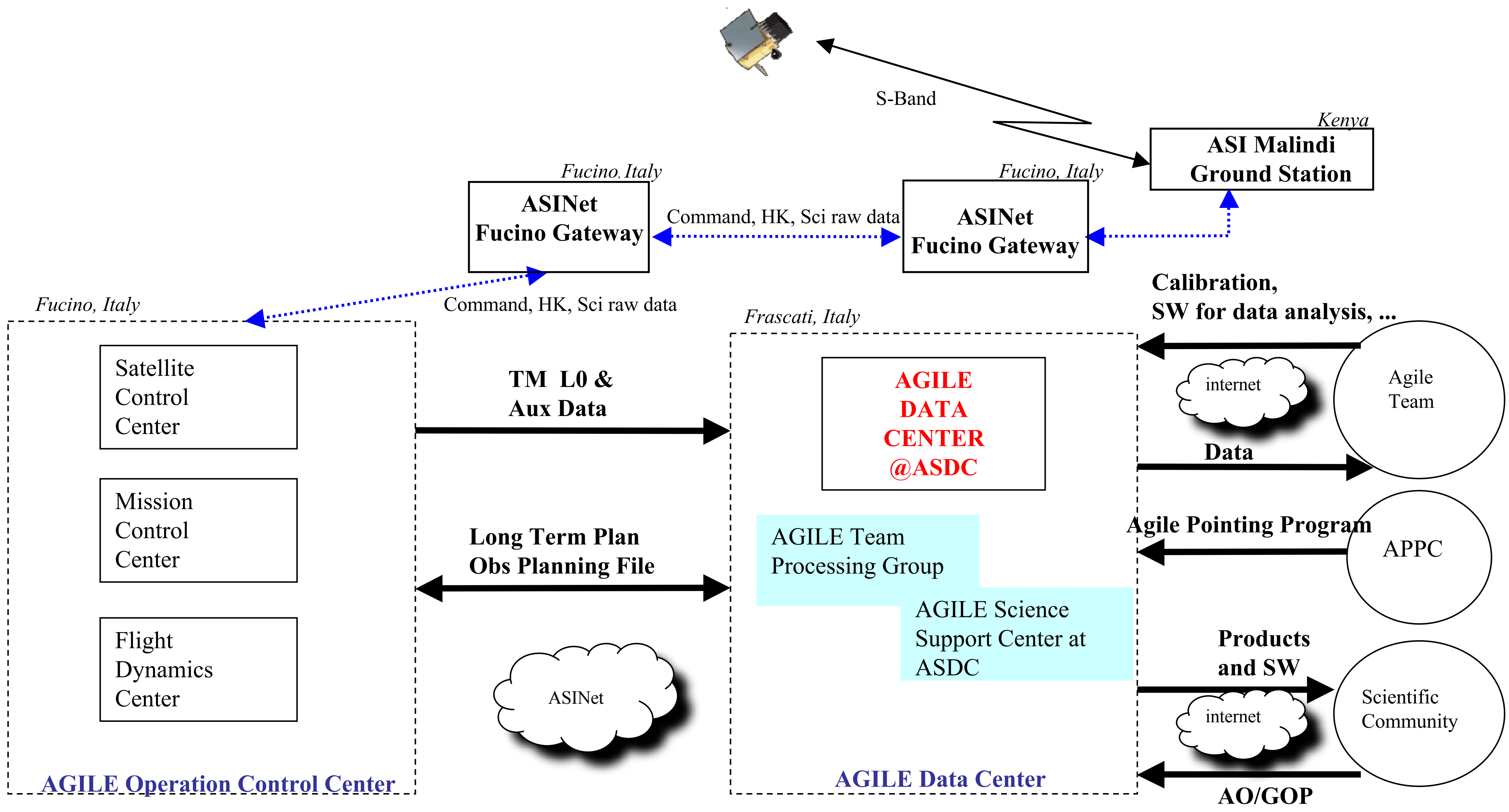


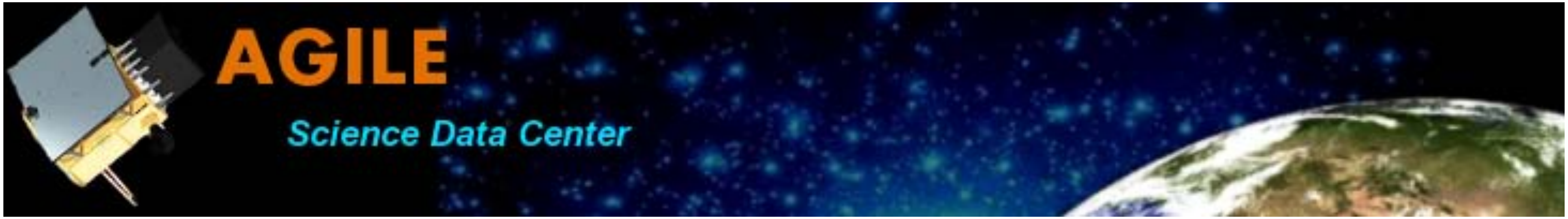
Energy
1 TeV
100 GeV
10 GeV
1 GeV
100 MeV
10 MeV
1 MeV
100 KeV
10 KeV
1 KeV
WHIPPLE
HEGRA
CAT
CANGAROO
GRANITE
MILAGRO
STACEE
CELESTE
H.E.S.S.
MAGIC
SolarTwo
VERITAS
ARGO
HAWC
CTA
LAWCA
AMS
FERMI
AGILE
EGRET
COMPTEL
INTEGRAL
FERMI
GRB Monitor
BATSE
OSSE
RXTE
BeppoSAX
SIGMA
HETE 2
Super AGILE
NuSTAR
ASCA
ROSAT
Chandra
XMM
Swift
Astro-H
1992
1996
2000
2004
2008
2012
2016
2020
Year
Aldo Morselli v.17 28/05/12



TZP
FUCINO
Malindi
(Kenya)
ASI Science
Data Center

AGILE GS Architecture

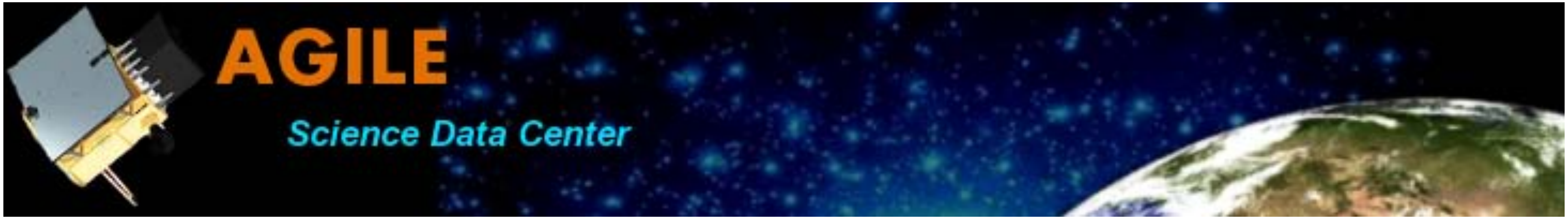




AGILE Telemetry raw data (Level-0) are down-linked every ~ 100 min to the ASI Malindi ground station in Kenya and transmitted first to the Telespazio Mission Control Center at Fucino, and then to the AGILE Data Center (ADC). Raw data are routinely received at ADC within ~ 5 min after the end of each contact.

ADC main tasks are:

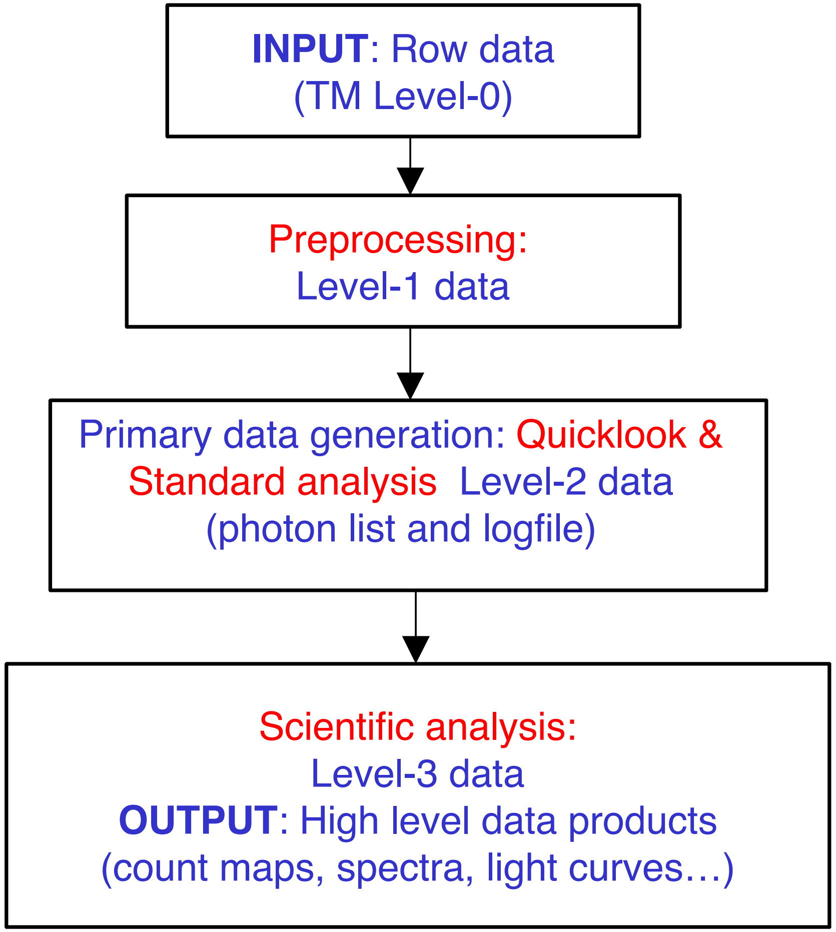
- data processing (real-time and reprocessing) and production of the data archives (from raw data to scientific level data through calibration level data),
- preliminary data analysis (Quick Look Analysis),
- management of the Guest Observer Program and of the AOs
- management of the Mission Planning (Long Term Plan preparation and emission),
- data and software distribution to the scientific community



- The ADC, based at ASDC-ESRIN, is in charge of all the scientific oriented activities related to the analysis and archiving of AGILE data:

From scientific telemetry (TM) Level–0:

- ✓ Preprocessing → Level-1 data
- ✓ Quick-Look Analysis (transient detection)
- ✓ Standard analysis → Level-2 data (photon list)
- ✓ Scientific analysis (source detection, diffuse gamma-ray background)
- ✓ Archiving and distributing all scientific AGILE data

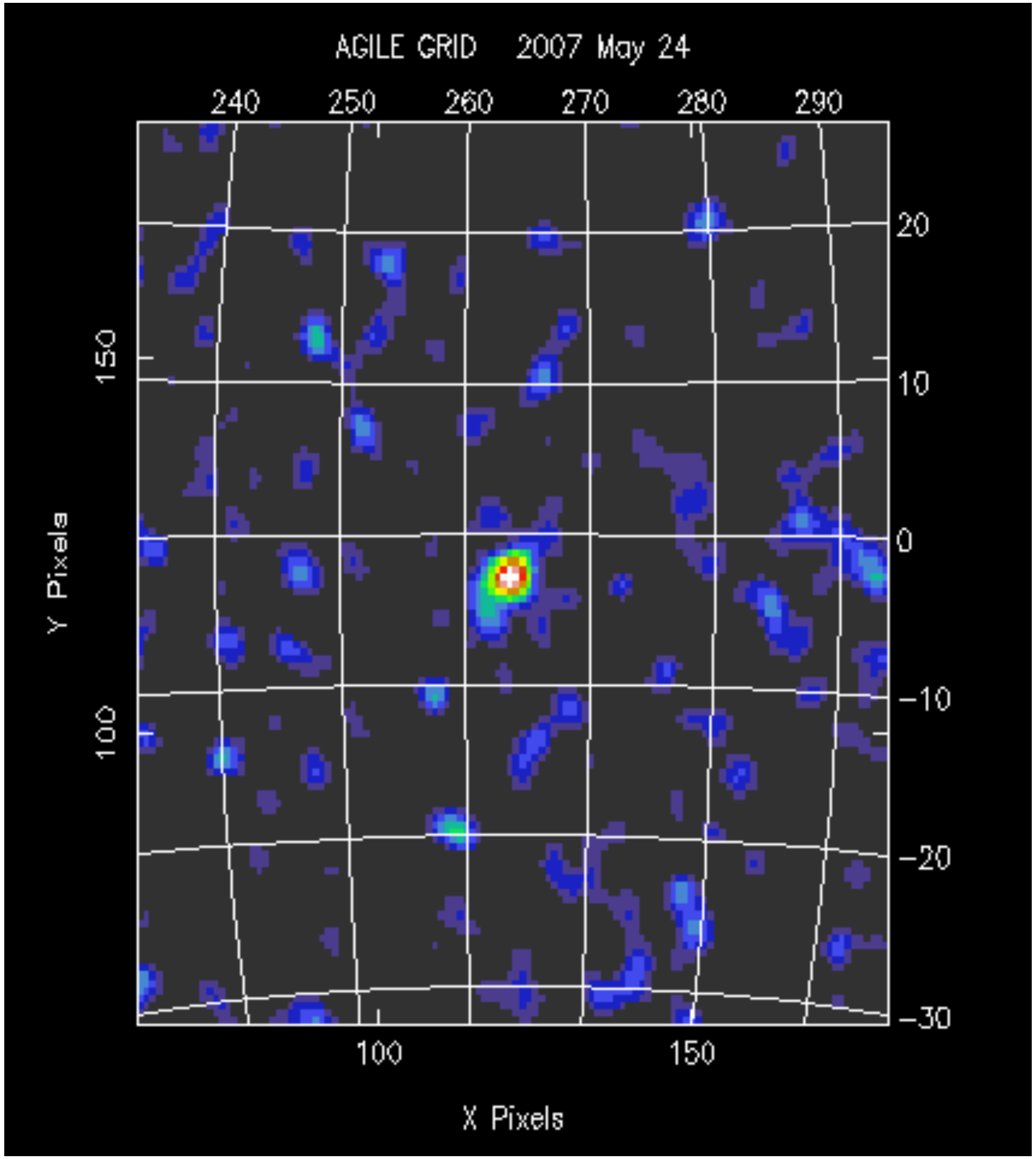


Commissioning Phase:

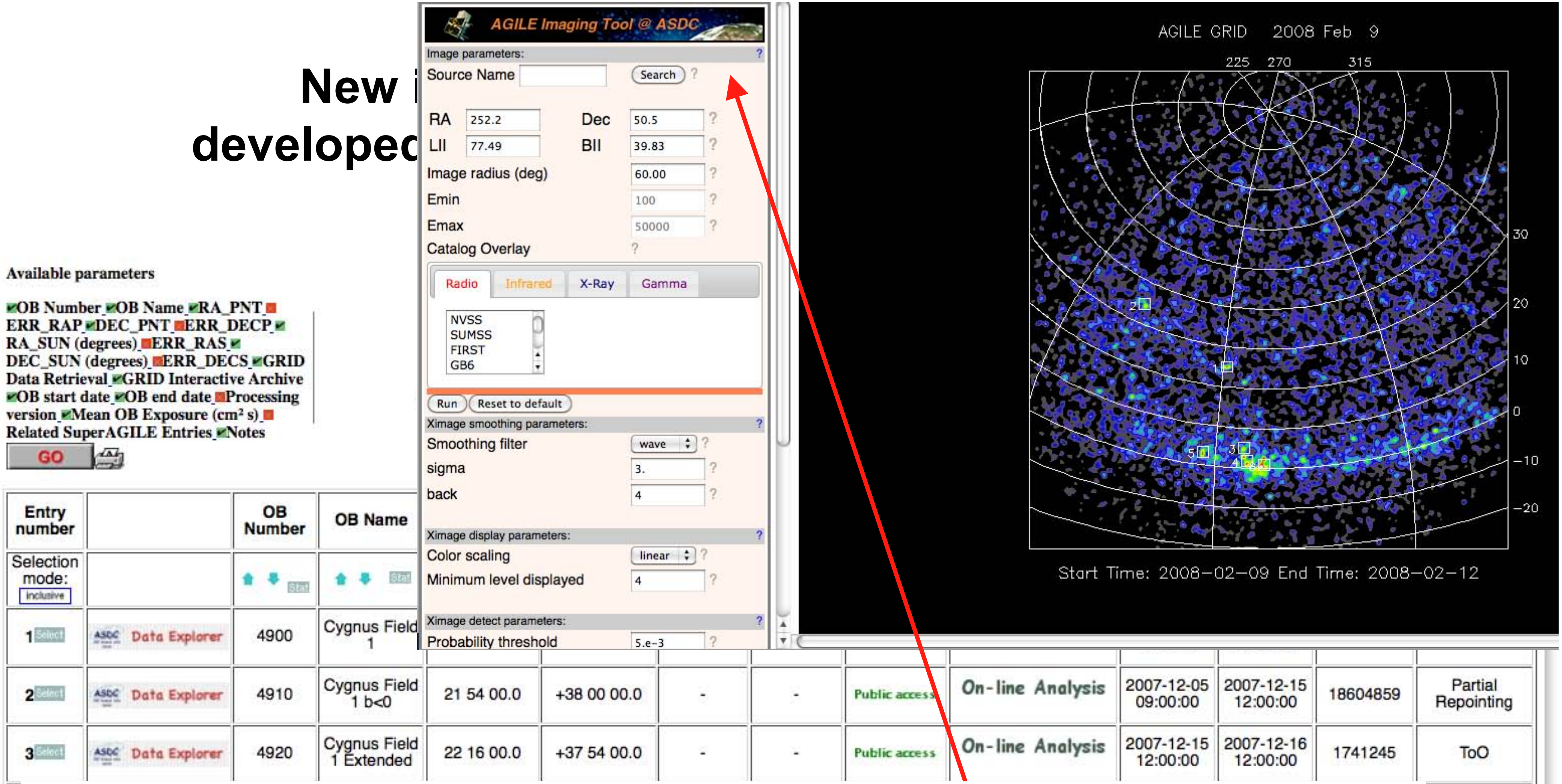
First GRID light

AGILE **Vela PSR** Count Map **by ADC, 24/5/2007**

(~ 20000 s)



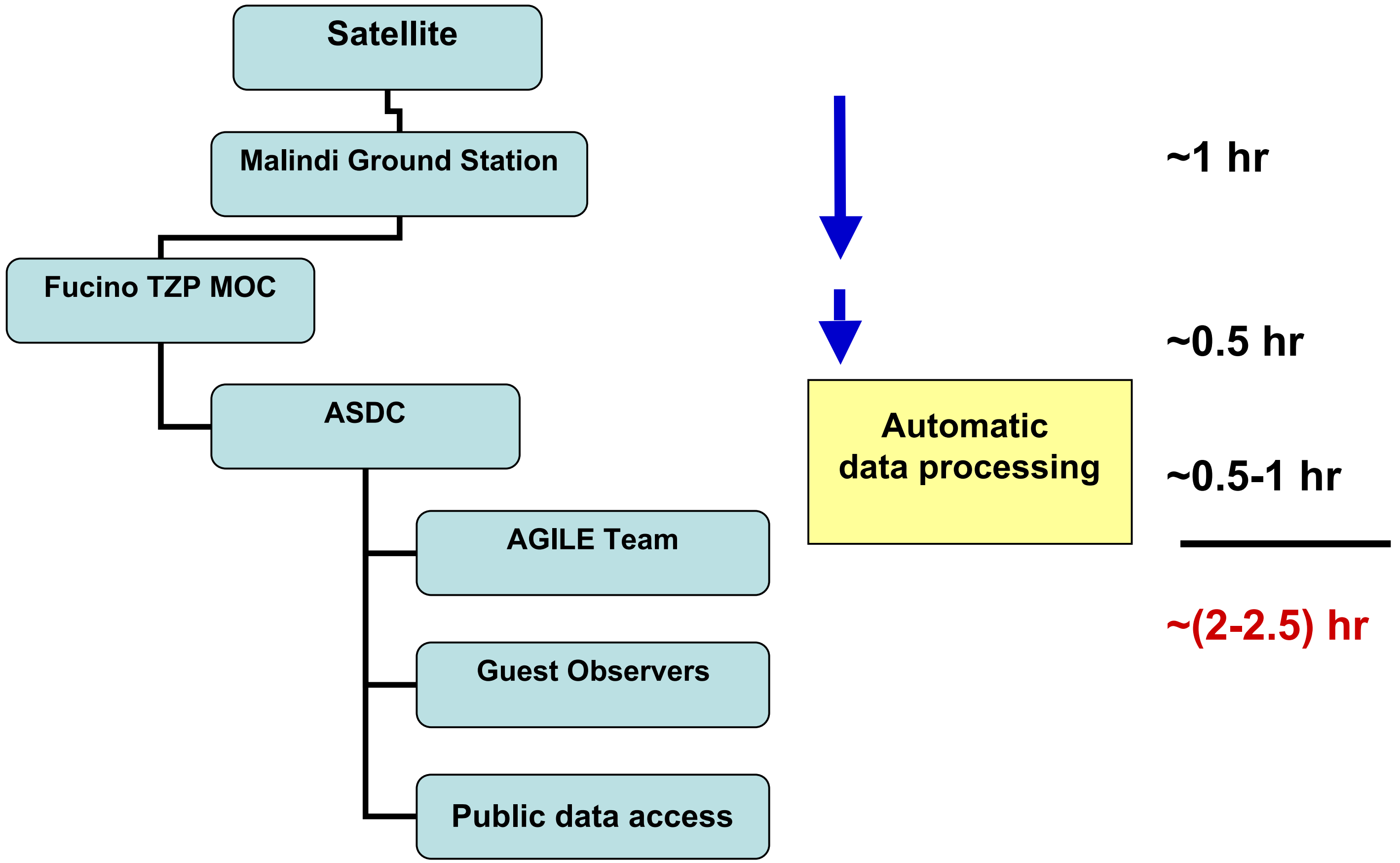
New i
develope



Ximage sw package adapted to gamma-rays

Allows web users to have a preview of the AGILE public data fields and perform an interactive preliminary analysis around a chosen sky position.

AGILE: “very fast” Ground Segment (with contained costs)



Record for a gamma-ray mission!

AGILE Science Alert System

- The system is distributed among the ADC @ ASDC and the AGILE Team Institutes (Trifoglio, Bulgarelli, Gianotti et al.)

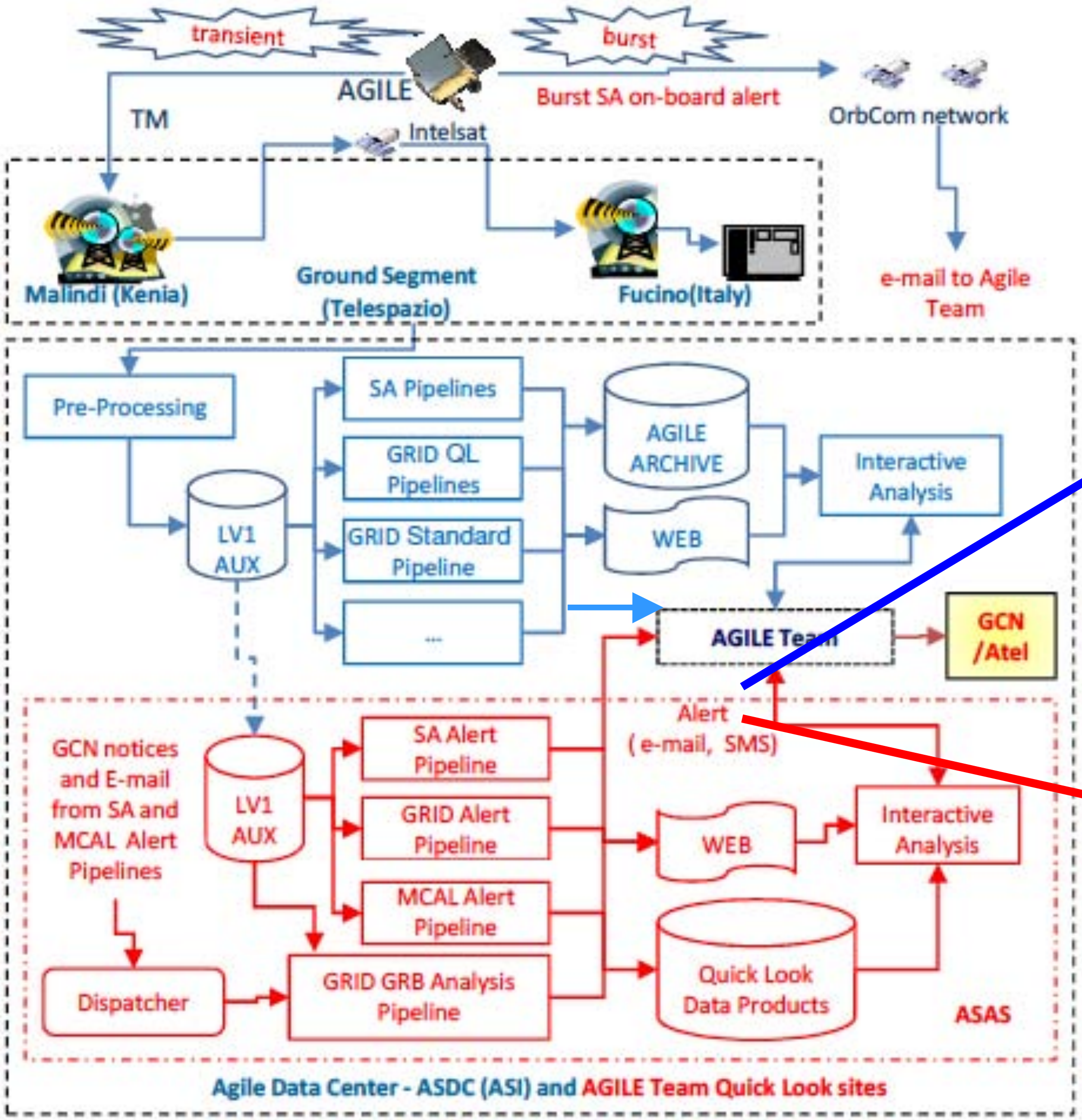
- Automatic Alerts to the AGILE Team are generated within **T_0 + 45 min (SA) and T_0 + 100 min (GRID)**

- GRID Alerts are sent via email (and sms) both on a contact-by-contact basis and on a daily timescale

- Refined manual analysis on most interesting alerts performed every day (daily monitoring)

- **101 ATel** (42 in pointing + 59 in spinning) and **38 GCN** published up to Dec 17, 2012

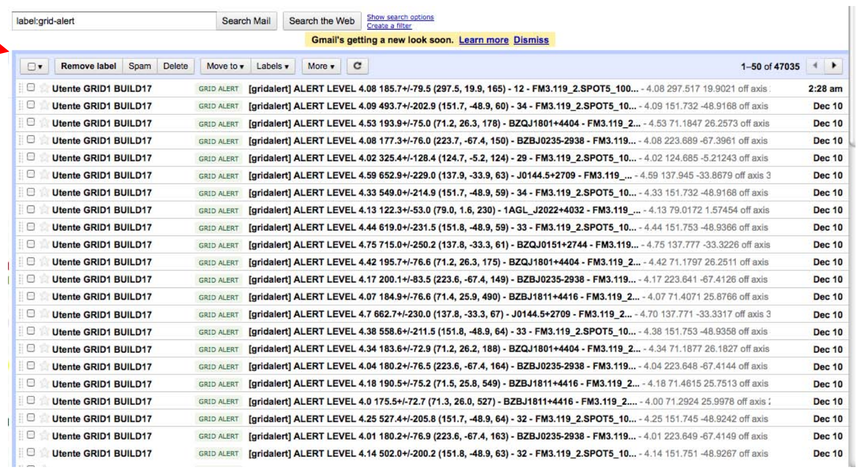
Selected alerts sent via email, sms



(Figure adapted from **M. Trifoglio et al.**)

Daily time scale (twice a day)

Contact-by-contact time scale (~100 min)



AGILE: 6th year in orbit

- AGILE demonstrates for the first time the covering of ~ 1/5 of the entire gamma-ray sky (FoV ~ 2.5 sr) with excellent angular resolution and competitive sensitivity.
- AGILE shows for the first time an optimal performance of its gamma-ray and hard X-ray imagers.
- **~ 30000 orbits, 14 Feb 2013**
- **Pointing observation** mode up to October 18, 2009 and **spinning observation mode** since October 2009.
- **Very good scientific performance, especially at ~ 100 MeV**
- **Guest Observer Program open to the scientific community:**

  Cycle-1: completed, Dec. 1, 2007 – Nov 30, 2008

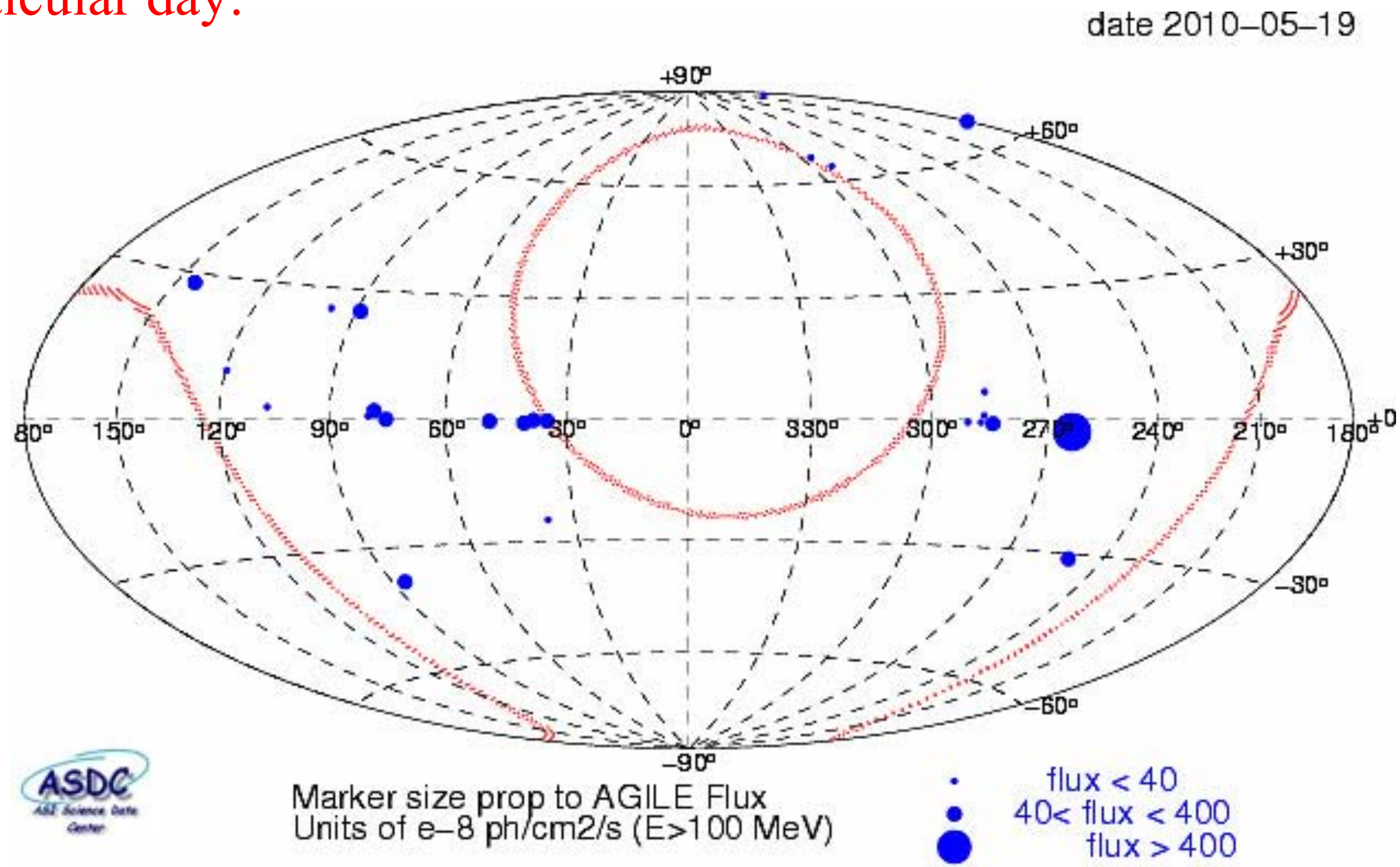
  Cycle-2: completed, Dec. 1, 2008 – Nov 30, 2009

  Cycle-3: completed, Dec. 1, 2009 – Nov 30, 2010

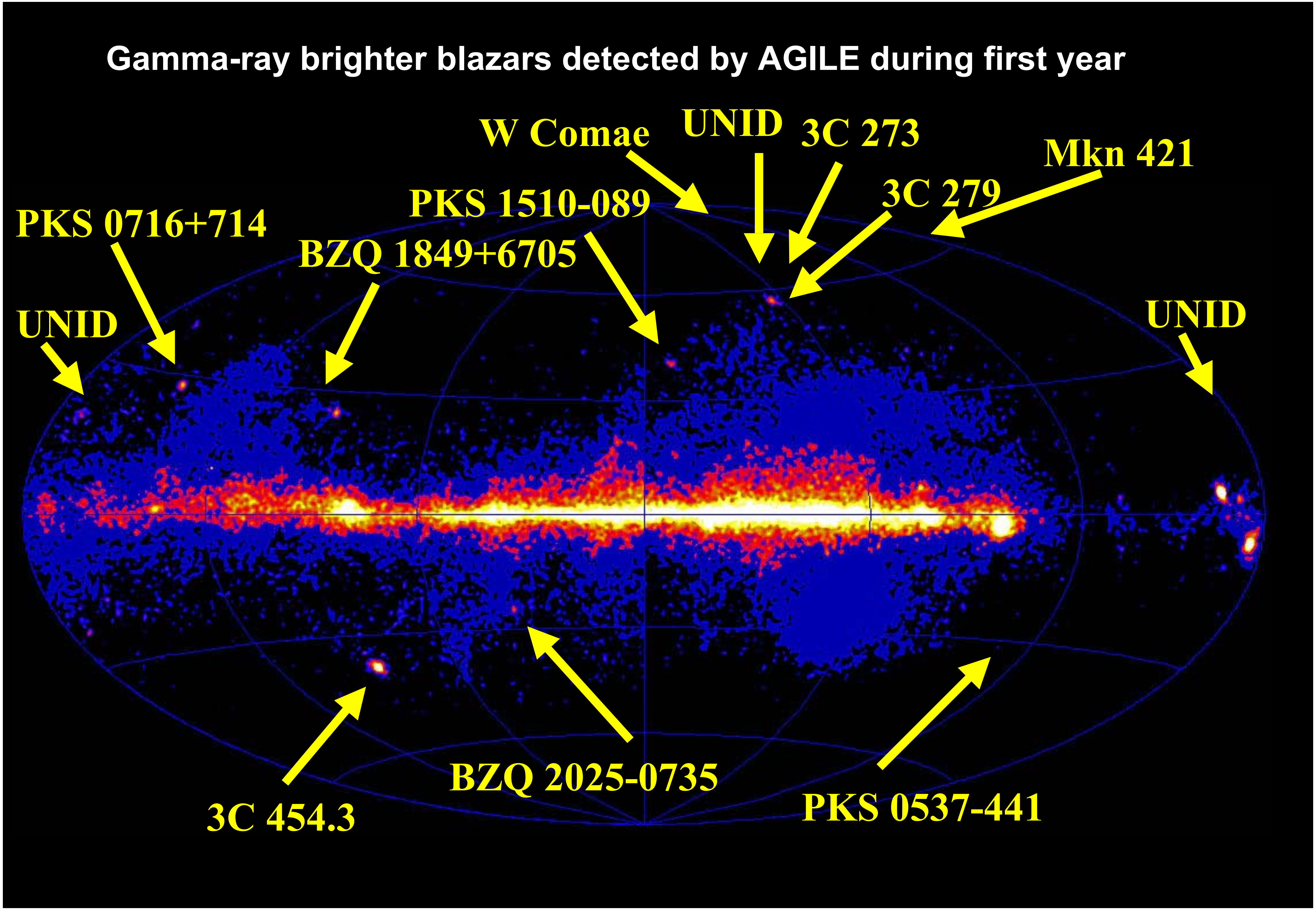
  Cycle-4: completed, Dec. 1, 2000 – Nov 30, 2011

  Cycle-5 and Cycle-6: on-going data taking

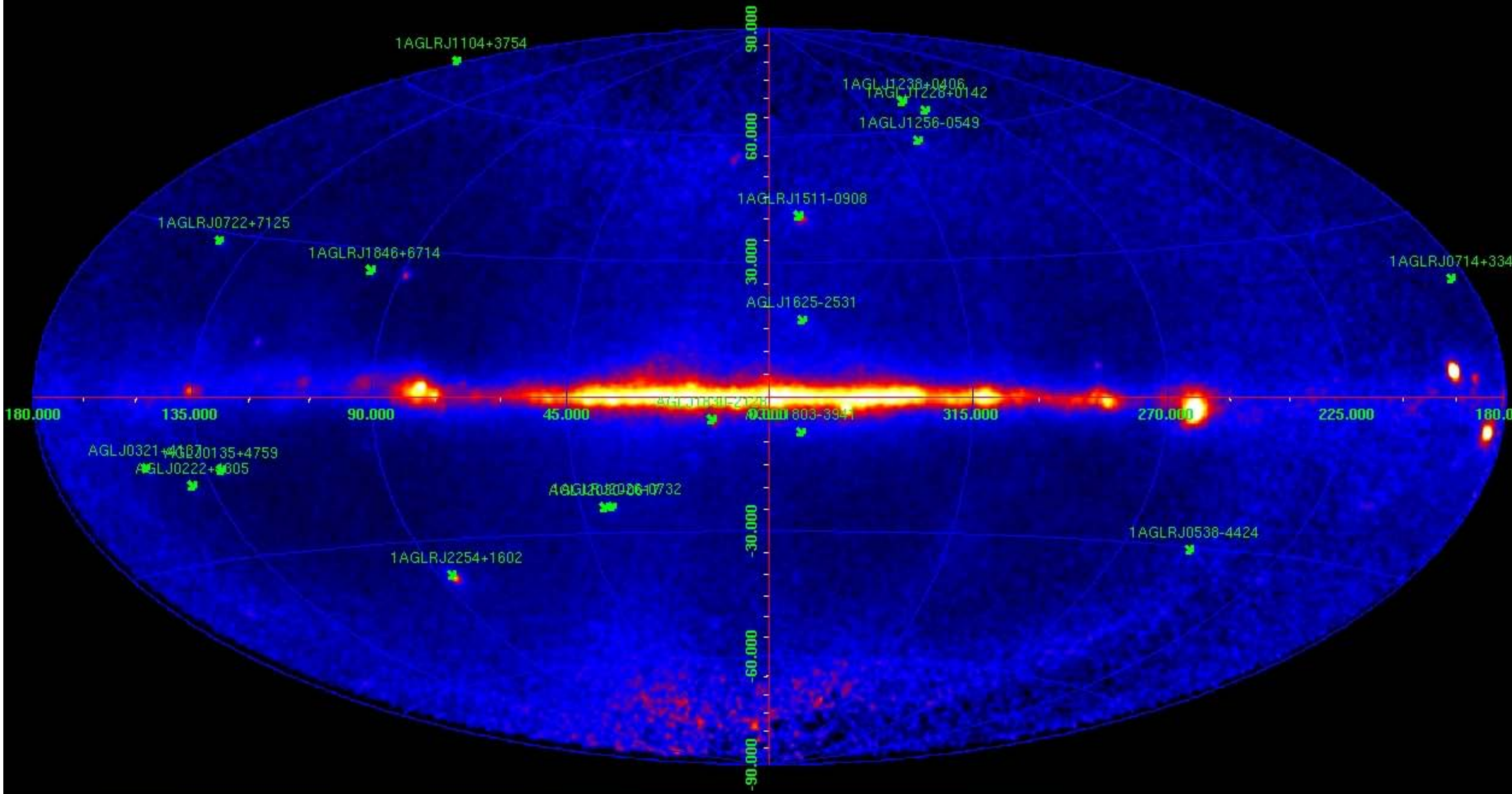
On November 4, 2009, toward the end of Cycle-2, AGILE scientific operations were reconfigured following a malfunction of the reaction wheel. The satellite is currently operating in a **spinning observing mode** and it is now surveying a large fraction of the sky every day. Example of the AGILE spinning sky-view on a particular day:



On December 3-4, 2009 the AGILE satellite detected the strongest γ-ray flare ever observed (E > 100 MeV). The flaring γ-ray source is in the active galaxy 3C454.3 ($z=0.859$, $F_\gamma > 2 \times 10^{-5}$ ph cm^{-2} s^{-1}, $L_{iso} = 6 \times 10^{49}$ erg s^{-1})


Gamma-ray brighter blazars detected by AGILE during first year
W Comae
UNID
3C 273
Mkn 421
3C 279
PKS 1510-089
PKS 0716+714
BZQ 1849+6705
UNID
UNID
3C 454.3
BZQ 2025-0735
PKS 0537-441

Gamma-ray brighter blazars detected by AGILE during the 2.3yr pointing period



Verrecchia et al., (variability study) in progress

AGILE first-years blazar studies summary:

• AGILE (as EGRET and now Fermi) detects **only few objects** with flux greater than 100 x 10^{-8} ph cm^{-2} s^{-1}. Selection effects or there is a subclass of blazar with peculiar characteristics?

• AGILE observations has brought to light a **more complex behaviour of blazars with respect to the standard SSC models**:

- the presence of two emission components in any BL Lacs

- the possible contributions of an hot corona as source of seed photons for the EC in FSRQs

• The study of multi-wavelength correlations and variability is the key to understanding the structure of the inner jet and the origin of the seed photons for the IC process.

AGILE AGN studies and the MW approach

- Optical/UV observations in different γ-ray states
- Radio/Optical/γ-rays
- Soft-X and γ-rays
- The GeV-TeV connection
- Peculiar variability

Observatory	Energy domain
VLBA/UMRAO	Radio
Spitzer	IR
REM	IR-Optical
WEBT-GASP	Radio-mm-Optical-IR
XMM-*Newton*	UV + soft X-ray
Swift	UV + soft X-ray + hard X-ray
Suzaku	Soft X-ray + hard X-ray
RXTE	Hard X-ray
INTEGRAL	Hard X-ray
Super-AGILE	Hard X-ray
AGILE/GRID	Gamma-ray
MAGIC	TeV
VERITAS	TeV
ARGO	TeV
H.E.S.S.	TeV

Adapted from Donnarumma, BOHEME Meeting, 2012

The AGILE blazars

AGILE investigated at least one object for each blazar category, e.g.:

FSRQ → 3C 454.3	LBL→ PKS 0537-441	IBL → S5 0716+714	HBL → MKN 421

Some sources were detected in an high state more than once, e.g.:

3C 454.3	PKS 1510-089	S5 0716+714	3C 273	PKS 1830-211

Variability level could be very different, e.g.:

Low → MKN 421	Extremely high→ PKS 1510-089 / 3C 454.3 / 4C+21.35

Gamma-ray activity could vary on different time scale, e.g.:

A few days → W Com / 4C 21+35	1-month→ PKS 1830-211	Several months → 3C 454.3

Adapted from Donnarumma, BOHEME Meeting, 2012

Optical-UV observations in different γ-ray states are able to constrain:

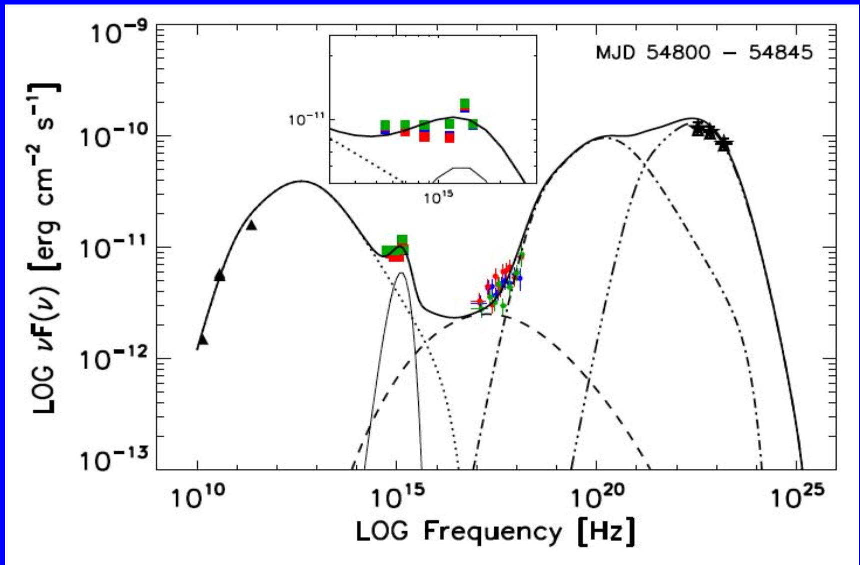
a) the acceleration efficiency given the evidence/lack of the thermal component in FSRQs

b) the external seed photon component responsible of the IC peak by estimating the accretion disk luminosity, with a better definition of the γ-ray dissipation region

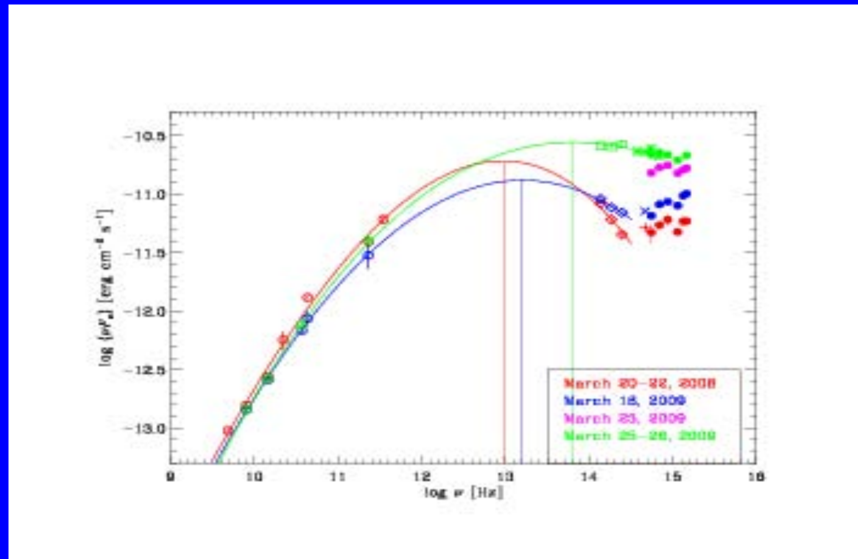
c) possible time lags between synchrotron and IC emissions in low synchrotron peak sources.

Evidence/lack of optical/UV thermal components vs gamma-ray states

3C 454.3



PKS 1510-089



Vercellone et al., 2010, ApJ, 712, 405,

3C 454.3 – October 2008 campaign

The thermal disc contribution is unveiled during the <u>low gamma-ray state</u>

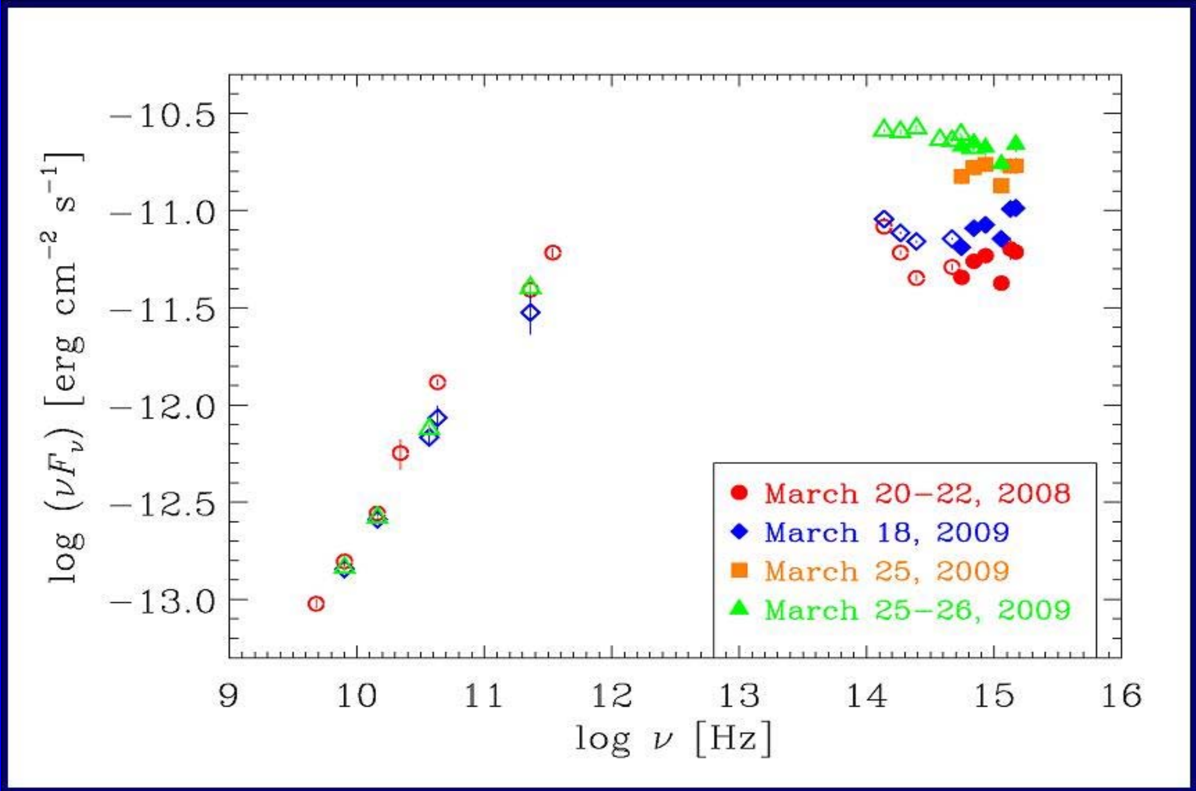
D'Ammando et al. 2011, A&A , 529, 145

PKS 1510-089 - March 2009 campaign

Evidence of accretion disk variation in different states (red – blue points)

Adapted from Donnarumma, BOHEME Meeting 2012

SED radio-to-UV of PKS 1510 in 2008-2009



D'Ammando et al. 2011, A&A 529, 145

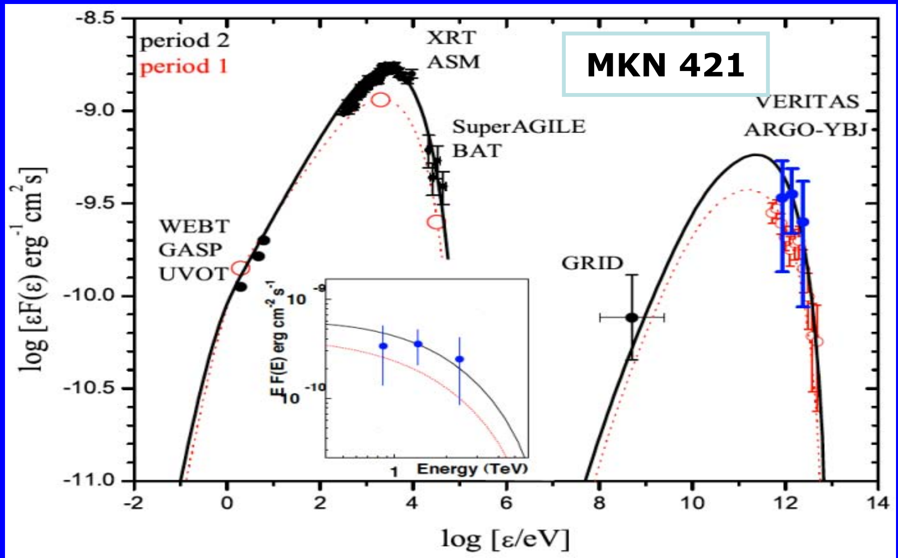
The flat spectrum observed on 25-26 March 2009 at optical and UV suggests an important contribution of the synchrotron emission in this part of the spectrum during the flaring activity

Considering that the synchrotron peak is usually observed in the infrared band in PKS 1510-089, this is an indication of a significative shift of the synchrotron peak during very high activity of the source at the end of March 2009

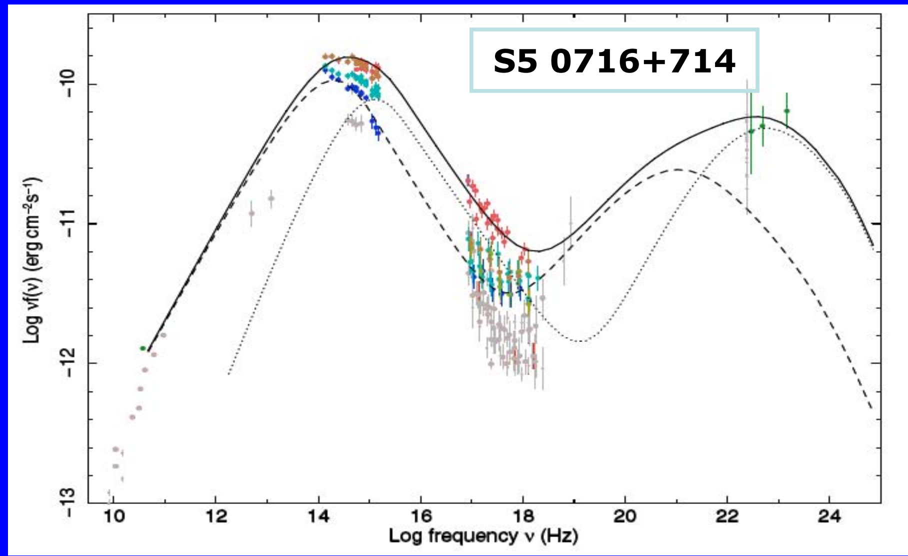
Slide adapted from Filippo D'Ammando, COSPAR 2010

SEDs

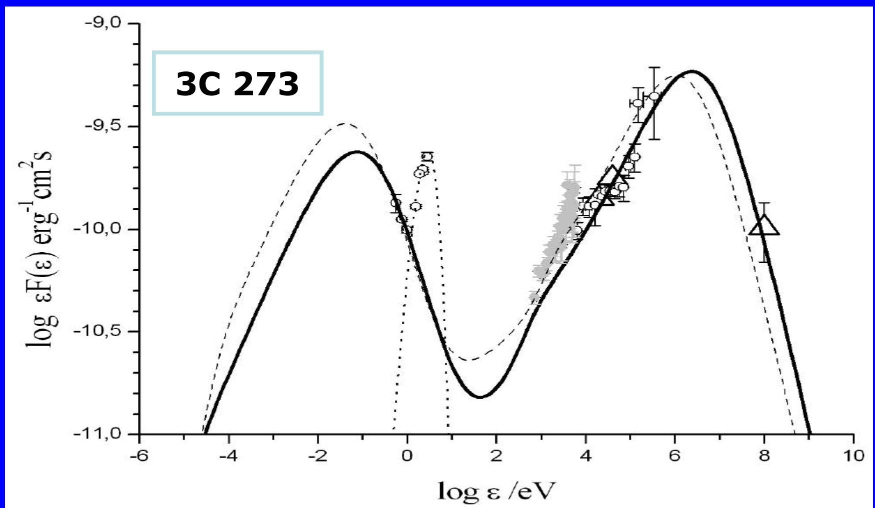
SSC 1-comp



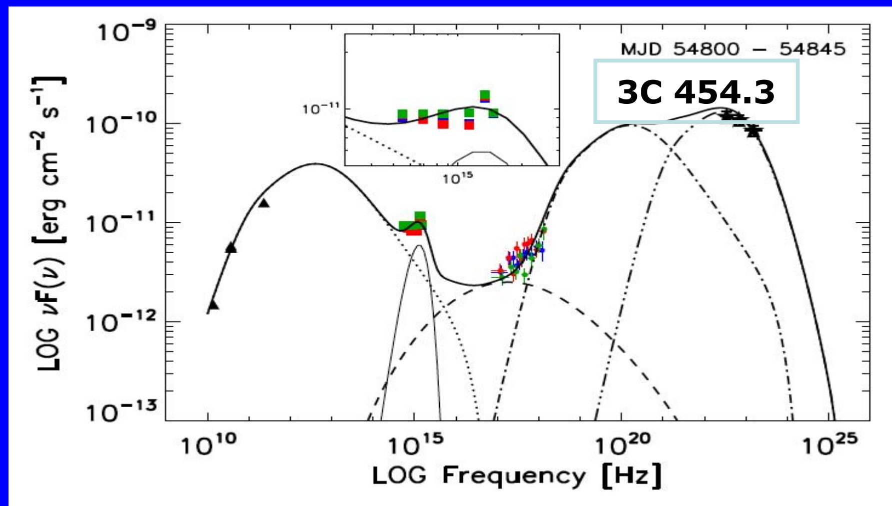
SSC 2-comp



EC(disk)

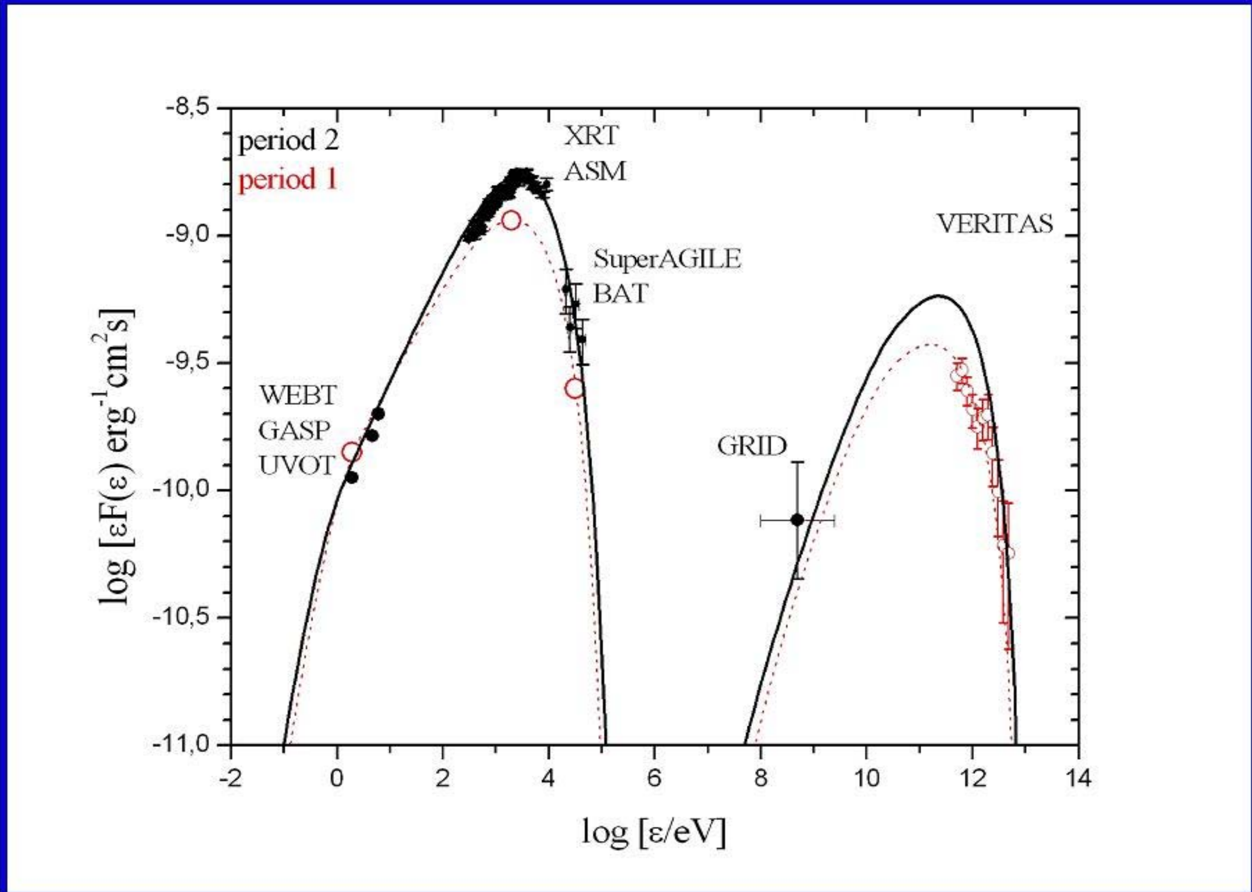


EC(BLR)



Adapted from Donnarumma, BOHEME Meeting 2012

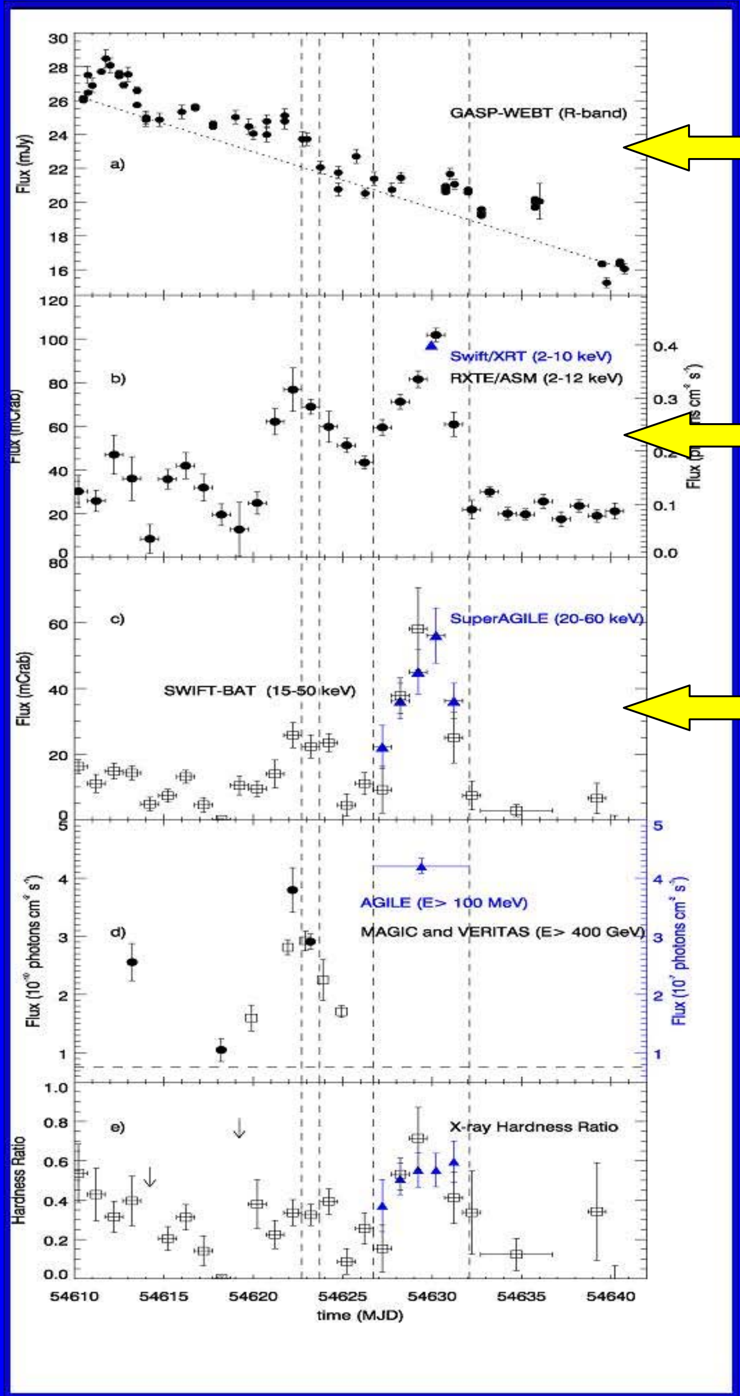
The broad band spectrum of Mrk 421 from optical to TeV



Donnarumma, et al. 2009, ApJ 691, L13

The gamma-ray flare can be interpreted in the framework of the SSC model in terms of *a rapid accelerations of leptons* in jet, in accordance also with the X-ray and VHE correlation observed

Slide adapted from Filippo D'Ammando, COSPAR 2010



optical

Soft, hard X-ray and TeV emissions seem to be correlated in agreement with the SSC scenario..

soft X-ray

..but the different behaviour at optical and X-rays could suggest a more complex scenario

hard X-ray

The optical and X-ray radiation could be produced in different regions of a helical jet, with the inner jet region that produces the X-rays and it is partially transparent to the optical radiation, whereas the outer region produces only the lower-frequency emission

Donnarumma, et al. 2009, ApJ, 691, L13

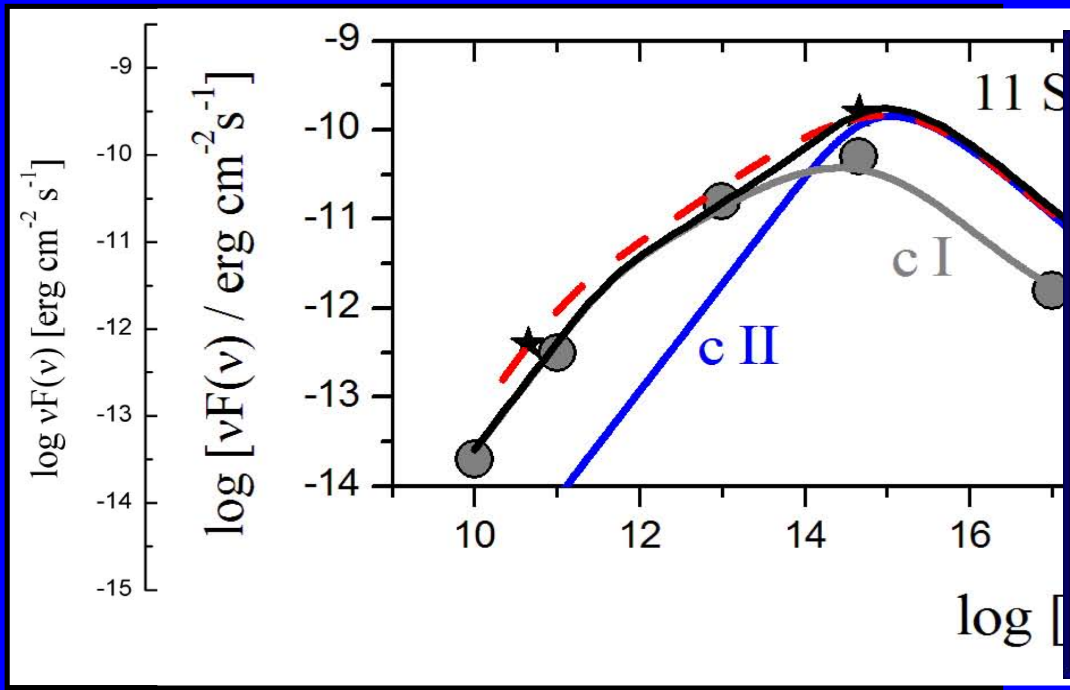
Two SSC components in the spectrum of S5 0716+714

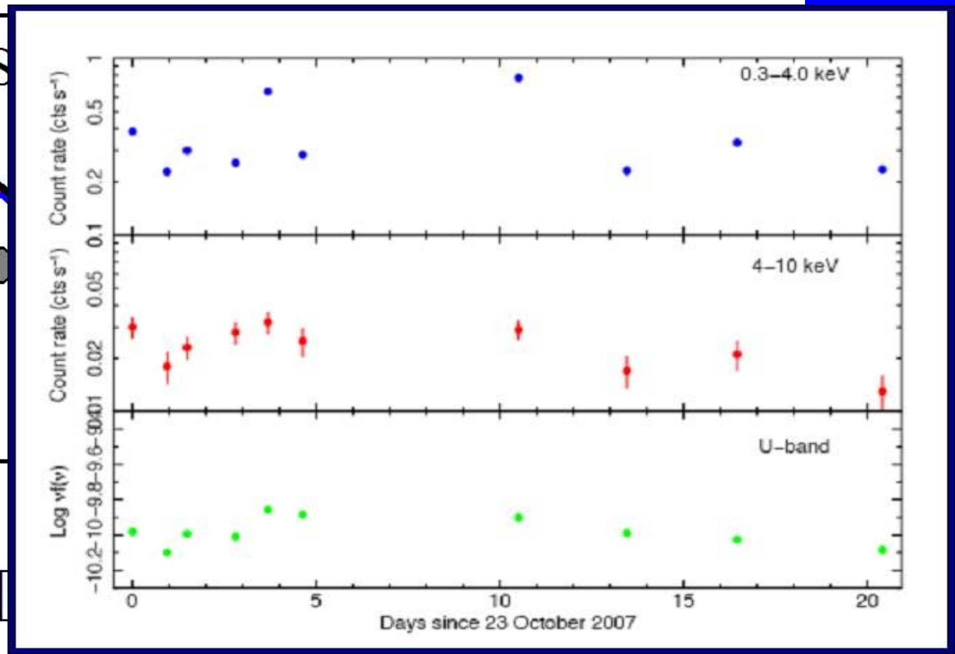
A one-zone SSC model fails to reproduce the SED of the two gamma-ray flares occurred on September and October 2007

Two SSC components reproduce the complex variability observed:

- a *slow variable component* responsible for the radio and hard X-ray emission (CI)

- a *fast variable component* responsible for the optical, soft X-ray and gamma-ray emission (CII)



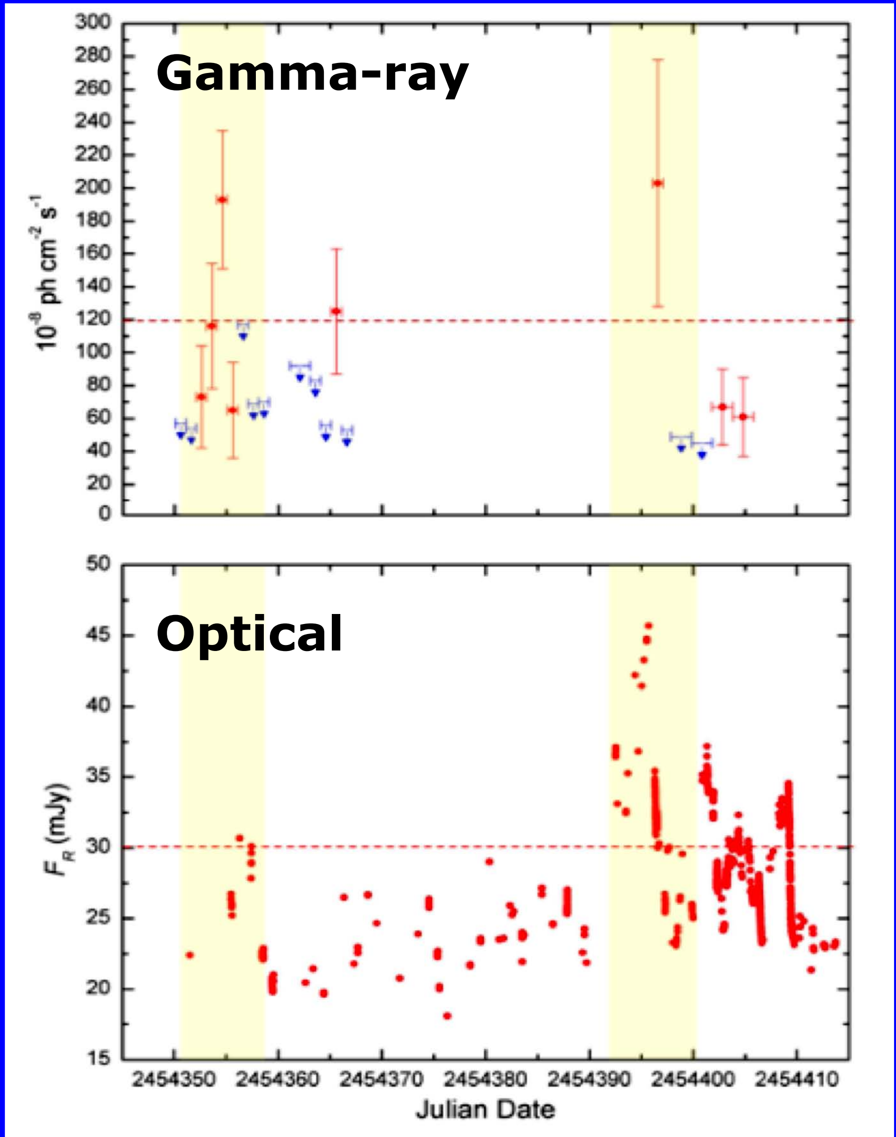


Chen, et al. 2008, A&A, 489, L37

Adapted from Giommi et al., 2008, A&A, 489, L49

Slide adapted from Filippo D'Ammando, COSPAR 2010

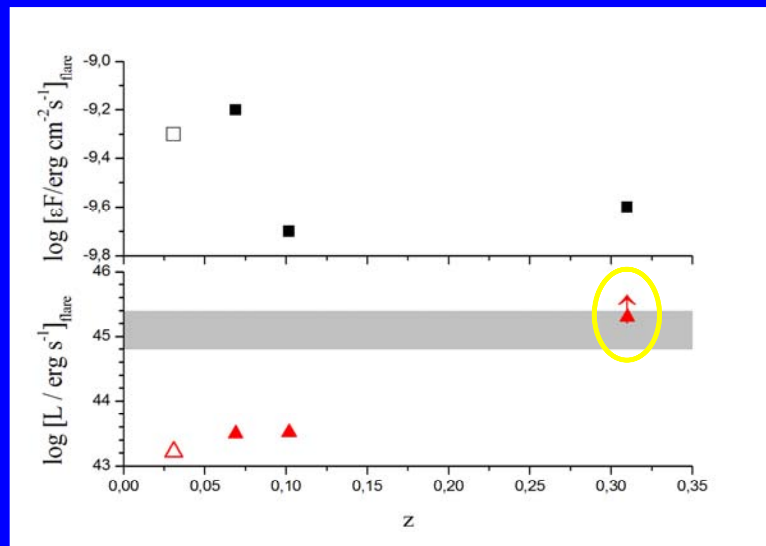
0716+714 in Sept-Oct 2007 approaches the BZ limit



Chen, et al. 2008, 489, L37

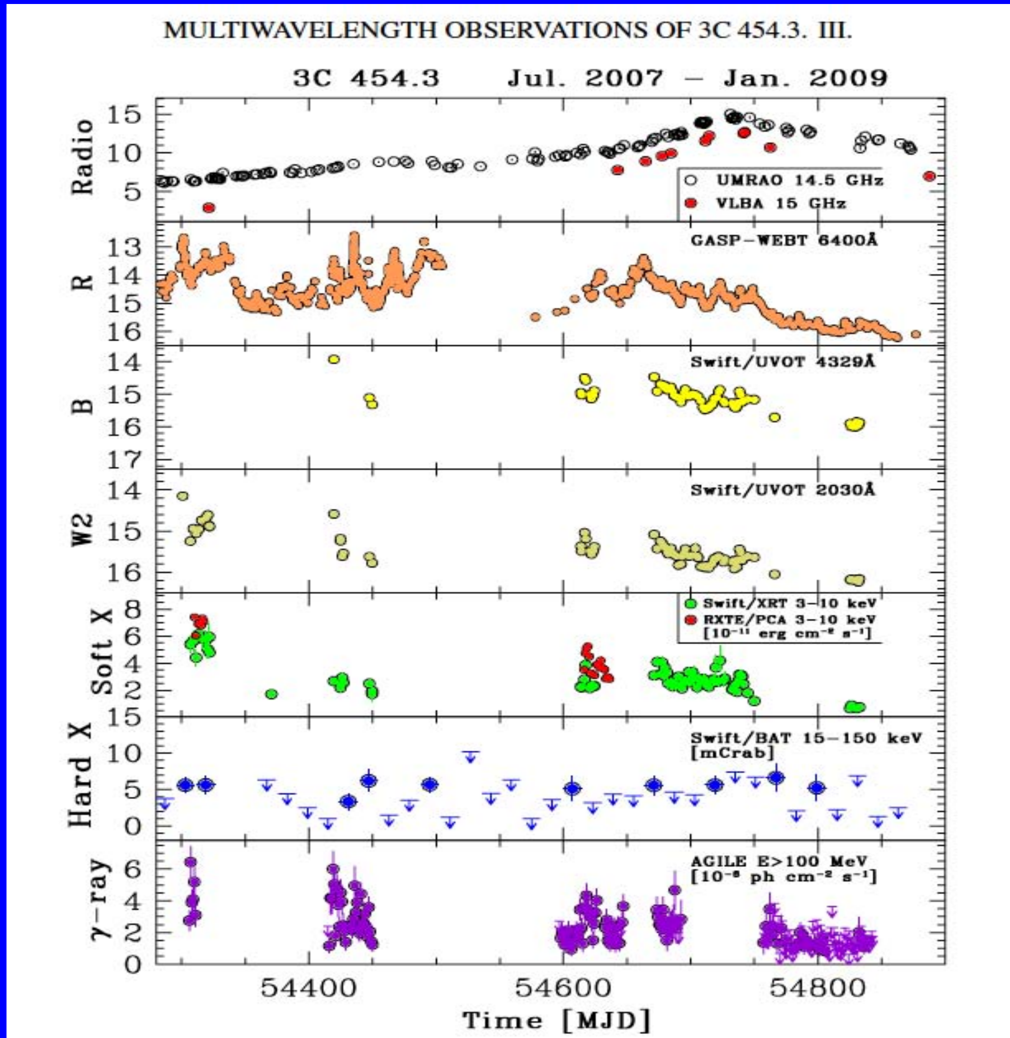
The fluxes detected during the gamma-ray flares of September and October 2007 are among the highest for a BL Lac object

The total power transported in the jet during these episodes is $P_{tot,\ flare} = (3.5 \pm 1.0) \times 10^{45}$ erg s^{-1}, approaching or slightly exceeding the maximum power generated by a spinning black hole of $10^9\ M_{\odot}$ via the BZ mechanism



Vittorini et al. 2009, ApJ, 706, L1433

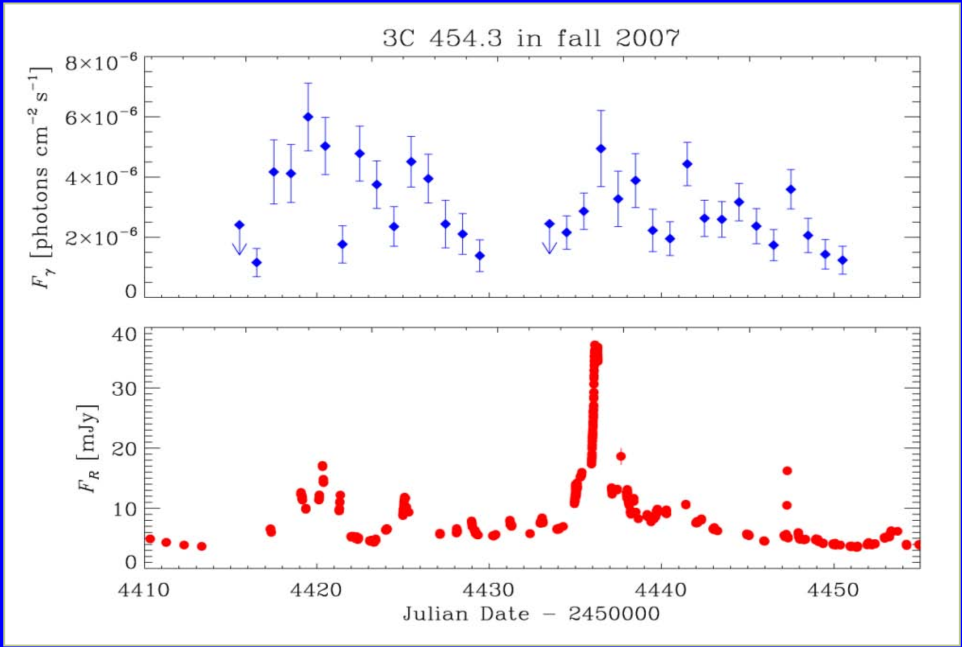
Long time-scale monitoring

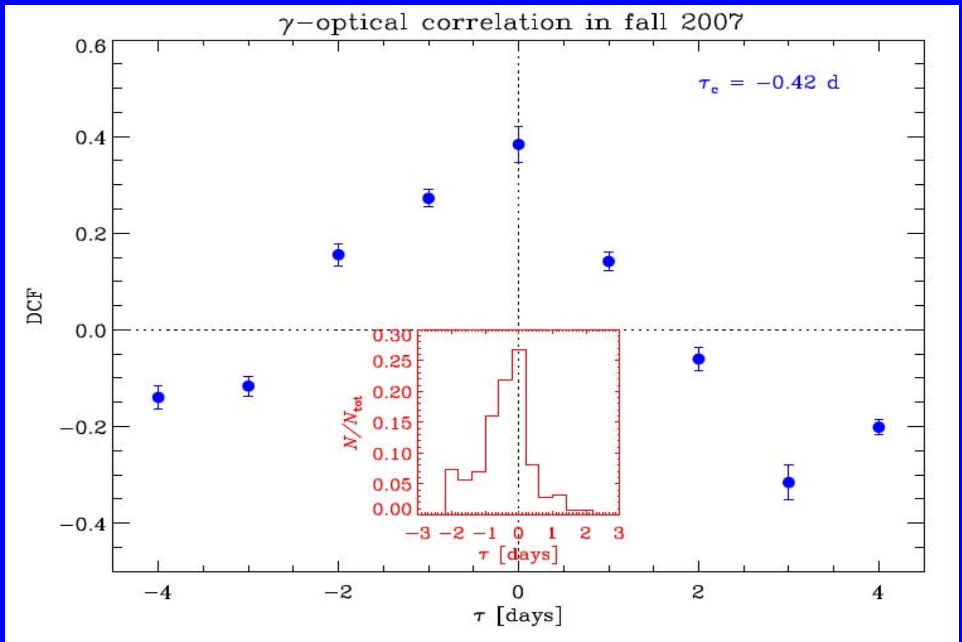


Vercellone et al., 2010, ApJ, 712, 405
18 months campaign on 3C 454.3

Adapted from Donnarumma, BOHEME Meeting 2012

Vercellone et al., 2010, ApJ, 712,405





Time-lags: 3C 454.3

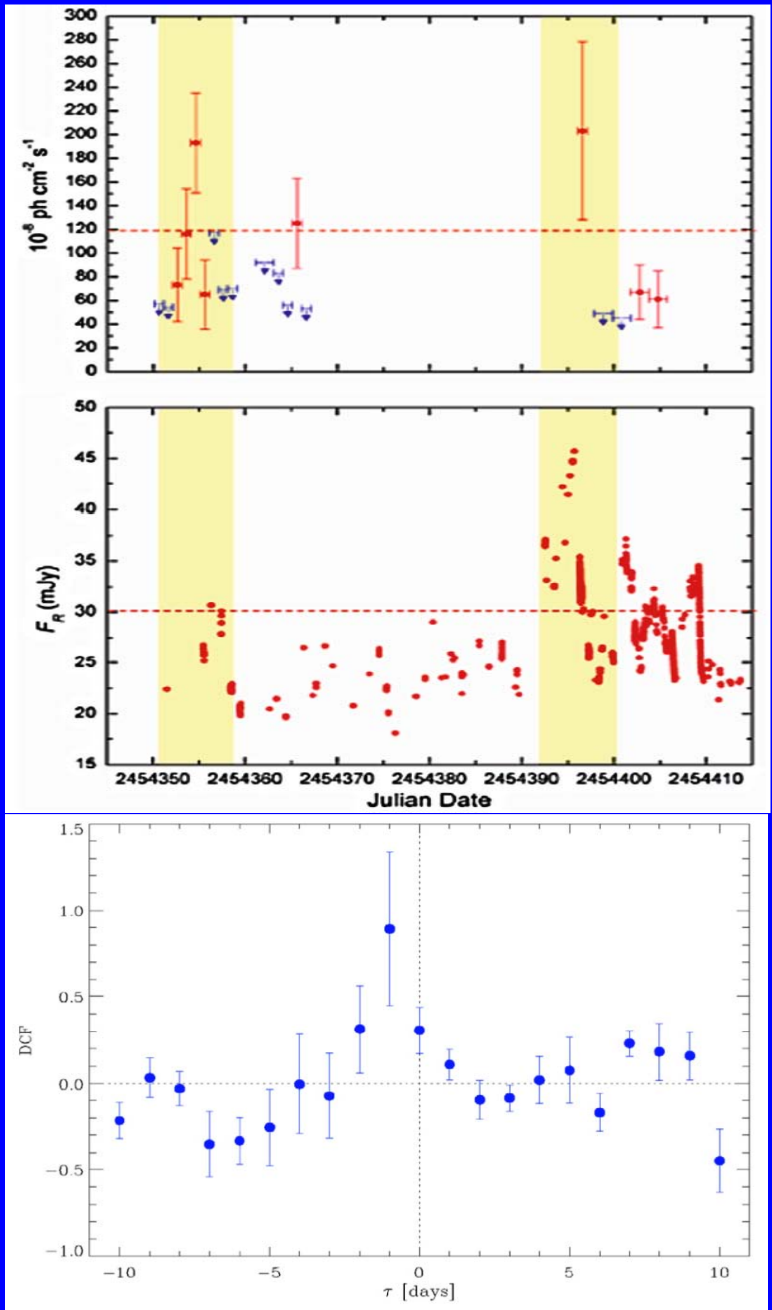
3C 454.3 – Nov.—Dec 2007 campaign

The shape of the DCF peak is asymmetric, and if we calculate the centroid distribution, we find that the time-lag is −0 .42 days, i.e. the γ-ray flux has a delay w.r.t the optical one of about half a day (see also Donnarumma et al. 2009).

Adapted from Donnarumma, BOHEME Meeting 2012

Time-lags: S5 0716+714

Chen et al., 2008, A&A, 489, L37



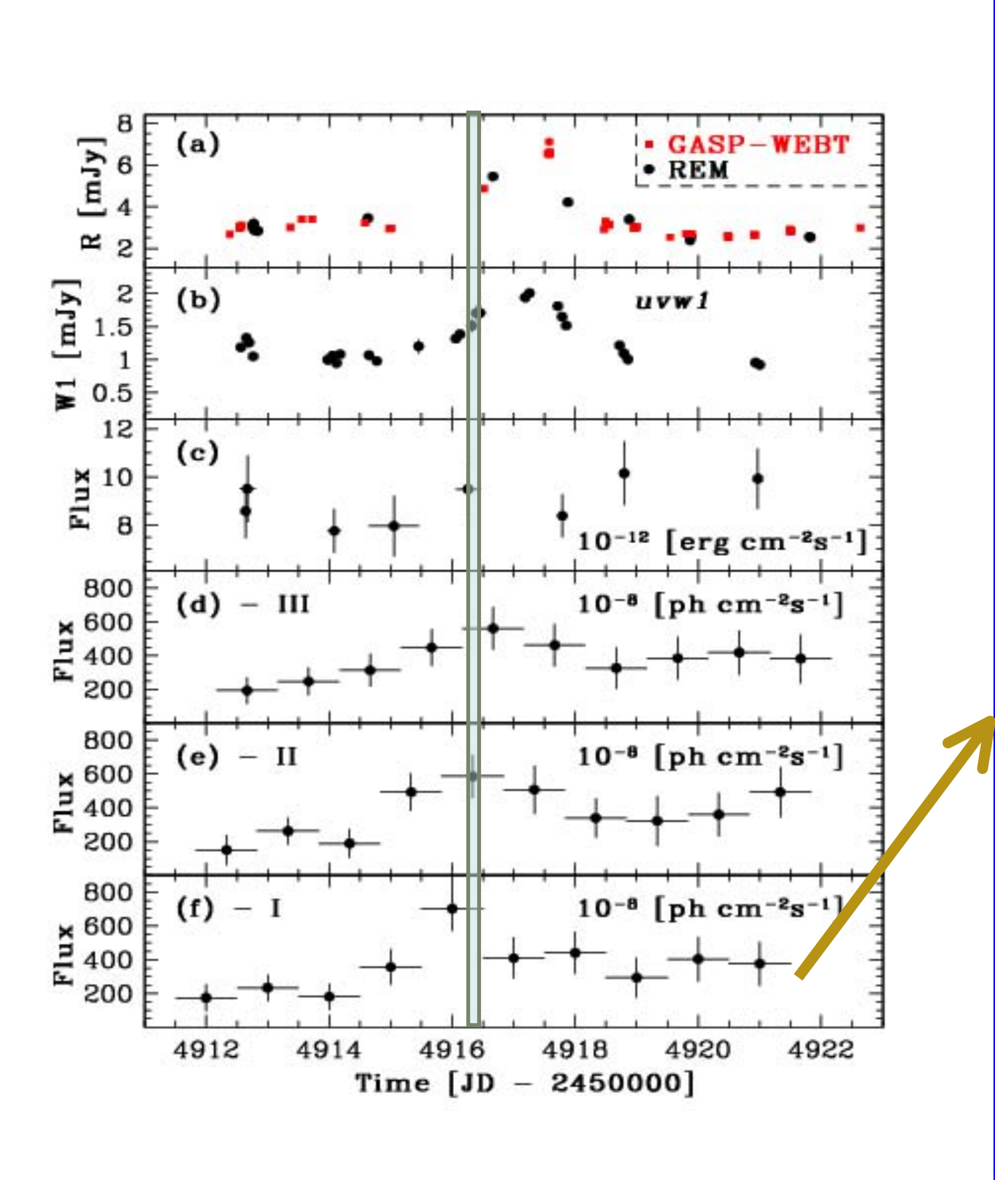
S5 0716+714: Sep.—Oct. 2007 campaign.

The DCF shows a significant peak for a time-lag of –1 day, suggesting a possible delay in the γ-ray flux variations with respect to optical ones.

Adapted from Donnarumma, BOHEME Meeting 2012

D’Ammando et al. 2011, A&A , 529, 145

Time-lags: PKS 1510-089



PKS 1510-089: March 1-30 2009 campaign

Optical /UV emission seems to be delayed by 1-2 days with respect to the γ-ray peak brightest peak .

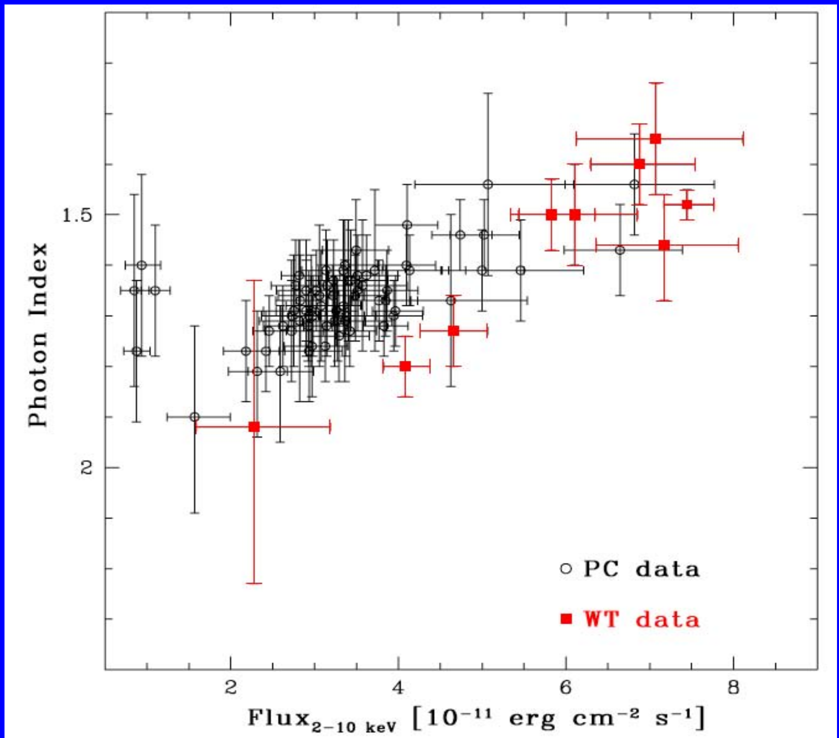
but, a phase-independent evaluation of the γ-ray peak (JD=2454916.33 ±0.5) led to reduce the optical/γ-ray delay (as found also in Abdo et al. 2010, ApJ 721, 1425).

Adapted from Donnarumma, BOHEME Meeting 2012

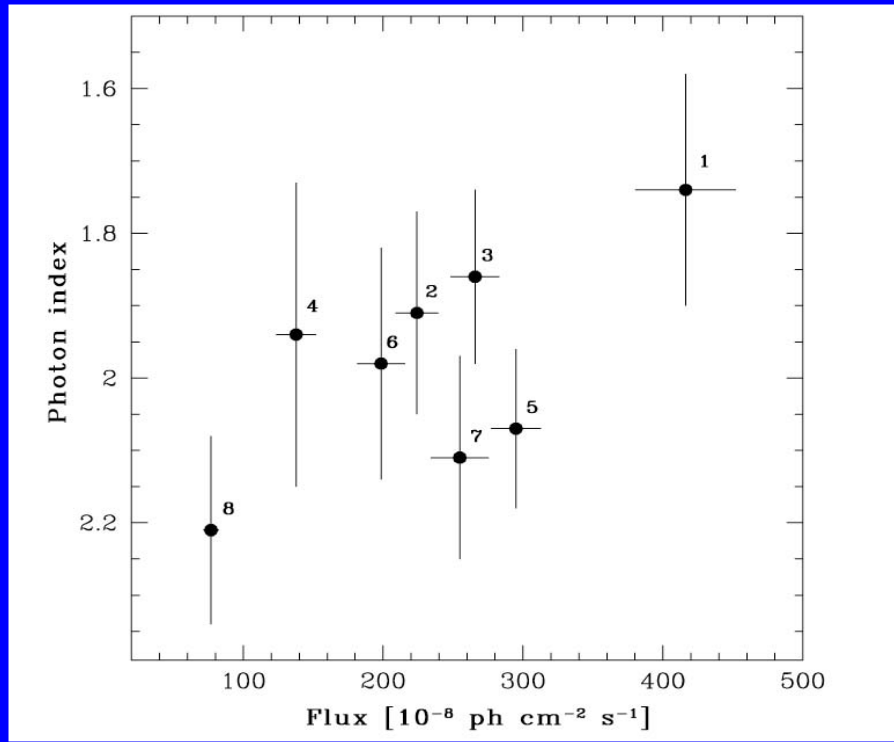
Spectral trend

Long-term X-ray data seem to show an harder-when-brighter spectral trend:
but only **hints** found in the **γ-ray data**

Swift/XRT



AGILE/GRID



3C 454.3: Vercellone et al., 2010, ApJ, 712, 405

Adapted from Donnarumma, BOHEME Meeting 2012

Data concerning PKS 1830 and 3C 454 suggest:

Optical activity may involve limited injection/acceleration of electrons in the jet. In fact, $\gamma_b < 700$ is implied to avoid a softer-when-brighter trend not actually observed in the Inverse Compton component

Two populations of electrons seem unavoidable

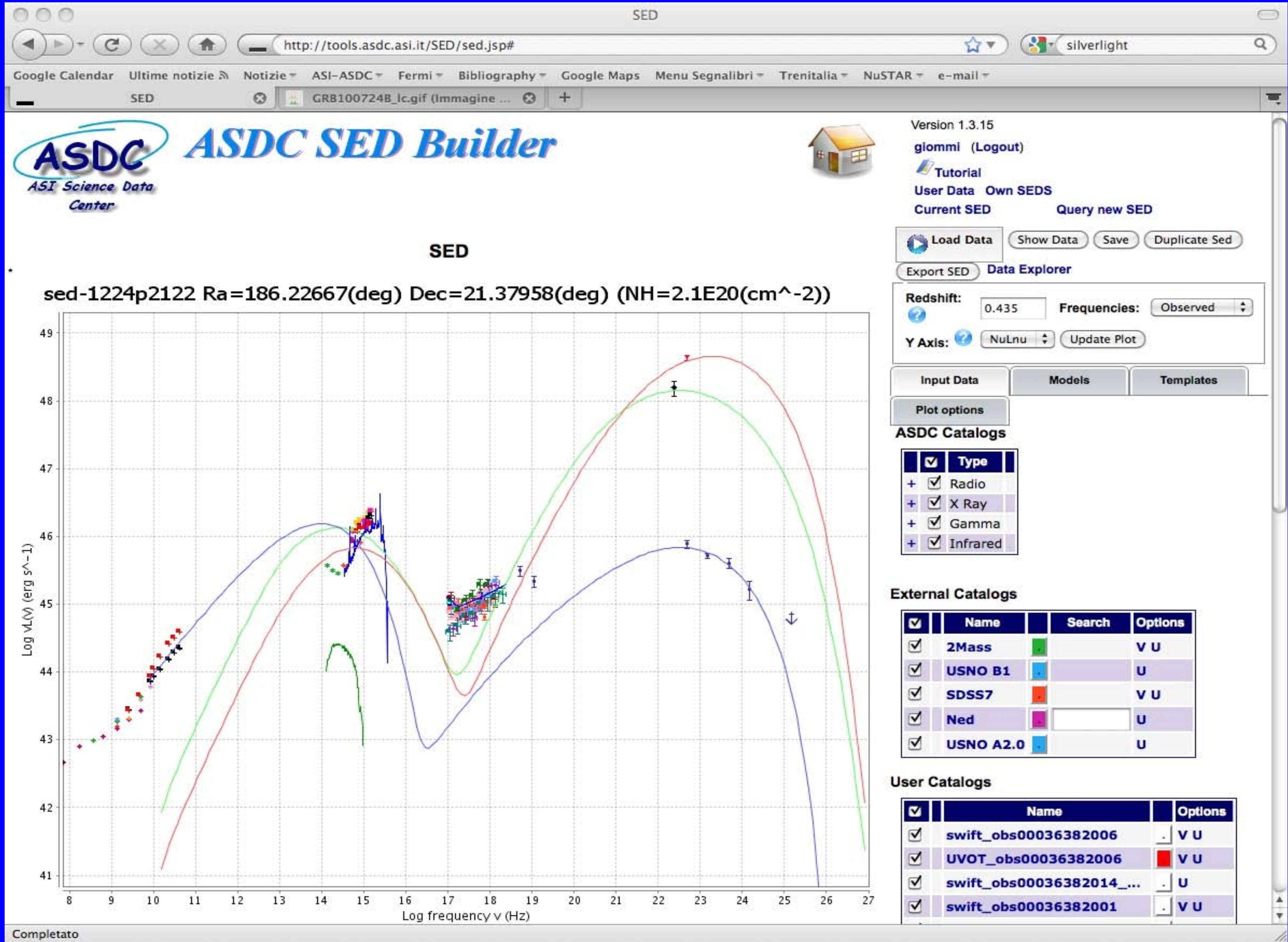
Even standard EC models are challenged!

In fact, variations in the external photon field seen by the blob are required to understand the observed complex γ-ray vs. Opt. correlations

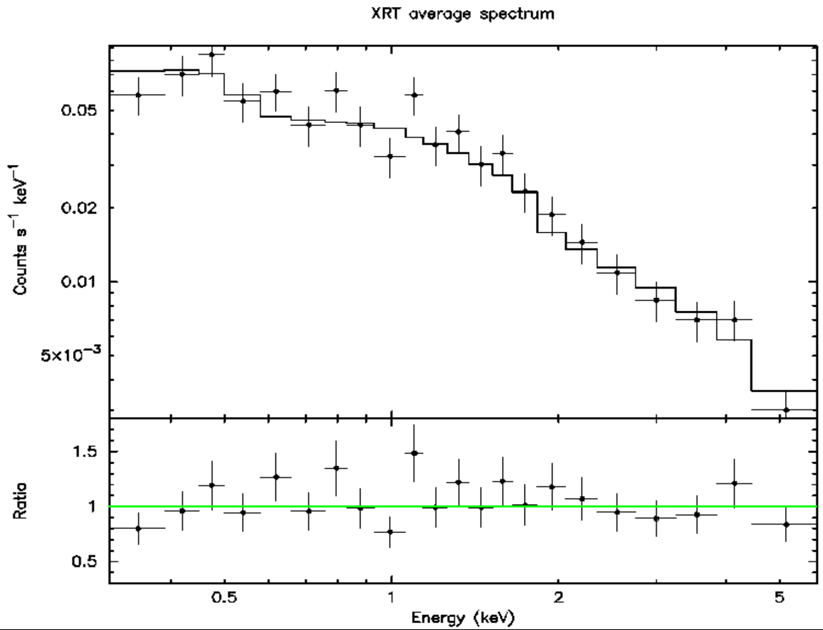
Adapted from Vittorini, Frascati Meeting 2012

The fast γ-ray flare of 4C +21.35 (PKS 1222+21)

17-19 June, 2010 (Pittori, work in progress)



Swift follow up results:



Swift/XRT average spectrum obtained from the six ToO observations on Jun 2010

Filter	Total Expos.	Mag
V	1184.1	15.25+/-0.05
B	1208.6	15.38+/-0.05
U	1262.7	14.40+/-0.04
UVW1	2660.8	14.12+/-0.02
UVM2	4483.7	13.93+/-0.03
UVW2	4745.0	13.93+/-0.05

Swift/UVOT average magnitudes obtained from the six ToO observations on Jun 2010

In the days following the γ-ray flare of June 2010, the source didn't show a significant variation (at 90% c.l.) neither of the spectral characteristics nor of the X-ray flux levels with respect to previous observations during quiescent γ-ray state.

GeV (AGILE, Fermi) and TeV (MAGIC) γ-ray observations:

- Hard spectrum with no cutoff, very fast variability of the order of ~10 min (!)
- Suggest a mechanism outside the BLR to avoid absorption. Very compact blob as jet gets refocused at large distances (Tavecchio et al., A&A 2011) ?

Think also to Crab nebula fast gamma-ray variability...

GeV-TeV connection

Backup slides

Table 3: AGILE Scientific Performance

Gamma-ray Imaging Detector (GRID)		
Energy Range	30 MeV – 50 GeV	
Field of view	~ 3 sr	
Sensitivity at 100 MeV (ph cm^{-2} s^{-1} MeV^{-1})	6×10^{-9}	(5σ in 10^6 s)
Sensitivity at 1 GeV (ph cm^{-2} s^{-1} MeV^{-1})	4×10^{-11}	(5σ in 10^6 s)
Angular Resolution at 1 GeV	36 arcmin	(68% cont. radius)
Source Location Accuracy	~5–20 arcmin	S/N~10
Energy Resolution	$\Delta E/E \sim 1$	at 300 MeV
Absolute Time Resolution	$\sim 1\ \mu s$	
Deadtime	$\sim 200\ \mu s$	
Hard X–ray Imaging Detector (Super-AGILE)		
Energy Range	10 – 40 keV	
Field of view	$107^\circ \times 68^\circ$	FW at Zero Sens.
Sensitivity (at 15 keV)	~5 mCrab	(5σ in 1 day)
Angular Resolution (pixel size)	~ 6 arcmin	
Source Location Accuracy	~2-3 arcmin	S/N~10
Energy Resolution	$\Delta E < 4$ keV	
Absolute Time Resolution	$\sim 4\ \mu s$	
Deadtime (for each of the 16 readout units)	$\sim 4\ \mu s$	
Mini-Calorimeter		
Energy Range	0.3 – 200 MeV	
Energy Resolution	~ 1 MeV	above 1 MeV
Absolute Time Resolution	$\sim 3\ \mu s$	
Deadtime (for each of the 30 CsI bars)	$\sim 20\ \mu s$	