AGILE: the past and the next 2 years

M. Tavani on behalf of the AGILE Team

7th AGILE Workshop, Sept. 29, 2009
The AGILE gamma-ray sky (E > 100 MeV)  
2 year exposure: July 2007 – June 2009
hard X-ray sources (18-60 keV), 2 years

SuperAGILE OBSERVED SOURCES
many results
many surprises
<table>
<thead>
<tr>
<th>Mission</th>
<th>Agency</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>COS–B</td>
<td>ESA</td>
<td>Aug. 1975 – Apr. 1982</td>
</tr>
<tr>
<td>AGILE</td>
<td>ASI</td>
<td>April 23, 2007</td>
</tr>
<tr>
<td>FERMI</td>
<td>NASA</td>
<td>June 11, 2008</td>
</tr>
</tbody>
</table>
AGILE: 2 and 1/2 years in orbit...

• ~ 12,600 orbits, September 29, 2009.

• very good scientific performance

• Cycle-1: Dec. 2007- Nov. 2008
• approved funding: 2010-2011
The AGILE Payload: the most compact instrument for high-energy astrophysics.

It combines for the first time a gamma-ray imager (30 MeV - 30 GeV) with a hard X-ray imager (18-60 keV) with large FOVs (1-2.5 sr) and optimal angular resolution.
AGILE: inside the cube…

HARD X-RAY IMAGER (SUPER-AGILE)

GAMMA-RAY IMAGER
SILICON TRACKER

(MINI) CALORIMETER

ANTICOINCIDENCE
## A quick comparison

<table>
<thead>
<tr>
<th></th>
<th>AGILE</th>
<th>FERMI/LAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_{\text{eff}}$ (100 MeV) (cm$^2$)</td>
<td>~400</td>
<td>~ 1000-2000</td>
</tr>
<tr>
<td>$A_{\text{eff}}$ (1 GeV) (cm$^2$)</td>
<td>500</td>
<td>~ 8000-10000</td>
</tr>
<tr>
<td>FOV (sr)</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Sky coverage</td>
<td>1/5</td>
<td>whole sky</td>
</tr>
<tr>
<td>Energy resolution (~ 400 MeV)</td>
<td>50 %</td>
<td>10 %</td>
</tr>
<tr>
<td>PSF (68 % cont. radius)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 MeV</td>
<td>3° - 4°</td>
<td>4° - 5°</td>
</tr>
<tr>
<td>1 GeV</td>
<td>&lt; 1°</td>
<td>&lt; 1°</td>
</tr>
</tbody>
</table>
PSF: real data vs. simulations  
(G.Pucella, A.Giuliani, A.Chen)

**Vela**

**E > 100 MeV**

**E > 400 MeV**
a spectral comparison with Fermi-LAT

\[ \frac{dN}{dE} = A \times E^{-\Gamma} e^{-E/E_c} \]

\[ \Gamma = 1.51 \quad E_c = 2.9 \text{ GeV} \]
## a comparison: 1-day exposure

<table>
<thead>
<tr>
<th></th>
<th>AGILE (GRID)</th>
<th>FERMI (LAT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOV (sr)</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>sky coverage</td>
<td>1/5</td>
<td>whole sky</td>
</tr>
<tr>
<td>Source livetime fraction</td>
<td>~ 0.5</td>
<td>~ 0.16</td>
</tr>
<tr>
<td>1-day exposure (30 degree off-axis, 100 MeV)</td>
<td>~ 2 $10^7$ cm$^2$ sec</td>
<td>~ (1-2) $10^7$ cm$^2$ sec</td>
</tr>
<tr>
<td>Attitude</td>
<td>fixed</td>
<td>variable</td>
</tr>
</tbody>
</table>
The AGILE 1-day exposure (E > 100 MeV) (30 Nov. 2008)
Example of the Super-AGILE View of the Galactic Plane  
(3.6 days, l=337, b=8)
ASAS Architecture

- The system is distributed among the ADC @ ASDC and the AGILE Team Institutes
- Automatic Alerts to the AGILE Team are generated within $T_0 + 45$ min (SA) and $T_0 + 100$ min (GRID)
AGILE Ground Segment

Satellite

Malindi Ground Station

Fucino TZP MOC

ASDC

AGILE Team

Guest Observers

Public data access

Automatic data processing

~1 hr

~0.5 hr

~0.5-1 hr

~(2-2.5) hr
Galactic Center
Cygnus Region
Carina-Vela Regions
Cygnus Region
Galactic Center
Main topics and discoveries

• Bright gamma-ray blazars
  (3C 454.3, PKS 1510-089, TX 0716+714)
• several (~10) new Pulsars and PWNs
• discovery gamma-ray transients in the Galaxy
• microquasar studies, Gamma-ray emission from Gal. compact objects
• SNRs and origin of cosmic rays
• gamma-Ray Bursts, Millisecond triggers, Terrestrial Flashes
Multifrequency science

- AGILE, FERMI
- Radio Telescopes (VLA, Mojave, Michigan)
- Optical Obs. Networks (GASP, REM, ...)
- SWIFT, Suzaku, XMM
- INTEGRAL
- TeV (MAGIC, HESS, VERITAS)
The brightest Gamma-ray blazars detected by AGILE
3C 454.3: the Crazy Diamond

July 2007

~10 sigma in 5.8 days
The brightest gamma-ray blazars detected by AGILE

- 3C 454.3
- HB 1510-089
- TXS 0716+714
- 3C 279
- 3C 273
- Mrk 421
- PKS 0537-441

- spectral properties
- radio/optical/X-ray vs. gamma
- BL Lacs and BZ limit
- why always the same blazars?
AGILE new gamma-ray PSR (Halpern et al. 2008)

PSR J2021-3651
New Gamma-Ray Pulsars

J2229+6114, J2021+3651, ...: Vela-like

J1513-5908: High B pulsar

J1824-2452: ms PSR in Globular Cluster

J1016-5857: possibly 3EG source

J1357-6429

J2043+2740: oldest gamma-ray pulsar

J1524-5625
Cassiopeia-Cygnus Region
Cygnus Region, IRAS and Canadian GP Survey
Cygnus Region, AGILE-GRID (E >100 MeV)
Galactic gamma-ray transients: an AGILE discovery

- GC region
- Cygnus region
- Carina region
- Crux region

- AGILE observes variability and detects new transients on time scales of 1 day at flux levels of $10^{-6} \text{ cm}^{-2}\text{s}^{-1}$, even in crowded, high diffuse emission Galactic plane regions.

- NO detectable simultaneous hard X-ray emission ($F < 20\text{-}30 \text{ mCrab, 18-60 keV, 1-day integration}$)
• very good imaging capability (in the range 100-400 MeV)

• several Galactic transient candidates (usually low-energy)
  – Examples, 24 Nov. 2007, Eta-Car, other transients

• statistically sound detection method identified, pre-trial vs. post-trial CL…
AGILE facts and surprises

• in general, no obvious X-ray source, Super-AGILE or INTEGRAL source

• some SWIFT follow-ups: no detections, (except one…)

• but…Eta-Car and Cygnus X-3 examples
Energetics…

• Gamma-ray luminosity above 100 MeV

\[ L = 7 \times 10^{34} \, d_{\text{kpc}}^2 \, \text{erg/s} \]
Energetics…

• Gamma-ray luminosity above 100 MeV
  \[ L = (\text{a few}) \times 10^{34} d^2_{\text{kpc}} \text{ erg/s} \]

• Compatible with WR/CWB expectations
  – It could be a class of WR/CWB or flaring stars

• But also it could be a NEW CLASS of (non-accreting or low X-ray) sources
monitored Micro-QSOs

- Cyg X-1
- Cyg X-3
- GRS 1915+105
- SS 433
- ....
<table>
<thead>
<tr>
<th>Source</th>
<th>(\Theta) (degrees)</th>
<th>(\beta)</th>
<th>(\Gamma)</th>
<th>(L_x/L_E)</th>
<th>(\gamma/\text{TeV})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyg X-1</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>0.1-1</td>
<td>~5 MeV</td>
</tr>
<tr>
<td>Cyg X-3</td>
<td>&lt; 14</td>
<td>&gt; 0.8</td>
<td>&gt; 1.6</td>
<td>0.1-1</td>
<td>?</td>
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<tr>
<td>SS 433</td>
<td>&lt; 70</td>
<td>0.26</td>
<td>1.03</td>
<td>0.01</td>
<td>no</td>
</tr>
<tr>
<td>GRS 1915+104</td>
<td>70</td>
<td>0.92</td>
<td>2.5</td>
<td>0.1-1</td>
<td>no</td>
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<tr>
<td>GRO J1655-40</td>
<td>&gt; 70</td>
<td>0.9</td>
<td>2.5</td>
<td>1</td>
<td>no</td>
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<tr>
<td>GRS 1758-258</td>
<td>?</td>
<td></td>
<td></td>
<td>0.1-1</td>
<td>no</td>
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<tr>
<td>XTE J1550-564</td>
<td>60-70</td>
<td>&gt; 0.8</td>
<td>1.5</td>
<td>0.1-1</td>
<td>no</td>
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<tr>
<td>Sco X-1</td>
<td>&gt; 70</td>
<td>&gt; 0.8</td>
<td>&gt; 1.6</td>
<td>0.1-1</td>
<td>no</td>
</tr>
<tr>
<td>LS I 61 303</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>10^{-4}</td>
<td>yes</td>
</tr>
<tr>
<td>LS 5039</td>
<td>&lt; 80</td>
<td>&gt; 0.2</td>
<td>?</td>
<td>10^{-4}</td>
<td>yes</td>
</tr>
</tbody>
</table>
MAGIC single isolated detection of Cyg X-1, 24 Sept. 2006, ~ 79 min. TeV flare
Cyg X-1 hard X-ray flux, Swift/BAT (15-50 keV)
Cygnus X-1 monitoring
Challenges…

• are Cyg X-1-like fast transients common?

• detect gamma-ray variability within 1 day…or even less

• what are the gamma-ray transients?

• Cyg X-3 remarkably detected in special states…and the others?
GRBs and Flashes

• only a few GRBs detected so far above 100 MeV

• AGILE very good timing capability, millisecond trigger

• Terrestrial Gamma-Ray Flashes (TGFs)
MCAL TGF cumulative spectrum
(Marisaldi et al., 2009)

cutoff PL model fitting with XSPEC

\[ F(E) \sim E^{-\alpha} e^{-E/E_0} \]

\[ \alpha = 0.4 \pm 0.3 \]

\[ E_0 = 8.5 \pm 1.6 \text{ MeV} \]

red. \( \chi^2 = 1.4 \)

(18 d.o.f.)

AGILE-MCAL crucial spectral contribution
• Normal lightnings involve a potential difference 
  \( DV \sim 500 \text{ kiloVolts} \)

• Terrestrial Gamma-Ray Flashes (TGF) involve 
  \( DV > 100 \text{ Mega Volts} \)
Conclusions

• Very exciting time for gamma-ray astrophysics

• AGILE focused on 100 MeV phenomena and simultaneous hard X-ray emission (or lack thereof…)

• AGILE and FERMI will provide a wealth of data on a variety of sources… be ready for variability!

• Special attention to Galactic microquasars and transients during the AGILE Cycle-3 observations
  * Quicklook and alert system

• Millisecond events, cosmic events and TGFs