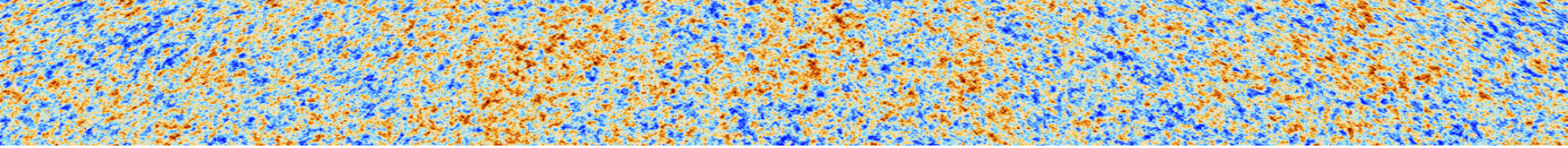


Multi-frequency CMB data analysis: a Science Data Center point of view

Gianluca Polenta

ASI Science Data Center

on behalf of the Italian CMB community

Outline

- CMB and multi-frequency data analysis
    - a few science cases
- Science Ground Segment and Science Data Centers
    - International context
    - SGS Activities in Italy
    - The ASI Science Data Center
- Challenges and opportunities
- Conclusions

CMB and multi-frequency data

1. Scientific exploitation of CMB observations and the analysis of multi-frequency maps has been already discussed:
    a. Excellent foreground cleaning is mandatory to extract primordial CMB polarisation B-modes
    b. Analysis of foregrounds is of scientific interest per sé
2. Here we move a step forward from multi-frequency to multi-mission analysis throughout the entire EM spectrum
3. A few science topics will be presented, but much more can be thought

CMB and multi-frequency data: Blazars

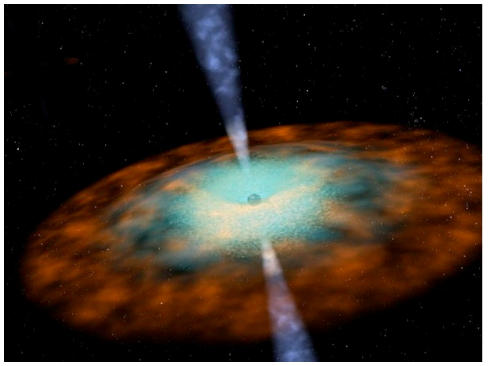
Class of AGN where the jet points very close to the line of sight

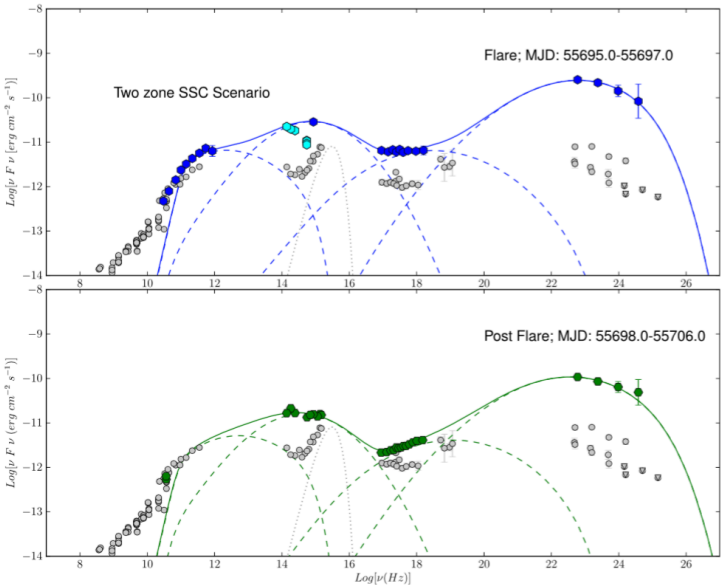
Dominant extragalactic sources in the radio, microwave, γ-ray and TeV bands

Broad-band SED with two bumps:

1. Synchrotron peak at ~10^{13} Hz
2. Inverse Compton peak at ~10^{22} Hz

MF studies are essential to constraint physical models for blazar emission





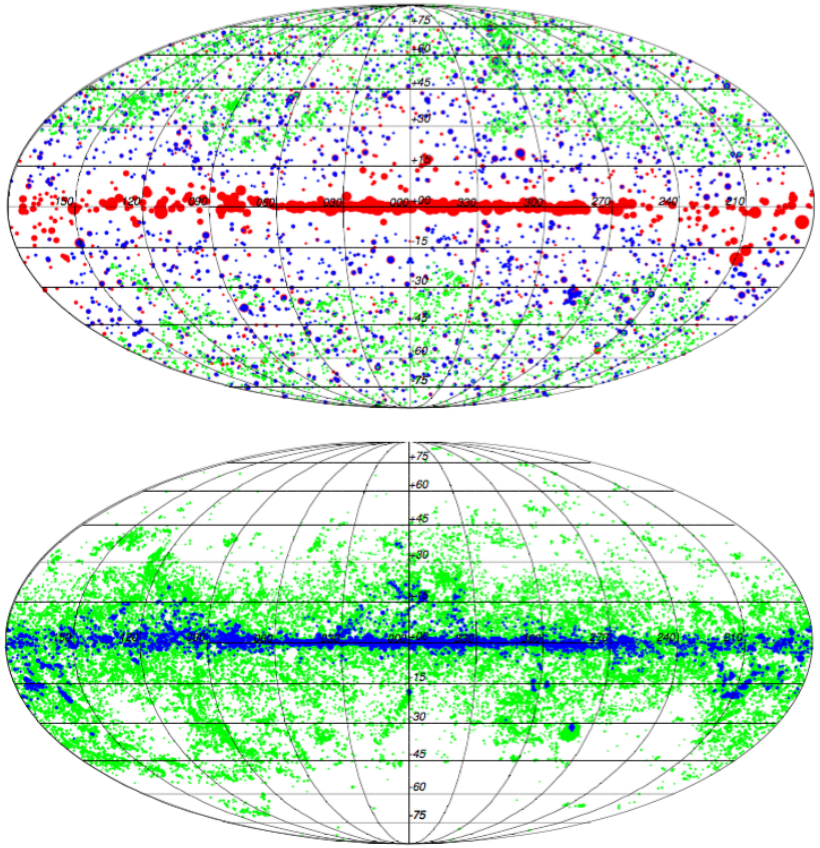
Cutini et al, 2012, MNRAS, 445:4316

CMB and multi-frequency data: Blazars

Significant contamination in CMB maps:

1. Bright sources are detected and masked out
2. Faint sources are accounted for in a statistical way

Exploiting MF/MM source catalogues to extrapolate flux density of faint blazars at CMB frequencies could potentially improve CMB map cleaning



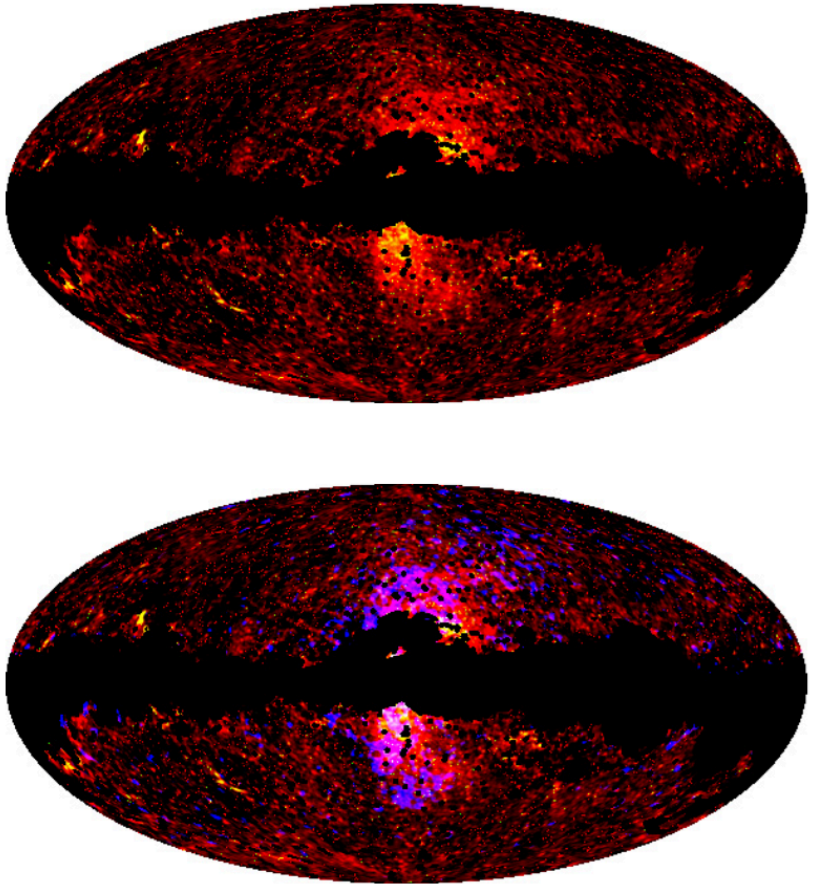
PCCS2, Planck Collaboration XXVI, 2015

CMB and multi-frequency data: γ-ray emission

Fermi bubbles and microwave haze

1. Microwave Galactic haze observed on Planck LFI maps, improving early evidences from WMAP
2. Spatial correlation between Planck haze and Fermi γ-ray bubbles
3. Microwave spectral index of the haze significantly harder than Galactic synchrotron emission
4. No consensus on its origin

CMB-γ correlation of diffuse emission could be of potential interest for dark matter studies



Planck Collaboration, PIP IX, 2013

Science Ground Segment and Data Centers

SGS is a key part of a mission:

1. Ensuring data processing and archiving to reach the scientific objectives of the mission
2. SGS lifetime related to the mission
3. SGS has to be considered as an instrument, for both needs and cost

SDC has a different/complementary role:

1. Enlarge scientific return and benefit outside the mission team to the entire scientific community and to the general public
2. Long term data preservation: legacy extends well beyond mission lifetime
3. Developing tools to access and analyse data
    a. A deep knowledge of mission data is needed, hence direct participation to the missions is essential
4. Supporting scientists in using mission data
    a. Be part of the scientific community to be trusted by scientists

International context

1. European Space & Astronomy Center – ESAC, ESA
    a. Planck Legacy Archive
    b. Visualisation tool, no quantitative analysis
2. Legacy Archive for Microwave Background Data Analysis – LAMBDA
    a. NASA archive, ground-based data are hosted as well
    b. No tools for online analysis
3. NASA/IPAC Infrared Science Archive – IRSA
    a. Online visualisation of multi-frequency catalogue data
4. Data format differs from one experiment to another
5. Virtual Observatory has the potential to help, but no great success so far
6. Very large data volumes, hence SDCs are usually complemented by High Performance Computing centers

SGS activities in Italy

Italy has leading roles on SGS for ESA cosmology missions:

- Planck LFI Data Processing Center based at INAF-OATS
    a. DPC manager, IOT responsibility, hardware
    b. Distributed approach for the pipeline
        - Gathering contributions from the scientific team (including DPC itself) and integrating them into the official pipeline
        - Optimal trade off between high-quality pipeline and DPC responsibility for validation and delivery of data products
- Euclid SGS
    a. SGS manager, Project Office and SDC-IT at INAF-OATS
    b. 3/10 Organisation Units are led by Italy: ASDC, INAF-IASFMI, and INAF-OAR (plus deputy role for another OU, Uniroma3)
    c. Lead of Galaxy Clustering and CMBxC Science WGs (INAF-OAB and SISSA), and lead of Survey WG (INAF-OAR)

Italy has also full responsibility of OLIMPO and LSPE DA pipeline

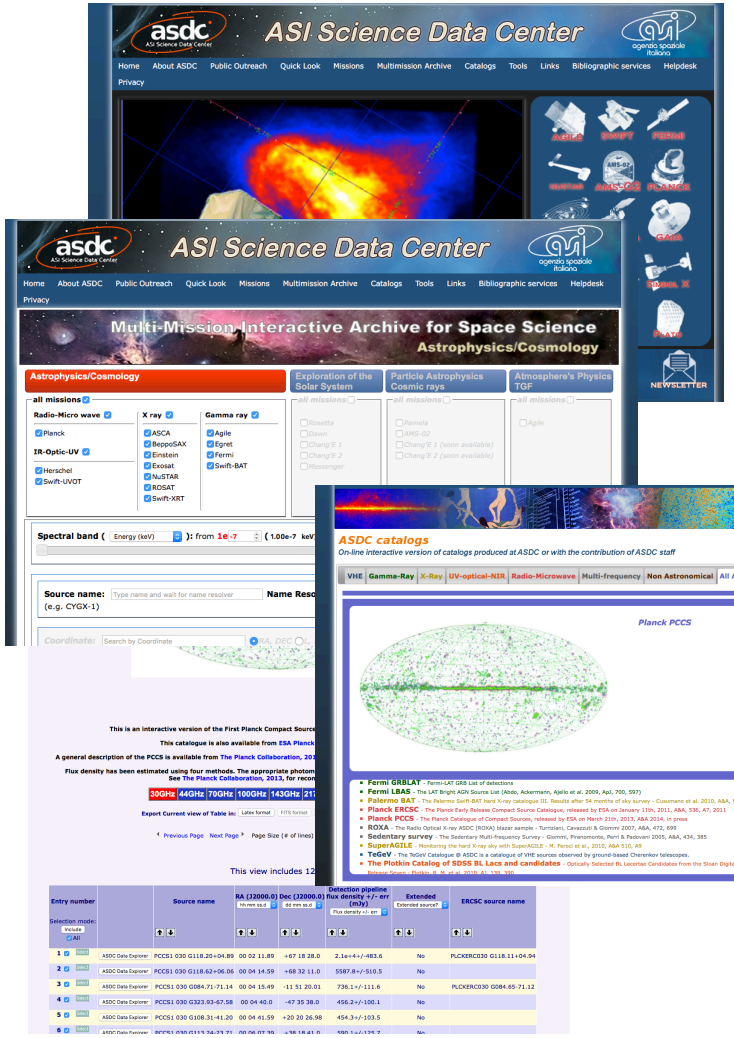
The ASI Science Data Center

Multi-frequency/multi-mission SDC

1. Supporting ASI funded missions from radio to TeV, including Solar System Exploration, particle astrophysics, and even atmospheric physics (TGFs)
2. Science-ready online tools: MMIA for space science, SED Builder, MATISSE, cosmic rays database

Cosmology missions:

1. Planck:
   a. Contributions to the DA pipeline
   b. Ingestion of Planck catalogues into ASDC online science tools
2. Euclid: OU-NIR lead, responsible for the near-IR photometer pipeline



The ASI Science Data Center

Multi-frequency/multi-mission science:

Simultaneous observation of blazars with Planck, Swift and Fermi satellites plus several ground-based observatories

Large coordination effort:

- MoU between three mission teams (ESA and NASA)
- Swift observation plan
- Data analysis harmonization

Planck early results XV, 2011, A&A, 536, A15

Giommi, Polenta, et al, 2012, A&A 541, A160

Léon-Tavares et al, 2012, ApJ 754, 23

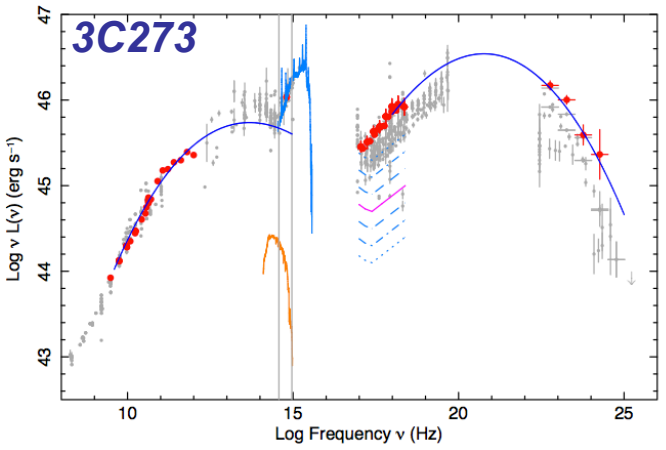
Cutini et al, 2012, MNRAS 445, 4316

A&A 541, A160 (2012)
DOI: 10.1051/0004-6361/201117825

Astronomy & Astrophysics

Simultaneous *Planck*, *Swift*, and *Fermi* observations of X-ray and γ-ray selected blazars

P. Giommi[2,3], G. Polenta[2,23], A. Lähteenmäki[1,19], D. J. Thompson[5], M. Capalbi[2], S. Cutini[2], D. Gasparrini[2], J. González-Nuevo[43], J. León-Tavares[1], M. López-Caniego[32], M. N. Mazziotta[33], C. Monte[14,33], M. Perri[2], S. Rainò[14,33], G. Tosti[35,15], A. Tramacere[28], F. Verrecchia[2], H. D. Aller[4], M. F. Aller[4], E. Angelakis[41], D. Bastieri[13,34], A. Berdyugin[45], A. Bonaldi[37], L. Bonavera[43,7], C. Burigana[26], D. N. Burrows[10], S. Buson[34], E. Cavazzuti[2], G. Chincarini[46], S. Colafrancesco[23], L. Costamante[47], F. Cuttaia[26], F. D'Ammando[27], G. de Zotti[22,43], M. Frailis[24], L. Fuhrmann[41], S. Galeotta[24], F. Gargano[33], N. Gehrels[5], N. Giglietto[14,33], F. Giordano[14], M. Giroletti[25], E. Keihänen[12], O. King[42], T. P. Krichbaum[41], A. Lasenby[6,38], N. Lavonen[1], C. R. Lawrence[36], C. Leto[2], E. Lindfors[45], N. Mandolesi[26], M. Massardi[22], W. Max-Moerbeck[42], P. F. Michelson[47], M. Mingaliev[44], P. Natoli[16,2,26], I. Nestoras[41], E. Nieppola[1,17], K. Nilsson[17], B. Partridge[18], V. Pavlidou[42], T. J. Pearson[8,29], P. Procopio[26], J. P. Rachen[40], A. Readhead[42], R. Reeves[42], A. Reimer[31,47], R. Reinthal[45], S. Ricciardi[26], J. Richards[42], D. Riquelme[30], J. Saarinen[45], A. Sajina[11], M. Sandri[26], P. Savolainen[1], A. Sievers[30], A. Sillanpää[45], Y. Sotnikova[44], M. Stevenson[42], G. Tagliaferri[21], L. Takalo[45], J. Tammi[1], D. Tavagnacco[24], L. Terenzi[26], L. Toffolatti[9], M. Tornikoski[1], C. Trigilio[20], M. Turunen[1], G. Umana[20], H. Ungerechts[30], F. Villa[26], J. Wu[39], A. Zacchei[24], J. A. Zensus[41], and X. Zhou[39]



Giommi, Polenta, et al, 2012, A&A, 541, A160

Challenges and opportunities

1. Short term
    a. Planck data yet to be fully exploited
        - Data distribution, i.e. maps
        - Multi-frequency/Multi-mission analysis
    b. OLIMPO and LSPE are scheduled to come soon
        - No consolidated plan yet for archiving and distribution

2. Mid term
    a. Multi-mission science with LSS data
    b. Several mm-wave experiments already planned in Europe and US are expected to produce data in a few years

3. Long term
    a. capitalize on a possible ESA M5 CMB mission

Conclusions

CMB Italian community has a consolidated SGS expertise:

a. Leading roles in ESA cosmology missions
b. Entire pipeline for Italian sub-orbital experiments

Italy has a SDC world-class facility at the ASDC

Multi-mission data analysis has the potential for:

a. Improving CMB and cosmology results
b. Addressing interesting scientific topics that cannot be studied with single mission data

This is where the ASDC can make the difference