

***The ASI Space Science Data Center (SSDC):
a multi-mission research infrastructure
for the management and distribution
of astronomical data***

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(INAF/OAR)**

OUTLINE

- Brief description of the ASI Space Science Data Center (**SSDC**)
- **Involvement** of INAF personnel and **leadership**
- Impact of the **scientific/technological** production on INAF community
- INAF and ASI **roles**
- **Future planning** and **critical issues** for INAF

THE ASI SPACE SCIENCE DATA CENTER (SSDC)

The **Space Science Data Center** (SSDC) is a research Infrastructure located in Rome managed by the Italian Space Agency (**ASI**) together with **INAF** and **INFN**

SSDC main mission:

- acquire, manage, process and distribute data from (mainly) space-based missions adopting FAIR principles
- ensure long term preservation of archives
- development of multi- frequency interactive science analysis tools



Founded in **2000** (formerly ASDC) after the experience acquired by the **BeppoSAX Science Data Centre** in 1990s. Operational scientific support to more than **25 space missions** (significant fraction of high energy astrophysics missions).

THE SSDC ORGANIZATION

SSDC management and organization involves several Research Institutes:

ASI – Italian Space Agency

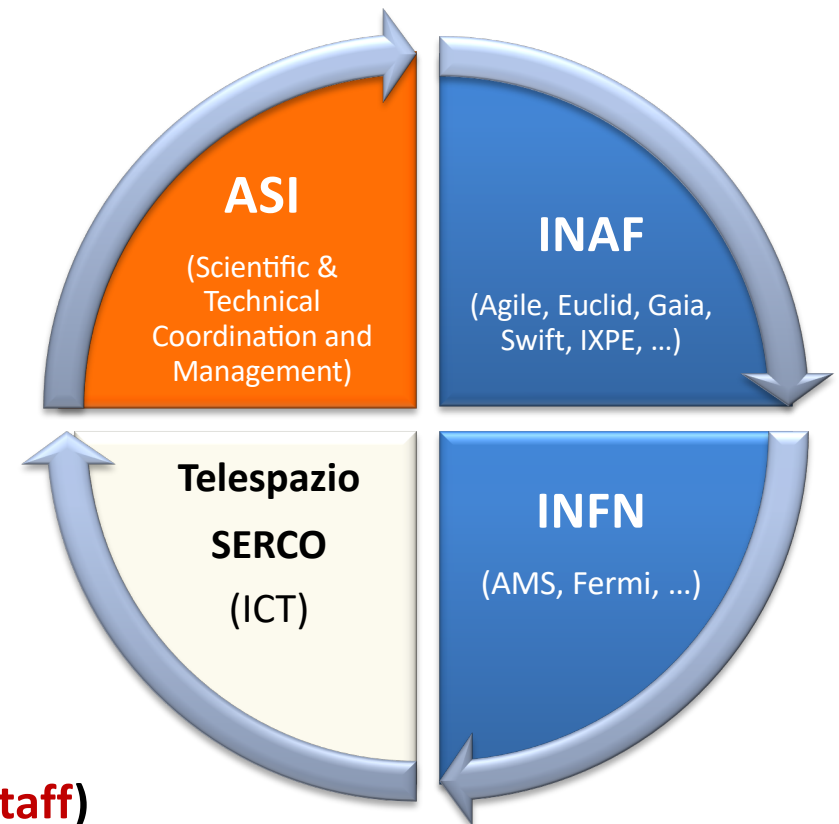
INAF – National Institute for Astrophysics

INFN – National Institute for Nuclear Physics

Industries are involved for Information and Communication Technology supports.

- SSDC team includes over 40 people:
scientists from ASI (7), INAF (18), INFN (9)
and **software engineers** from Telespazio & SERCO (7), all expert in different fields.

18 INAF scientists operating at the SSDC (including **9 staff**)



Effective approach: Developers and Users belong to same communities.

THE SSDC ORGANIZATION

SSDC managed by:

ASI – Italian Space Agency

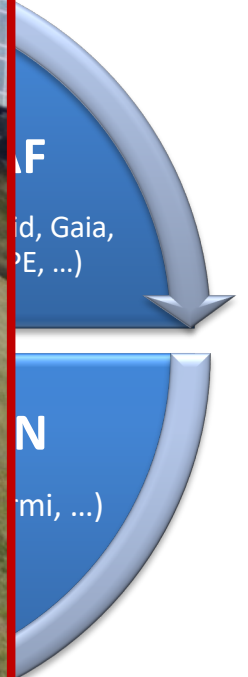
INAF – National Institute for Astrophysics

INFN – National Institute of Nuclear Physics

Industries are involved in the Communication and Data Management

- SSDC team includes:
 - scientists and software engineers
 - SERCO (7)

18 INAF scientists



Effective approach: Developers and Users belong to same communities.

INAF ACTIVITIES AT THE SSDC

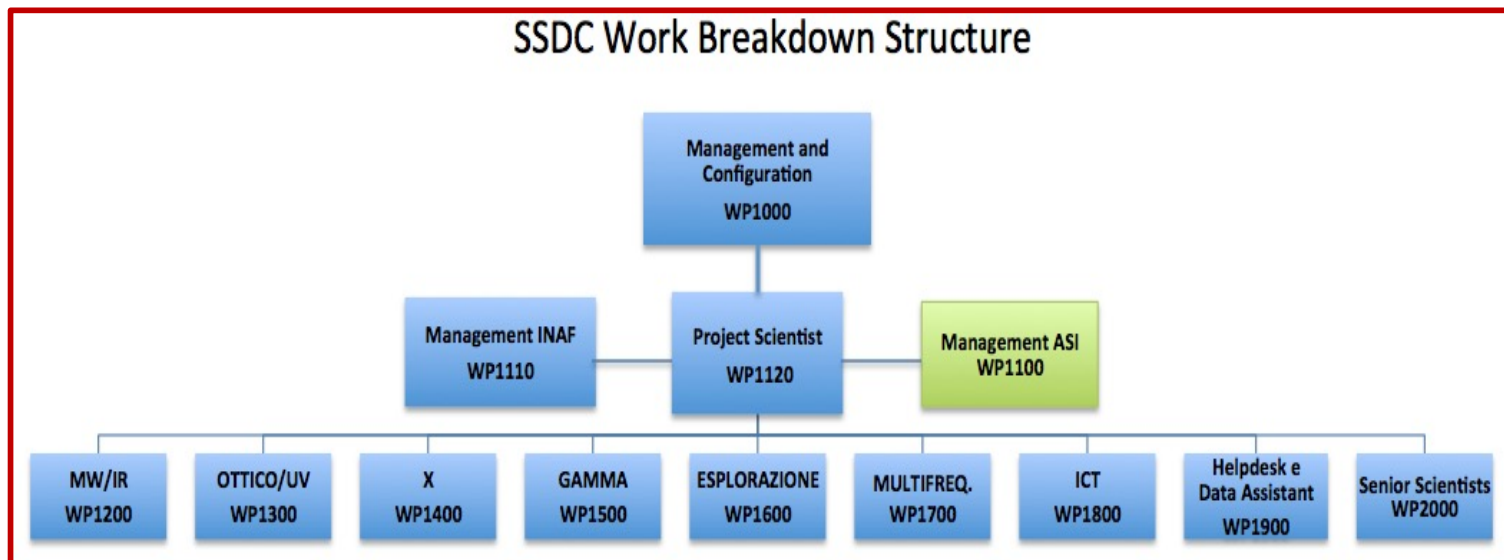
The **activities** carried out with **leadership INAF** at the SSDC includes:

- Development of **interactive science analysis tools** in a multi-frequency environment (data fusion)
- Data **visualization** and **exploration** tools
- Science mission **data processing, archiving** and **distribution**
- Databases and **data mining** tools for **very large** scientific datasets
- Scientific **data reduction** and **analysis software** pipelines
- Scientific **Ground Segments** for space missions

SSDC **INAF TEAM** ORGANIZATION

INAF Project Scientist: ensures the technical-programmatic coordination of the INAF Team activities and is responsible towards ASI for the validity and completeness of the scientific and technical results achieved.

SSDC WBS: the activities are mainly articulated by reference energy band.



For each **WP**, a person **responsible** for the planned activities is identified. Some WPs are also organized into sub-WPs that collect the various missions of interest

LIST OF SSDC **INAF** MISSIONS AND ACTIVITIES

- **Microwaves and Infrared:** Planck, Herschel, Euclid, JWST
- **Optical and Ultraviolet:** Gaia, PLATO, CHEOPS, Swift-UVOT
- **X-rays:** BeppoSAX, Swift, NuSTAR, IXPE, HERMES, eXTP, HXMT
- **Gamma-rays:** AGILE, ASTRI, CTA
- **Solar System:** MATISSE (Multi-purpose Advanced Tool for the Solar System Exploration)
- **Multi-Frequency and VO:** Multi-Mission Interactive Archive (**MMIA**), Multi-Frequency **Data Explorer**, **SED Builder**
- **Information and Computing Technologies (ICT)**

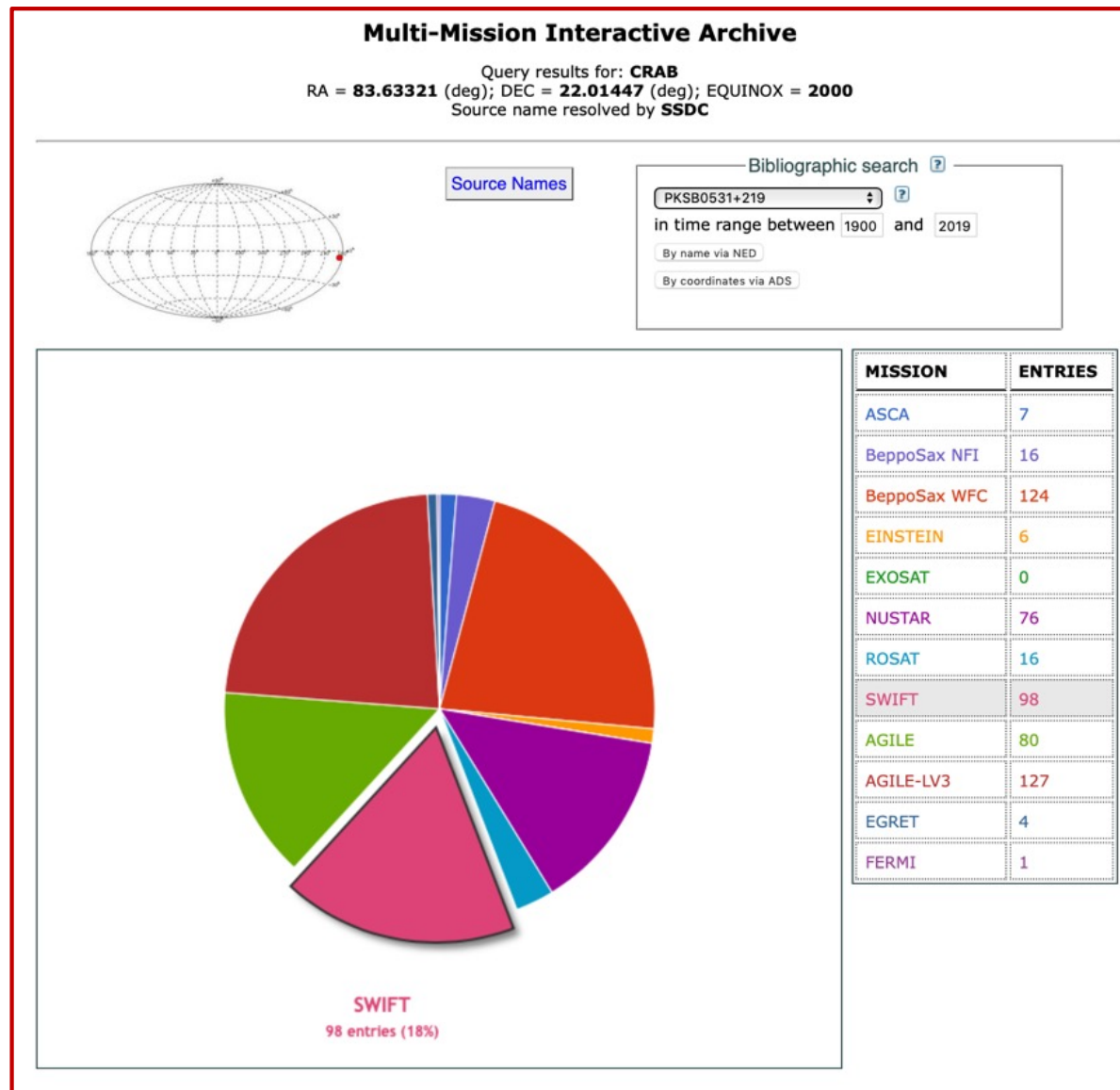
THE SSDC SCIENCE GATEWAY

The screenshot shows the SSDC website interface. At the top, the SSDC logo is on the left, the title "Space Science Data Center" is in the center, and the ASI logo is on the right. Below the title is a navigation menu with links: Home, About SSDC, News and Communication, Quick Look, Missions, Multimission Archive, Catalogs, Tools, Links, Bibliographic services, Helpdesk, and Privacy. The main content area features a large, colorful image of a nebula on the left and a grid of satellite icons on the right. The grid includes icons for AGILE, SWIFT, FERMI, XMM-NEWTON, AMS-02, PLANCK, SOLAR SYSTEM, PAMELA, GAIA, HERSCHEL, BEppo, SIMBOL X, CHEOPS, EUCLID, and PLATO. Below the grid is a row of tool icons: SED BUILDER, SKY EXPLORER, MATISSE, GAIA PORTAL, COSMIC RAY DATABASE, SSDC MULTIMISSION ARCHIVE FOR SPACE SCIENCE, SSDC CATALOGS, SSDC BIBLIOGRAPHY TOOL, and AGILE-LV3 data analysis. Two red ovals highlight the satellite grid and the tool row. An orange arrow points from a text box on the left to the tool row. A blue arrow points from a text box on the right to the satellite grid.

Science Tools for on-line access to data in a multifrequency environment

On-line Access to Space Missions Data Archives

THE SSDC MULTI-MISSION INTERACTIVE ARCHIVE (2)



- **Uniform User Interface**
- **Direct Data Access**
- **Preview of High Level Data Products**
- **On-line Interactive Scientific Analysis tools to enhance the data scientific return**

THE SSDC MULTI-MISSION INTERACTIVE ARCHIVE (3)

Entry number	Archive	Interactive Analysis	Target Name	obsid	RA (J2000) hh mm ss.d	Dec (J2000) dd mm ss.d	time	public_date	exposure_a
1 <input checked="" type="checkbox"/> Select	SSDC Data Explorer	Data Access Interactive Analysis	CAS_A	40001019002	23 23 21.04	+58 49 19.2	Aug 18, 2012 19:46:00	Sep 23, 2014 00:00:00	293673.6108
2 <input checked="" type="checkbox"/> Select	SSDC Data Explorer	Data Access							404.9947
3 <input checked="" type="checkbox"/> Select	SSDC Data Explorer	Data Access							844.6137
4 <input checked="" type="checkbox"/> Select	SSDC Data Explorer	Data Access							849.5534
5 <input checked="" type="checkbox"/> Select	SSDC Data Explorer	Data Access							253.7978
6 <input checked="" type="checkbox"/> Select	SSDC Data Explorer	Data Access							773.6114
7 <input checked="" type="checkbox"/> Select	SSDC Data Explorer	Data Access							5932.51
8 <input checked="" type="checkbox"/> Select	SSDC Data Explorer	Data Access							577.6606

NuSTAR Imaging Tool @ SSDC

Set Image parameters:

Image Centered On:

RA (deg) Dec (deg)

LII (deg) BII (deg)

Source name: [Search](#)

Image half size (pixel)

Emin (keV)

Emax (keV)

Catalog Overlay [i](#)

☒ Radio ☒ IR ☐ X-Ray ☐ Gamma

[Sources cats](#)

AT20G
ATCAPMN
B3
CRATES

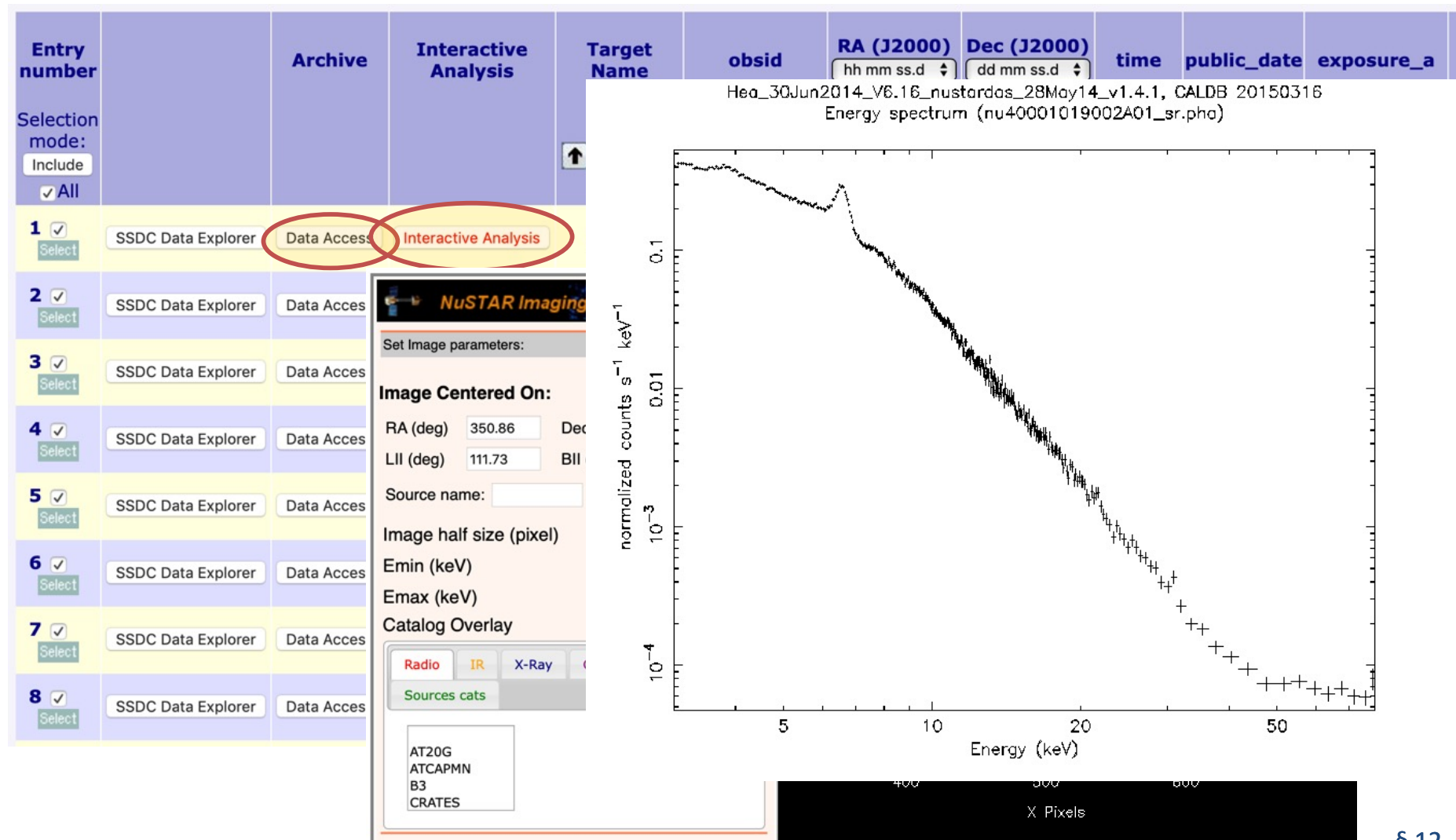
Cas_A

NUSTAR FPMA 2012 Aug 18 Exposure: 329352 s

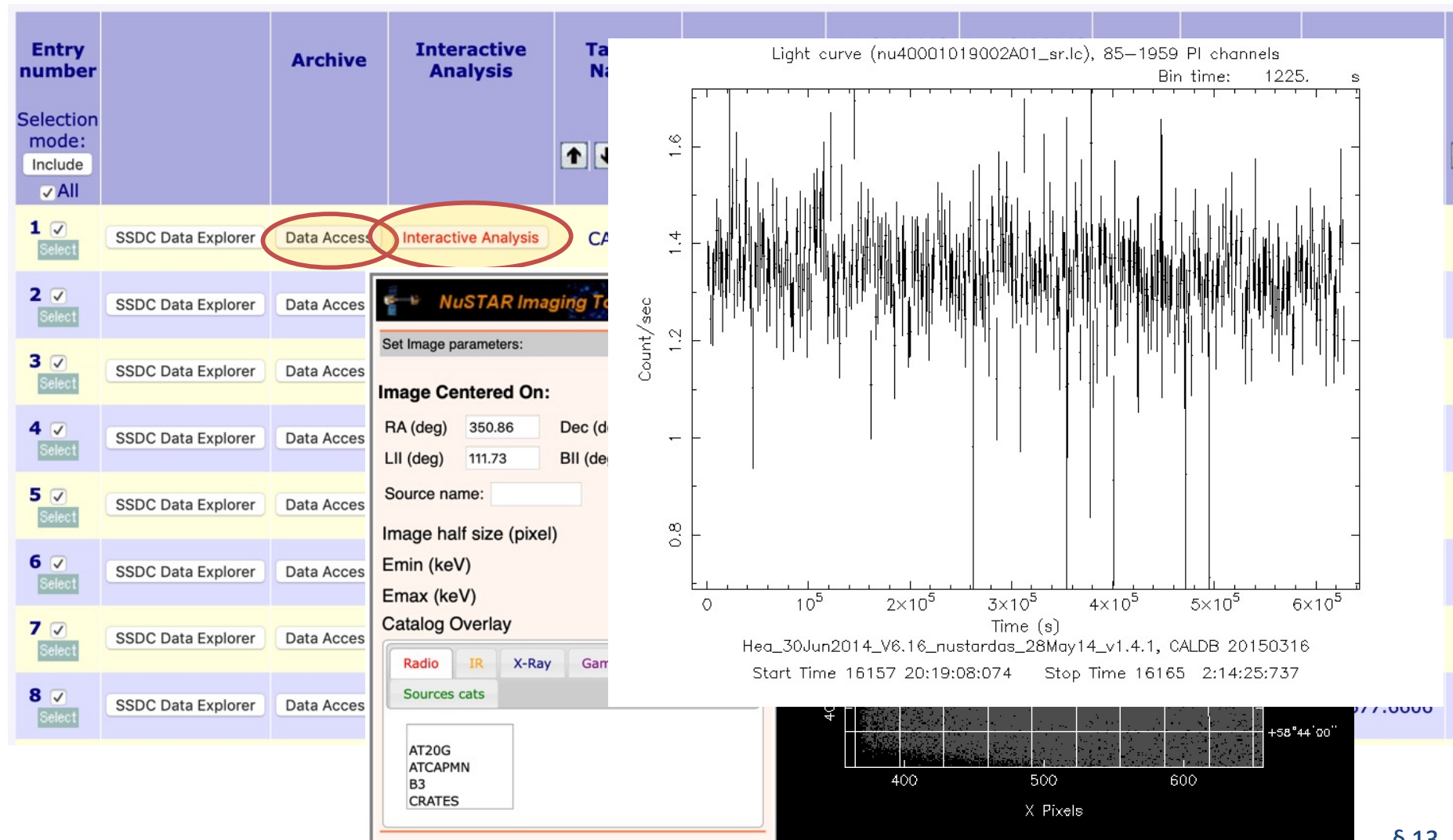
Y Pixels

X Pixels

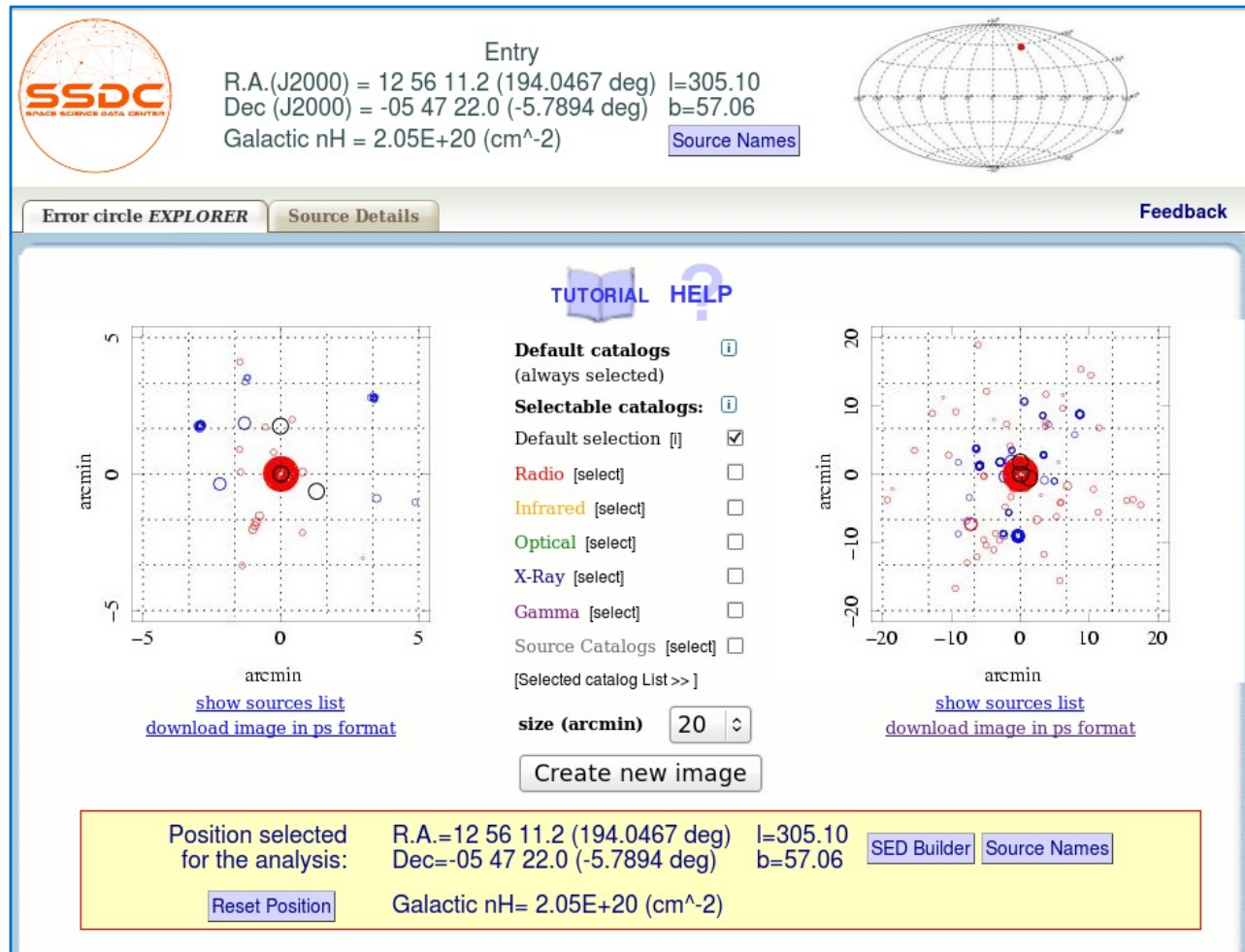
THE SSDC MULTI-MISSION INTERACTIVE ARCHIVE (3)



THE SSDC MULTI-MISSION INTERACTIVE ARCHIVE (3)



THE SSDC MULTI-FREQUENCY DATA EXPLORER



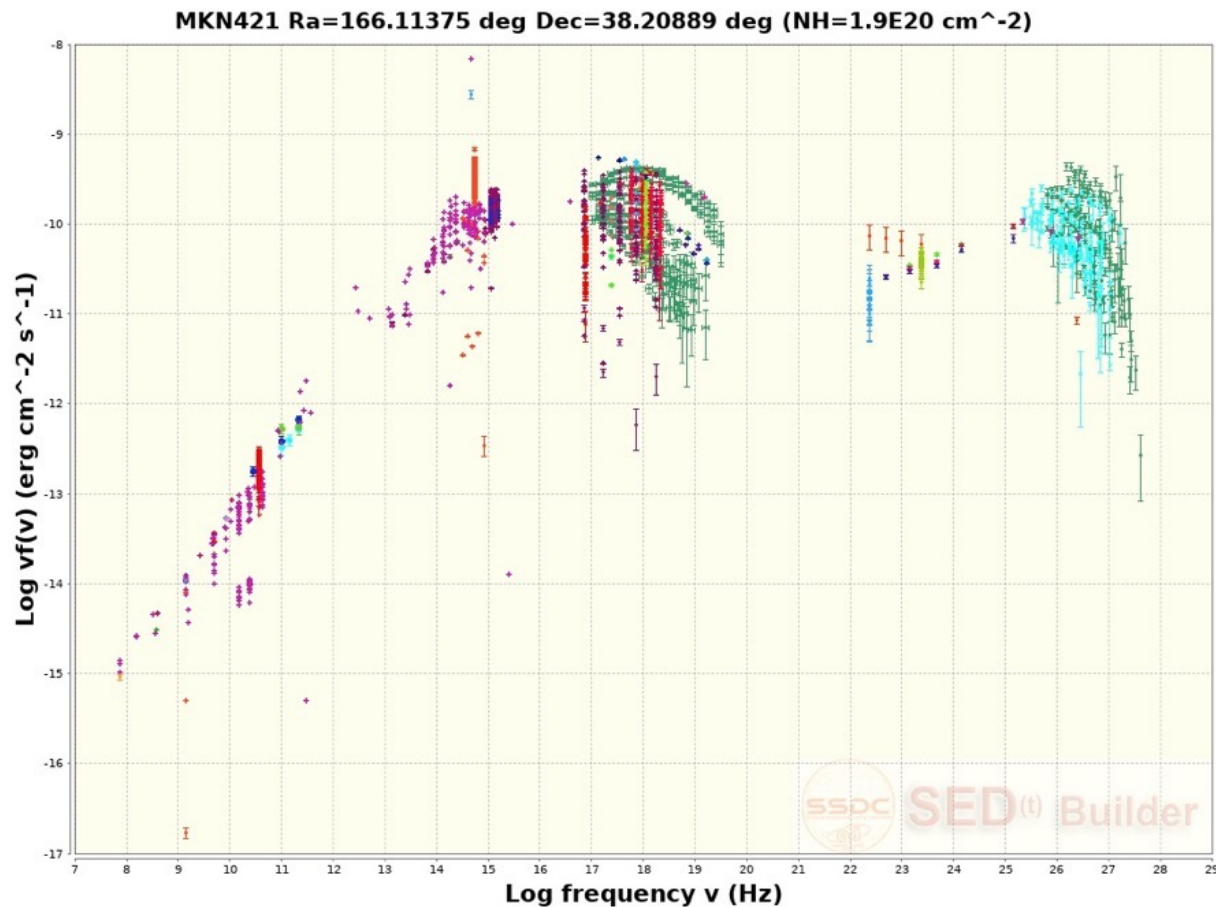
- fast visualization of a portion of sky centered on a specific source in all the energy bands
- cross-matching between archival catalogues
- direct link with science archives and external services including VO

THE SSDC MULTI-FREQUENCY **SED BUILDER**



SED^(t) Builder

A tool to build and handle spectral energy distributions and multifrequency light curves.



- generation and display of the Spectral Energy Distribution (SED) of astrophysical sources
- transparent access to SSDC-resident catalogs and to external archives (from radio to TeV energies)

THE GAIA PORTAL AT THE SSDC

Some numbers on Gaia DR2

1 692 919 135

position on the sky & magnitudes

550 737

Variable stars

76 956 778

Radius & Luminosity

161 497 595

Surface Temperature

1 331 909 727

parallax & proper motion

7 224 631

Radial Velocity

Some numbers on External Catalogues

2 264 263 282

Pan-STARRS1

61 176 401

APASSdr9

910 468 688

PPMXL

469 029 929

SDSSdr9

2 519 913

Tycho2

747 634 026

AllWISE

MUST KNOW

about Gaia DR2 CROSS-MATCH with External Catalogues

2 DIFFERENT NOT-SYMMETRIC XM ALGORITHMS

DENSE CATALOGUES	SPARSE CATALOGUES
LEADING : Gaia	LEADING : External Catalogue
SECOND : External Catalogue	SECOND : Gaia

BestNeighbour Table	
✓ NUMBER OF MATES	✗ NUMBER OF MATES
✓ NUMBER OF NEIGHBOURS	✓ NUMBER OF NEIGHBOURS
✓ BESTNEIG MULTIPLICITY	✗ BESTNEIG MULTIPLICITY
✓ ANGULAR DISTANCE	✓ ANGULAR DISTANCE
✓ GAIA ASTROMETRIC PARAMS	✓ GAIA ASTROMETRIC PARAMS

Neighbourhood Table	
✓ NUMBER OF MATES	✗ NUMBER OF MATES
✓ NUMBER OF NEIGHBOURS	✓ NUMBER OF NEIGHBOURS
✓ BESTNEIG MULTIPLICITY	✗ BESTNEIG MULTIPLICITY
✓ ANGULAR DISTANCE	✓ ANGULAR DISTANCE
✓ GAIA ASTROMETRIC PARAMS	✓ GAIA ASTROMETRIC PARAMS

XM CONCEPTS

- ### MATES

2 Gaia objects with the SAME BestNeighbour in the External Catalogues
- ### GOOD NEIGHBOURS

for a given leading catalogue object, a GoodNeighbour is a nearby object in the second catalogue whose position is compatible (within position errors) with the target. All GoodNeighbours are listed in the Neighbourhood Table.
- ### BEST NEIGHBOUR

for a given leading catalogue object, a BestNeighbour is the GoodNeighbour with the highest score. All BestNeighbours are listed in the BestNeighbour Table.
- ### SCORE

The score is a Figure of Merit based on geometric distance and local density of the second catalogue. The score is computed for all GoodNeighbours. Highest the score, best the match.
- ### GAIA ASTROMETRIC PARAMS

indicates the number of astrometric parameters available for this source in Gaia:
2 = only RA and DEC were available

to access our GaiaPortal USER MANUAL

THE IMPORTANCE OF BEING A REGISTERED USER

REGISTERED

- ✓ QUERY : **ASYNCHRONOUS MODE**
a mail will be sent to you with a link to results at the end of the Job
- ✓ QUERY TIMEOUT : **60 minutes**
- ✓ RESULT ENTRIES : **MAX 10 million**
- ✓ OUTPUT FILE : 1) direct link in the mail
2) available in the Query Result tab
3) stored on servers for 1 week
- ✓ QUERY HISTORY : **SAVED and ALWAYS AVAILABLE** at any login
- ✓ QUERY on LIST of sources : **AVAILABLE** MAX 1000 sources

ANONYMOUS

- ✗ QUERY : **SYNCHRONOUS MODE**
wait for results at the end of the Job
- ✗ QUERY TIMEOUT : **5 minutes**
- ✗ RESULT ENTRIES : **MAX 100.000**
- ✗ OUTPUT FILE : **available in the Query Result tab**
- ✗ QUERY HISTORY : **NOT AVAILABLE**
- ✗ QUERY on LIST of sources : **NOT AVAILABLE**

use LOGIN link at the top of this page!

CREDIT AND CITATION of Gaia DR2

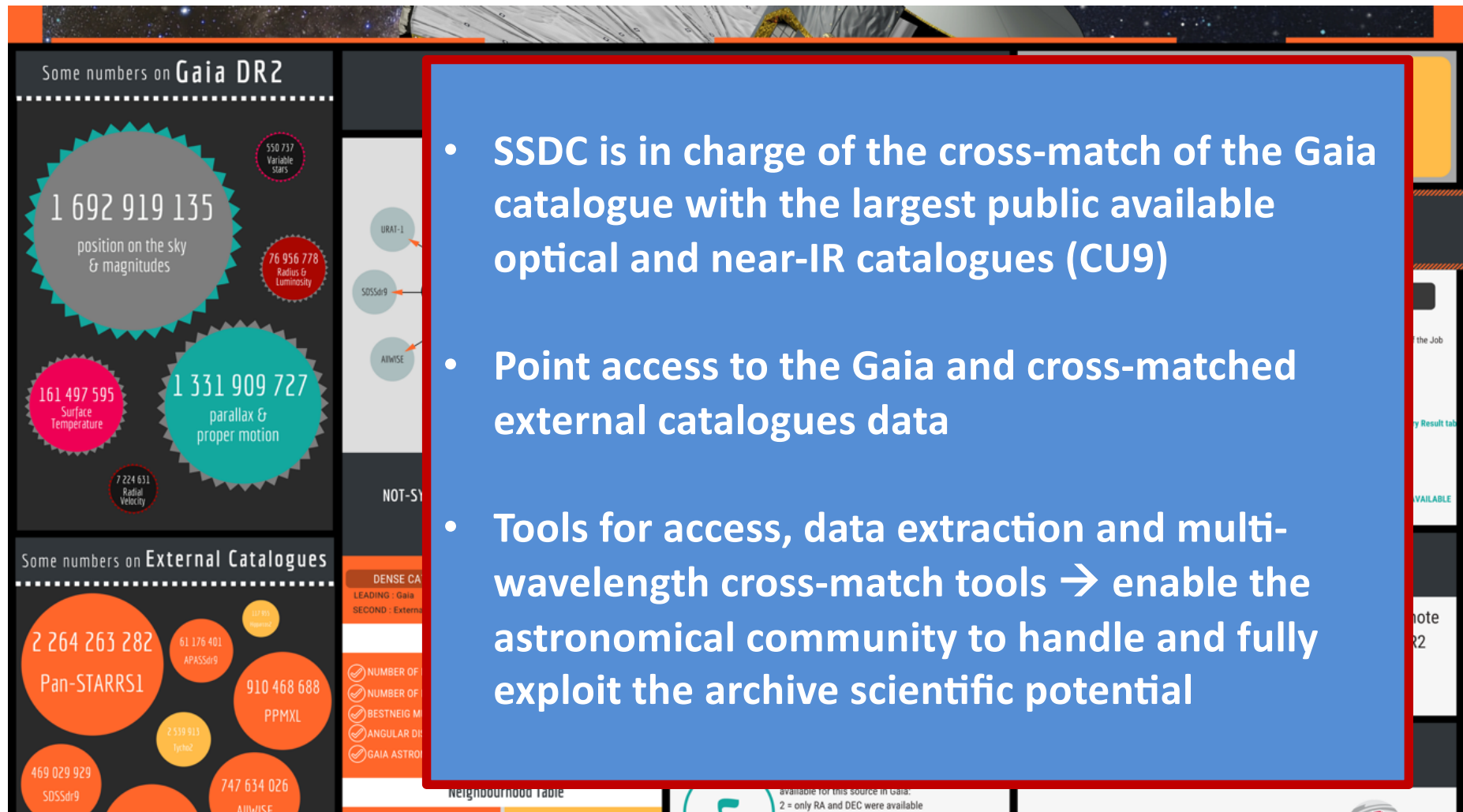
If you use Gaia DR2 data in your paper, please, take a note of our Guide on how to acknowledge and cite Gaia DR2

[HERE](#)

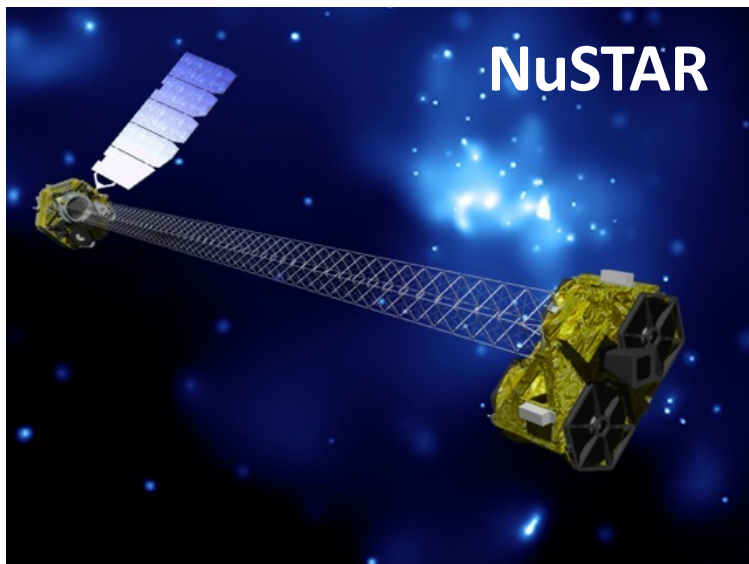
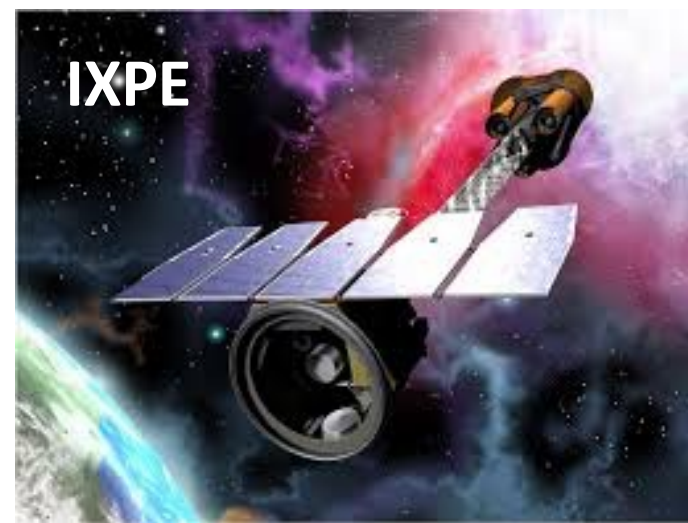
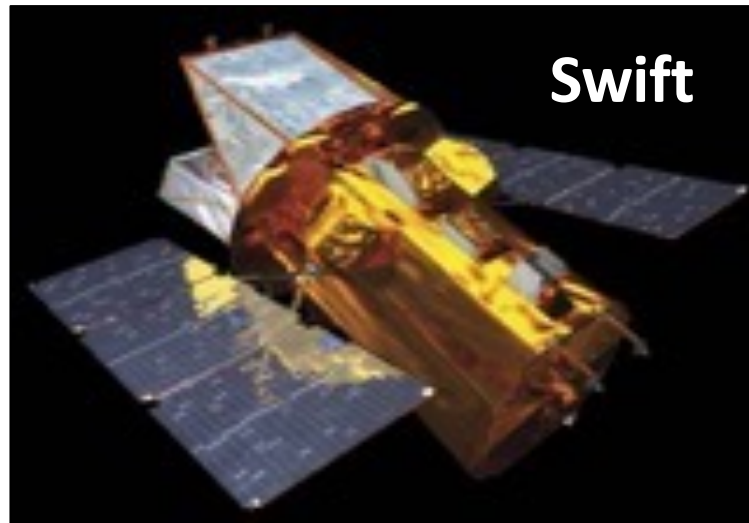
USEFUL LINKS

about Gaia and Gaia DR2 data

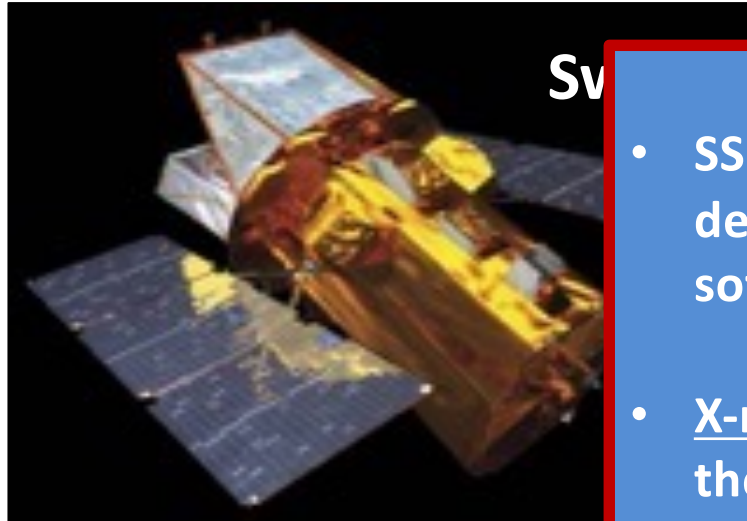
THE GAIA PORTAL AT THE SSDC



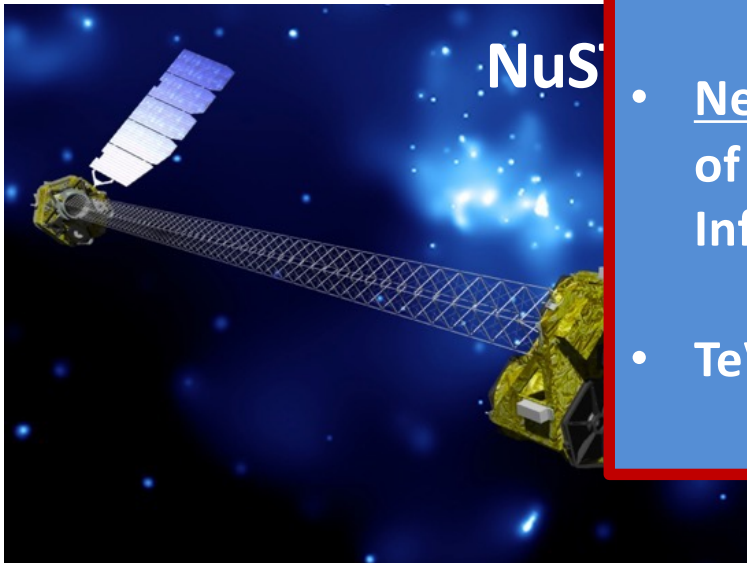
SCIENTIFIC DATA REDUCTION AND ANALYSIS SOFTWARE



SCIENTIFIC DATA REDUCTION AND ANALYSIS SOFTWARE



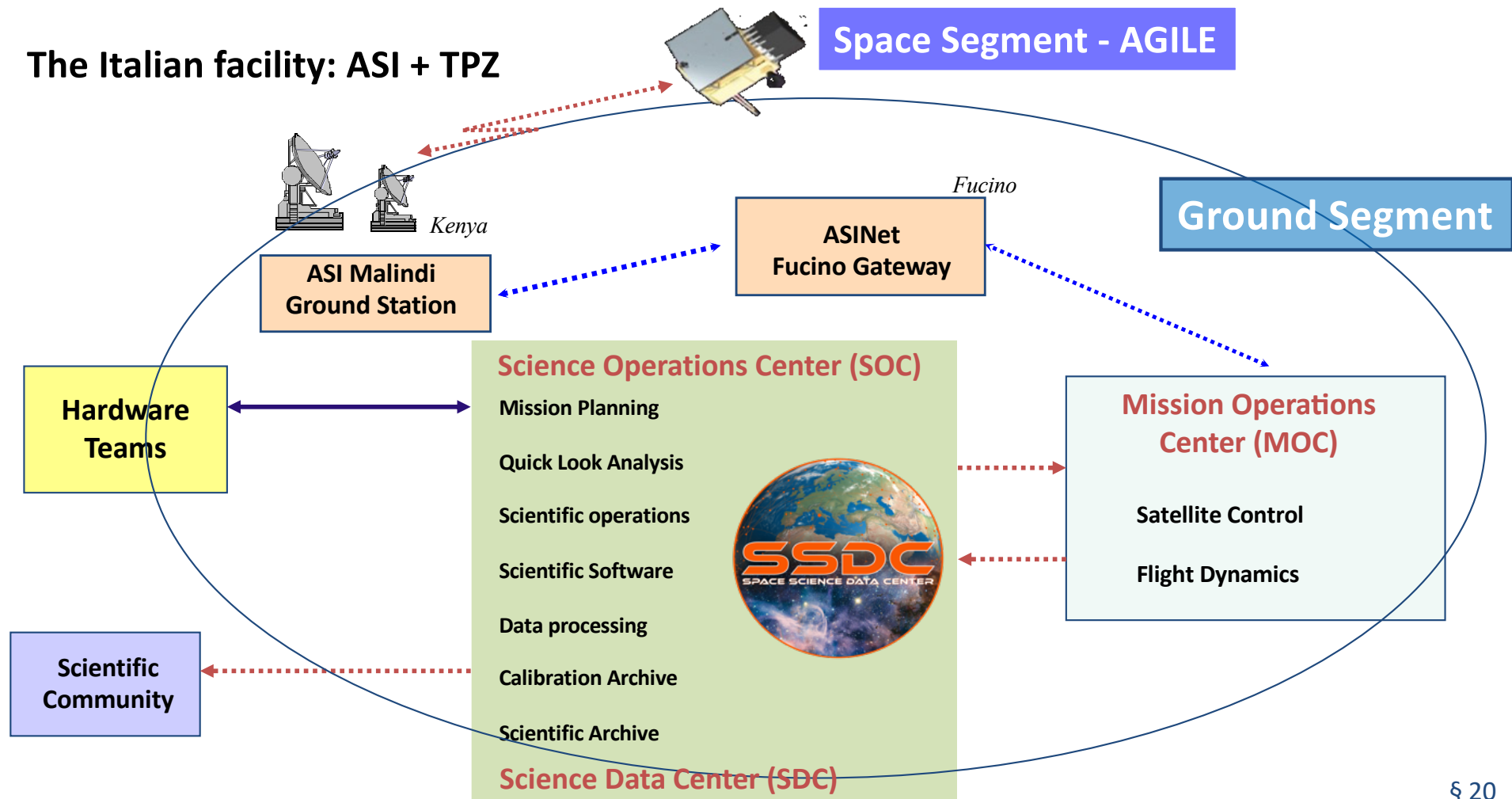
Swift



NuSTAR

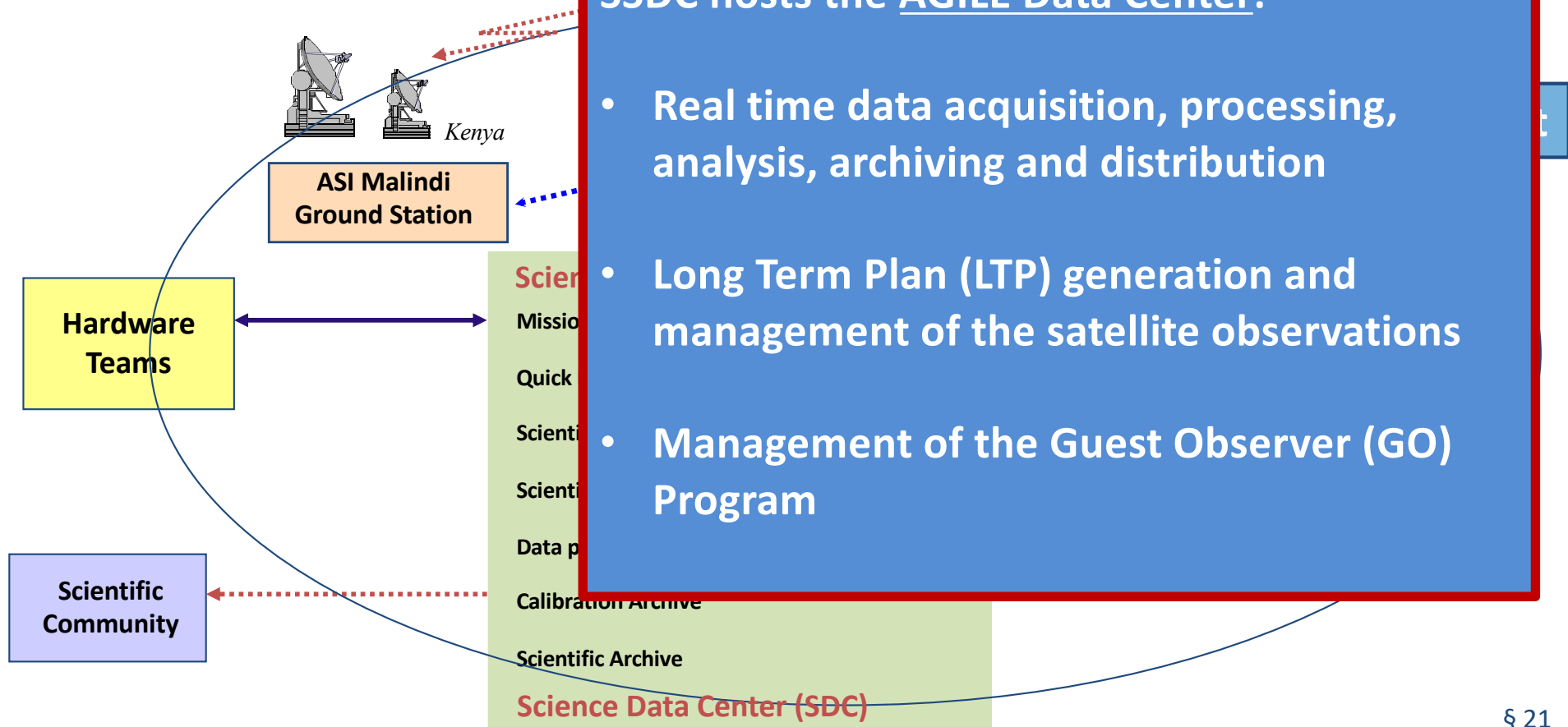
- SSDC long-standing expertise in the development of scientific data reduction software packages for space missions
- X-rays (NASA): SSDC major responsibilities in the design and development of Swift, NuSTAR and IXPE official software packages
- Near-infrared/optical (ESA): SSDC responsible of several WPs composing the Euclid Near InfraRed imaging data (NIR) Science Pipeline
- TeV band (IACTs): ASTRI and CTA

SCIENTIFIC **GROUND SEGMENTS** FOR SPACE MISSIONS



SCIENTIFIC **GROUND SEGMENTS** FOR SPACE MISSIONS

The Italian facility: ASI + TPZ



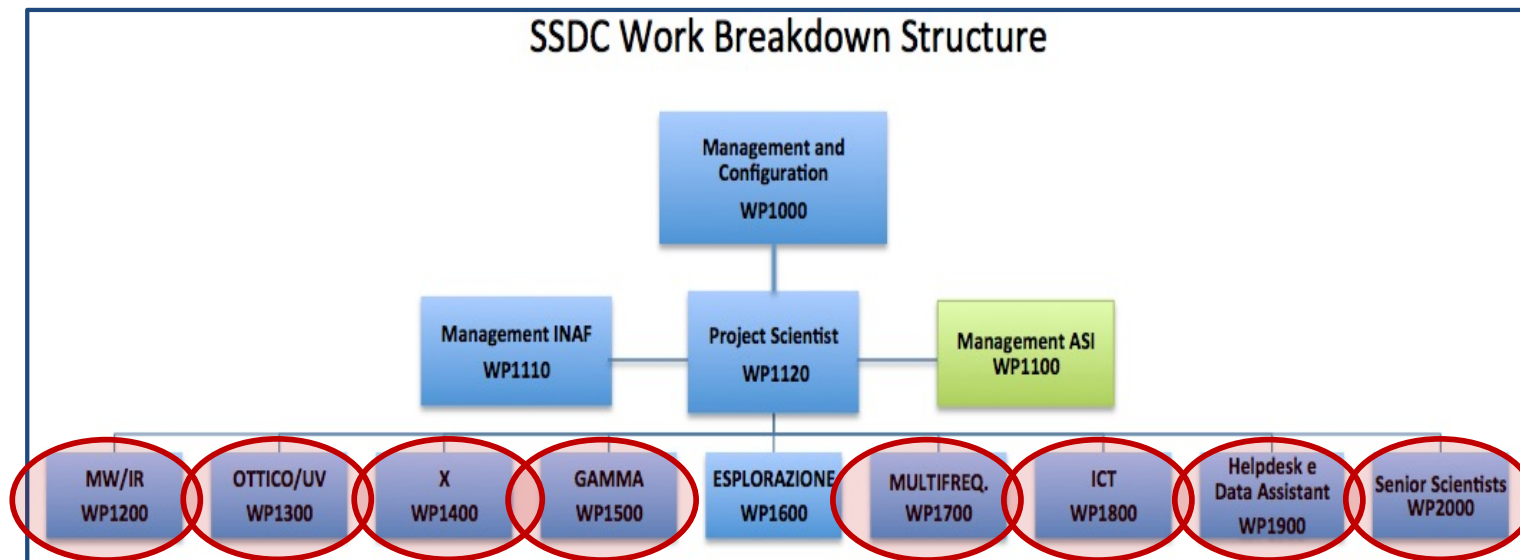
WP “ESPLORAZIONE DEL SISTEMA SOLARE” (SOLAR SYSTEM)

Sviluppo di **MATISSE** (*Multi-purpose Advanced Tool for the Solar System Exploration*), un tool per l'esplorazione dei dati provenienti dagli strumenti di esplorazione del Sistema Solare. In particolare, il tool rende disponibili on-line dati ed ha funzioni avanzate di visualizzazione dei dati.

Attraverso **MATISSE**, SSDC ha partecipato e partecipa a varie missioni di esplorazione del sistema solare (tra cui **SHARAD-MRO**, **MARSIS-Mars Express**, **Rosetta**, **Dawn**, **Chang-e**, **LICIACube-DART**, **JIRAM-Juno**, **CaSSIS** e **Ma-MISS** di **ExoMars**, **RIME-JUICE**).

INVOLVEMENT OF INAF PERSONNEL AND LEADERSHIP

INAF scientists play a **leading role** in all the activities/space missions described in the previous slides.



- INAF scientists based at the SSDC (18, including 9 staff) demonstrates the ability to capitalize on the **technological** and **scientific experience** acquired at the SSDC
- Over **40 scientists** have been formed in SSDC (ex ASDC) in the last 25 years, the most part of them has now permanent positions in SSDC or similar institutions
- Involvement of several **Senior Scientists** to open the data center to the scientific community

SCIENTIFIC AND TECHNOLOGICAL **IMPACT ON INAF COMMUNITY**

Present-day astrophysics is characterized by **very large** amounts of **heterogeneous** data (e.g., photons in the whole electromagnetic spectrum, polarization data, cosmic rays, neutrinos, gravitational waves) that is rapidly growing with time.

The availability of **dedicated software tools** and **infrastructures** that allow to access, explore and analyze such data is critical in order to fully exploit this huge volume of information and keep the research at a competitive level.

In this context, the SSDC as a modern **multi-mission** and **multi-disciplinary international** science data center is a unique opportunity for INAF.

SSDC is **required** and **used** by the national and international astronomical community:

- high quality **data** storage, management and distribution **services**, + **support to space projects** (e.g., ground segment tasks expertise)
- **250/day visits** (web page + science tools + mission pages), **~50%** from Italy

INAF AND ASI ROLES (1/2)

The SSDC is managed by the Italian Space Agency (**ASI**) together with **INAF** and **INFN**.

INAF is the institution most involved in the co-management of the SSDC, with a contribution also from **INFN**.

The activities carried out by **INAF** are:

- part of a general framework of collaboration with ASI (“**Accordo Quadro ASI-INAF**”)
- started in **2005** when INAF, at the invitation of ASI, started to actively participate in the management of the center
- handled through specific contracts (“**Accordi Attuativi**”)

The role of **INAF** in the SSDC evolution in the last 15 years has been and is crucial to creating a truly multi-mission data center.

The contribution of INAF with its specialized and qualified *know-how* is very important.

INAF AND ASI ROLES (2/2)

Role of the Italian Space Agency (ASI):

- ASI guarantees the possibility of entering into **bilateral agreements** with other **space agencies** (e.g., ESA, NASA, JAXA, etc.)
- ASI financing ensures the **presence of the industrial component** (essential to ensure a high standard of the service provided and its maintenance) and provides the **infrastructures** (ASI headquarters) and the **hardware** (high-volume storage and processing servers)

ASI is both maintaining a high investment in the infrastructure and also enforcing SSDC's activities:

- recent inclusion of **various staff units** (7)
- activities expansion in **new areas** (Space Weather, space surveillance activities, Near-Earth Objects database, Fly-Eye data center, new missions)

The **evolution** and **enhancement** of the SSDC has been discussed by an ASI/INAF/INFN Technical Committee and it is going to be submitted to the top-level managements.

FUTURE PLANNING

1) Support/participation to new space missions:

- HERMES
- eXTP
- Theseus
- Athena
- Fly-Eye telescope
- ...

2) Participation in the construction of a **national scientific data center for Space Weather**, called **ASI Space Weather Infrastructure (ASPI)**: collection, analysis and distribution of Space Weather data and simulations

→ supporting the scientific community in an intrinsically multi-disciplinary activity through a single portal

3) Synergy with other infrastructures on activities in **support of interoperability**, such as the **Virtual Observatory**, exploiting the natural complementarity between ground-based observations and space missions

CRITICAL ISSUES FOR INAF

Specific professional figures needed:

- **archive/data scientists** (data organization, data description, astronomical classification taxonomies, data mining, machine learning, visualization, and astrostatistics)

Difficulty in finding profiles of this type

Need to **train** young researchers and technologists

Need to ensure **career prospects** in these areas in **INAF**