Finanziato dall'Unione europea
NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA
ICSC
Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing

FERMI use case and Data Model

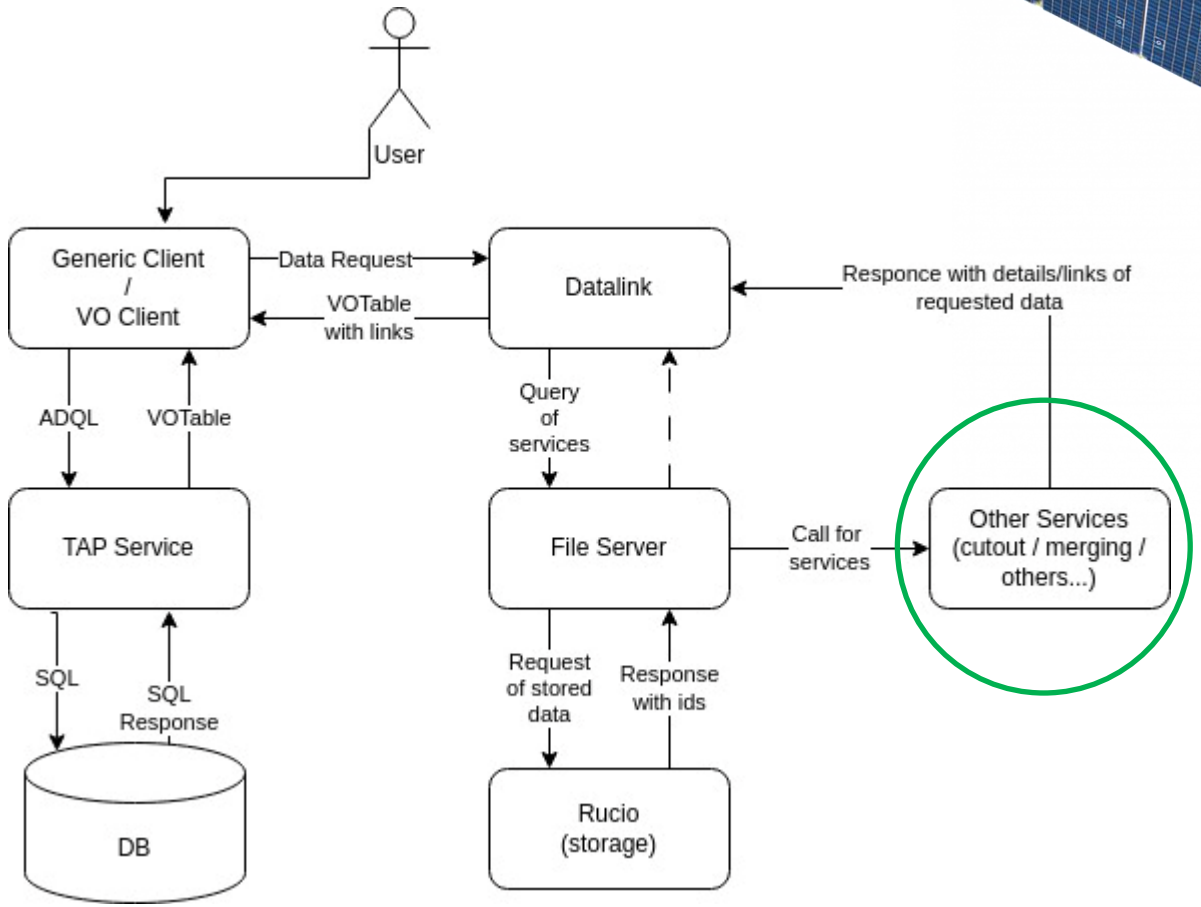
Andrea Adelfio (INFN-PG)

Spoke 3 General Meeting, Elba 5-9 / 05, 2024

Scientific Rationale

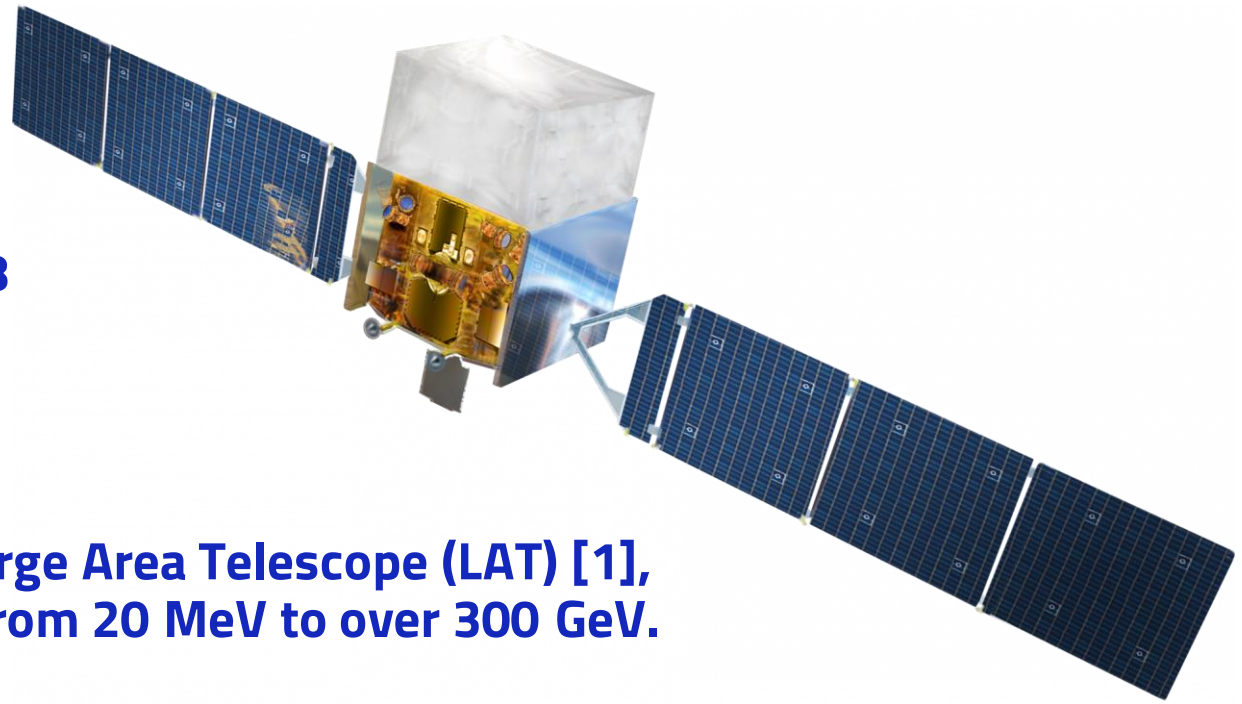
To have the Fermi data products accessible from the interoperable data lake infrastructure, i.e., accessible by any astronomer who has interest in the data and in making smart cross filtering on the data.

Scientific Rationale



With this use case we ask to add cutout and merging services in the application side of the infrastructure.

Fermi satellite



The Fermi Gamma-ray Space Telescope is a space observatory launched by NASA in 2008 to study high-energy gamma rays.

The primary instrument on board Fermi is the Large Area Telescope (LAT) [1], which detects gamma rays in the energy range from 20 MeV to over 300 GeV.

The Gamma-ray Burst Monitor (GBM) [2], designed to observe gamma-ray bursts in the energy range from 8 keV to 40 MeV.

(1) Atwood 2009 - THE LARGE AREA TELESCOPE ON THE FERMI GAMMA-RAY SPACE TELESCOPE MISSION
(2) Meegan 2009 - THE FERMI GAMMA-RAY BURST MONITOR

Data products: FT1 and FT2

Order of 10-100 Gigabytes

Index of /FTP/fermi/data/lat/weekly/1s_spacecraft

Name	Last modified	Size	Description
Parent Directory		-	
README	14-Mar-2022 10:29	453	
lat_1sec_spacecraft_weekly_w009_p310_v001.fits	02-Mar-2022 17:12	26M	
lat_1sec_spacecraft_weekly_w010_p310_v001.fits	02-Mar-2022 17:12	80M	
lat_1sec_spacecraft_weekly_w011_p310_v001.fits	02-Mar-2022 17:12	78M	
lat_1sec_spacecraft_weekly_w012_p310_v001.fits	02-Mar-2022 17:12	80M	
lat_1sec_spacecraft_weekly_w013_p310_v001.fits	02-Mar-2022 17:12	80M	
lat_1sec_spacecraft_weekly_w014_p310_v001.fits	02-Mar-2022 17:12	79M	
lat_1sec_spacecraft_weekly_w015_p310_v001.fits	02-Mar-2022 17:12	80M	
lat_1sec_spacecraft_weekly_w016_p310_v001.fits	02-Mar-2022 17:12	79M	
lat_1sec_spacecraft_weekly_w017_p310_v001.fits	02-Mar-2022 17:12	80M	
lat_1sec_spacecraft_weekly_w018_p310_v001.fits	02-Mar-2022 17:12	80M	
lat_1sec_spacecraft_weekly_w019_p310_v001.fits	02-Mar-2022 17:13	80M	
lat_1sec_spacecraft_weekly_w020_p310_v001.fits	02-Mar-2022 17:13	80M	
lat_1sec_spacecraft_weekly_w021_p310_v001.fits	02-Mar-2022 17:13	79M	
lat_1sec_spacecraft_weekly_w022_p310_v001.fits	02-Mar-2022 17:13	80M	
lat_1sec_spacecraft_weekly_w023_p310_v001.fits	02-Mar-2022 17:13	79M	
lat_1sec_spacecraft_weekly_w024_p310_v001.fits	02-Mar-2022 17:13	80M	

Index of /FTP/fermi/data/lat/weekly/photon

Name	Last modified	Size	Description
Parent Directory		-	
README	14-Mar-2022 10:29	438	
lat_photon_weekly_w009_p305_v001.fits	28-Feb-2022 17:44	16M	
lat_photon_weekly_w010_p305_v001.fits	28-Feb-2022 17:44	55M	
lat_photon_weekly_w011_p305_v001.fits	28-Feb-2022 17:44	54M	
lat_photon_weekly_w012_p305_v001.fits	28-Feb-2022 17:44	58M	
lat_photon_weekly_w013_p305_v001.fits	28-Feb-2022 17:44	56M	
lat_photon_weekly_w014_p305_v001.fits	28-Feb-2022 17:44	56M	
lat_photon_weekly_w015_p305_v001.fits	28-Feb-2022 17:44	54M	
lat_photon_weekly_w016_p305_v001.fits	28-Feb-2022 17:44	53M	
lat_photon_weekly_w017_p305_v001.fits	28-Feb-2022 17:44	80M	
lat_photon_weekly_w018_p305_v001.fits	28-Feb-2022 17:44	56M	
lat_photon_weekly_w019_p305_v001.fits	28-Feb-2022 17:44	56M	

Data products: FT1 and FT2

Index of /FTP/fermi/data/lat/weekly/1s_spacecraft

HDU	Extension	Type	Dimensions
0	PRIMARY	NULL	NULL
1	SC_DATA	table	164×514394

lat_1sec_spacecraft_weekly_w009_p310_v001.fits 02-Mar-2022 17:12 26M
lat_1sec_spacecraft_weekly_w010_p310_v001.fits 02-Mar-2022 17:12 80M
lat_1sec_spacecraft_weekly_w011_p310_v001.fits 02-Mar-2022 17:12 78M
lat_1sec_spacecraft_weekly_w012_p310_v001.fits 02-Mar-2022 17:12 80M
lat_1sec_spacecraft_weekly_w013_p310_v001.fits 02-Mar-2022 17:12 80M
lat_1sec_spacecraft_weekly_w014_p310_v001.fits 02-Mar-2022 17:12 79M
lat_1sec_spacecraft_weekly_w015_p310_v001.fits 02-Mar-2022 17:12 80M
lat_1sec_spacecraft_weekly_w016_p310_v001.fits 02-Mar-2022 17:12 79M
lat_1sec_spacecraft_weekly_w017_p310_v001.fits 02-Mar-2022 17:12 80M
lat_1sec_spacecraft_weekly_w018_p310_v001.fits 02-Mar-2022 17:12 80M
lat_1sec_spacecraft_weekly_w019_p310_v001.fits 02-Mar-2022 17:13 80M
lat_1sec_spacecraft_weekly_w020_p310_v001.fits 02-Mar-2022 17:13 80M
lat_1sec_spacecraft_weekly_w021_p310_v001.fits 02-Mar-2022 17:13 79M
lat_1sec_spacecraft_weekly_w022_p310_v001.fits 02-Mar-2022 17:13 80M
lat_1sec_spacecraft_weekly_w023_p310_v001.fits 02-Mar-2022 17:13 79M
lat_1sec_spacecraft_weekly_w024_p310_v001.fits 02-Mar-2022 17:13 80M

Index of /FTP/fermi/data/lat/weekly/photon

HDU	Extension	Type	Dimensions
0	PRIMARY	NULL	NULL
1	EVENTS	table	98×1605321
2	GTI	table	16×107

lat_photon_weekly_w010_p305_v001.fits 28-Feb-2022 17:44 55M
lat_photon_weekly_w011_p305_v001.fits 28-Feb-2022 17:44 54M
lat_photon_weekly_w012_p305_v001.fits 28-Feb-2022 17:44 58M
lat_photon_weekly_w013_p305_v001.fits 28-Feb-2022 17:44 56M
lat_photon_weekly_w014_p305_v001.fits 28-Feb-2022 17:44 56M
lat_photon_weekly_w015_p305_v001.fits 28-Feb-2022 17:44 54M
lat_photon_weekly_w016_p305_v001.fits 28-Feb-2022 17:44 53M
lat_photon_weekly_w017_p305_v001.fits 28-Feb-2022 17:44 80M
lat_photon_weekly_w018_p305_v001.fits 28-Feb-2022 17:44 56M
lat_photon_weekly_w019_p305_v001.fits 28-Feb-2022 17:44 56M

Technical Objectives: Spacecraft and Photons cross filtering

START (s)
STOP (s)
SC_POSITION (m)
LAT_GEO (deg)
LON_GEO (deg)
RAD_GEO (m)
RA_ZENITH (deg)
DEC_ZENITH (deg)
B_MCILWAIN (Gauss)
L_MCILWAIN (Earth_Radii)
GEOMAG_LAT (deg)
LAMBDA (deg)
IN_SAA
RA_SCZ (deg)
DEC_SCZ (deg)

RA_SCX (deg)
DEC_SCX (deg)
RA_NPOLE (deg)
DEC_NPOLE (deg)
ROCK_ANGLE (deg)
LAT_MODE
LAT_CONFIG
DATA_QUAL
LIVETIME (s)
QSJ_1
QSJ_2
QSJ_3
QSJ_4
RA_SUN (deg)
DEC_SUN (deg)
SC_VELOCITY (m/s)

Technical Objectives: Spacecraft and Photons cross filtering

START (s)
STOP (s)
SC_POSITION (m)
LAT_GEO (deg)
LON_GEO (deg)
RAD_GEO (m)
RA_ZENITH (deg)
DEC_ZENITH (deg)
B_MCILWAIN (Gauss)
L_MCILWAIN (Earth_Radii)
GEOMAG_LAT (deg)
LAMBDA (deg)
IN_SAA
RA_SCZ (deg)
DEC_SCZ (deg)

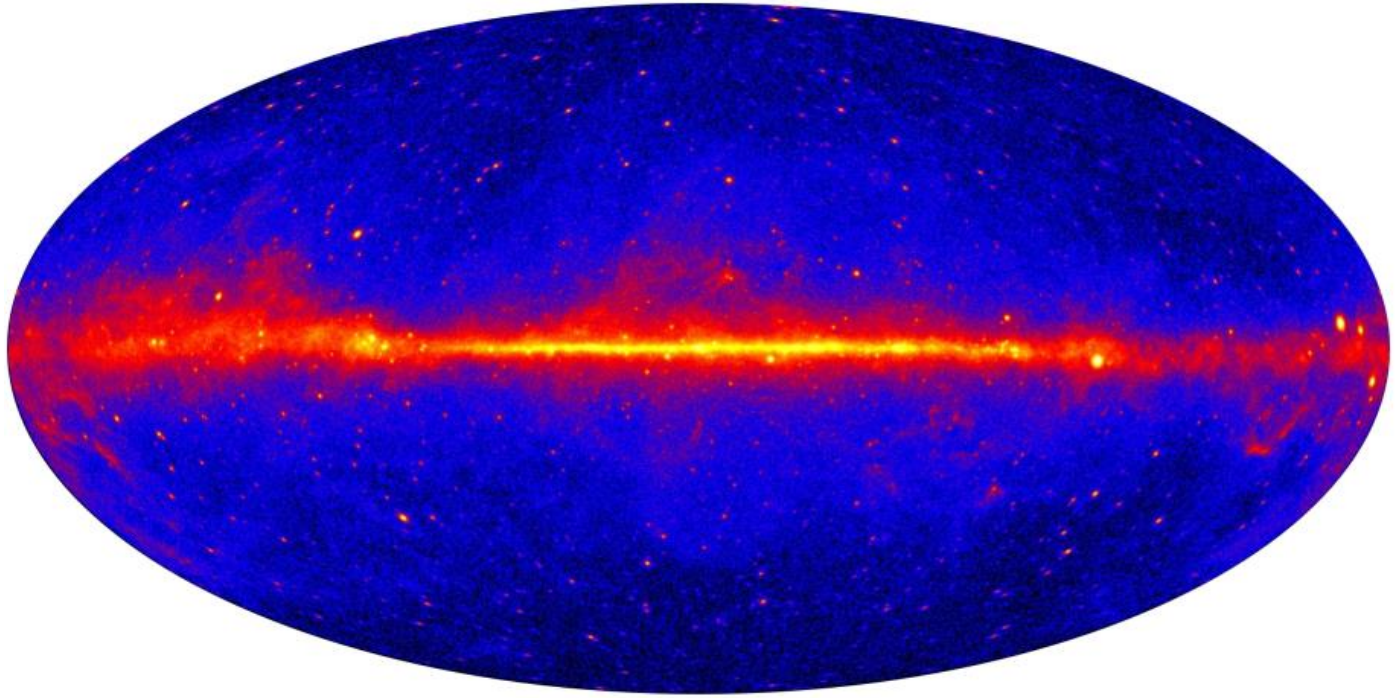
RA_SCX (deg)
DEC_SCX (deg)
RA_NPOLE (deg)
DEC_NPOLE (deg)
ROCK_ANGLE (deg)
LAT_MODE
LAT_CONFIG
DATA_QUAL
LIVETIME (s)
QSJ_1
QSJ_2
QSJ_3
QSJ_4
RA_SUN (deg)
DEC_SUN (deg)
SC_VELOCITY (m/s)

Technical Objectives: Spacecraft and Photons cross filtering

RA_ZENITH (deg)
DEC_ZENITH (deg)

FILTERS

Fermitools



Data products: FT1 and FT2

Index of /FTP/fermi/data/lat/weekly/1s_spacecraft

HDU	Extension	Type	Dimensions
0	PRIMARY	NULL	NULL
1	SC_DATA	table	164×514394

lat_1sec_spacecraft_weekly_w009_p310_v001.fits 02-Mar-2022 17:12 26M
lat_1sec_spacecraft_weekly_w010_p310_v001.fits 02-Mar-2022 17:12 80M
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lat_1sec_spacecraft_weekly_w014_p310_v001.fits 02-Mar-2022 17:12 79M
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lat_1sec_spacecraft_weekly_w016_p310_v001.fits 02-Mar-2022 17:12 79M
lat_1sec_spacecraft_weekly_w017_p310_v001.fits 02-Mar-2022 17:12 80M
lat_1sec_spacecraft_weekly_w018_p310_v001.fits 02-Mar-2022 17:12 80M
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lat_photon_weekly_w019_p305_v001.fits 28-Feb-2022 17:44 56M

Data products: FT1 and FT2

Index of /FTP/fermi/data/lat/weekly/1s_spacecraft

HDU	Extension	Type	Dimensions
0	PRIMARY	NULL	NULL
1	SC_DATA	table	16x514394

lat_1sec_spacecraft_weekly_w009_p310_v001.fits 02-Mar-2022 17:12 26M
lat_1sec_spacecraft_weekly_w010_p310_v001.fits 02-Mar-2022 17:12 80M
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lat_photon_weekly_w018_p305_v001.fits 28-Feb-2022 17:44 56M
lat_photon_weekly_w019_p305_v001.fits 28-Feb-2022 17:44 56M

Data products: FT1 and FT2

Index of /FTP/fermi/data/lat/weekly/1s_spacecraft

```
SIMPLE  = T
BITPIX  = 8
NAXIS   = 0
EXTEND  = T
CHECKSUM= '4TGG5QGD4QGD4QGD'
DATASUM = '0         '
TELESCOP= 'GLAST     '
INSTRUME= 'LAT       '
EQUINOX = 2000.
RADECSYS= 'FK5       '
DATE    = '2023-11-29T23:06:06'
DATE-OBS= '2023-11-30T01:22:03.6690'
DATE-END= '2023-12-07T00:39:24.0941'
TSTART  = 723000128.669092
TSTOP   = 723602369.094183
TIMESYS = 'TT        '
TIMEUNIT= 's         '
GPS_OUT = F
```

Index of /FTP/fermi/data/lat/weekly/photon

```
SIMPLE  = T
BITPIX  = 8
NAXIS   = 0
EXTEND  = T
DATASUM = '0         '
TELESCOP= 'GLAST     '
INSTRUME= 'LAT       '
EQUINOX = 2000.
RADECSYS= 'FK5       '
DATE    = '2024-02-22T04:20:58'
DATE-OBS= '2024-02-22T01:36:13.9999'
DATE-END= '2024-02-29T00:44:15.9999'
TSTART  = 730258579.
TSTOP   = 730860261.
TIMEUNIT= 's         '
TIMEZERO= 0.
```

Data products: FT1 and FT2

Index of /FTP/fermi/data/lat/weekly/1s_spacecraft

```
SIMPLE  = T
BITPIX  = 8
NAXIS   = 0
EXTEND  = T
CHECKSUM= '4TGG5QGD4QGD4QGD'
DATASUM = '0         '
TELESCOP= 'GLAST     '
INSTRUME= 'LAT       '
EQUINOX = 2000.
RADECSYS= 'FK5       '
DATE    = '2023-11-29T23:06:06'
DATE-OBS= '2023-11-30T01:22:03.6690'
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TSTART  = 723000128.669092
TSTOP   = 723602369.094183
TIMESYS = 'TT        '
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GPS_OUT = F
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Index of /FTP/fermi/data/lat/weekly/photon

```
SIMPLE  = T
BITPIX  = 8
NAXIS   = 0
EXTEND  = T
DATASUM = '0         '
TELESCOP= 'GLAST     '
INSTRUME= 'LAT       '
EQUINOX = 2000.
RADECSYS= 'FK5       '
DATE    = '2024-02-22T04:20:58'
DATE-OBS= '2024-02-22T01:36:13.9999'
DATE-END= '2024-02-29T00:44:15.9999'
TSTART  = 730258579.
TSTOP   = 730860261.
TIMEUNIT= 's         '
TIMEZERO= 0.
```

Data products: FT1 and FT2

NAME	LABEL	IS CUSTOM	TO BE IMPORTED	TO BE FILTERED	TO BE QUERIED	IN RESULTS VIEW (DEFAULT)
NAXIS_HDU0		N	Y	N	N	N
EXTEND		N	Y	N	N	N
CHECKSUM_HDU0		N	Y	N	N	N
TELESCOP		N	Y	N	Y	Y
INSTRUME		N	Y	N	Y	Y
EQUINOX		N	Y	N	Y	Y
RADECSYS		N	Y	N	N	N
DATE		N	Y	N	Y	N
DATE_OBS	Observation start date	N	Y	Y	Y	Y
DATE_END	Observation end date	N	Y	Y	Y	Y
TSTART	Start MET (s)	N	Y	Y	Y	Y
TSTOP	End MET (s)	N	Y	Y	Y	Y
TIMEUNIT		N	Y	N	N	N
TIMEZERO		N	Y	N	N	N
TIMESYS		N	Y	N	N	N
TIMEREF		N	Y	N	N	N
CLOCKAPP		N	Y	N	N	N
GPS_OUT		N	Y	N	N	N
MJDREFI		N	Y	N	N	N
MJDREFF		N	Y	N	N	N
OBSERVER		N	Y	N	Y	Y
FILENAME		N	Y	N	Y	Y
ORIGIN		N	Y	N	N	N
CREATOR		N	Y	N	N	N
VERSION		N	Y	N	Y	Y
PROC_VER		N	Y	N	N	N

For the data model preparation we need to select which metadata (fields) will be:

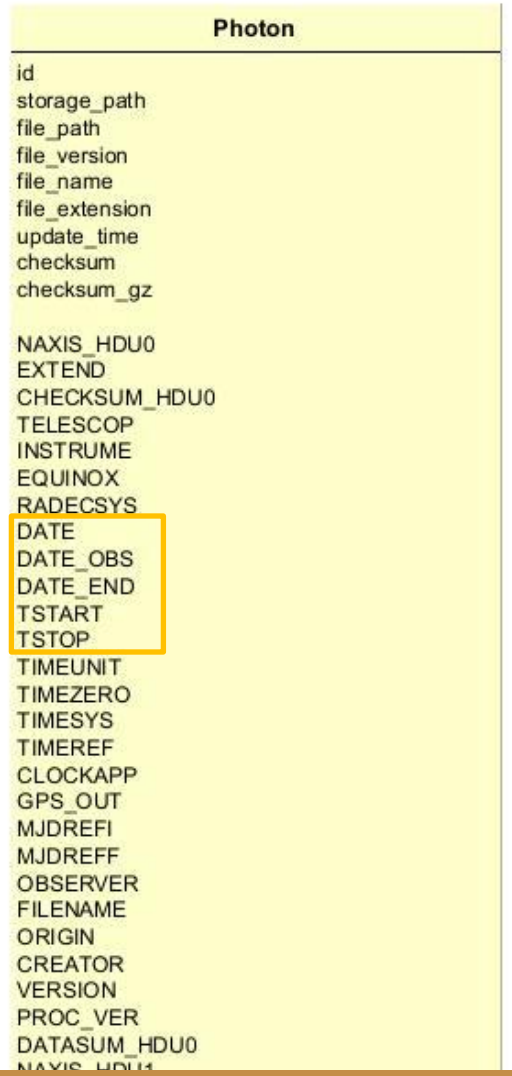
- **imported in the database;**
- **filtered from the portal;**
- **queried in the SQL;**
- **showed as results in the portal.**

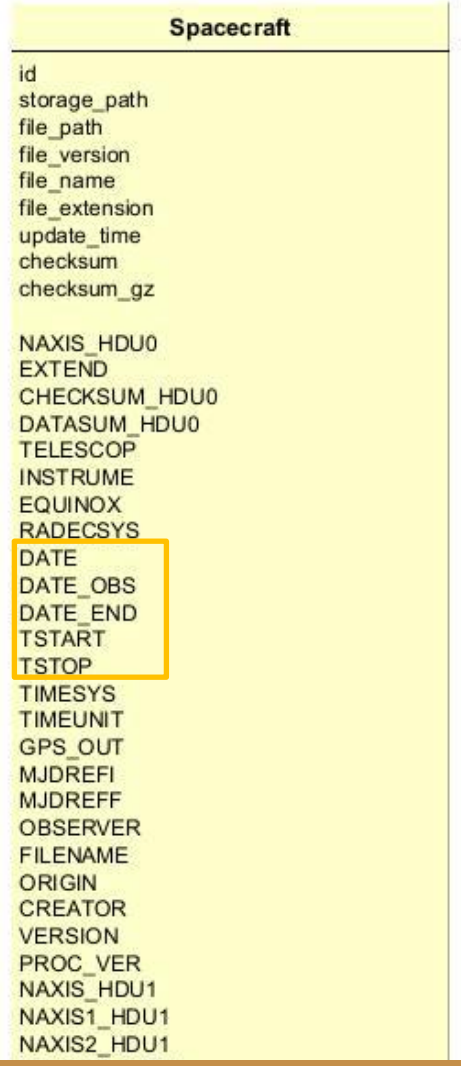
Methodologies

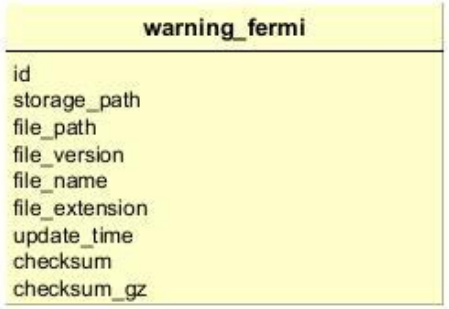
We create a Data Model based on the metadata that we get from the headers (for now).

These metadata will be added in the database.

Then we select which fields will be used as filters in the portal (i.e. filters in the SQL query), and which will be shown as results.



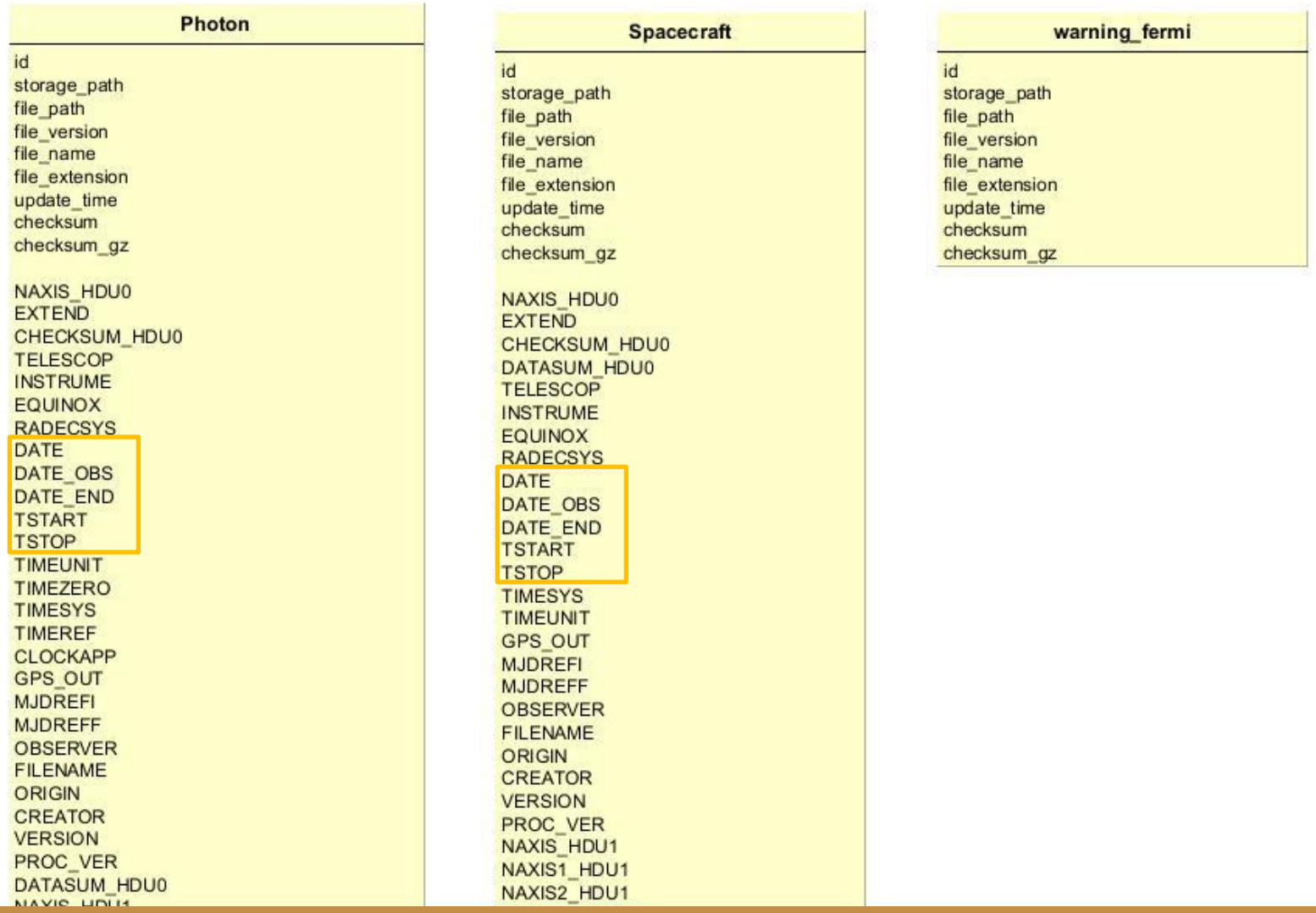




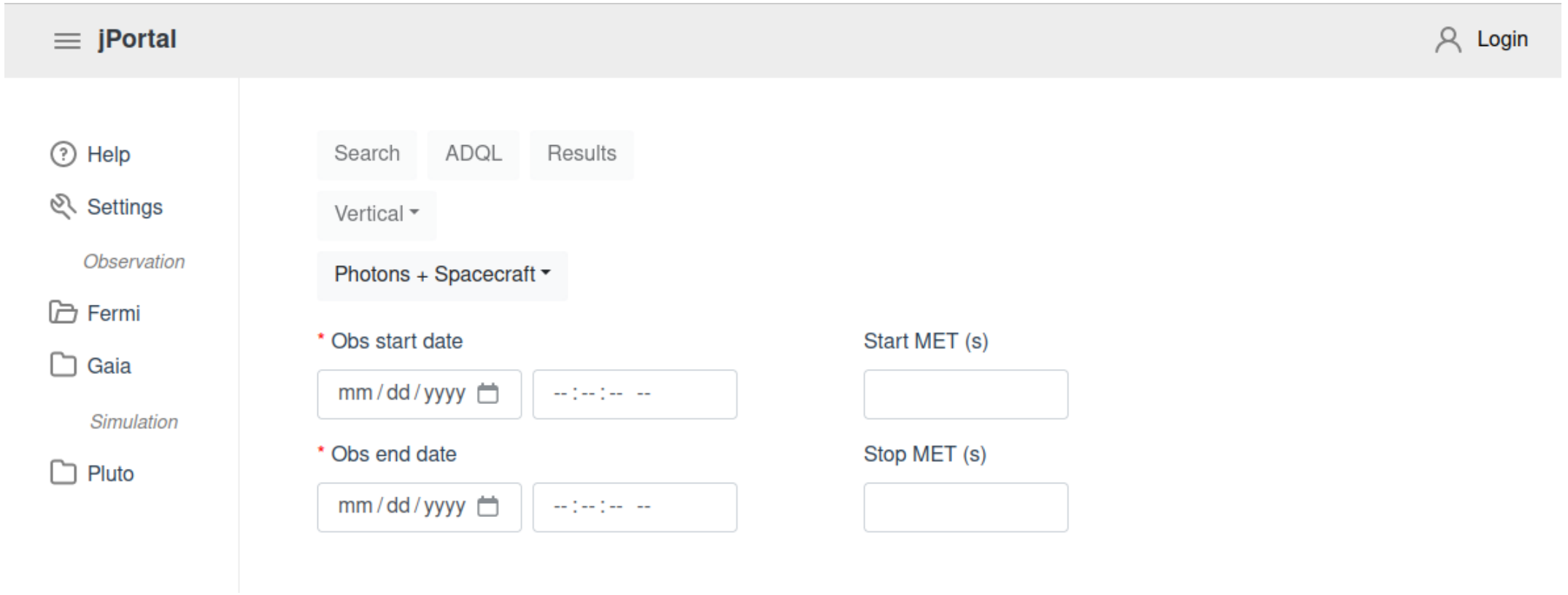
Methodologies

To link the different data products in a unique result we need a field that is common between the two tables and unique.

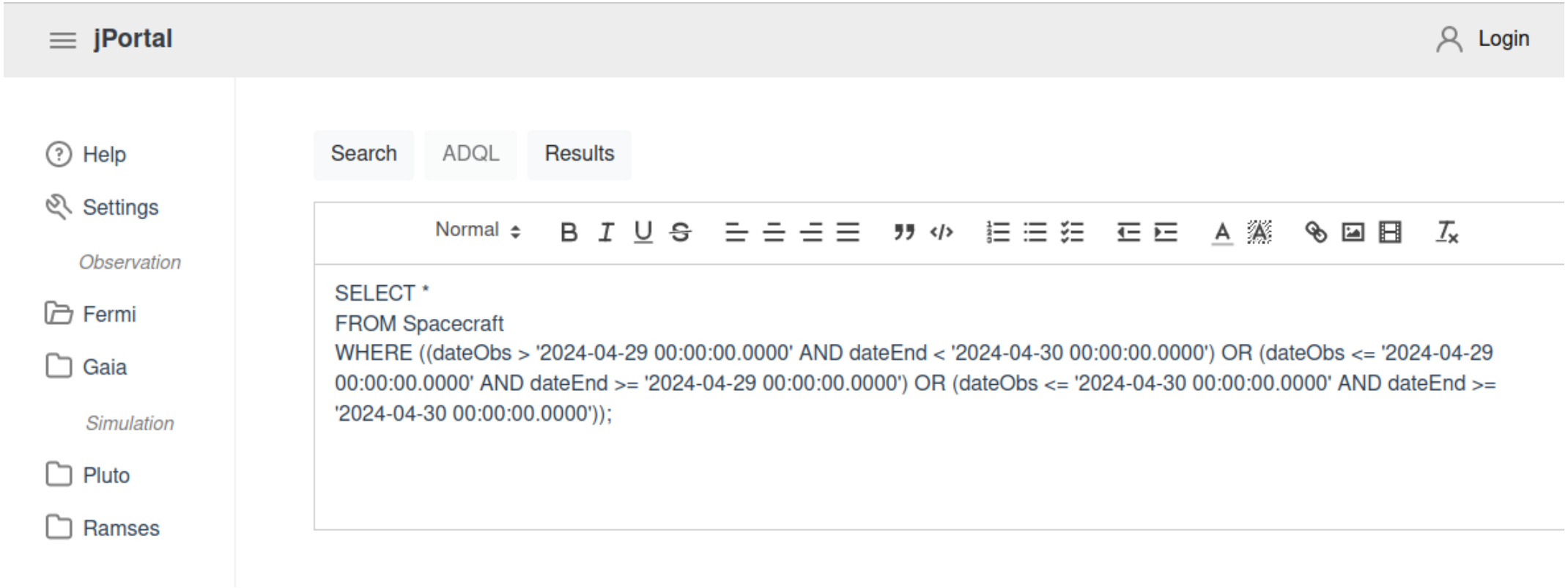
We added the field ''WEEK'' that is populated during the extraction of the metadata from the files headers.



Solutions


jPortal
Login
Help
Settings
Observation
Fermi
Gaia
Simulation
Pluto
Search
ADQL
Results
Vertical
Photons + Spacecraft
* Obs start date
mm / dd / yyyy
-- : -- : -- --
Start MET (s)
* Obs end date
mm / dd / yyyy
-- : -- : -- --
Stop MET (s)

Solutions


jPortal
Login
Help
Settings
Observation
Fermi
Gaia
Simulation
Pluto
Ramses
Search
ADQL
Results
Normal
SELECT *
FROM Spacecraft
WHERE ((dateObs > '2024-04-29 00:00:00.0000' AND dateEnd < '2024-04-30 00:00:00.0000') OR (dateObs <= '2024-04-29 00:00:00.0000' AND dateEnd >= '2024-04-29 00:00:00.0000') OR (dateObs <= '2024-04-30 00:00:00.0000' AND dateEnd >= '2024-04-30 00:00:00.0000'));

Next Steps

Select the new filters to add based on the astronomers needs (e.g. the most common filtering usually applied when working on both FT1 and FT2).

Extend the data model for the fields that refer to the scientific data contained in the fits files.

Implementation of the cross filtering on data via the Fermi Tools.

... see you tomorrow afternoon at the round table!

Thank you!

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Gaia use case

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SCIENTIFIC RATIONALE

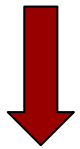
- Study and implement a prototype open source based platform tailored for supporting and allowing scientific analysis oriented of subsets of extracted Gaia data and metadata alongside the Gaia data-database and data lake at DPCT, e.g. Gaia GW use case on different platform

Credits: ESA/DPAC

- The GAIA operations DM is not suitable for technical/scientific exploitation

OBJECTIVES

- To create a database and filesystem platform capable of extracting all sources within a specific area of the sky and associating with each source the information regarding its transits.



We need fast queries and analysis of data from different perspectives:

- Run queries at billions of rows (sources) per second for each CPU core
- Switching between a source oriented search by row (space) to a columnar search by transit (time) leveraging both indexing methods without the need to duplicate the DB volume;

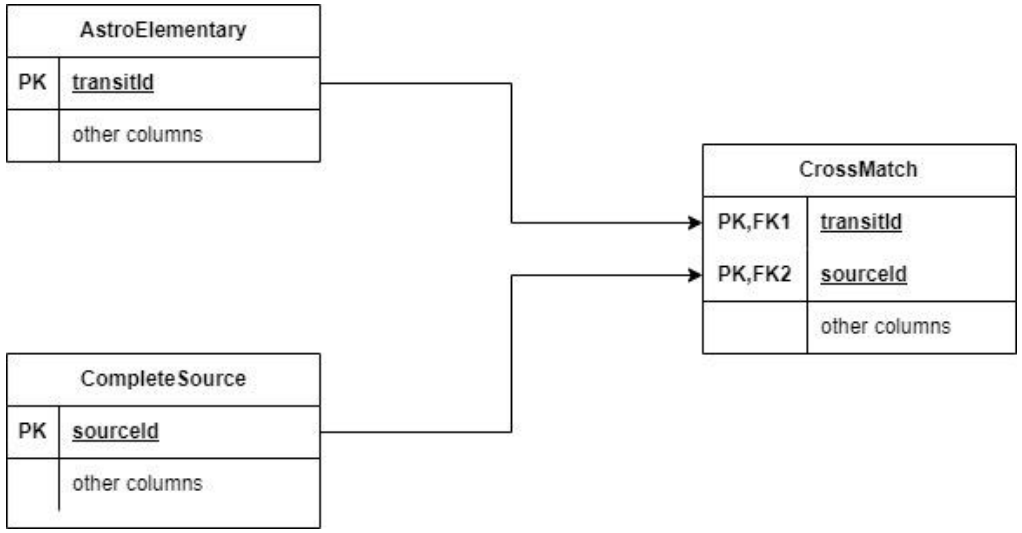
We need also to pre-aggregating and pre-calculating the information in the database before delivering to the users.

DATA

CompleteSource: source information (180 attributes) ,
~ 4.8 TB with 2.793*10^9 elements.

AstroElementary: transit information (33 attributes),
~ 41 TB with 99.9*10^9 elements.

CrossMatch: association of sources and transits (8 attributes),
~ 1.4 TB with 88.997*10^9 elements.



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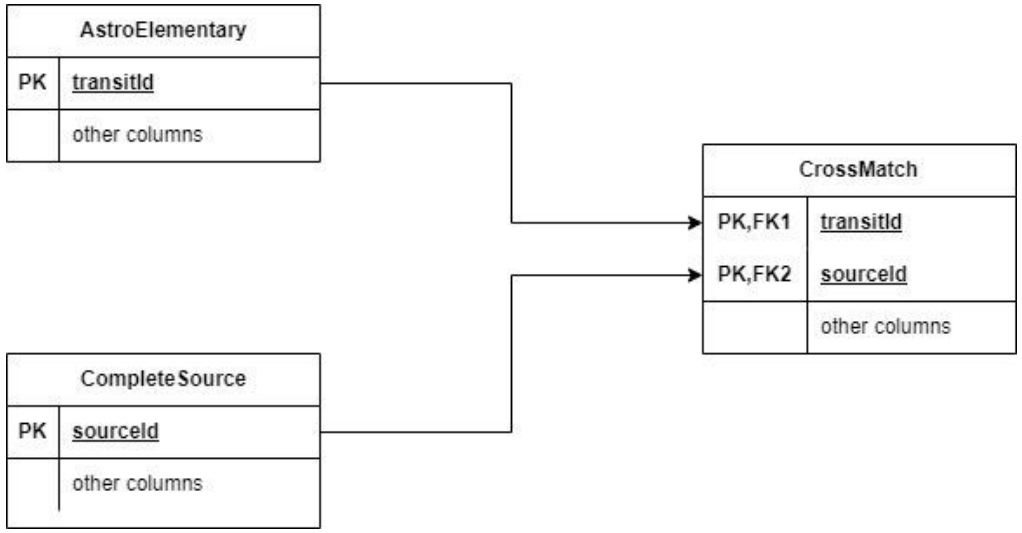

CHALLENGES

- ❑ DM and metadata definition to be queried on in an efficient way
- ❑ Blob attributes as links to other tables.
- ❑ The Data are covered by an NDA - NO PUBLIC DATA

GBIN

- Used gbinreader to interpret Gaia gbin data in Python.
- Converted gbin to another format for easier usage.
- GBIN files can contain multiple CS/XM/AE entries.


```
'sourceId': 3376960784291370112,
'alpha': 1.6257970447712626,
'alphaStarError': 415.1820205532908,
'delta': 0.389743536501208,
'deltaError': 304.3747106045399,
'linDecompNormalsParamSolved': 31,
'muAlphaStar': None,
'muAlphaStarError': None,
'muDelta': None,
'muDeltaError': None,
'radialVelocity': None,
'radialVelocityError': None,
'varpi': None,
'varpiError': None,
'linDecompNormals': [0.17978651002121898,
0.21658186521428793, 0.021359902368825224,
0.15672888162006487, -0.007329793929945749,
0.1774723087349154, -0.12139129917298573,
0.09194578488838766, -5.103146522638524e-05,
0.01918613887682385, -0.1353116037702648,
0.09556740757878916, -5.341107177382422e-05,
0.0028955756289015286, 0.019095000561812434,
4.645244283992821e-18, -3.3773274466869448e-18,
1.875151880209317e-21, -1.0141508864111856e-19,
-9.097583078950226e-20, 0.0010000000474974513],
'refEpoch': '<javaobj:gaia.cu1.tools.time.GaiaTime>',
'colConstLevel': None,
'f2': 1.2288812398910522,
'noiseFlag': 8,
'solutionId': 1636042515805110273,
'bpMean': None,
'fieldOriginators': '<javaobj:java.util.EnumMap>',
'gMean':
'<javaobj:gaia.cu1.mdb.cu5.photpipe.phot.dmimpl.Mean
'rpMean': None,
'Gof': 0.0,
'assumedModelOrigin': 0,
```


Disclaimer: example with fake data


```
'assumedModelOrigin': 0,
'assumedPhysicalMultiple': False,
'assumedVariableCombSpec': False,
'astrometricDuplicateSourceId': 0,
'astrometricPseudoColor': None,
'astrometricPseudoColorError': None,
'astrometryFromEarlierCycle': False,
'bpIntegratedSpectrum': None,
'converged': True,
'deltaQ': None,
'emissionLinesCombined': False,
'epoch': None,
'excessNoise': 9.363175726773374,
'excessNoiseSig': 16.60973007898822,
'expectedSigToNoise': None,
'gRvs': None,
'gRvsConstancyProbability': None,
'gRvsError': None,
'hasRadVelSpeBarSys': False,
'inPencilBeam': False,
'inverseConditionNumber': 2.485626464476809e-05,
'ipdFracHighGof': 11,
'ipdFracMultiPeak': 0,
'ipdFracOddWin': 0,
'ipdGofHarmonicAmplitude': 194292.4375,
'ipdGofHarmonicPhase': 39.968650817871094,
'isGrvsValid': False,
'isPhotometricOutlier': False,
'isRadVelVariable': False,
'isSB2': False,
'isWeakClassification': False,
'matchedObservations': 2,
'matchedObservationsUsedByAgis': 2,
'meanFluxExcess': None,
'meanOnBoardGMag': 20.7109375,
'meanVarpiFactorAc': 0.7114633321762085,
'meanVarpiFactorAl': -0.5583772659301758,
```

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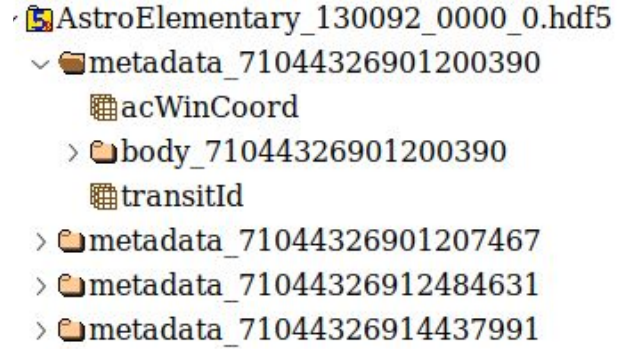
FITS FORMAT

- Initially considered FITS format but faced challenges
- Created FITS files for each gbin, defining expected structures.
- Introduced primary header to map SourceId/TransitId.
- Challenges with FITS rigid structure for dynamic needs.

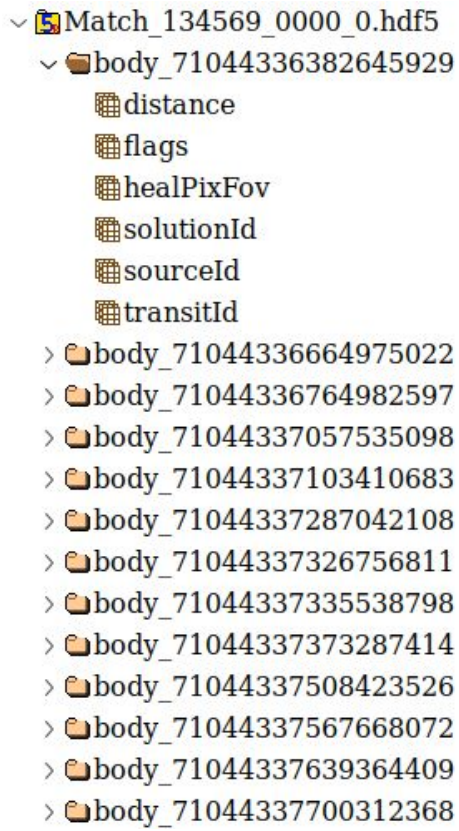
HDF5 FORMAT

- Considered HDF5 for more flexible structure.
- Created HDF5 files with layered structure (metadata in first layer).
- Intuitive search
- Better blob integration
- Exploring size reduction strategies.



CONCLUSION & FUTURE STEPS

- The next step will be to create queries to extract specific information about sources and transits.



Thank you for your attention!