An Interactive Multi-Instrument Database of Solar Flares

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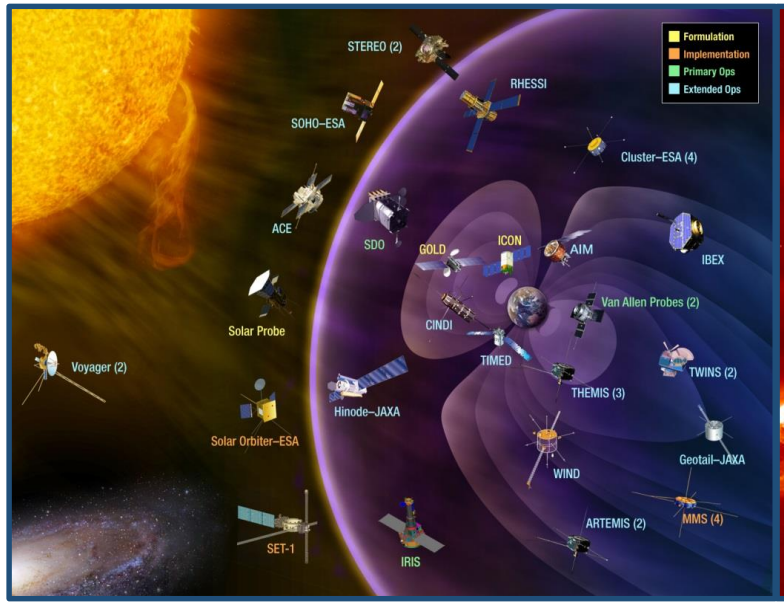
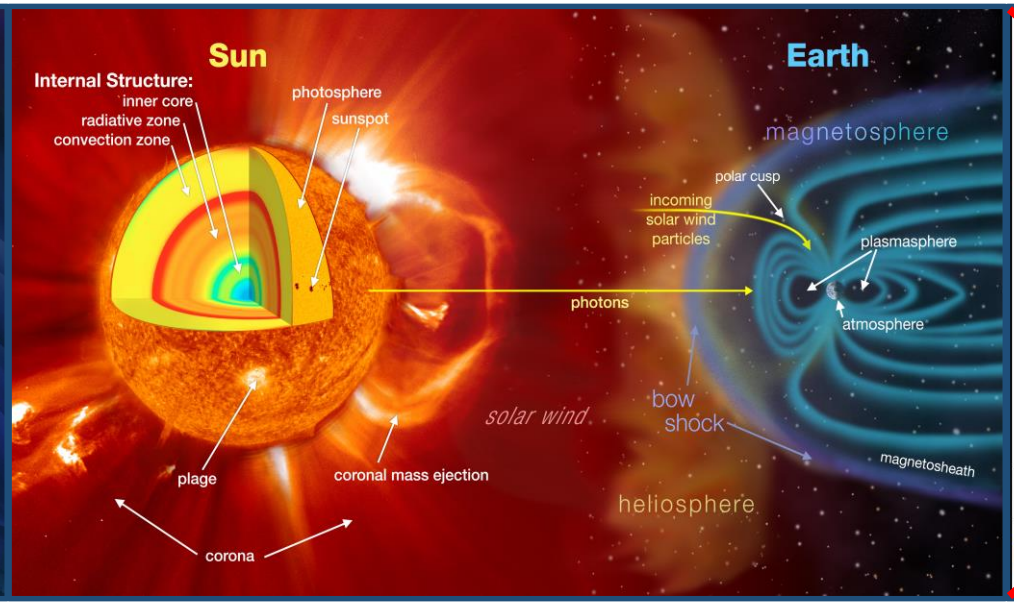
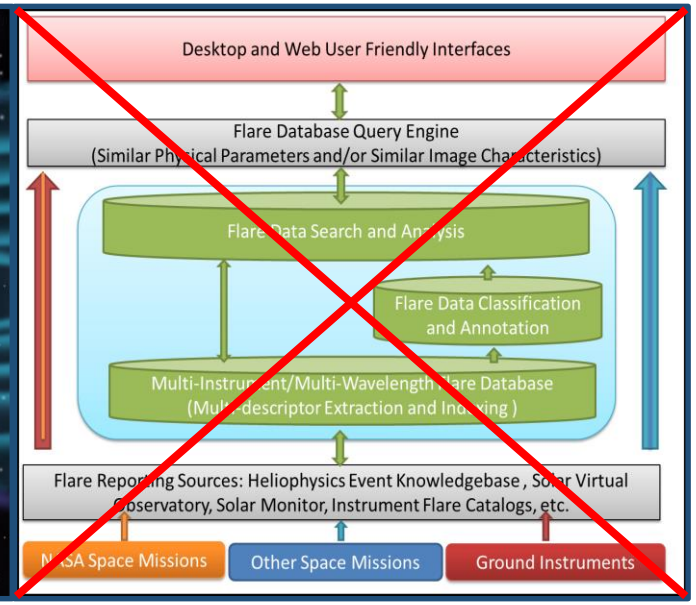
Introduction and Motivation

- Solar Flares represent the most prominent manifestation of the Sun's magnetic activity. They cover the whole range of electromagnetic radiation spectrum, from radio- to gamma-rays, observed by many NASA space missions, including: Solar Dynamics Observatory (SDO), Solar and Heliospheric Observatory (SoHO), STEREO, RHESSI, IRIS, Hinode, Fermi, and GOES; as well as ground-based observatories.
- For a complete understanding of the flares it is necessary to perform a combined multi-wavelength analysis and classify large amounts of scientific data produced by space-based and ground-based observatories. Such classification and analysis will allow us to get clearer physical picture the observed phenomena, from their onset to space weather impacts.
- Currently flare records made by different instruments are stored separately from each other. Matching records from different flare lists and search for the flare events with specific physical characteristics are complicated tasks.







Announcement of Helioportal (IMIDSF)

An Interactive Multi-Instrument Database of Solar Flares (IMIDSF, a title Helioportal project, https://helioportal.nas.nasa.gov/) is a comprehensive flare database integrating records from various existing flare and flare-related event catalogs and allowing users to

- Identify the uniquely-matching events
- Search for uniquely-matching events with certain physics-based descriptors

The IMIDSF is a collaborative project among the NASA Advanced Supercomputing (NAS) Division, NASA Ames Heliophysics Modeling and Simulation team, and the New Jersey Institute of Technology's Department of Physics, Department of Computer Science and the Center for Computational Heliophysics.

As part of a larger effort to provide a data portal for collaborative heliophysics research, NAS Division staff integrated and added security checks to the Interactive Multi-Instrument Database of Solar Flares (IMIDSF) in a new heliophysics portal, hosted on the NAS website: http://helioportal.nas.nasa.gov.

The IMIDSF is currently the primary component of the Helioportal, which was developed for efficient data search, integration of different flare lists, and representation of observational data. IMIDSF is fully functional and allows users to search for uniquely identified flare events based on physical characteristics (descriptors) and availability of observations of a particular set of instruments.

Helioportal Milestones

June 2015: Project receives NASA support

Design and Implementation of a Multi-Instrument Database of Solar Flares (NASA NNX15AN48G, PI Gelu Nita, Co-Is: Alexander Kosovichev and Vincent Oria)

January 2016: NJIT-NASA Workshop on Computational Heliophysics

First presentation of the Database of Solar Flares. Workshop supported by 2015 Faculty Seed Grant from NJIT, PI Alexander Kosovichev

April 2016: Space Weather Workshop

First live demonstration of the Database of Solar Flares (E-poster)

February 2017: The IMIDSF launch is announced

The Interactive Multi-Instrument Database of Solar Flares (IMIDSF, https://solarflare.njit.edu/) is released. The launch is announced in Solarnews.

July 2017: The IMIDSF paper is published in ApJS

Sadykov V.M., Kosovichev A.G., Oria V., and Nita G.M. *"An Interactive Multi-instrument Database of Solar Flares"*. 2017, The Astrophysical Journal Supplement Series, Volume 231, Issue 1, article id. 6.

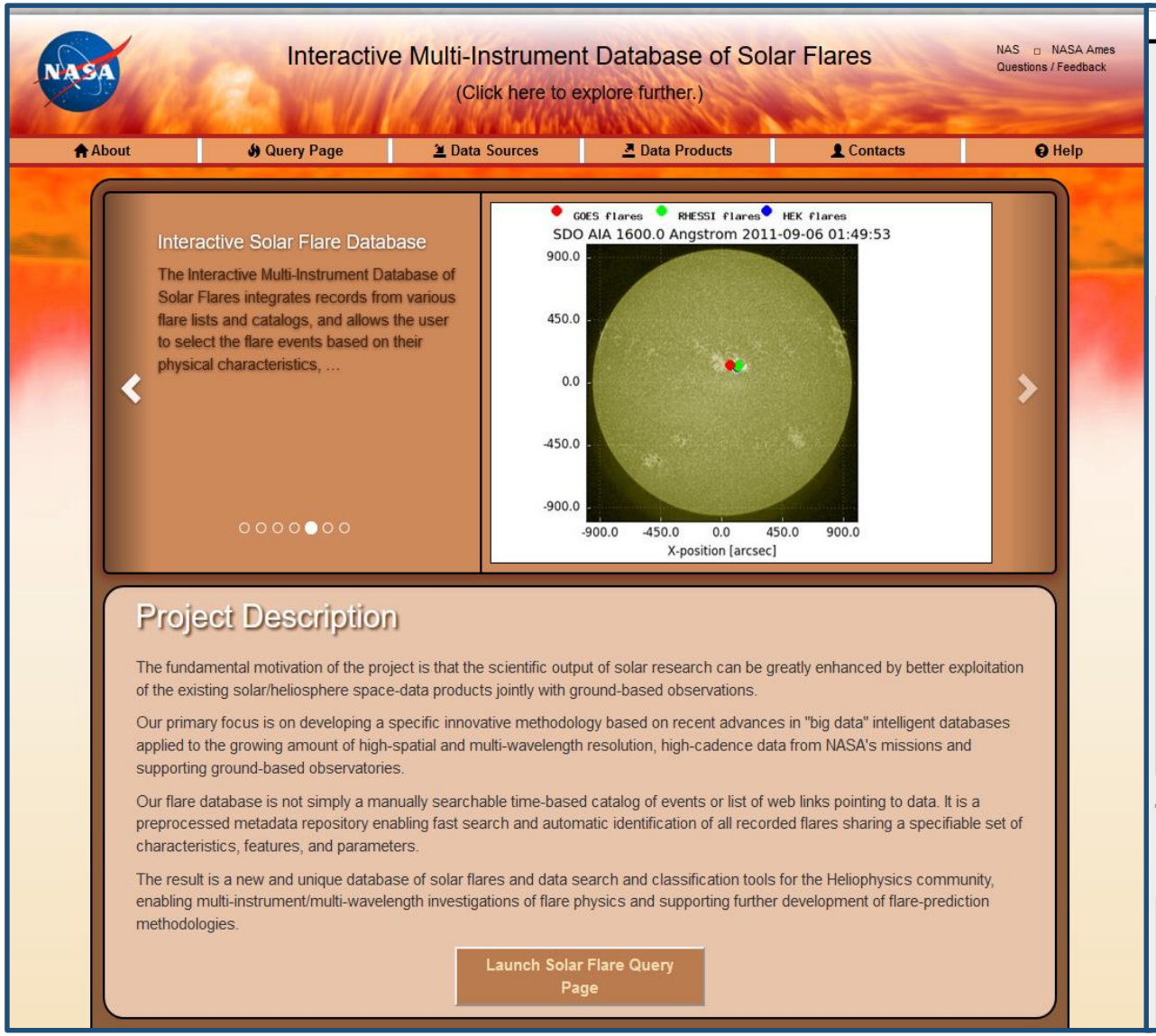
August 2017: IMIDSF transfer to Helioportal is started

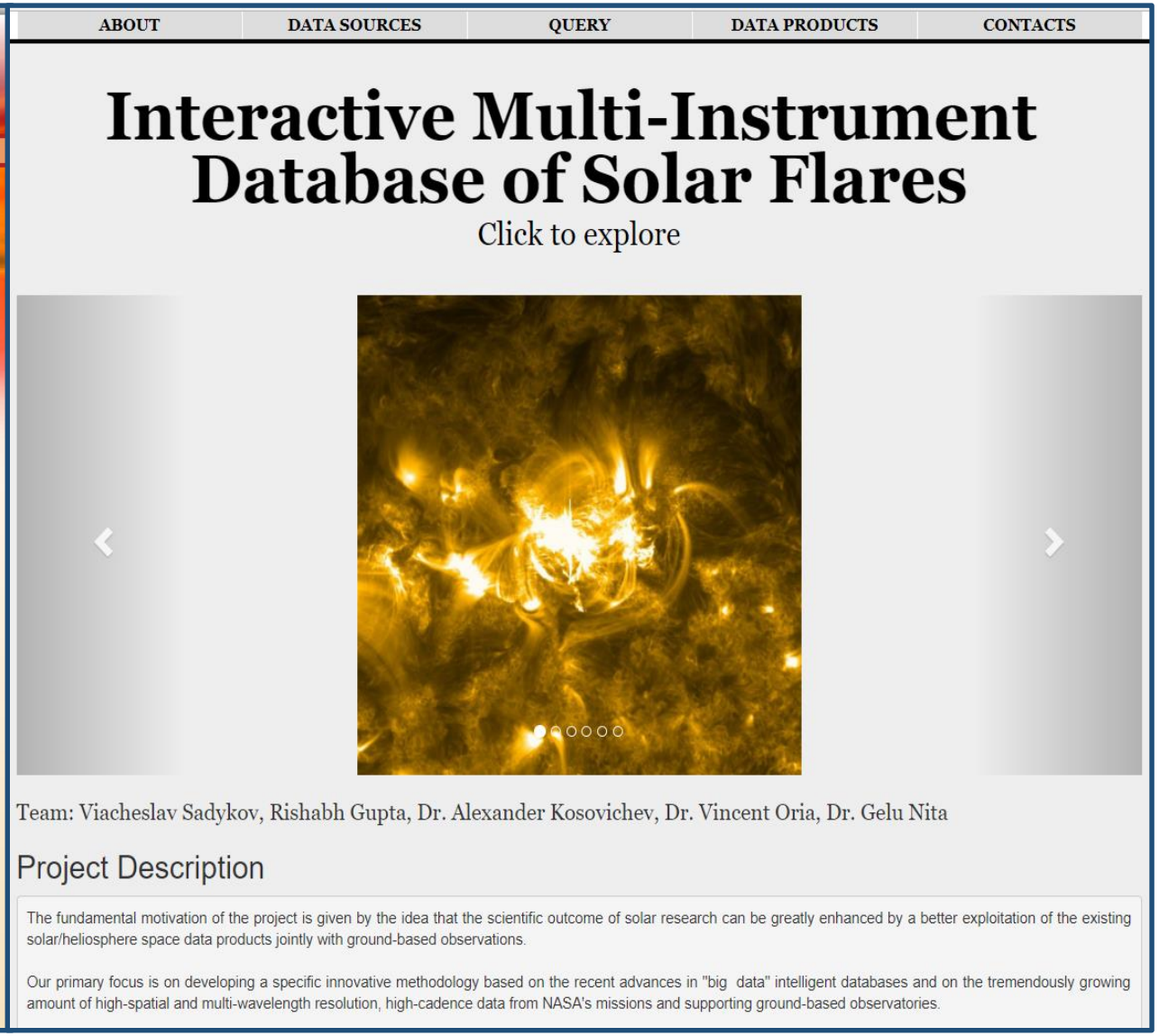
February 2018: The Helioportal is launched

The project is open for public, https://helioportal.nas.nasa.gov

Helioportal
Live Demonstration

Interactive Multi-Instrument Database of Solar Flares (IMIDSF, https://helioportal.nas.nasa.gov/, https://solarflare.njit.edu/)

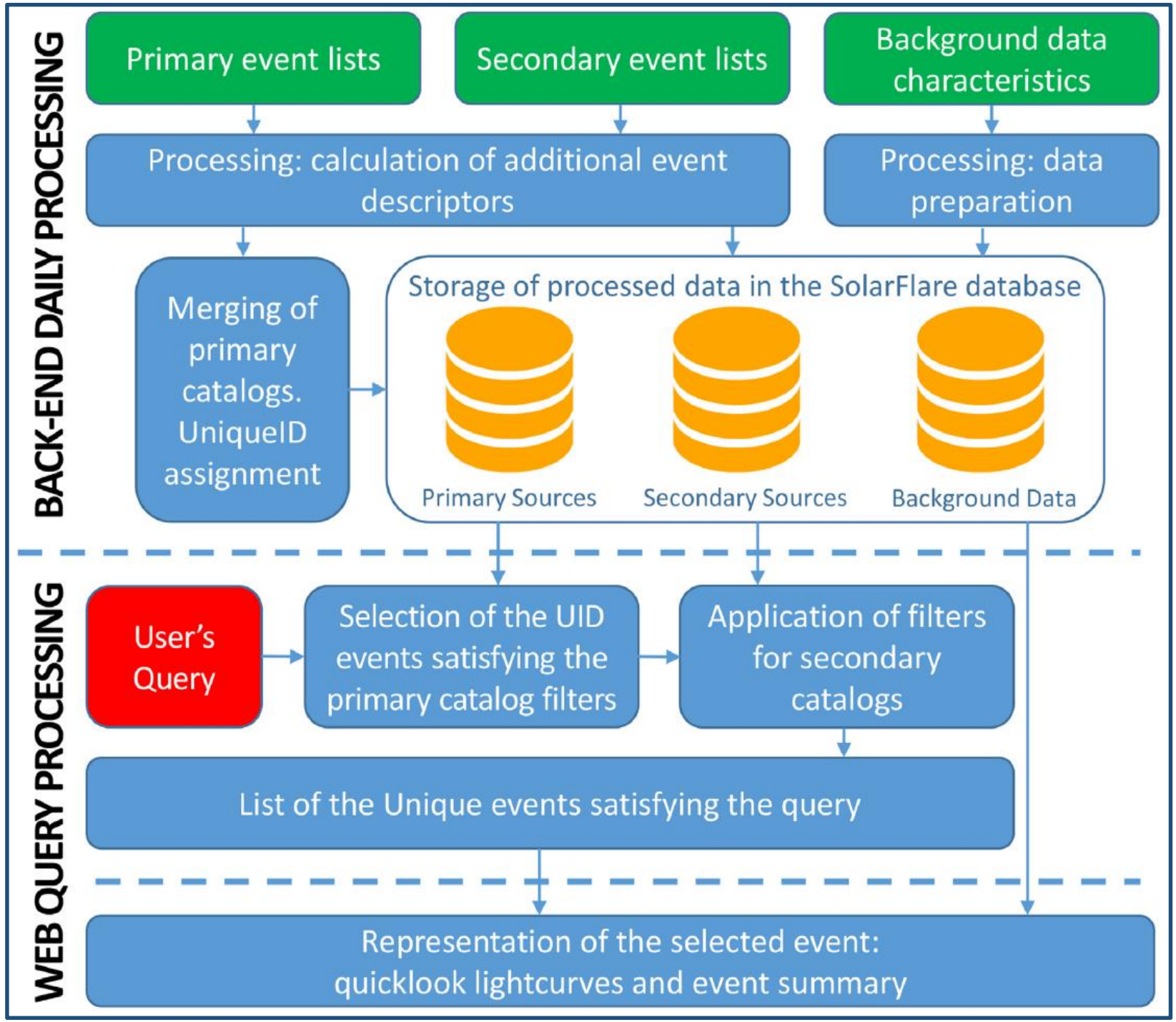




IMIDSF Structure

Helioportal consists of several functional elements:

1. **Back-End MySQL database** containing primary and secondary event lists and background data sources
2. **Back-End daily-update system (PHP and Python scripts)** for data upload, processing and enrichment
3. **Front-End web application** with the user query form and presentation of the query results and event summary



Helioportal Data Sources

Primary Event Lists		
GOES flare list	2002 Jan – current time	ftp://ftp.swpc.noaa.gov/pub/warehouse/
RHESSI flare list	2002 Feb – current time	http://hesperia.gsfc.nasa.gov/hessidata/dbase/
HEK flare list	2010 Feb – current time	https://www.lmsal.com/isolsearch
Secondary Event Lists		
IRIS observing logs	2013 Jul – current time	http://iris.lmsal.com/search/
Hinode flare catalog	2006 Nov – 2016 Jul	http://st4a.stelab.nagoya-u.ac.jp/hinode_flare/
Fermi GBM flare catalog	2008 Nov – current time	https://hesperia.gsfc.nasa.gov/fermi/gbm/qlook/
Nobeyama coverage check	2010 Jan – current time	ftp://solar-pub.nao.ac.jp/pub/nsro/norp/xdr/
OVSA flare catalog	2002 Jan – 2003 Dec	http://www.ovsa.njit.edu/data/
EOVSA flare catalog	2017 Jan – current time	http://www.ovsa.njit.edu/wiki/index.php/Expanded_Owens_Valley_Solar_Array
CACTus CME catalog	2002 Jan – current time	http://sidc.oma.be/cactus/
Filament eruption catalog	2010 Apr – 2014 Oct	http://aia.cfa.harvard.edu/filament/
Konus-WIND flare catalog	2002 Jan – 2016 Jul	http://www.ioffe.ru/LEA/Solar/index.html
Background Data Characteristics		
GOES X-ray light curves (and T&EM)	2002 Jan – current time	https://umbra.nascom.nasa.gov/goes/fits/
SDO/EVE ESP light curves	2010 Feb – current time	http://lasp.colorado.edu/eve/data_access/
Nobeyama Polarimeter data	2010 Jan – current time	ftp://solar-pub.nao.ac.jp/pub/nsro/norp/xdr/

Helioportal Data Enrichment and Processing

Calculation of GOES Temperature and Emission measure:

- TEBBS algorithm (Ryan et al. 2012) is used to calculate T and EM for the flare events together with their uncertainties
- Peak values of T and EM are used as flare event descriptors, and the light curves are available for each event summary page

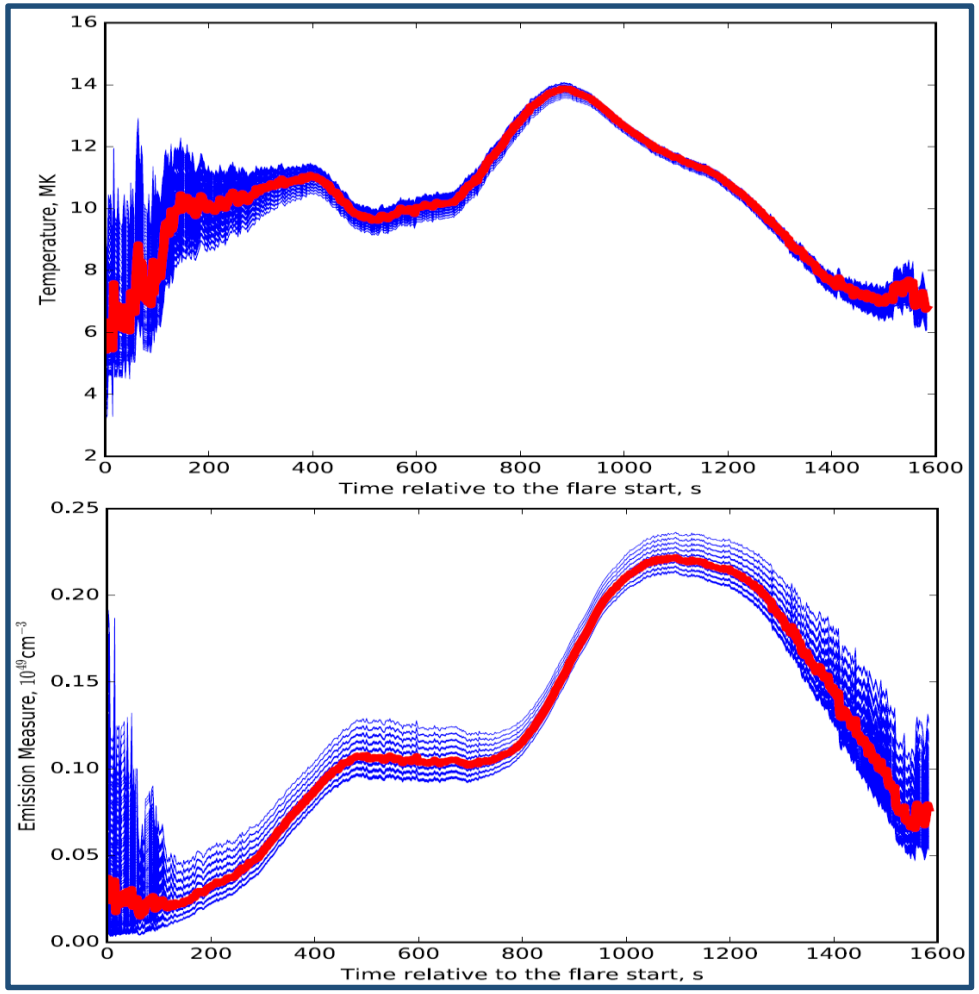
Other Data Processing details:

- SDO/EVE ESP and Nobeyama light curves are smoothed with 5 sec cadence
- Coordinates are determined/corrected for GOES events

UniqueID assignment algorithm:

1. Select the event from GOES flare list and assign the UniqueID "gev_yyyymmdd_hhmmss" to it. Find the set of the time-overlapping events from RHESSI and HEK catalogs. The events with the same AR and located less than Δ=250`` from GOES event receive the same UniqueID. The events with missing coordinate and AR information receive the same UniqueID.
2. Repeat the procedure for RHESSI events and overlapping in time HEK events ("rhessi_yyyymmdd_hhmmss").
3. Repeat the procedure for sets of HEK events overlapping in time ("hek_yyyymmdd_hhmmss").

The data enrichment and processing is performed on daily basis



Example of the temperature (right panel) and EM (left panel) calculations using the TEBBS algorithm for the SOL2016-02-15T04:02:00 event (C3.9 class flare). The blue curves represent the physically possible temperature and EM solutions. The red light curves represent the best-estimate solution.

Examples of Application

Statistical Study of Chromospheric Evaporation in Solar Flares

- To connect energy fluxes deposited in solar flares and the properties of the responding solar plasma and compare results with the RHD chromospheric evaporation simulations, **the dataset of flares simultaneously observed by IRIS** (here in the fast-scanning regime) **and RHESSI is required**

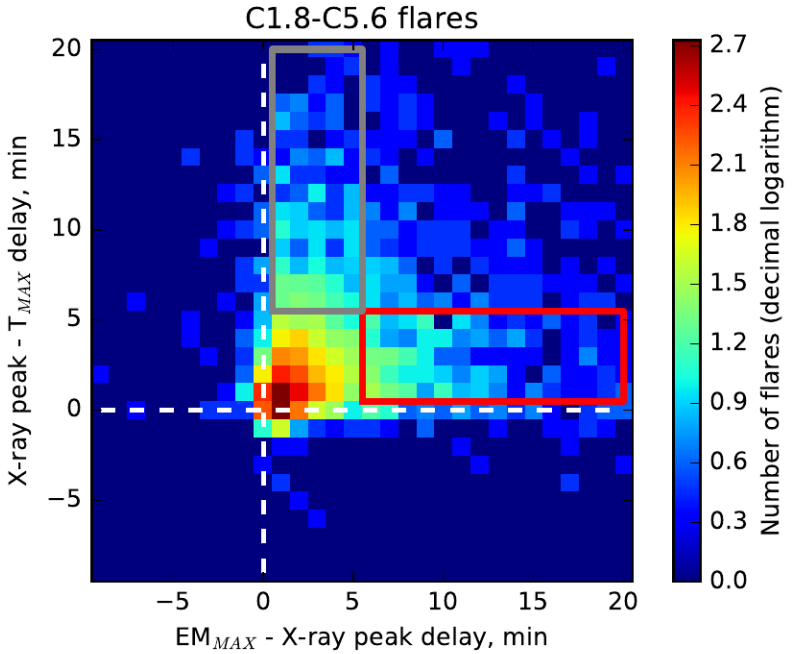
Statistical study of Soft X-ray Emission Properties and Timescales from GOES observations

- The results of the application of TEBBS algorithm (T and EM calculations) for GOES flares detected from 2002 until today **are available as a data product at Helioportal** (https://helioportal.nas.nasa.gov/). **IMIDSF allows us to integrate GOES and RHESSI flares** and catch the difference between the flares with different timescale relations.

Forecasting of Solar Flares using Machine-Learning Methods

- Helioportal allows the users to request **the statistics of flares for each AR** in one click. Integration of the AR magnetic field descriptors (SHARP parameters and PIL parameters) with flare events is planned. It is also possible to request **not only the GOES class but other physical characteristics of solar flares**, and, in principle, work on the prediction of these characteristics.

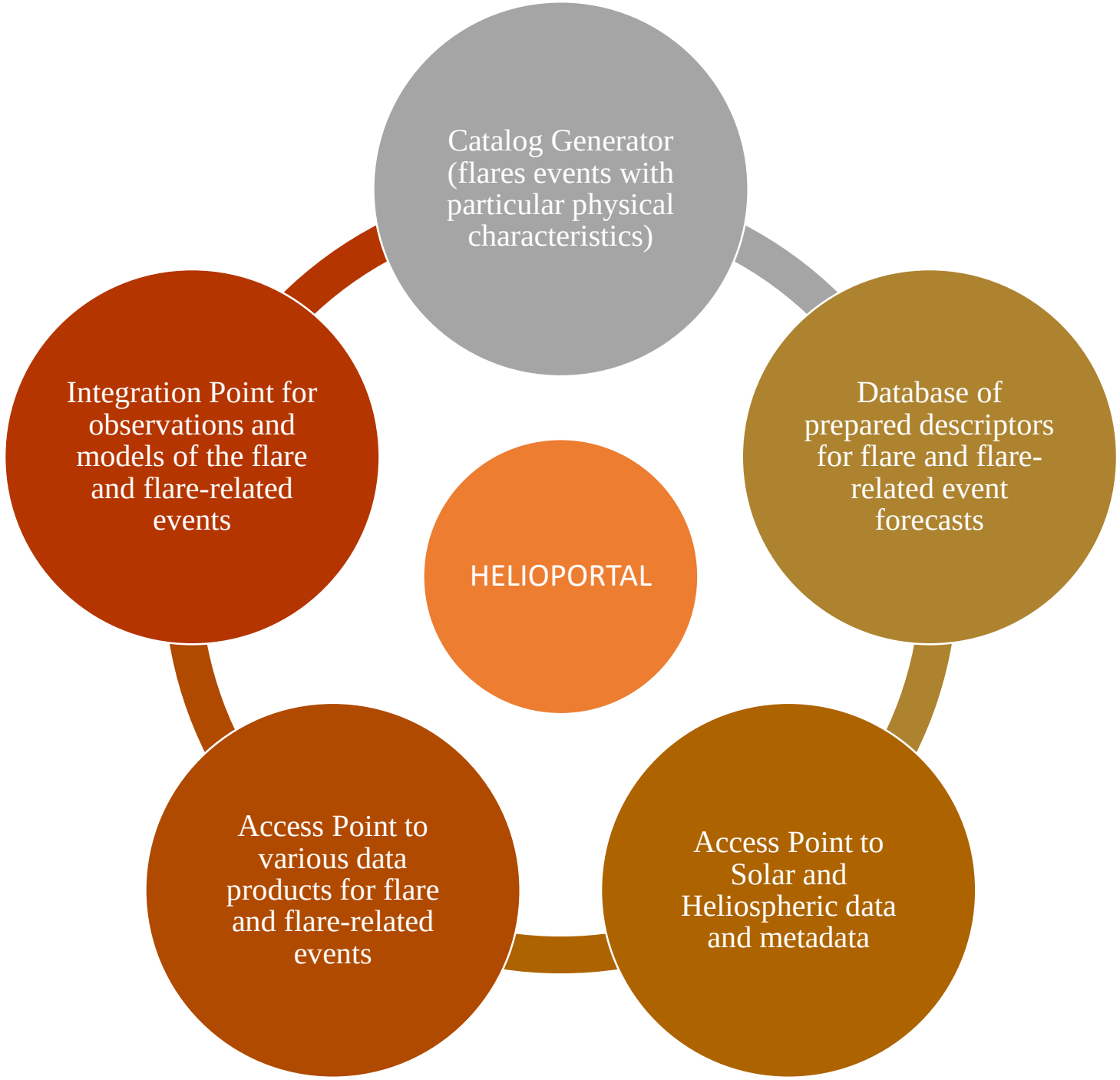
SOLID	GOES class	RHESSI energy range, keV	IRIS mode	IRIS cadence, s	Hinode coverage
SOL2014-02-13T01:32:00	M1.8	6-12	Coarse raster, 8 slits	41.7	XRT, EIS
SOL2014-02-13T02:41:00	M1.0	3-6	Coarse raster, 8 slits	41.7	XRT
SOL2014-03-29T17:35:00	X1.0	100-300	Coarse raster, 8 slits	71.9	SOT FG, XRT, EIS
SOL2014-06-12T18:03:00	M1.3	25-50	Coarse raster, 8 slits	21.3	XRT
SOL2014-11-07T10:13:00	M1.0	12-25	Coarse raster, 16 slits	24.3	SOT FG, SOT SP, XRT, EIS
SOL2014-12-04T18:05:00	M6.1	25-50	Dense raster, 16 slits	33.8	SOT FG, SOT SP, XRT
SOL2015-03-11T11:21:00	C5.8	12-25	Coarse raster, 8 slits	75.0	SOT SP
SOL2015-08-27T04:48:00	M2.9	25-50	Coarse raster, 8 slits	23.9	SOT SP, XRT
SOL2015-11-04T13:31:00	M3.7	50-100	Coarse raster, 16 slits	49.5	-



Future Plans

Our long-term goal is to expand the functionality of the Helioportal. We are currently developing the database containing metadata for Solar Events, Active Regions and Observations. We plan to include the following into new database:

- Increase number of flare and flare-related event sources and observational characteristics/logs
- Include Active Region characteristics (PIL characteristics, SHARP parameters) and integrate them with solar events
- Integrate solar events with existing models; provide initial conditions for models
- Provide multi-level access to the database (possibility to work with both the products of integration and catalogs before integration; started)
- Provide various data products (subsurface flow maps, NLFFF extrapolations for flaring ARs etc)
- Develop IDL and Python packages to access the database, requests catalogs and data products
- Integrate with other resources



Conclusion

What is implemented so far?

Integration of different flare lists (GOES, RHESSI, HEK, Fermi GBM, Hinode, OVSA, Konus-Wind), flare-related event catalogs (CACTus CME, Filament eruption) and observing logs (IRIS, Nobeyama)

Identification of the uniquely-matched flare events based on time and position information

Search for the flare events based on their physical descriptors

- Stored in the original flare lists (GOES class, RHESSI duration, etc)
- Calculated by our efforts (GOES Temperature and Emission Measure using TEBBS, time delay between their peaks, etc)
- Representing instrumental characteristics (mode of IRIS spectral observations, Hinode observing instrument, etc)

Summary page for each uniquely-matched event (dynamic graphs, data available for download, cross-mission summary, user-defined similarity search)

We plan that in the longer term the Helioportal becomes not only the flare record integration and request point but fully-functional solar observational and modeling data and metadata integration and request platform


Thank You for
Your Attention!