How to access Solar Orbiter data

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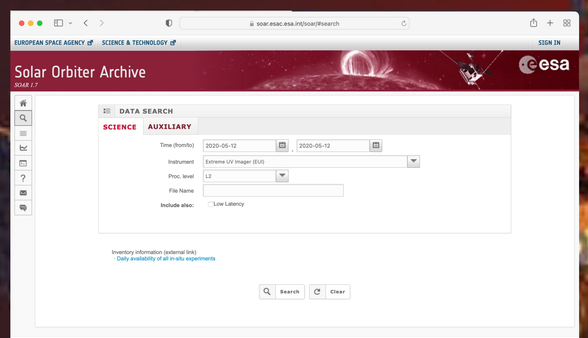
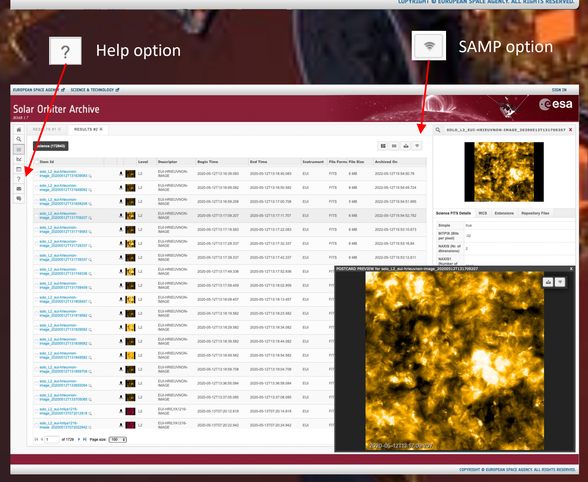
Introduction

Solar Orbiter is an ESA/NASA mission launched on 10 February 2020 to study the Sun and solar wind. Its highly elliptical orbit takes it as close as 0.28 AU. After a nearly two-year cruise phase, the remote sensing part of the science mission started in earnest with observations during the first close perihelion pass, running from 2 March to 5 April 2022. All in situ science data are available starting from 2020, as well as remote sensing data from EUI and SPICE, with the other instruments being added soon.

Solar Orbiter Archive (SOAR)

The primary archive for Solar Orbiter data is **soar.esac.esa.int** (SOAR) at the ESA European Space Astronomy Centre outside of Madrid, Spain. Below, we show a simple search using the web interface.





SAMP Interface

The above web archive supports the Simple Application Messaging Protocol (SAMP). This allows the results to be sent to view applications such as Autoplot and JHelioviewer. Information on SAMP can be found using the Help option.

HTML Interface

Users can develop their own software by passing ADQL queries as HTML strings (e.g. with curl). For example, this URL can be used to find all the currently available descriptors (i.e. datasets) in CSV format:

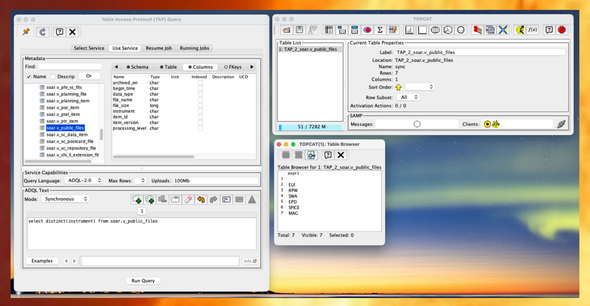
http://soar.esac.esa.int/soar-sl-tap/tap/sync?REQUEST=doQuery&LANG=ADQL&FORMAT=CSV&QUERY=SELECT+DISTINCT+descriptor+FROM+v_sc_data_item+ORDER+BY+descriptor

TAP interface

The SOAR archive follows the IVOA Table Access Protocol (TAP). This allows access through standard third party applications such as TOPCAT, using the URL

http://soar.esac.esa.int/soar-sl-tap/tap

Below, we show a simple query using **TOPCAT**.

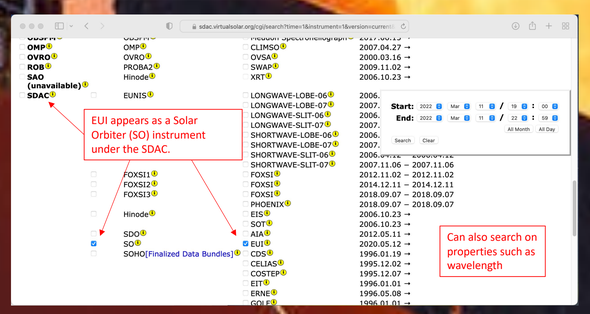


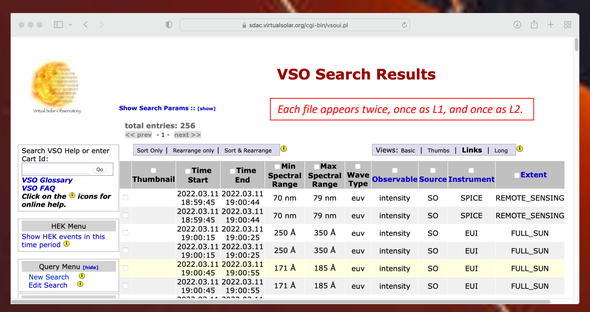
NASA/GSFC Archive

Data from the SOAR archive is mirrored daily into the Solar Data Analysis Center (SDAC) at the NASA Goddard Space Flight Center in Greenbelt, MD. From there it is made available to services such as the Virtual Solar Observatory (VSO), and the Space Physics Data Facility (SPDF).

VSO Interface

The Virtual Solar Observatory (**virtualsolar.org**) serves remote sensing data from Solar Orbiter. Currently, the VSO serves EUI data, with serving SPICE data under development. Below, we show an example of searching for EUI data using the VSO web interface.





Future SOAR access via VSO

The VSO team is currently completing work on sending TAP queries directly to SOAR. When completed, the VSO web client, and the IDL/SolarSoft client will both handle TAP queries. The addition of TAP via the VSO SunPy client will be completed later.

IDL/SolarSoft Interfaces

Routines exist within the IDL Solar Software (SolarSoft) library for accessing data through both the VSO and SOAR interfaces.

VSO access through IDL/SolarSoft

Routines for accessing data from the VSO have existed in the SolarSoft library for a number of years. These routines work the same for Solar Orbiter data as they do for other missions. Below is an example of using **vso_search.pro** to search for EUI data. The results of this search can then be downloaded using **vso_get.pro**.

```
IDL> files = vso_search('2021-04-28', inst='eui')
Records Returned : SDAC_SO : 1070/1070
IDL> help, /structure, files
** Structure VSORECORD, 17 tags, length=272, data length=268:
   TIME            STRUCT    -> VSOTIME Array[1]
   EXTENT          STRUCT    -> VSOEXTENT Array[1]
   WAVE            STRUCT    -> VSOWAVE Array[1]
   DETECTOR        STRING    ''
   INSTRUMENT      STRING    'EUI'
   SOURCE          STRING    'SO'
   PROVIDER        STRING    'SDAC_SO'
   INFO            STRING    'L2'
   PHYSOBS         STRING    'intensity'
   FILEID          STRING    'data/so/eui/L2/2021/04/28/solo_L2_eui-'...
   SIZE            FLOAT           36501.0
   EXPTIME         FLOAT           10.0000
   DARK            LONG                 0
   ECLIPSE         LONG                 0
   PERCENTD        FLOAT           0.00000
   URL             STRING    ''
   GETINFO         STRING    ''
IDL>
```

SOAR access through IDL/SolarSoft

Routines also exist in SolarSoft to communicate with the Madrid SOAR archive.

The routine **soar_list.pro** searches over a time range, with multiple options:

```
Result = SOAR_LIST('2020-05-30', 'EUI')
Result = SOAR_LIST(['2020-05-30T12', '2020-05-30T14'], 'EUI')
Result = SOAR_LIST('2020-05-30', 'EUI', PROCESSING_LEVEL=1)
Result = SOAR_LIST('2020-05-30', 'EUI', SEARCH='HRI')
```

The last option provides the ability to search within filenames. Here, we're limiting the search to files from EUI High Resolution Imager (HRI).

The routine **soar_search.pro** finds the file closest to the specified time.

Use **soar_get.pro** to download the files.

VSO access through SunPy

VSO can be queried, and files retrieved, using Fido.search and Fido.fetch methods, respectively, in SunPy via the VSO SunPy client:

```
import sunpy
from sunpy.net import Fido, attrs as a
import astropy.units as u
results = Fido.search(a.Time("2021-03-26 00:00:00", "2021-03-26 20:00:00"),
          a.Instrument('eui'))
results = Fido.search(a.Time("2021-03-26 00:00:00", "2021-03-26 20:00:00"),
          a.Instrument('eui'),
          a.Wavelength(wavemin=171*u.angstrom,wavemax=185*u.angstrom))
files = Fido.fetch(results)                --to retrieve multiple files
files = Fido.fetch(results[0,0])           --to retrieve a single file
```

SOAR access through SunPy

David Stansby has written a plugin for SunPy that directly accesses the SOAR for Solar Orbiter data. The plugin is available on GitHub:

https://github.com/dstansby/sunpy-soar

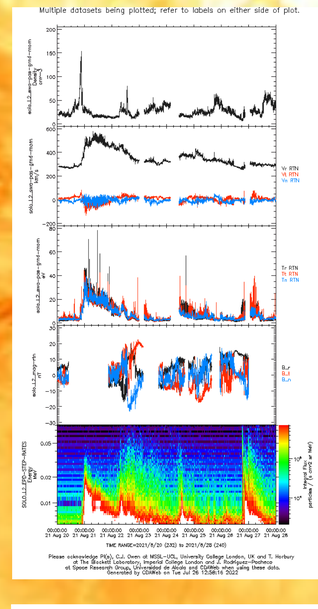
Importing sunpy_soar registers the client with sunpy:

```
import sunpy_soar
from sunpy.net import Fido
import sunpy.net.attrs as a
```

From there, use Fido as above.

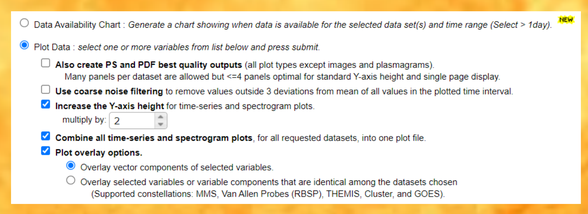
SPDF/CDAWeb

The Space Physics Data Facility (SPDF) (**spdf.gsfc.nasa.gov**) is a standard resource for heliophysics data, and is the NASA focal point for serving in situ data from the Solar Orbiter mission. The CDAWeb (**cdaweb.gsfc.nasa.gov**), as a component of the SPDF, supports interactive plotting of variables from multiple instruments on multiple investigations simultaneously on arbitrary, user-defined time-scales. It also supports data retrieval in both CDF or ASCII format.



Example plot of SWA plasma data (density, velocity in RTN, temperature component in RTN), MAG, and EPD STEP rates data from Solar Orbiter.

Recently added: Users can obtain data availability charts for selected data sets and time intervals.



SPDF Python and IDL Support

The SPDF has provided Python and IDL codes to access the data. Click "Info" next to the dataset name in the CDAWeb explorer page.