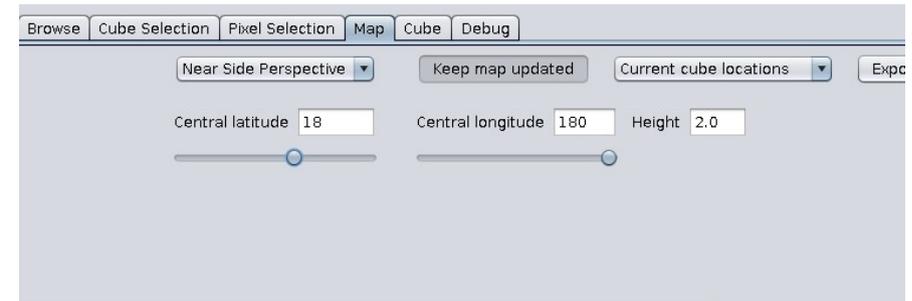
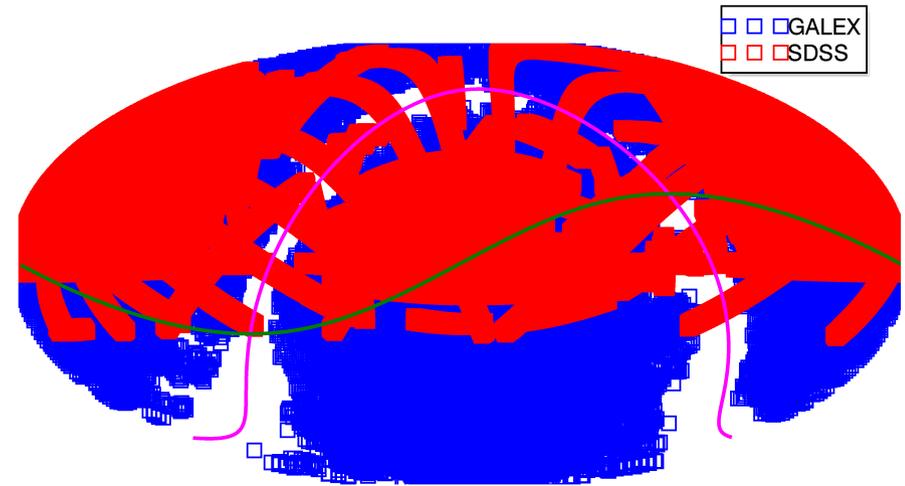
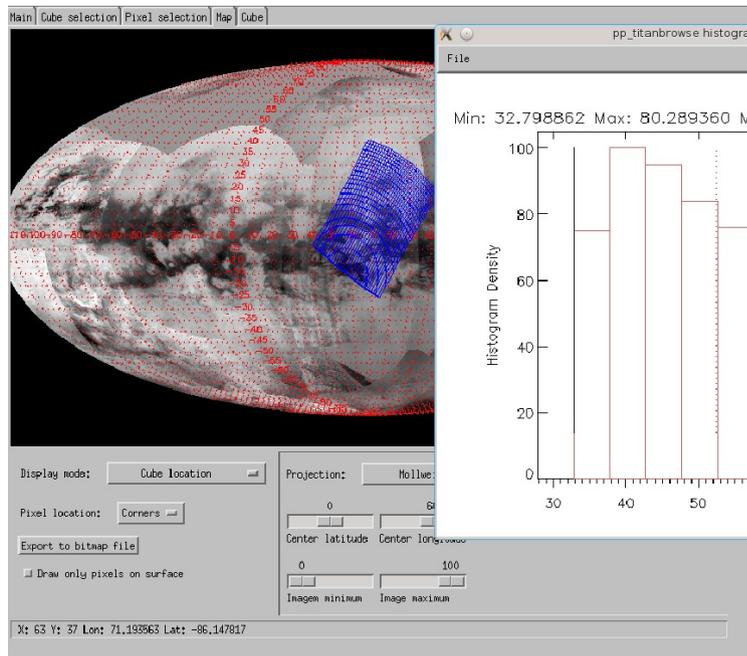


# Data mining for the Solar System



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# Why new tools?

Many astronomical and planetary archives (SDSS, PDS, MAST,...) have enabled new research possibilities.

# Why new tools?

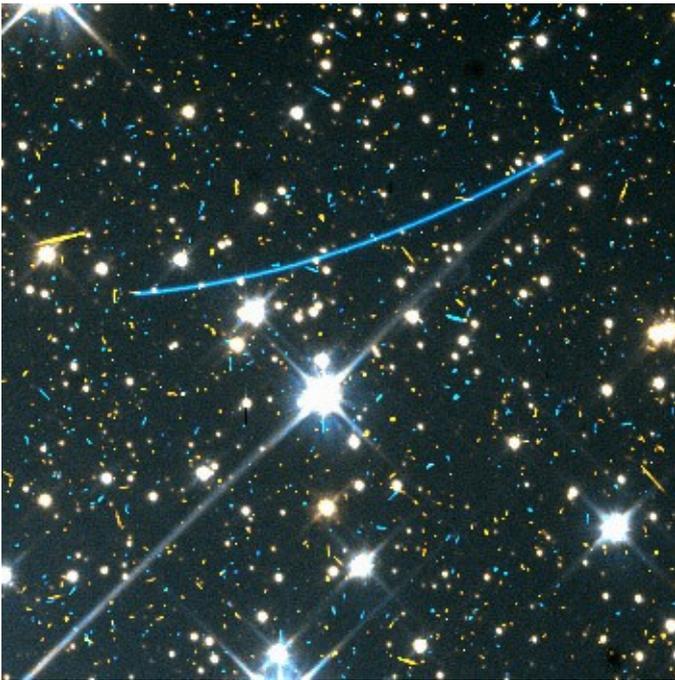
Many astronomical and planetary archives (SDSS, PDS, MAST,...) have enabled new research possibilities.

They still lack functionality in two areas:

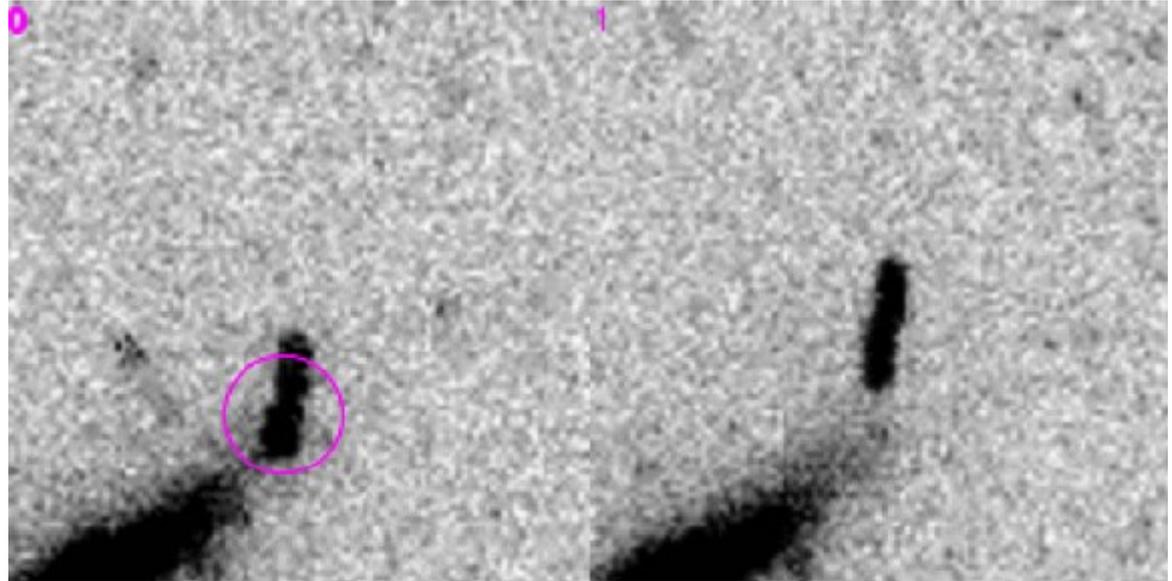
- Astronomical archives index images by position in the sky – cannot search for Solar System objects.
- Planetary remote sensing archives do not have common interfaces and do not support well hyperspectral observations.

# Mining astronomical archives

Archives have millions of images.  
We know over 600 thousand Solar System objects.



(Evans & Stapelfeldt, 2012)



(Fuentes et al., 2010)

Which images contain Solar System bodies?  
How can we search them? What can they tell us?

# Data ingestion and processing

NASA/JPL and IAU/MPC databases, for orbital, physical and taxonomic data.

Calculate orbits of all known objects into the past.

Match trajectories with survey footprints:

1) **GALEX**: 0.15, 0.23  $\mu\text{m}$ , 4"/pix  $< \sim 21$  mag, allsky

2) **SDSS DR10**: 0.36, 0.47, 0.62, 0.75, 0.89  $\mu\text{m}$ , 0.4"/pix,  $< \sim 22$  mag

3) **2MASS**: 1.25, 1.65  $\mu\text{m}$ , 2.17  $\mu\text{m}$ , 1"/pix,  $< \sim 16$  mag, allsky

4) **WISE**: 3.4, 4.6, 12, 22  $\mu\text{m}$ , 6.1-12"/pix,  $< \sim 8-17$  mag, allsky

# Data ingestion and processing

NASA/JPL and IAU/MPC databases, for orbital, physical and taxonomic data.

Calculate orbits of all known objects into the past.

Match trajectories with survey footprints:

The screenshot shows the MyWebSQL interface. The top left has the MyWebSQL logo (version 3.6) and the top right shows the connection details: localhost | mysql5 - MariaDB Server 5.5.3, Logged in as: pp\_ssvo@localhost. The main area is divided into a menu bar (Database, Objects, Data, Tools, Information, Interface, Help) and a content area. The content area has tabs for Query Results, Messages, Information, and History. The Query Results tab is active, displaying a table with 483 records. The table has columns: #, d\_spkid, t\_spkid, ID\_, SPKID\_, FULL\_NAME\_, PDES\_, NAME\_, PREFIX\_, NEO\_, PHA\_, H\_, G\_, M1\_. The first three rows are visible. Below the table, it shows '483 record(s)' and '0.43 ms' execution time. The SQL Editor tab is also active, showing a query: 

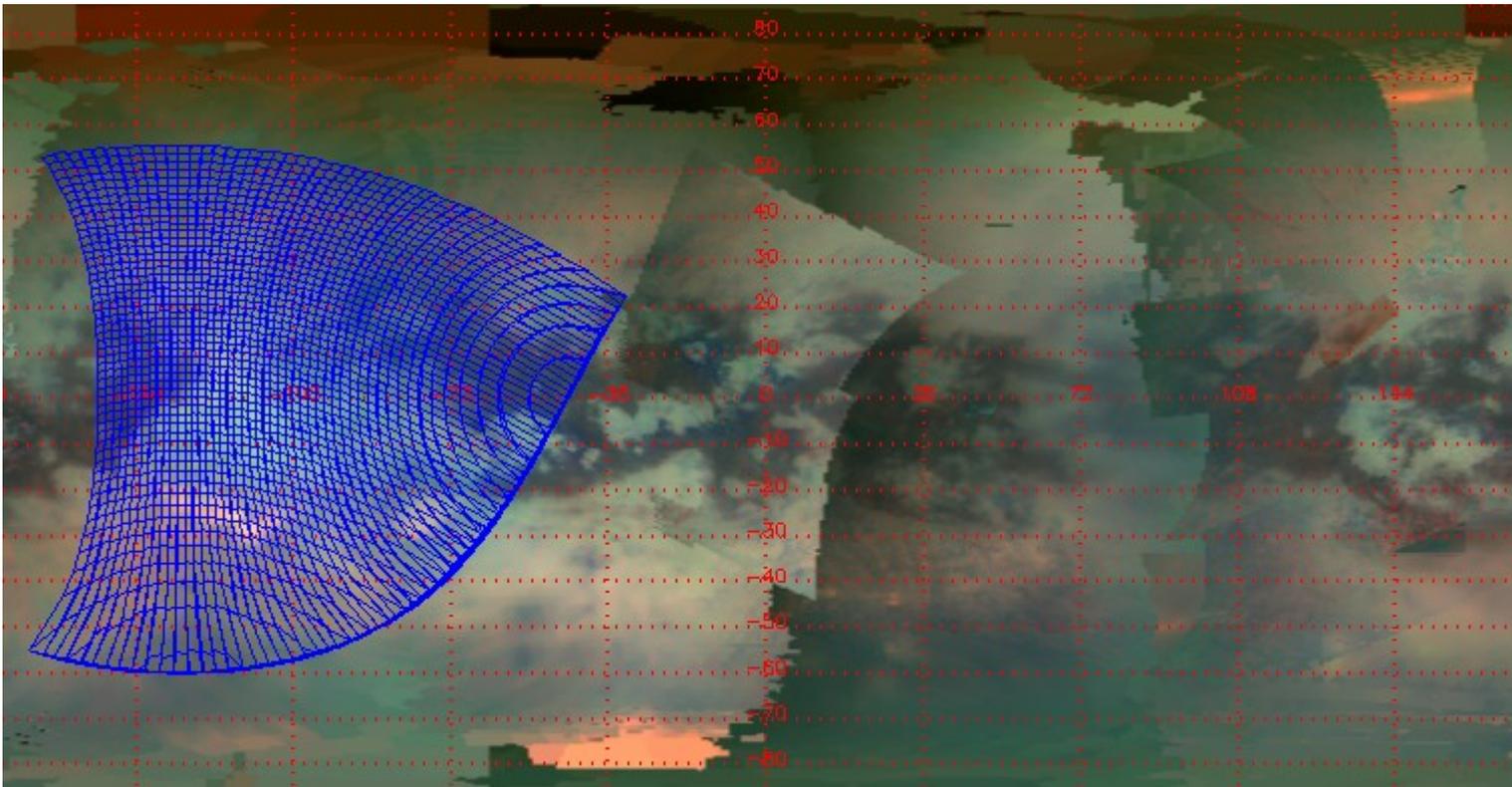
```
1 select d.spkid_ as d_spkid, t.spkid_ as t_spkid, sbdb.*
2   from dr10matches_run2 as d
3   join twomassmatches_run2 as t
4   on d.spkid_=t.spkid_
5   join sbdb on sbdb.spkid_=d.spkid_
6
7
8
```

#	d_spkid	t_spkid	ID_	SPKID_	FULL_NAME_	PDES_	NAME_	PREFIX_	NEO_	PHA_	H_	G_	M1_
1	2047563	2047563	a0047563	2047563	47563 (2000 AW149)	47563			N	N	14.3	0	0
2	2047563	2047563	a0047563	2047563	47563 (2000 AW149)	47563			N	N	14.3	0	0
3	2010552	2010552	a0010552	2010552	10552 Stockholm (1993 BH13)	10552	Stockholm		N	N	13.7	0	0

# Remote sensing observations

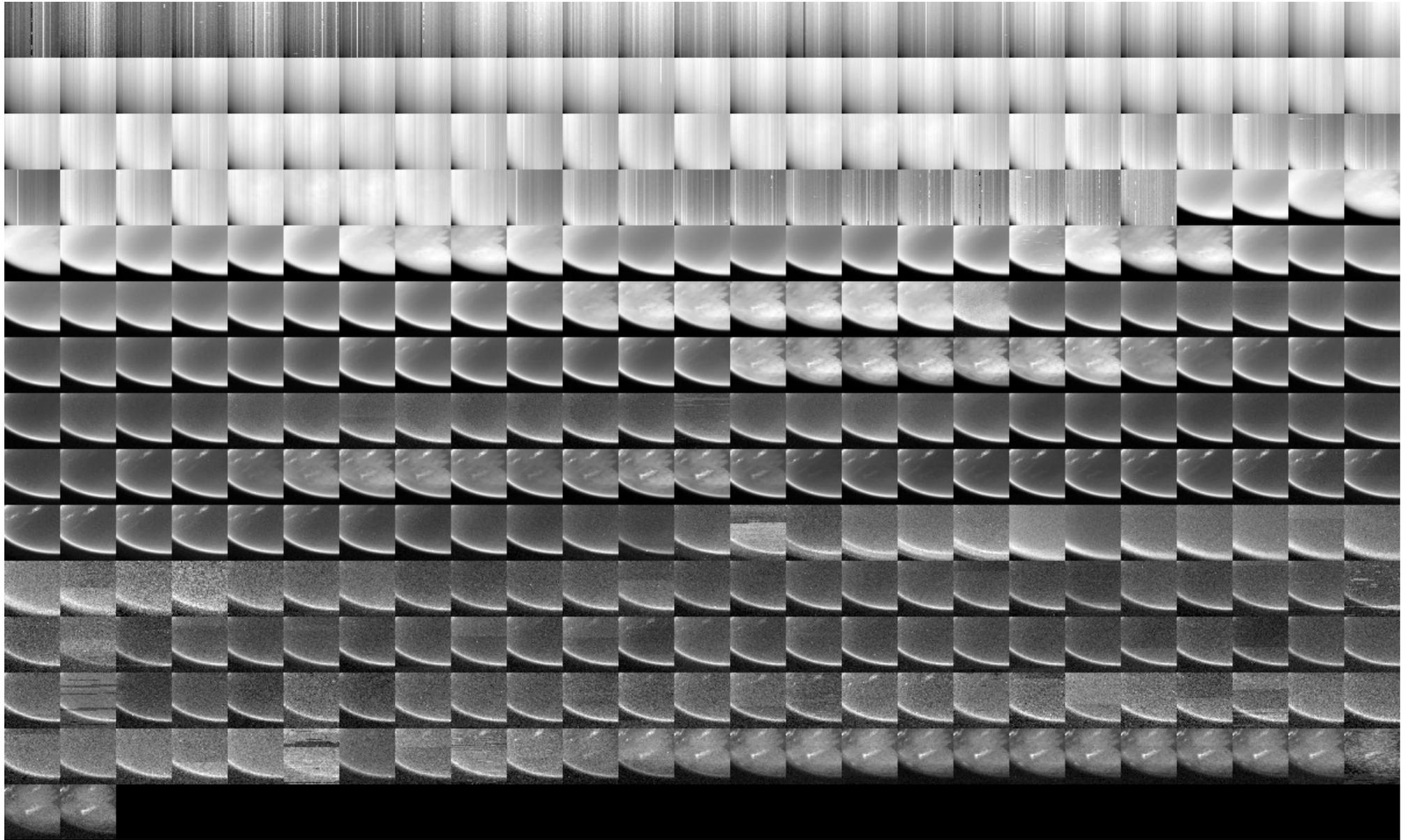
Some objects are visited by spacecraft.

These observations (remote sensing) need cartography.



Titan (Cassini VIMS)

# Hyperspectral remote sensing



Titan, 0.35 to 5.1  $\mu\text{m}$  (Cassini VIMS)

# titanbrowse

Hyperspectral remote sensing archive.

Allows for arbitrary complex queries based on metadata **and spectra (fluxes)**

**Integrated interactive visualization with correct cartography.**

Demonstration online system: jtitanbrowse (Cassini VIMS Titan observations)



band

1,5412  $\mu\text{m}$

Display mode: Image

Backplane selection

- LATITUDE
- LONGITUDE
- LAT\_0
- LAT\_1

Display mode: None

Draw grid

Plot spectrum

Cube: lsb\_0034934669\_0

X: 255 Z: 176 Value: 0

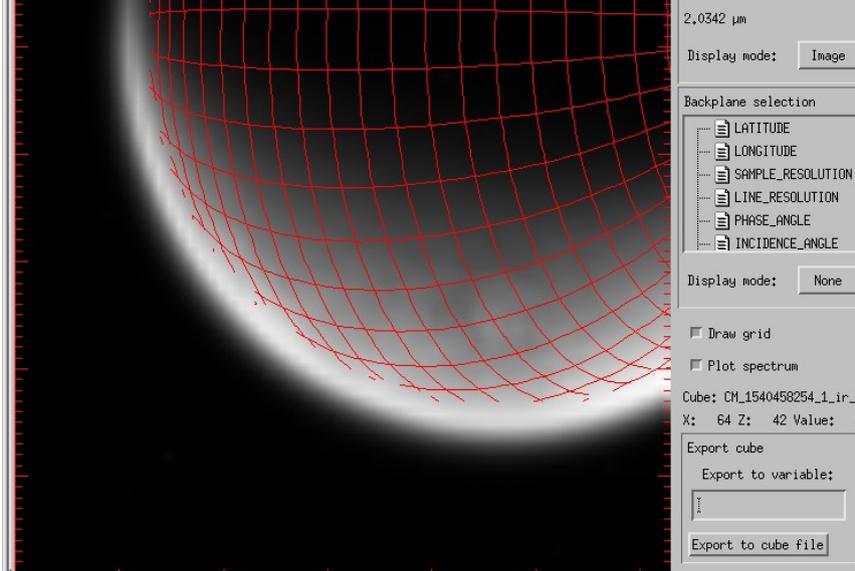
Lat: 67.624 Lon: -73.624

Alt: 0.0000E+00

Export cube

Export to variables: [ ]

Export to cube file: [ ]



2,0342  $\mu\text{m}$

Display mode: Image

Backplane selection

- LATITUDE
- LONGITUDE
- SAMPLE\_RESOLUTION
- LINE\_RESOLUTION
- PHASE\_ANGLE
- INCIDENCE\_ANGLE

Display mode: None

Draw grid

Plot spectrum

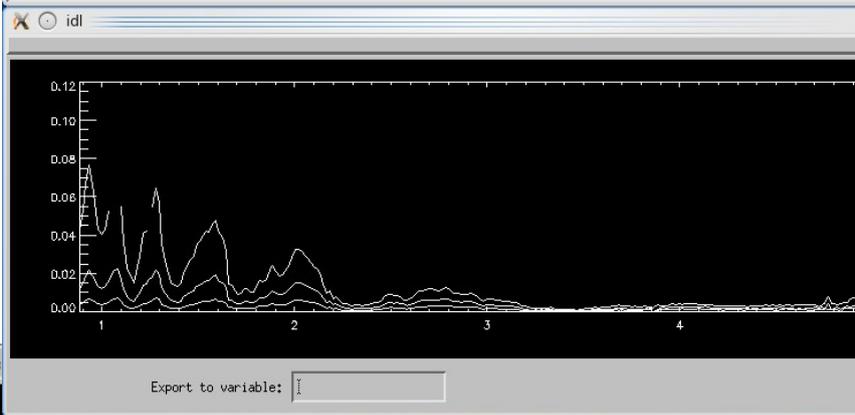
Cube: CM\_1540485266\_1\_ir\_0

X: 64 Z: 42 Value: 0

Export cube

Export to variable: [ ]

Export to cube file: [ ]



Export to variable: [ ]

rowse\_gui

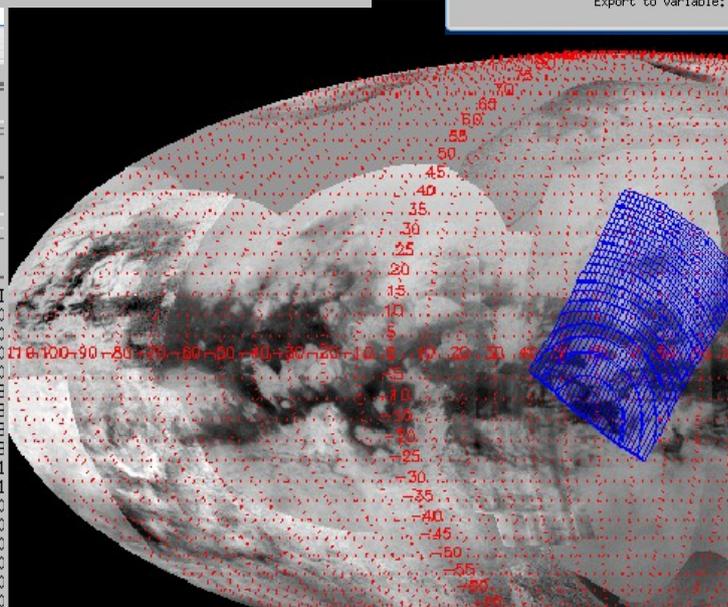
Pixel selection Map Cube

Function for selection

FUNCTION\_0) gt 0.5d0) and ( \_c\_68\_ gt 0.02d0)

Selected pixels: 951

Wavelength ( $\mu\text{m}$ )	CUBE	X	Z	LATI
.7380	CM_1540485266_1_ir_0	56	2	-4.0
.7544	CM_1540485266_1_ir_0	57	2	-4.0
.7711	CM_1540485266_1_ir_0	58	2	-4.0
.7877	CM_1540485266_1_ir_0	59	2	-4.0
.8040	CM_1540485266_1_ir_0	60	2	-3.9
.8200	CM_1540485266_1_ir_0	61	2	-3.9
.8362	CM_1540485266_1_ir_0	62	2	-3.9
.8529	CM_1540485266_1_ir_0	63	2	-3.9
.8693	CM_1540485266_1_ir_0	50	3	-4.1
.8868	CM_1540485266_1_ir_0	52	3	-4.1
.9026	CM_1540485266_1_ir_0	53	3	-4.0
	CM_1540485266_1_ir_0	54	3	-4.0
	CM_1540485266_1_ir_0	55	3	-4.0
	CM_1540485266_1_ir_0	56	3	-4.0
	CM_1540485266_1_ir_0	57	3	-4.0
	CM_1540485266_1_ir_0	58	3	-4.0



File

Min: 32.798862 Max: 80.289360 M

