

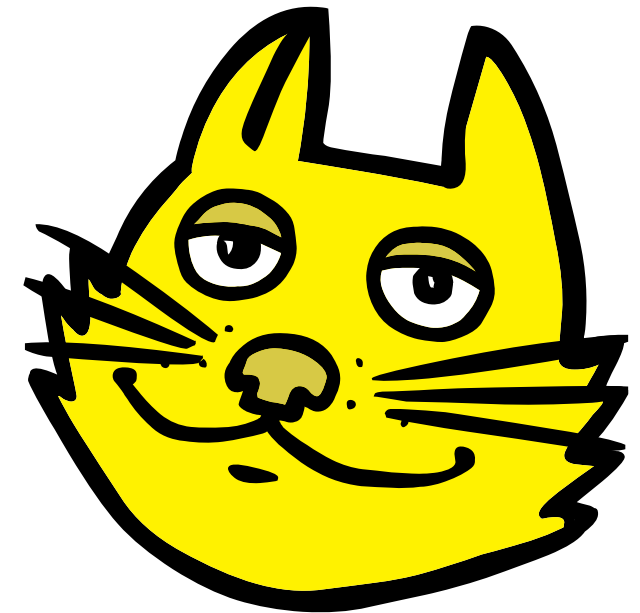
TOPCAT for Time Domain

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IVOA Interop
Görlitz

Time Domain Interest Group

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`$Id: tctime.tex,v 1.13 2025/11/06 16:48:55 mbt Exp $`

Outline

- Introduction
- File formats
- HAPI
- Time calculations and conversions
- Visualisation
- Examples

TOPCAT and Time Series

You can use TOPCAT for time series data

- TOPCAT's good with tables
- Time series are tables (with one column giving time)
- TOPCAT understands quite a few time-series friendly data formats
- So you can do I/O and format conversion, view data/metadata, add/manipulate columns, visualise series

But TOPCAT is **not** a dedicated time series tool

- It mostly sees samples as an (unordered) set of records
- It's not good at understanding trends or patterns
 - ▷ ... though visualisation can help *you* to do that
- No resampling, period determination, Fourier analysis etc

See also STILTS for command-line usage

File Formats

Time-series-friendly I/O formats:

- CDF, PDS4 (both input only)
- (see also HAPI)

General purpose formats:

- VOTable, FITS, CSV, ECSV, Parquet, ASCII, IPAC

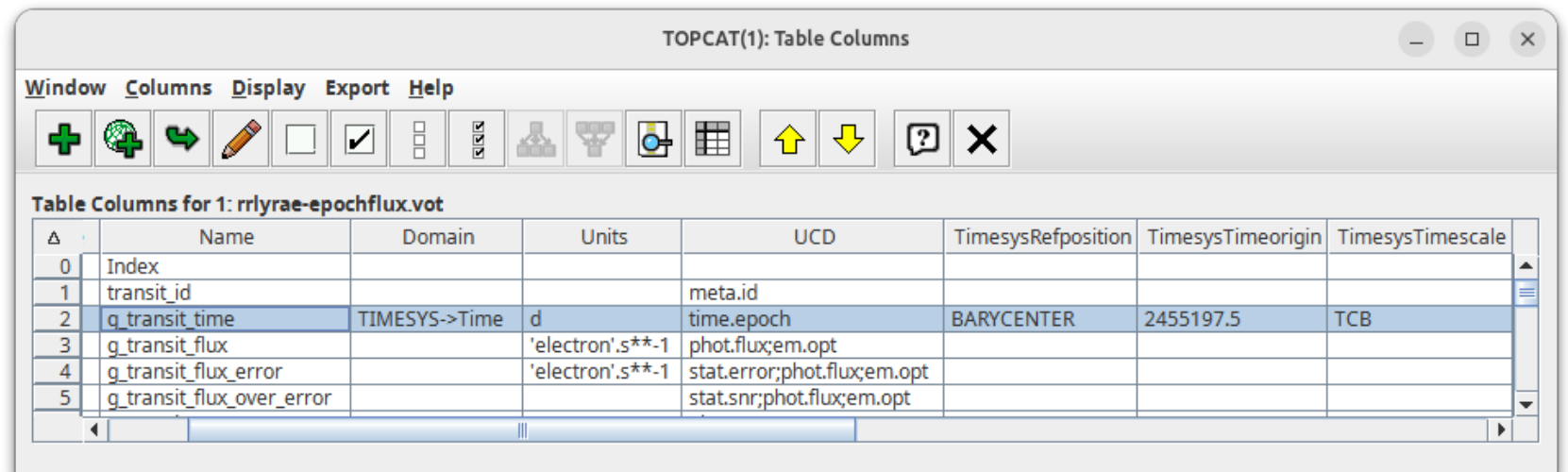
Time Data Input

TOPCAT tries to identify time columns when reading tables

- Some formats mark epoch columns specially:
 - ▷ CDF, PDS4, Parquet, HAPI, IPAC, VOTable
- Otherwise, TOPCAT uses some [heuristics](#) to guess what might be an epoch
 - ▷ Column metadata: UCDs, units, xtypes, utypes, column names
 - ▷ For metadata-poor formats (CSV, ASCII): does it look like ISO-8601?

These columns are marked internally as epoch values

- For most purposes treated as original numeric/string values (MJD, JD, year, Unix seconds, ISO-8601, ...)
- But where required (mostly Time plot) the absolute epoch can be determined



TOPCAT(1): Table Columns

Window Columns Display Export Help

Table Columns for 1: rrlyrae-epochflux.vot

Δ	Name	Domain	Units	UCD	TimesysRefposition	TimesysTimeorigin	TimesysTimescale
0	Index						
1	transit_id			meta.id			
2	q_transit_time	TIMESYS->Time	d	time.epoch	BARYCENTER	2455197.5	TCB
3	q_transit_flux		'electron'.s**-1	phot.flux;em.opt			
4	q_transit_flux_error		'electron'.s**-1	stat.error;phot.flux;em.opt			
5	q_transit_flux_over_error			stat.snr;phot.flux;em.opt			

Time Data Manipulation

There are a few **time-related functions** in the expression language:

- Conversions between ISO-8601, MJD, JD, Decimal year, Unix (milli)seconds, Julian/Besselian epoch:

`mjdToIso, mjdToDecYear, ..., isoToMjd, decYearToMjd, ...`

- Calendar conversions:

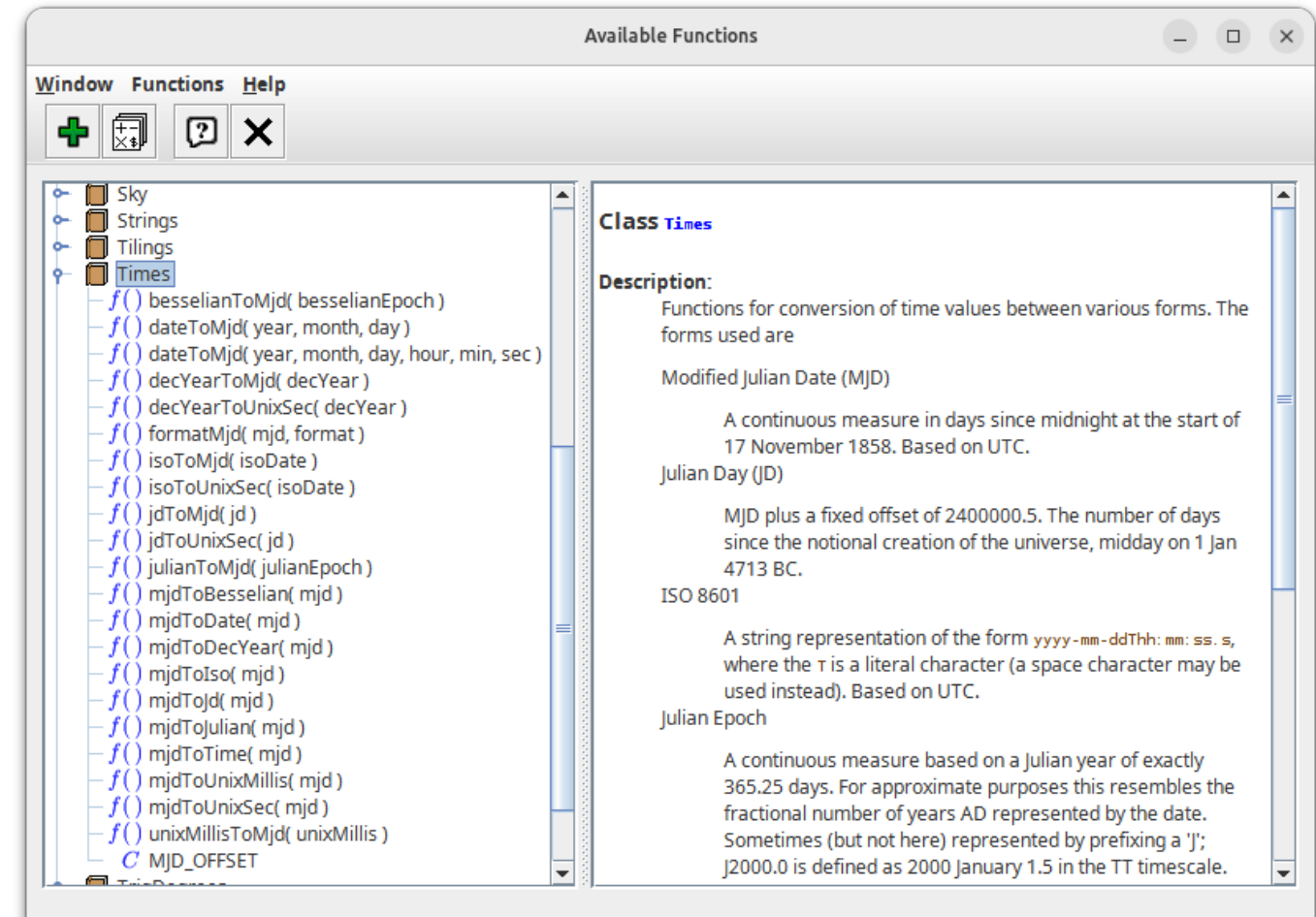
`dateToMjd(year, month, day[, hour, min, sec])`

- Formatting:

`formatMjd(mjd, format)`

Should there be more?

- Sugestions welcome
- But note these only operate within a single row



Heliophysics Data Application Programmer's Interface

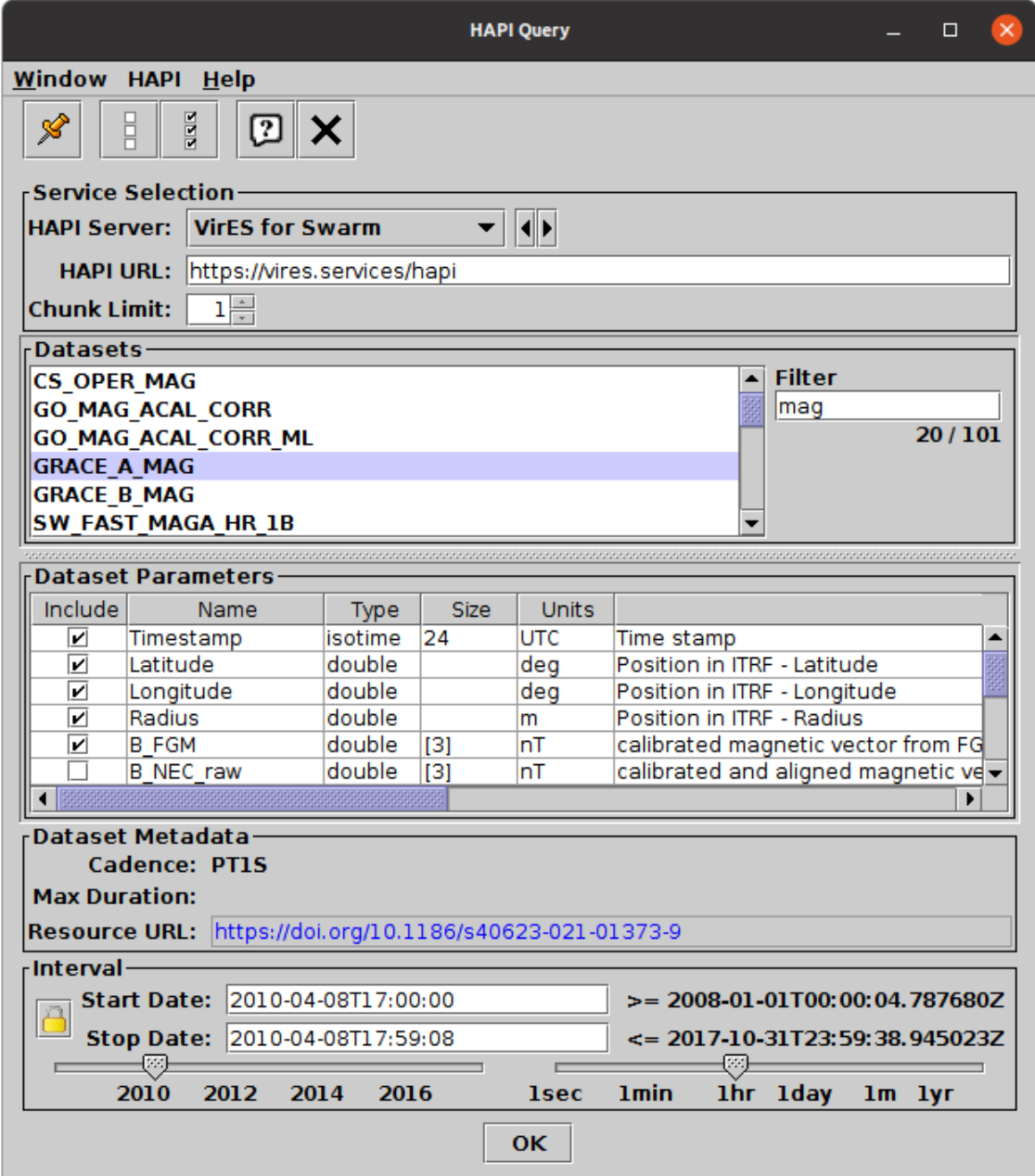
- **HAPI** is a service specification for time series data used (mostly) in Heliophysics

TOPCAT/STILTS support

- TOPCAT has a **HAPI load dialogue**
 - ▶  **Load** window or **VO** menu
- There's also a **HAPI Input Scheme** for use from STILTS
- TOPCAT/STILTS can be used to convert HAPI queries to other formats (VOTable, CSV, FITS, ...)

```
stilts tpipe in=':hapi:https://vires.services/hapi;GRACE\_A\_MAG;
start=2009-01-01T00:00:00;stop=2009-01-01T00:00:10;
parameters=Latitude,Longitude'
out=hapi.fits
```

- Large/multi-chunk queries supported



The screenshot shows the 'HAPI Query' window with the following sections:

- Service Selection:**
 - HAPI Server: VirES for Swarm
 - HAPI URL: https://vires.services/hapi
 - Chunk Limit: 1
- Datasets:**
 - CS_OPER_MAG
 - GO_MAG_ACAL_CORR
 - GO_MAG_ACAL_CORR_ML
 - GRACE_A_MAG (selected)
 - GRACE_B_MAG
 - SW_FAST_MAGA_HR_1B
- Filter:** mag (20 / 101)
- Dataset Parameters:**

Include	Name	Type	Size	Units	Description
☒	Timestamp	isotime	24	UTC	Time stamp
☒	Latitude	double		deg	Position in ITRF - Latitude
☒	Longitude	double		deg	Position in ITRF - Longitude
☒	Radius	double		m	Position in ITRF - Radius
☒	B_FGM	double	[3]	nT	calibrated magnetic vector from FG
☐	B_NEC_raw	double	[3]	nT	calibrated and aligned magnetic ve
- Dataset Metadata:**
 - Cadence: PT1S
 - Max Duration:
 - Resource URL: https://doi.org/10.1186/s40623-021-01373-9
- Interval:**
 - Start Date: 2010-04-08T17:00:00
 - Stop Date: 2010-04-08T17:59:08
 - Timeline: 2010 2012 2014 2016
 - Units: 1sec 1min 1hr 1day 1m 1yr

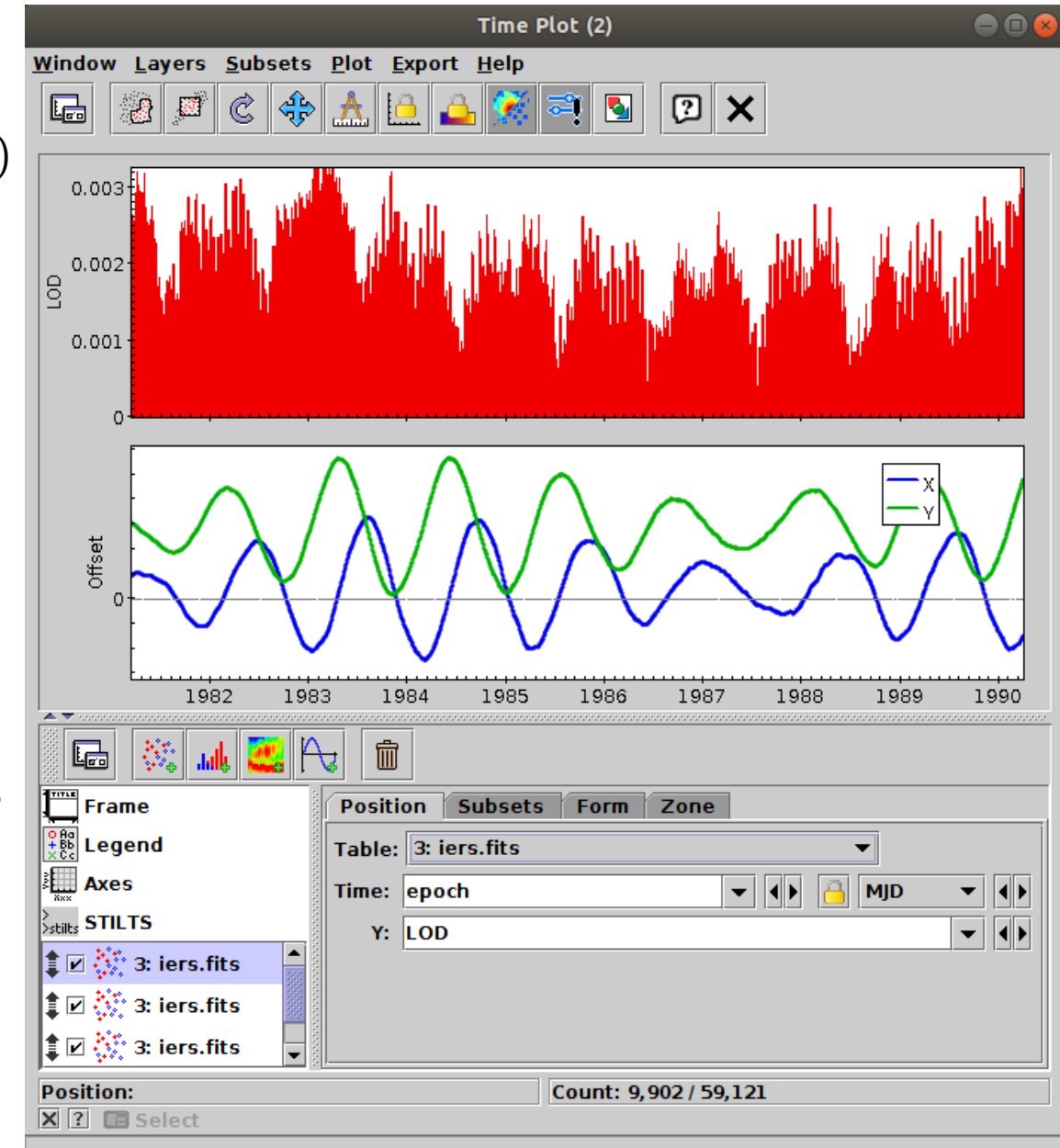
OK

Time Plot



Time Plot window

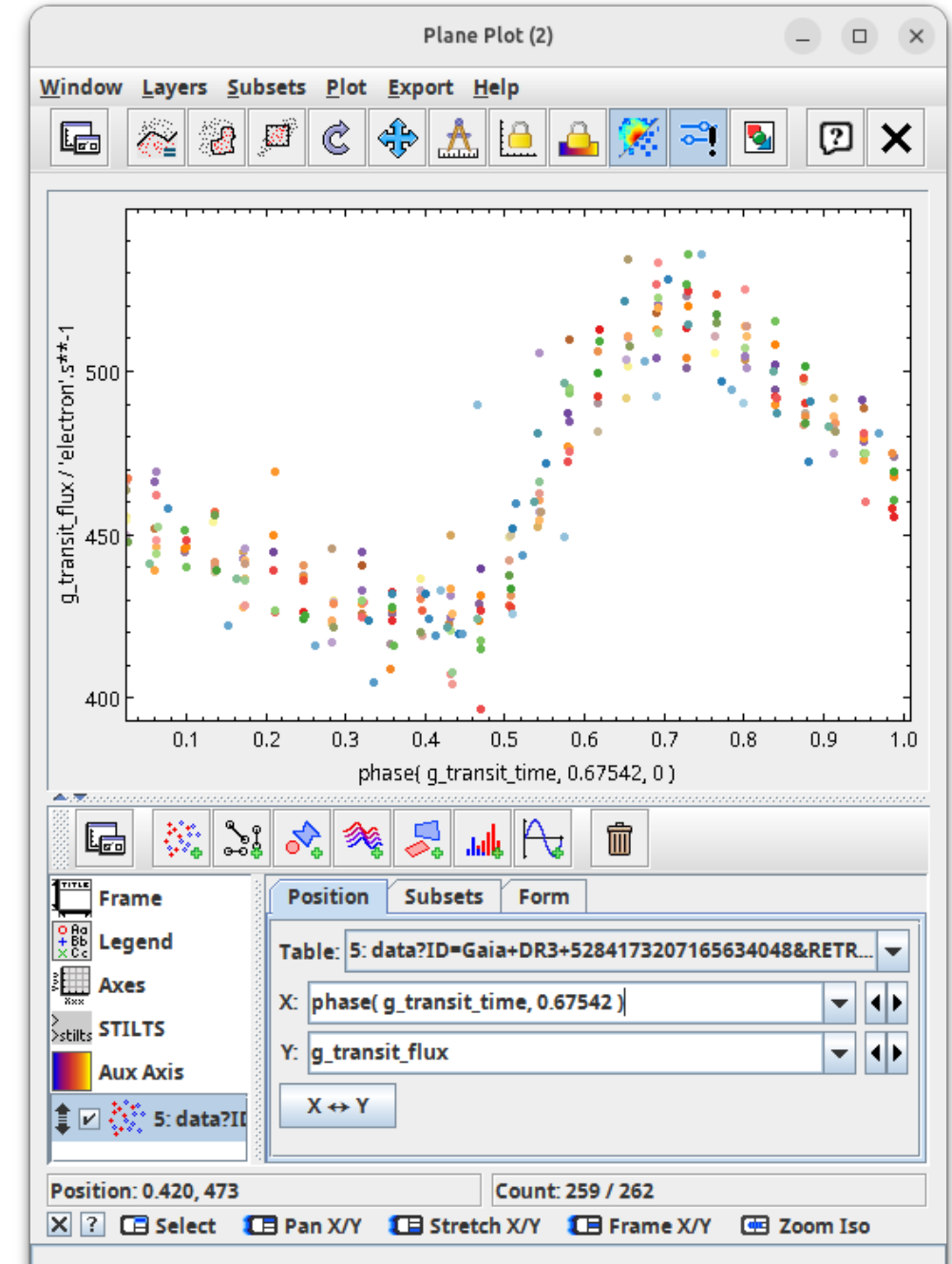
- Like other plot windows, but
 - ▷ Horizontal axis labelled with epoch (ISO-8601, Year, MJD, Unix)
 - ▷ Horizontal coord automatically interpreted or override (yr, MJD, Unix)
 - ▷ Major/minor ticks in sensible places (year, month, day, sec, ...)
 - ▷ Stack multiple plot **zones** vertically using the same Time axis
- Zone configuration
 - ▷ Each zone can contain one or multiple datasets
 - ▷ X/Y/Aux Axis configuration is independent per-zone
 - ▷ Configuration is flexible, but it can be a bit fiddly
- Plot layer types
 - Scatter-plot like:  Mark,  Line,  Fit,  Error,  Label,  Fill,  Quantile,  Grid
 - Histogram like:  Histogram,  KDE,  KNN,  Densogram,
 -  Spectrogram
 -  Function
- Good for time series data
 - ▷ Easy to zoom in/out horizontally
 - ▷ Handles multi-million row time series



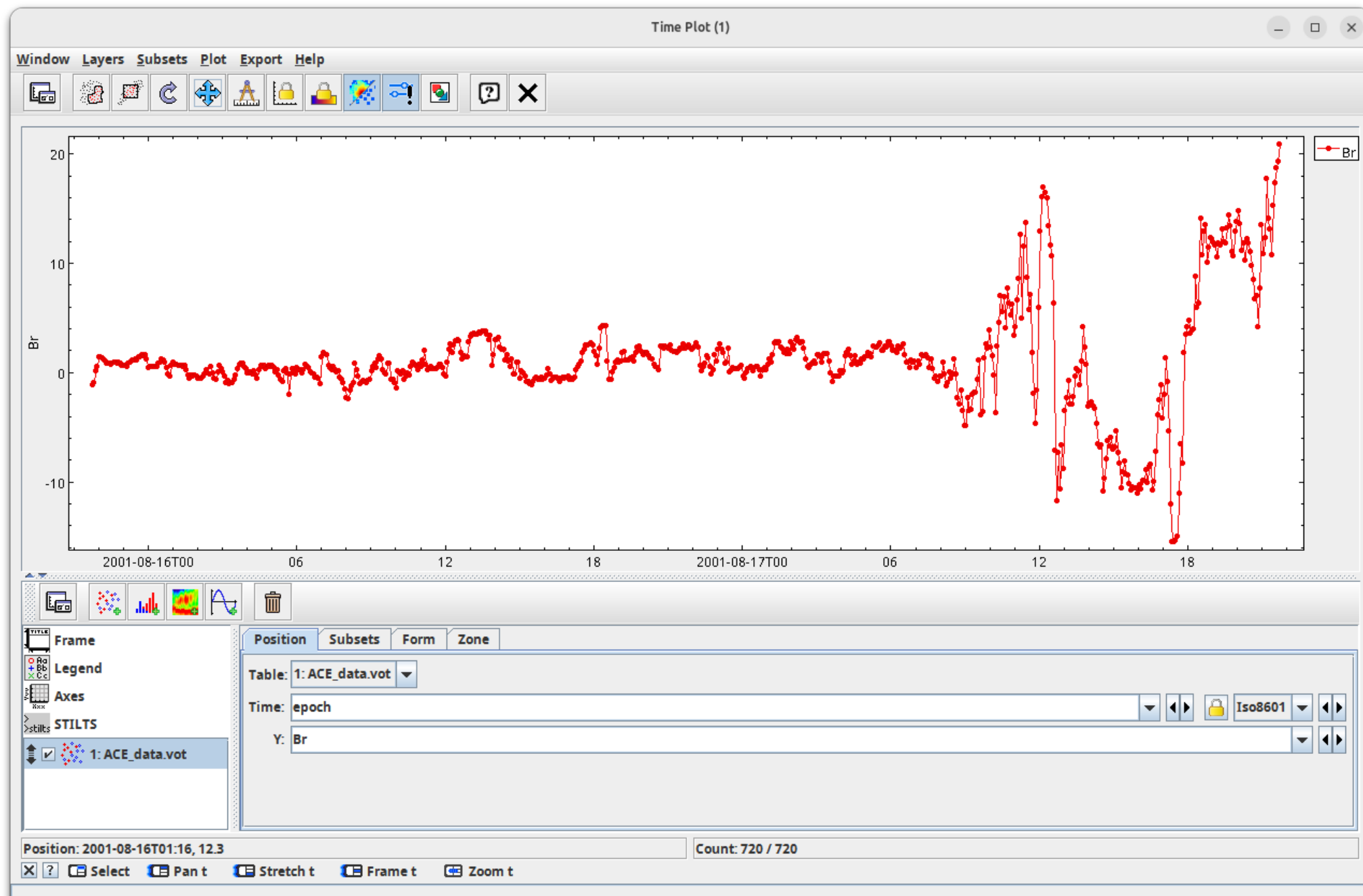
Folded Time Series

Period folding

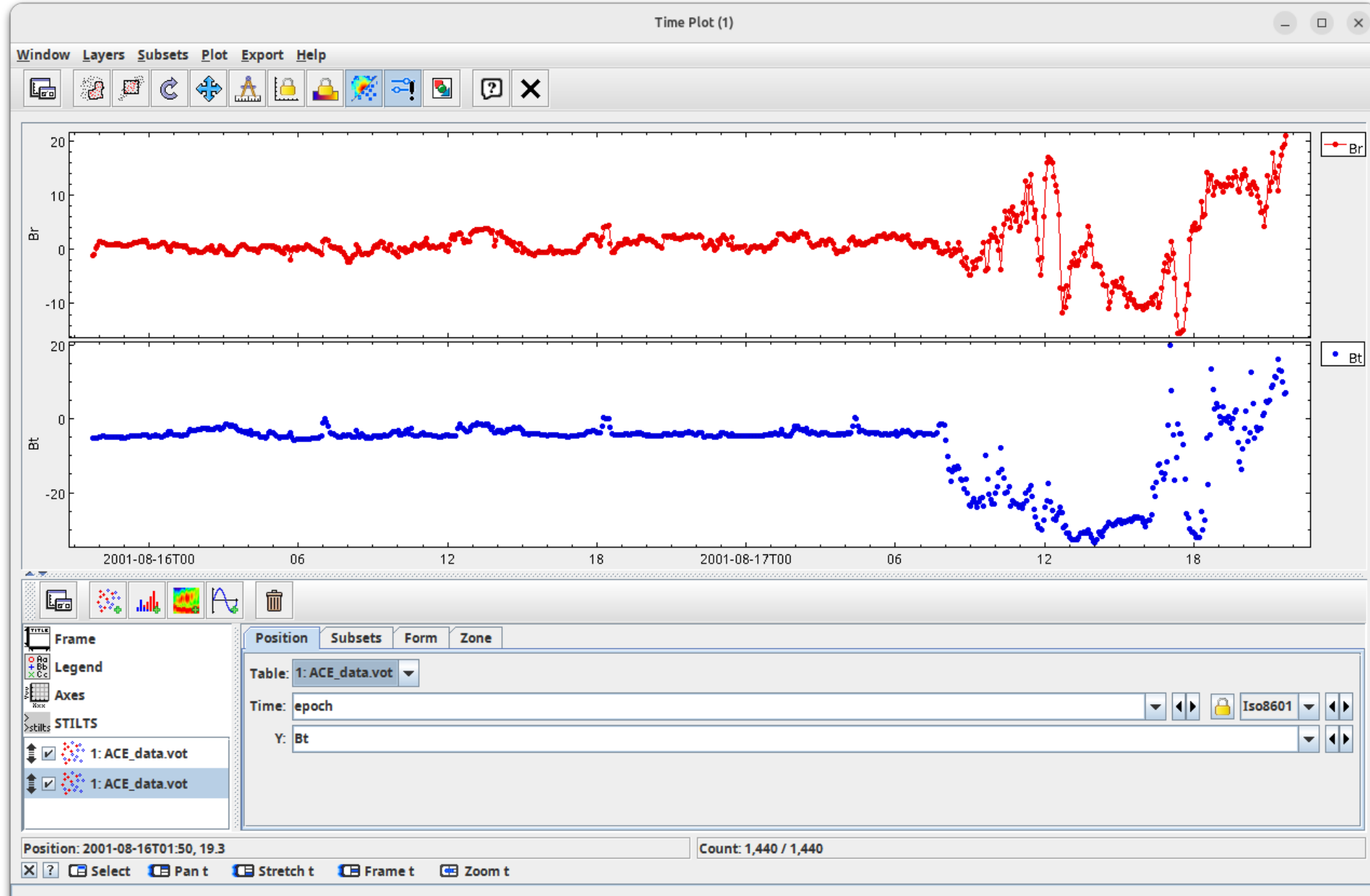
- No special arrangements in the plot windows
- You need to know the period (TOPCAT won't calculate it for you)
- Use the Plane Plot (not Time Plot)
- Use phase-folded time for X coordinate
 - ▷ Convenient function `phase(t, period[, t0, phase0])`
 - ▷ ... or just use modulus operator `"%"`



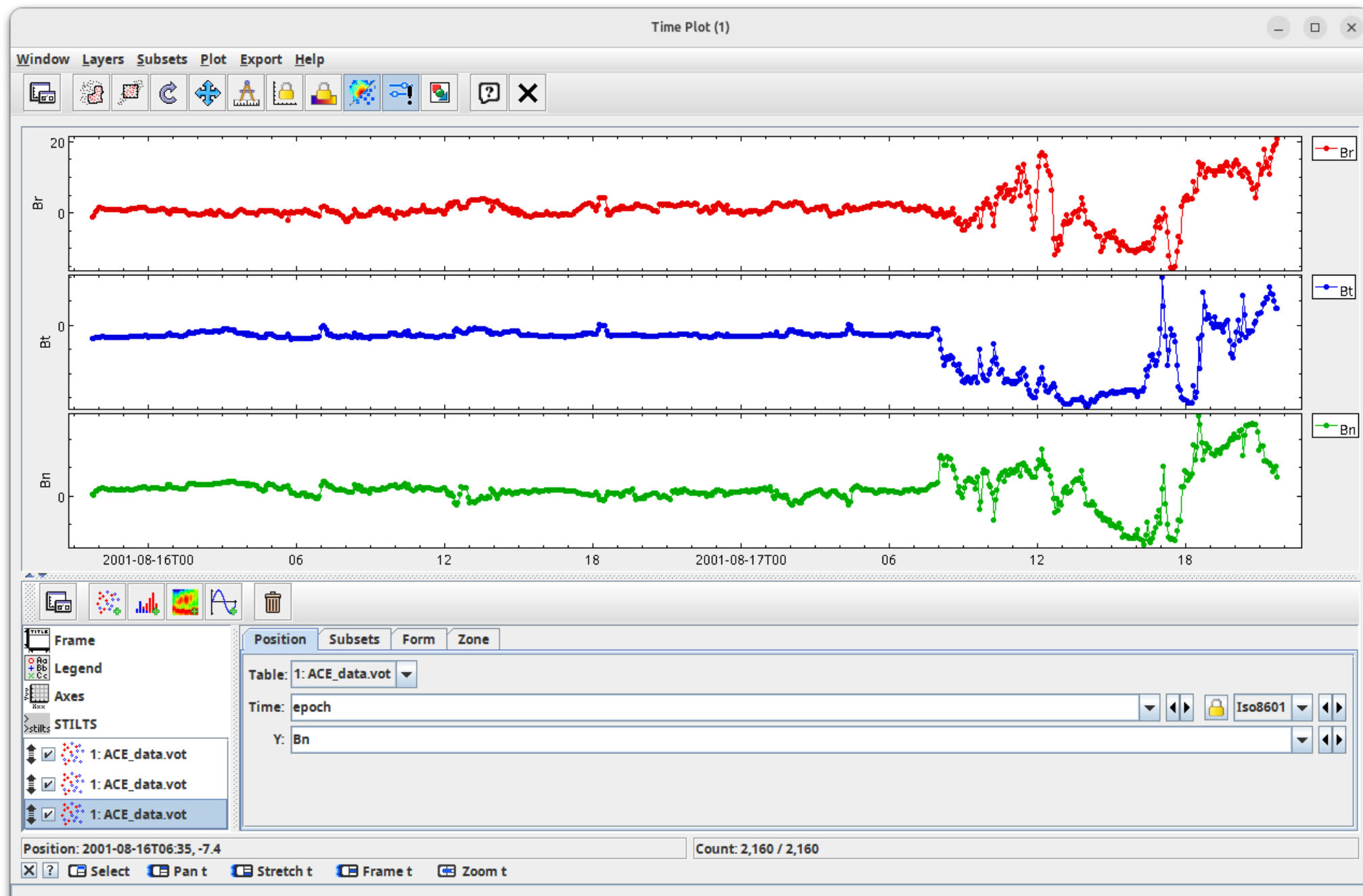
Example 1



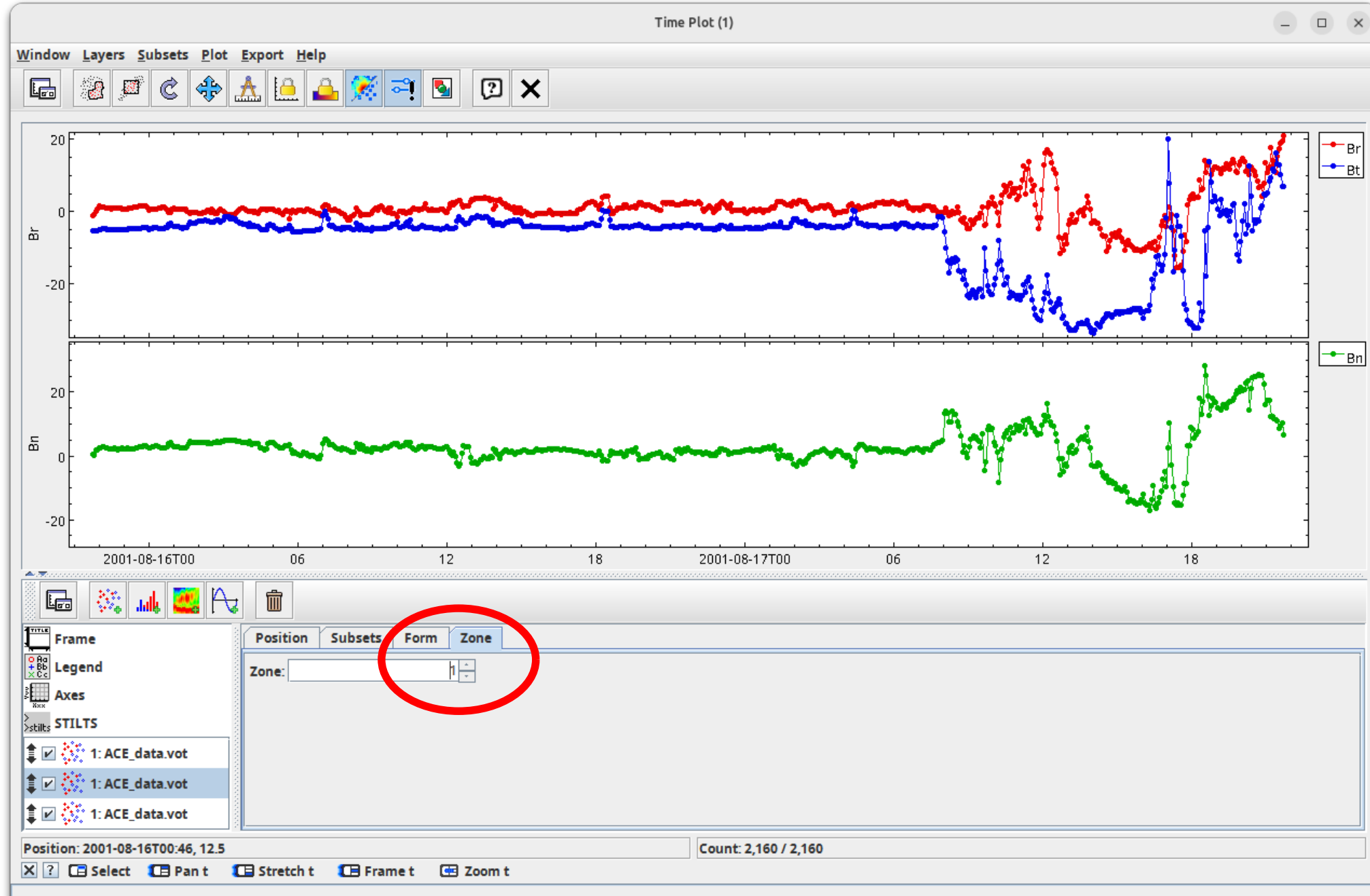
Example 1



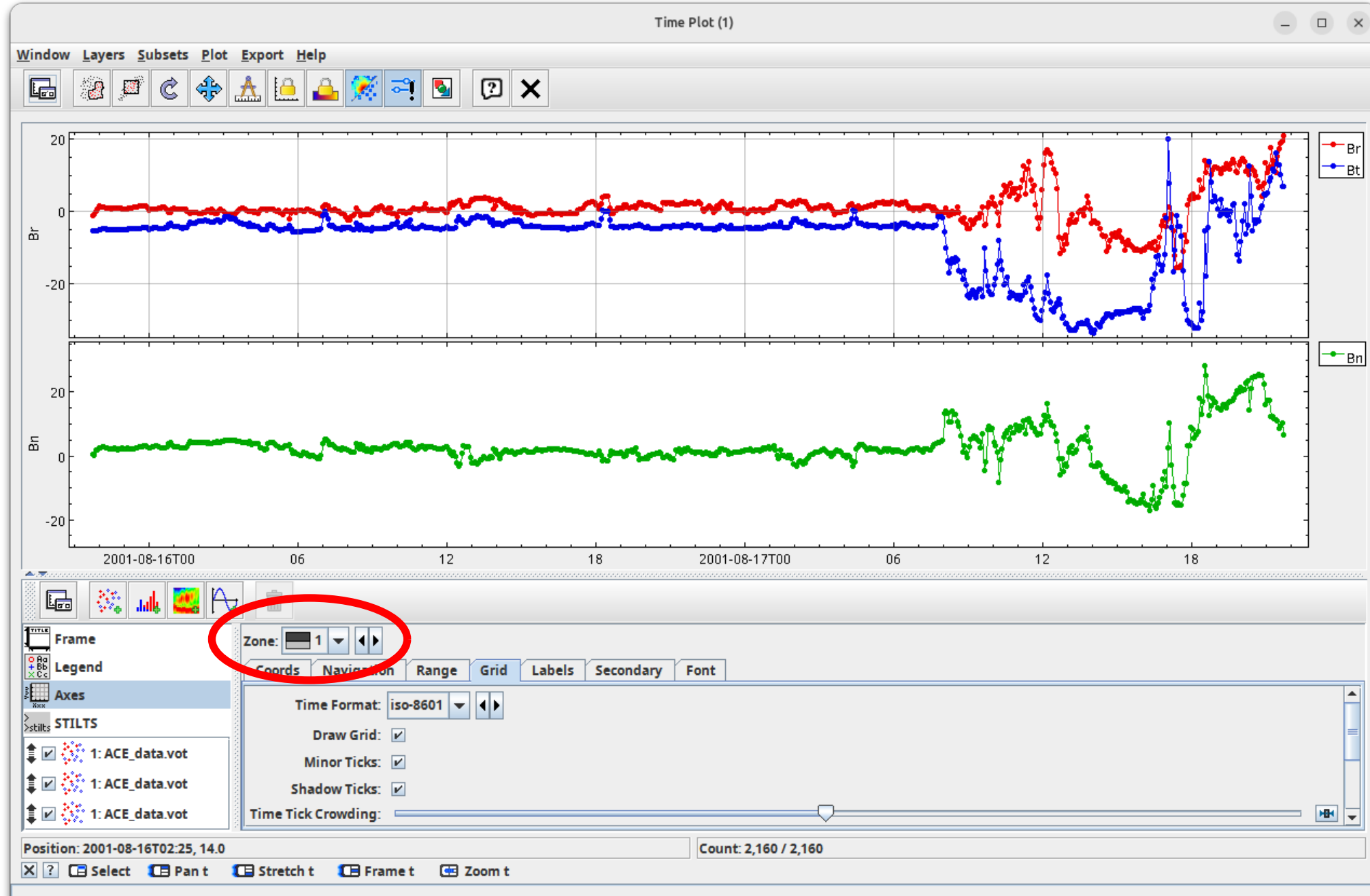
Example 1



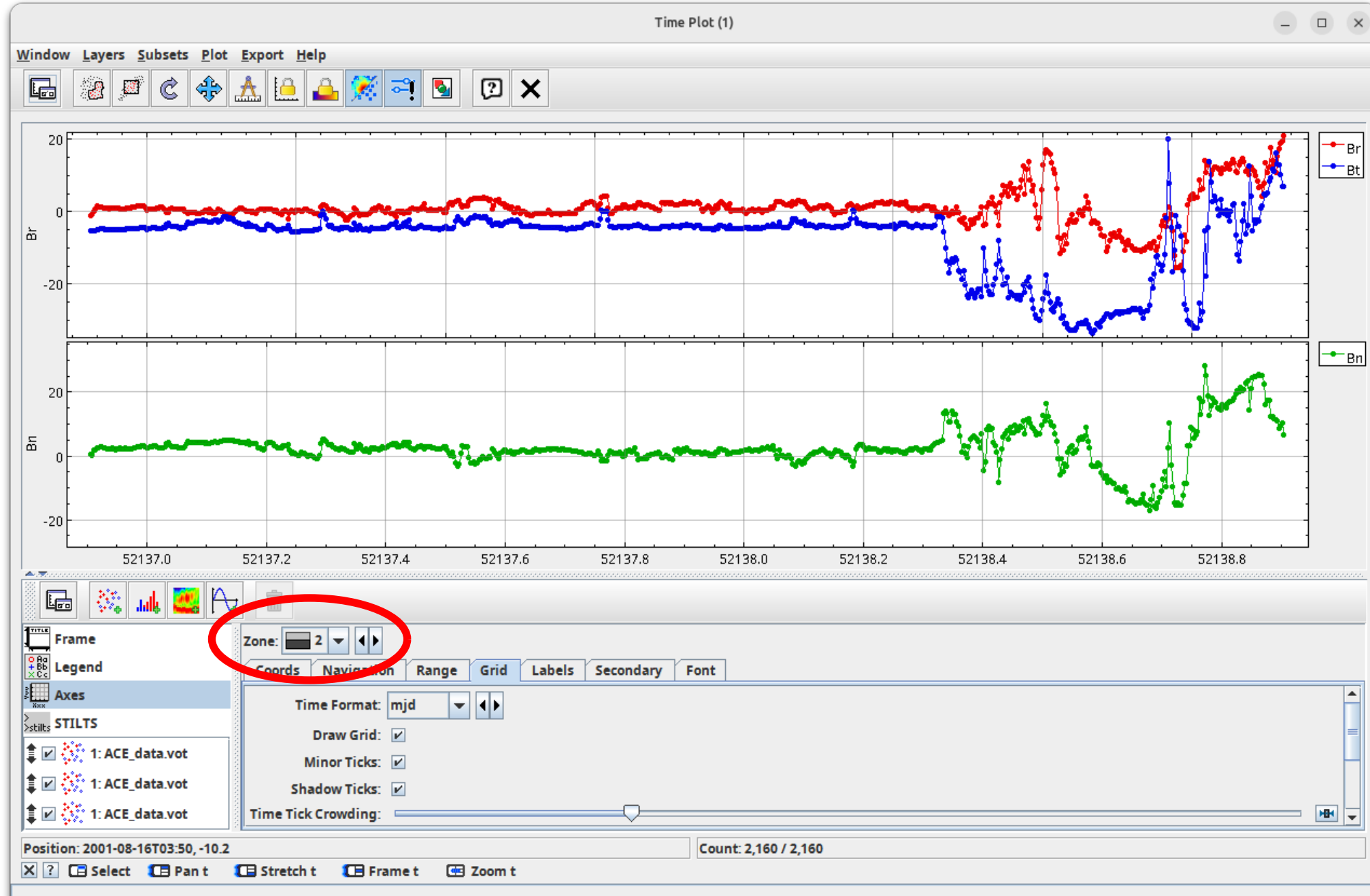
Example 1



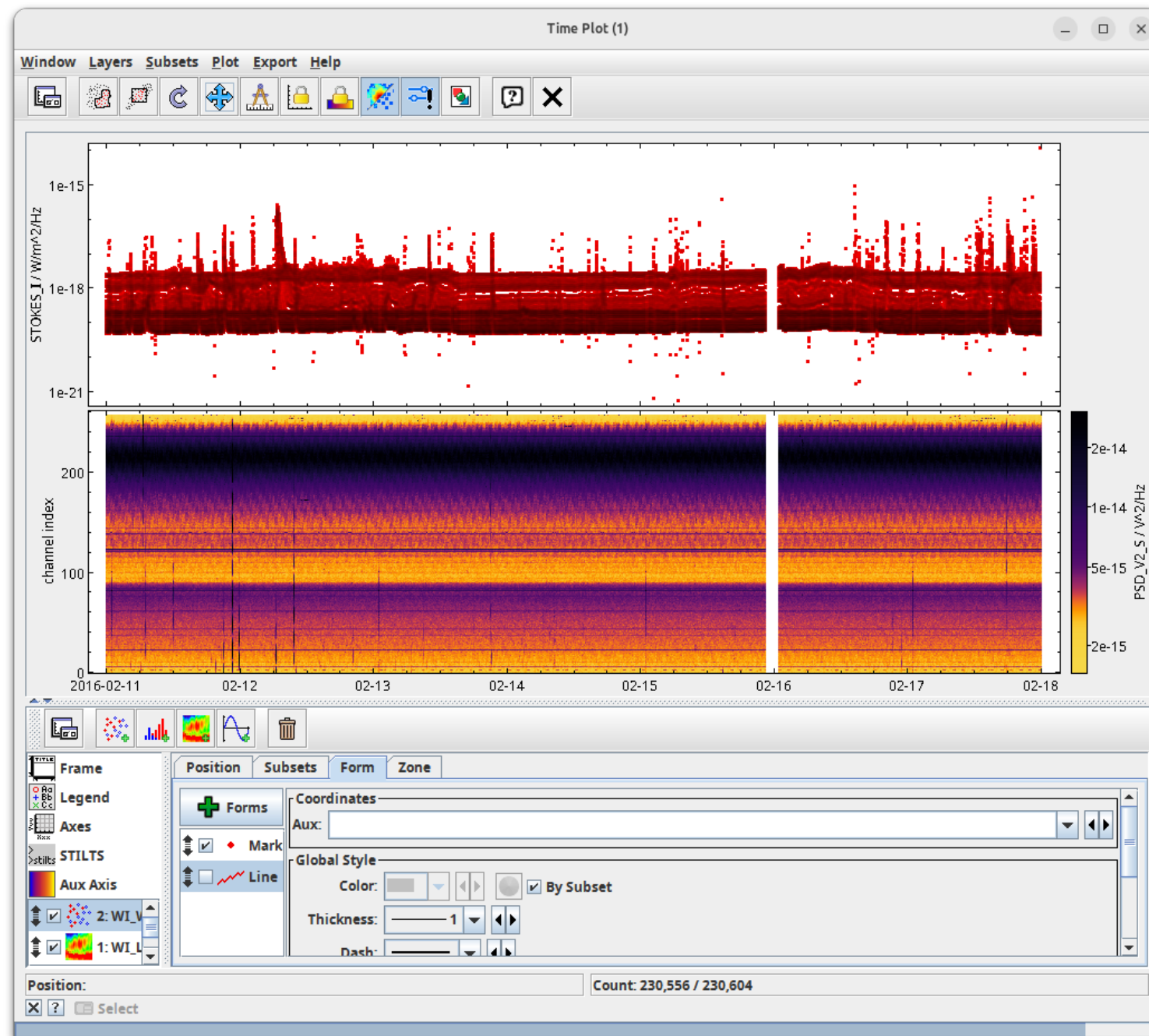
Example 1



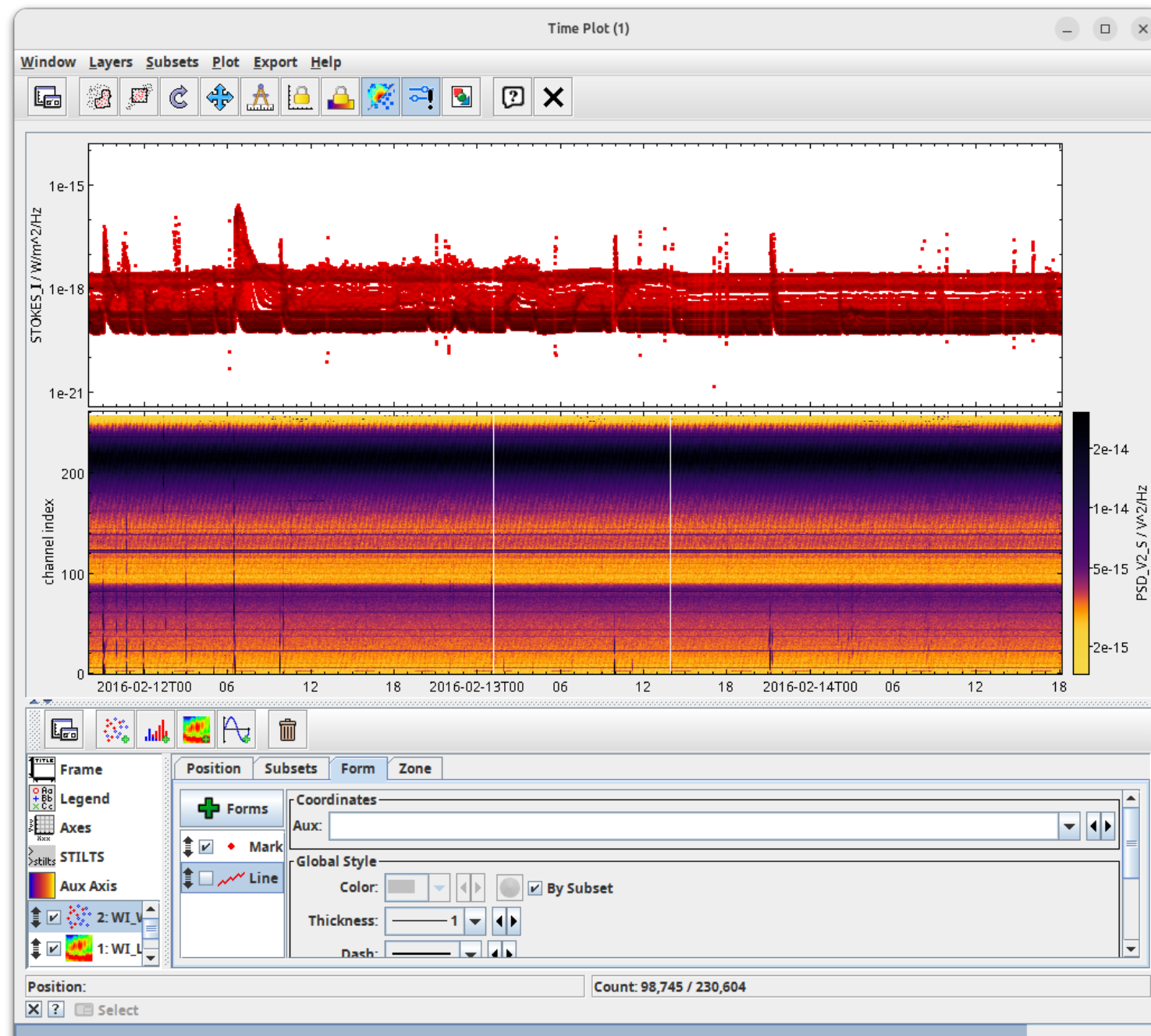
Example 1



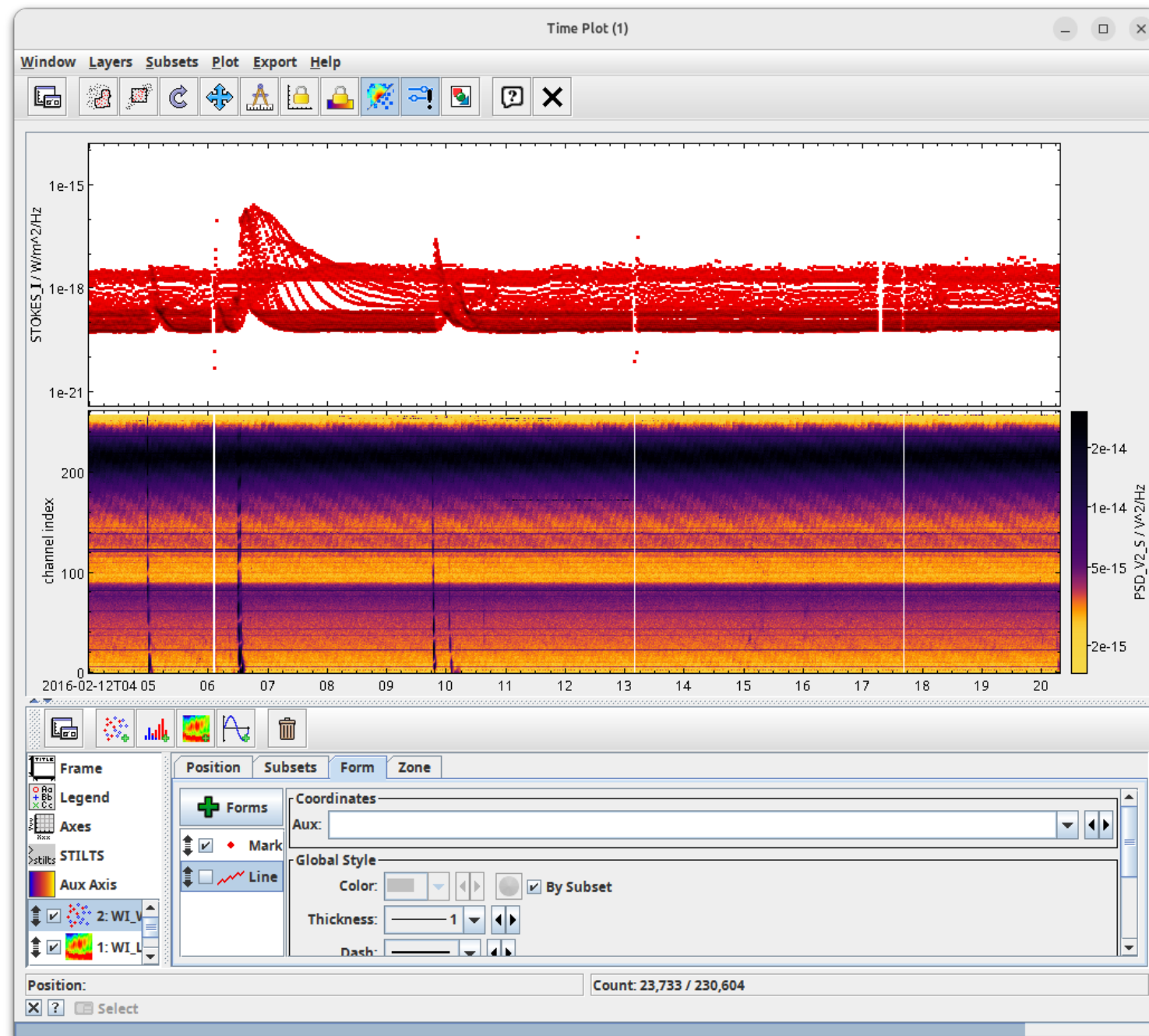
Example 2



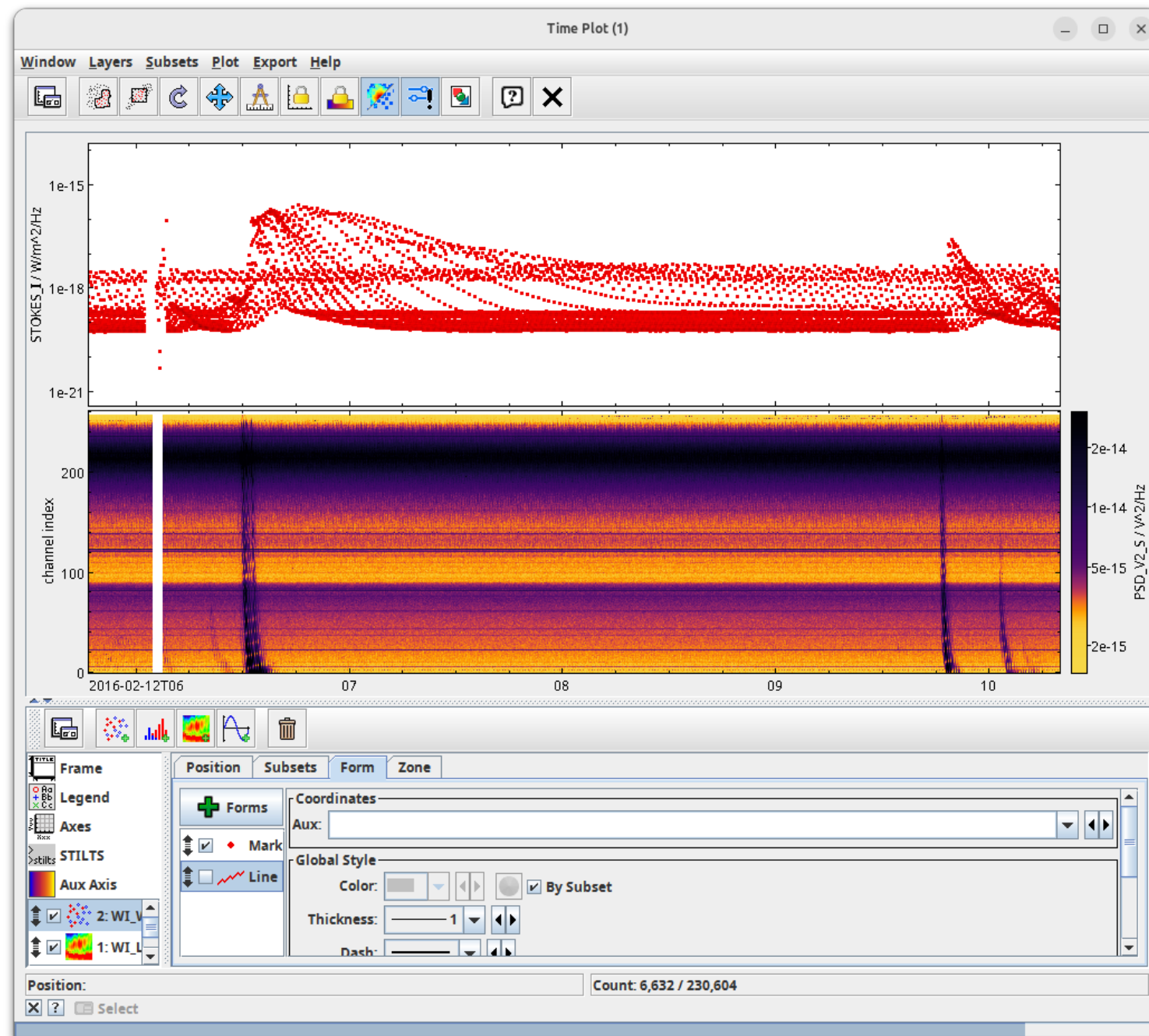
Example 2



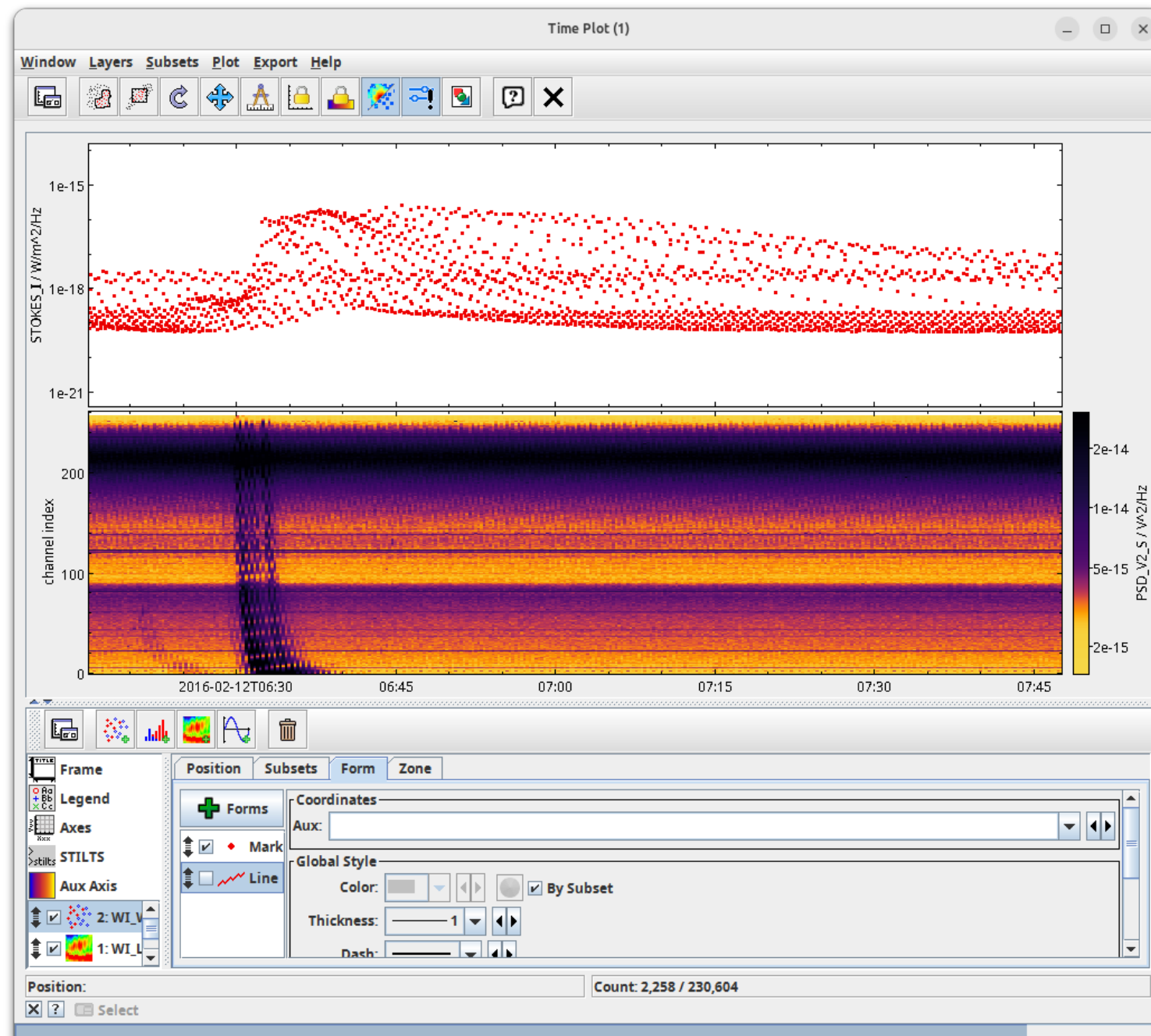
Example 2



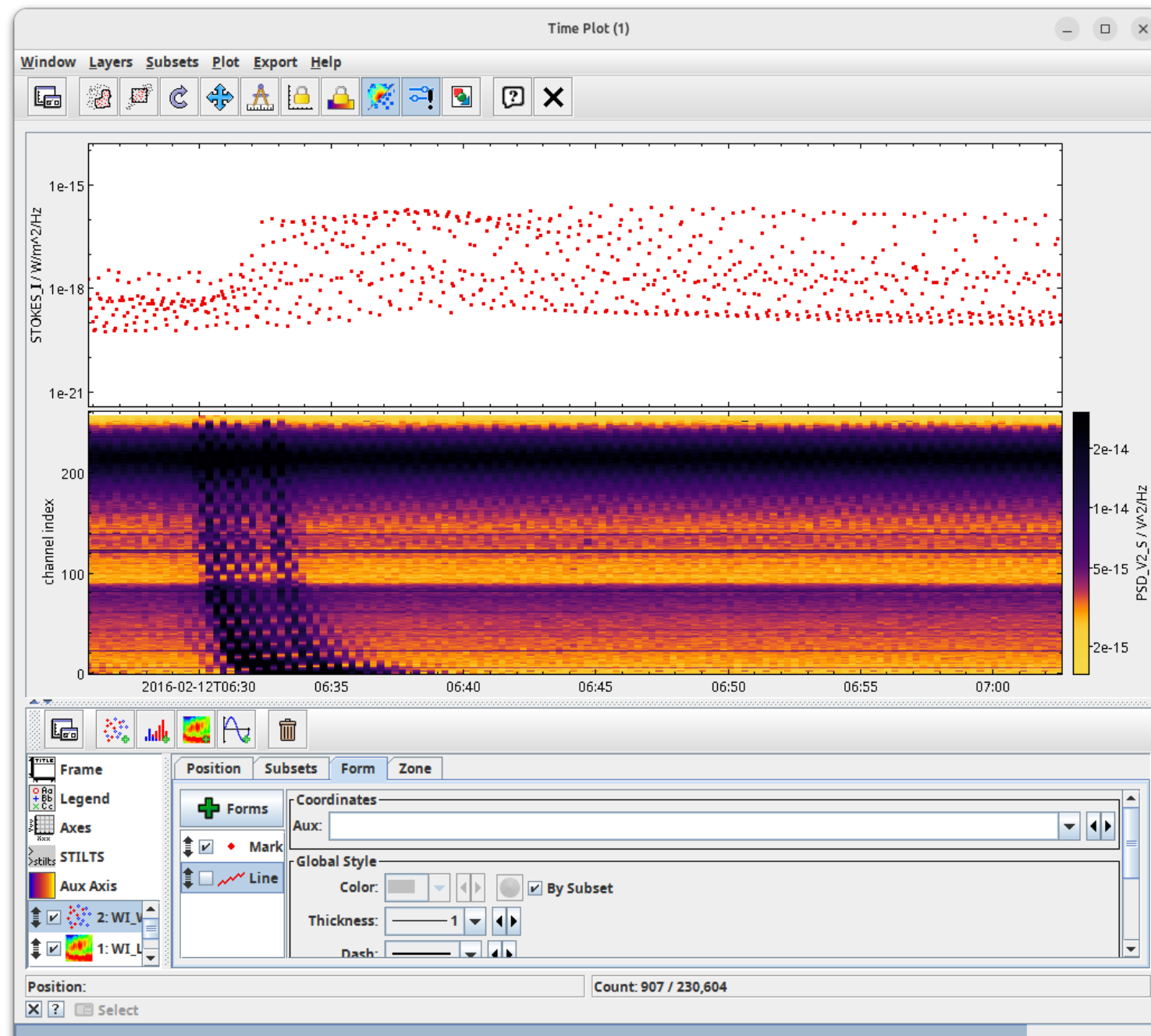
Example 2



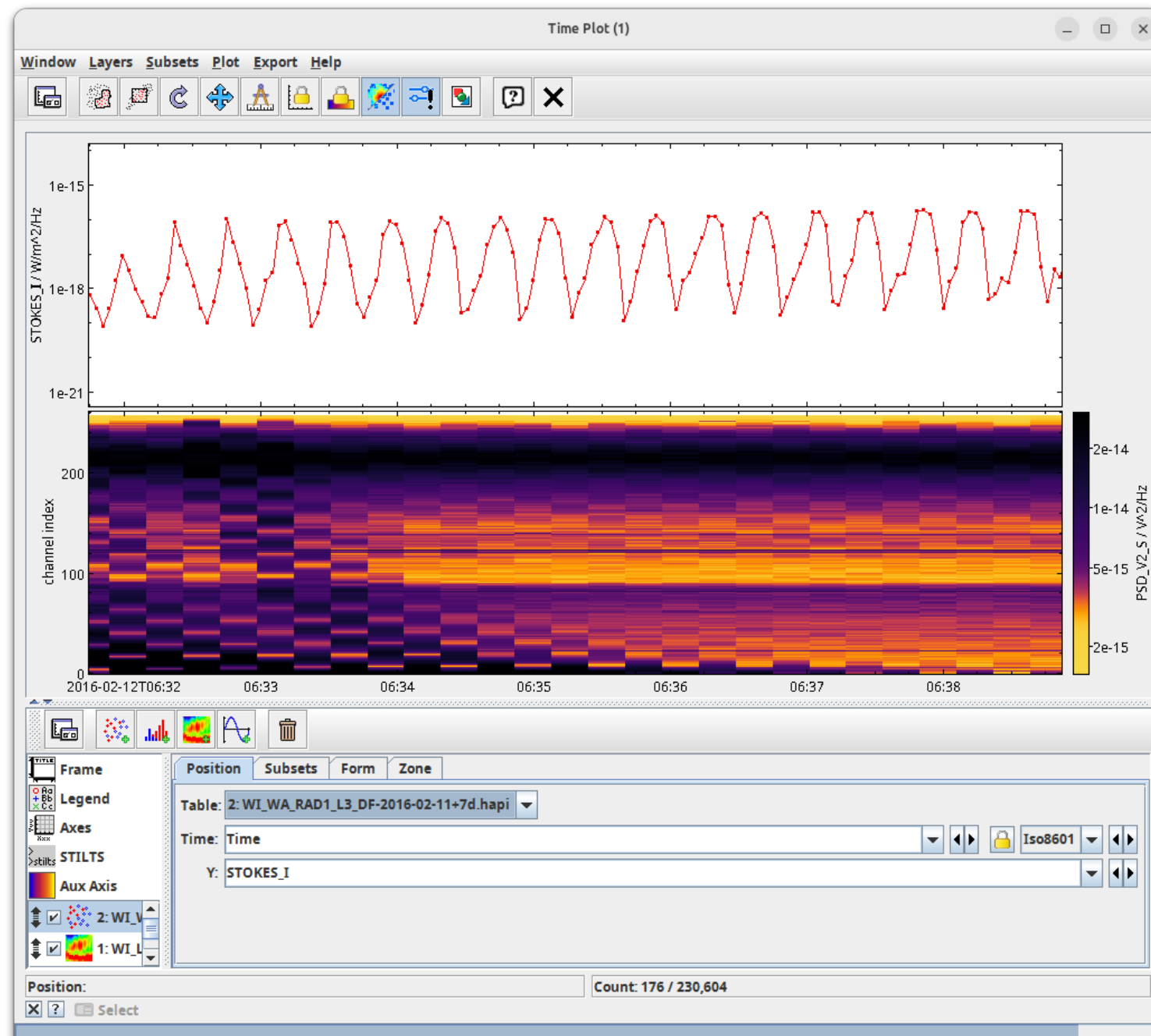
Example 2



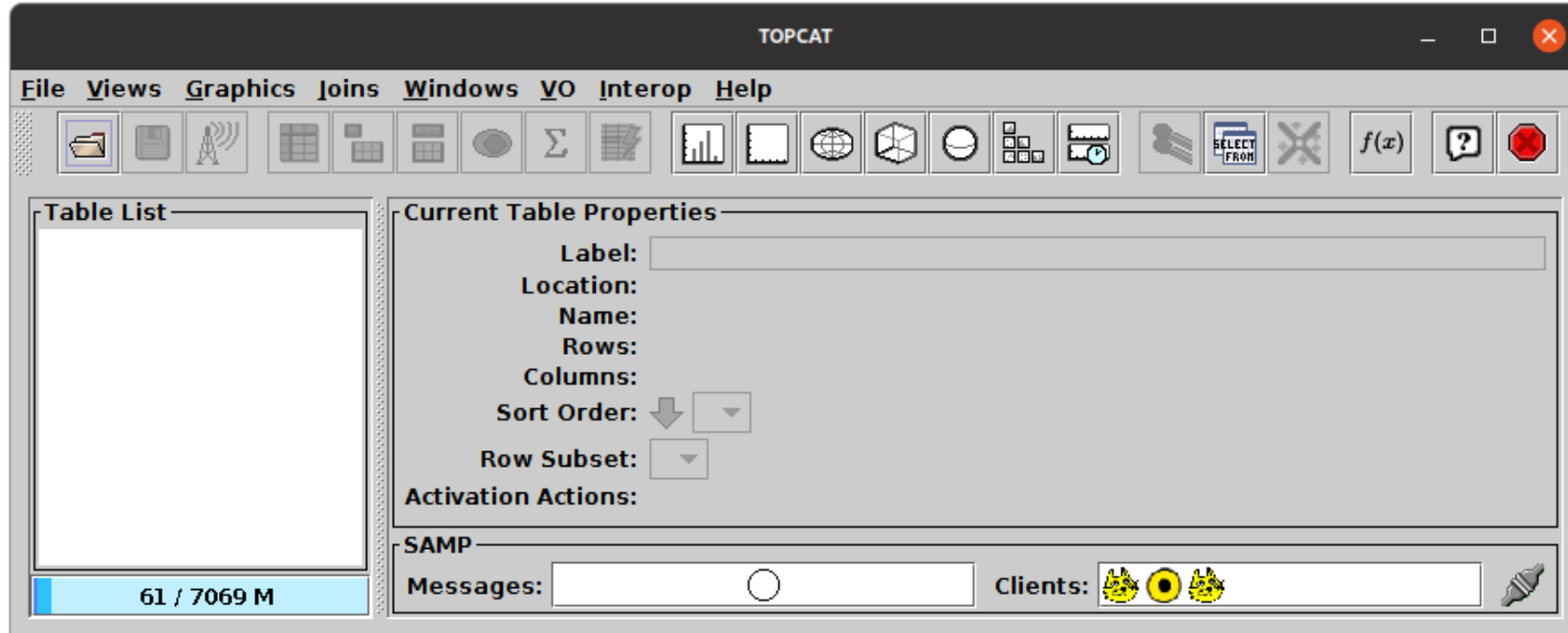
Example 2



Example 2

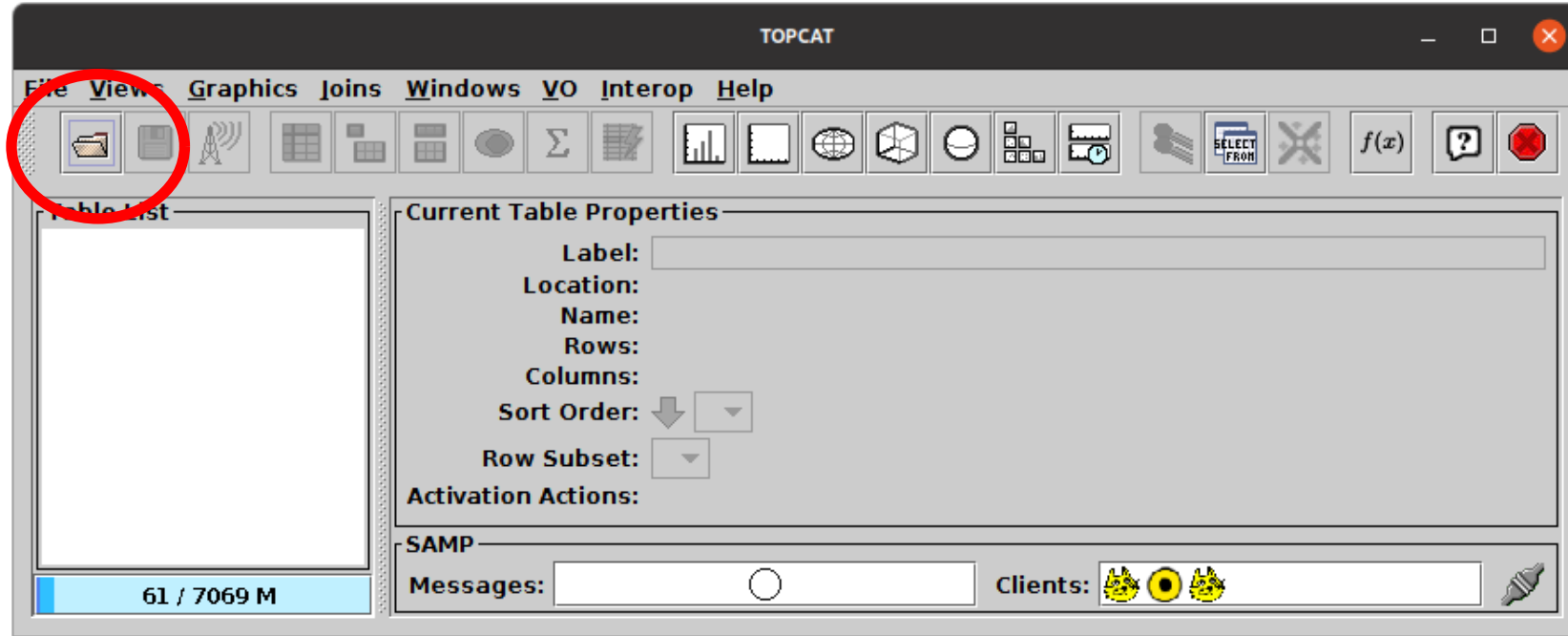


Example 3



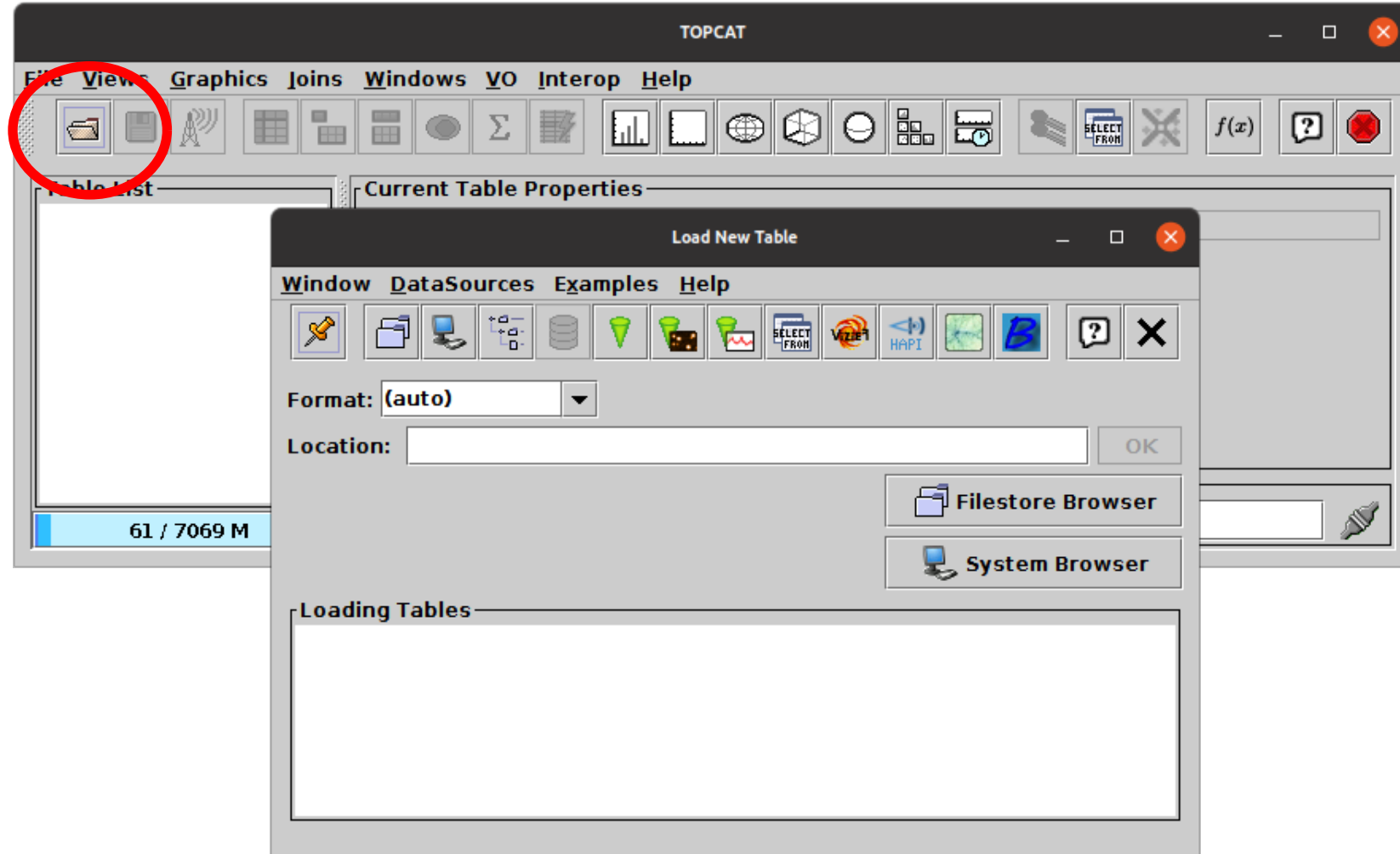
Load data from HAPI service

Example 3



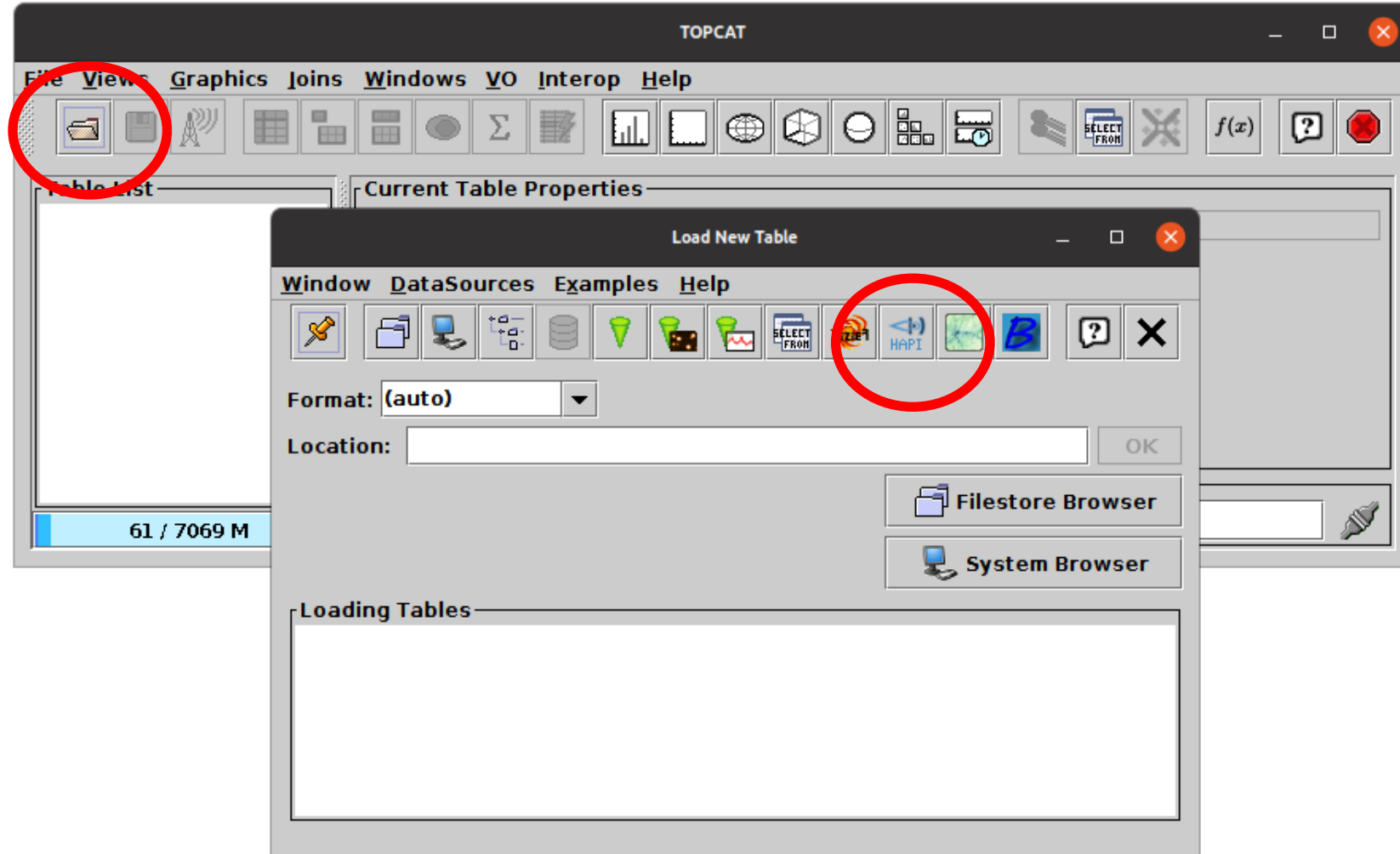
Load data from HAPI service

Example 3



Load data from HAPI service

Example 3



Load data from HAPI service

Example 3

The image shows two overlapping windows from the TOPCAT software. The TOPCAT window is in the background, and the HAPI Query window is in the foreground.

TOPCAT Window:

- The **File** menu is circled in red.
- The **Load New Table** dialog is open, showing the **Window** menu and the **HAPI** icon circled in red.
- The **Format** is set to **(auto)**.
- The **Location** field is empty.
- The **Loading Tables** section is empty.

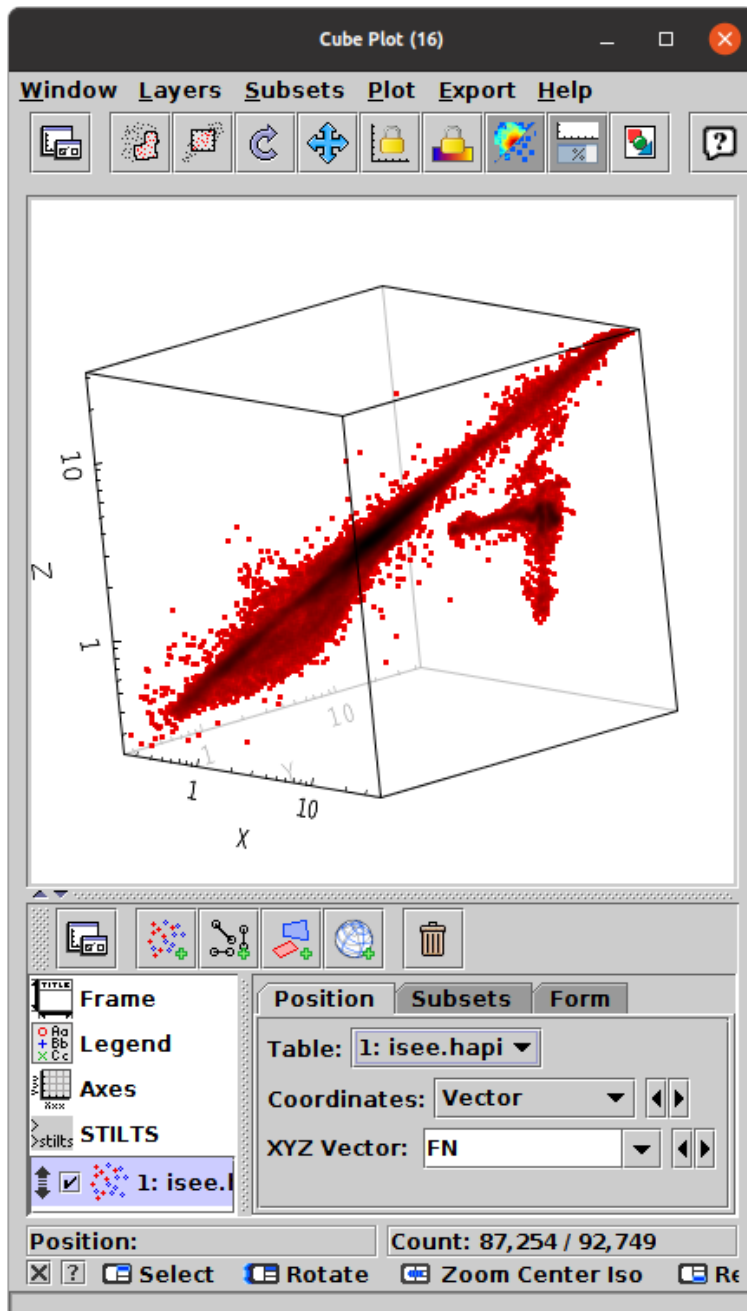
HAPI Query Window:

- Service Selection:**
 - HAPI Server: **CDAWeb**
 - HAPI URL: <https://cdaweb.gsfc.nasa.gov/hapi>
 - Chunk Limit: **1**
- Datasets:**
 - Filter: **isee** (14 / 3401)
 - Selected dataset: **ISEE1_H0_FE**
- Dataset Parameters:**

Include	Name	Type	Size	Units	
☒	Time	isotime	24	UTC	
☐	HARVEY STATUS	integer			Harvey Experiment Status (0 = Off)
☐	MOZER STATUS	integer			Mozzer Experiment Status (0 = Off)
☐	MODE	integer			Instrument Mode
☐	FORMAT	integer			Format
☒	SPIN PERIOD	double		Seconds	Spin Period
☒	THEO_GSE_X	double		km	Spacecraft Position X (GSE)
☒	THEO_GSE_Y	double		km	Spacecraft Position Y (GSE)
☒	THEO_GSE_Z	double		km	Spacecraft Position Z (GSE)
☒	FN	double	[6]	cm ⁻³	Electron density at 0.5 sec resolution
- Dataset Metadata:**
 - Cadence:
 - Max Duration:
 - Resource URL: https://cdaweb.gsfc.nasa.gov/misc/Notes1.html#ISEE1_H0_FE
- Interval:**
 - Start Date: **1979-05-04T13:22:04** >= 1977-10-29T12:41:25Z
 - Stop Date: **1979-06-03T23:59:51Z** <= 1979-06-03T23:59:51Z
 - Timeline: 1978 1979 1sec 1min 1hr 1day 1m 1yr
- OK** button

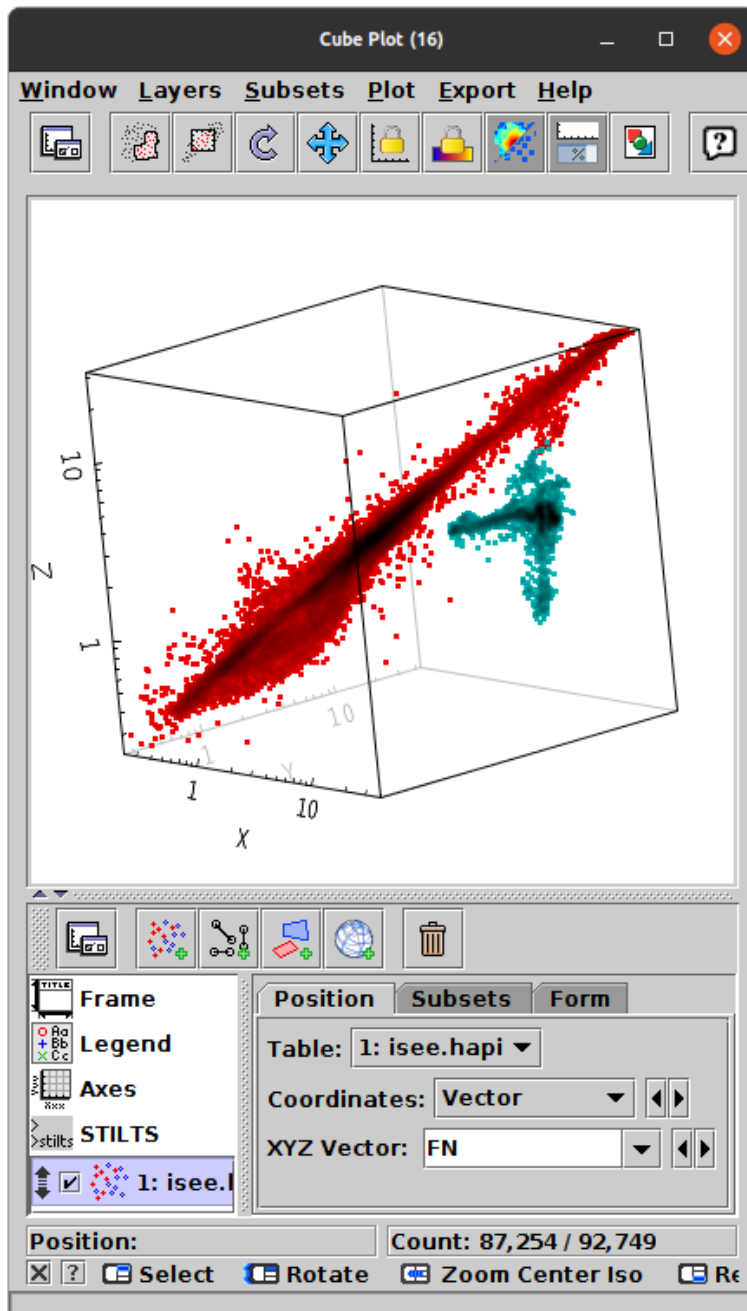
Load data from HAPI service

Example 3



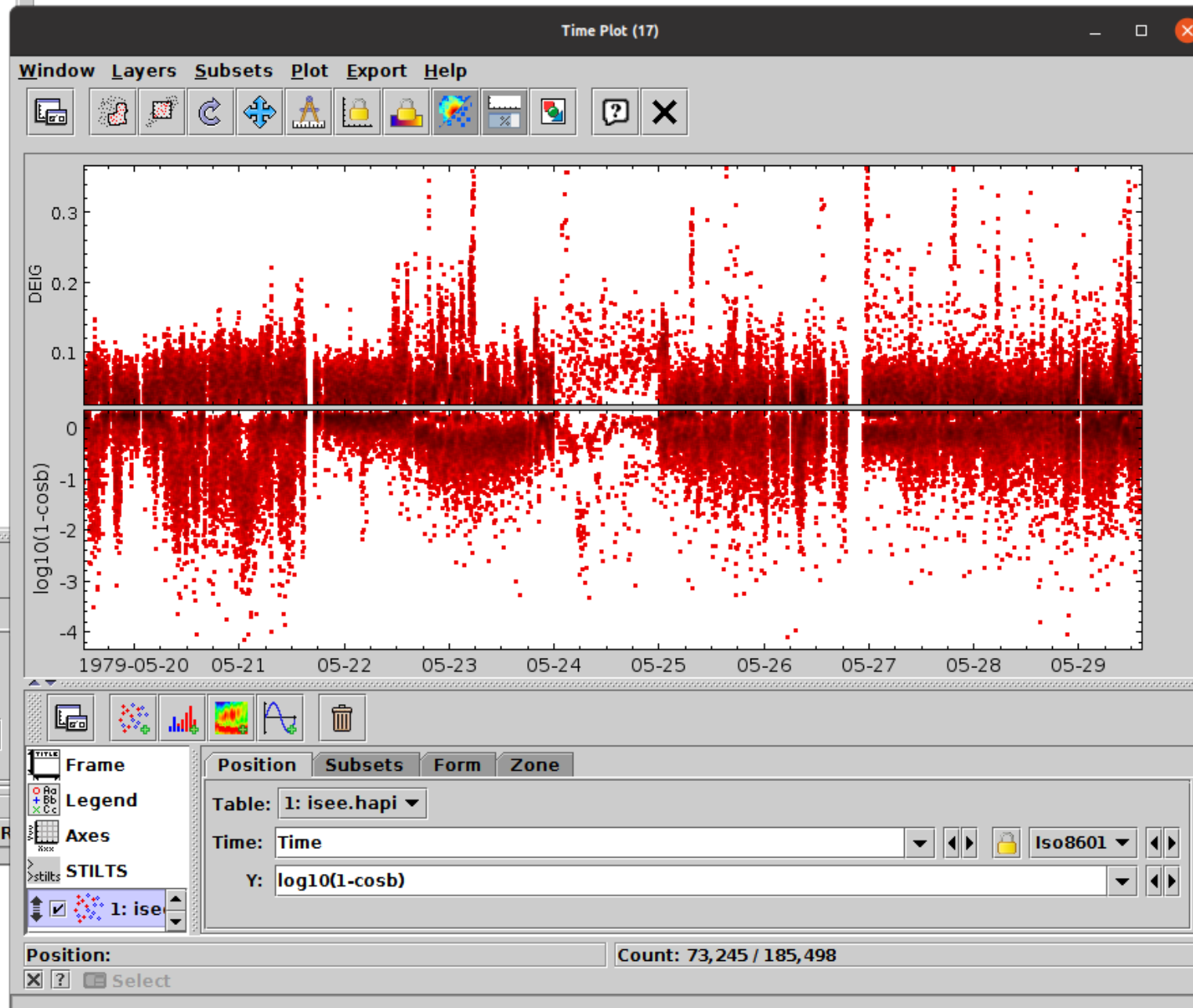
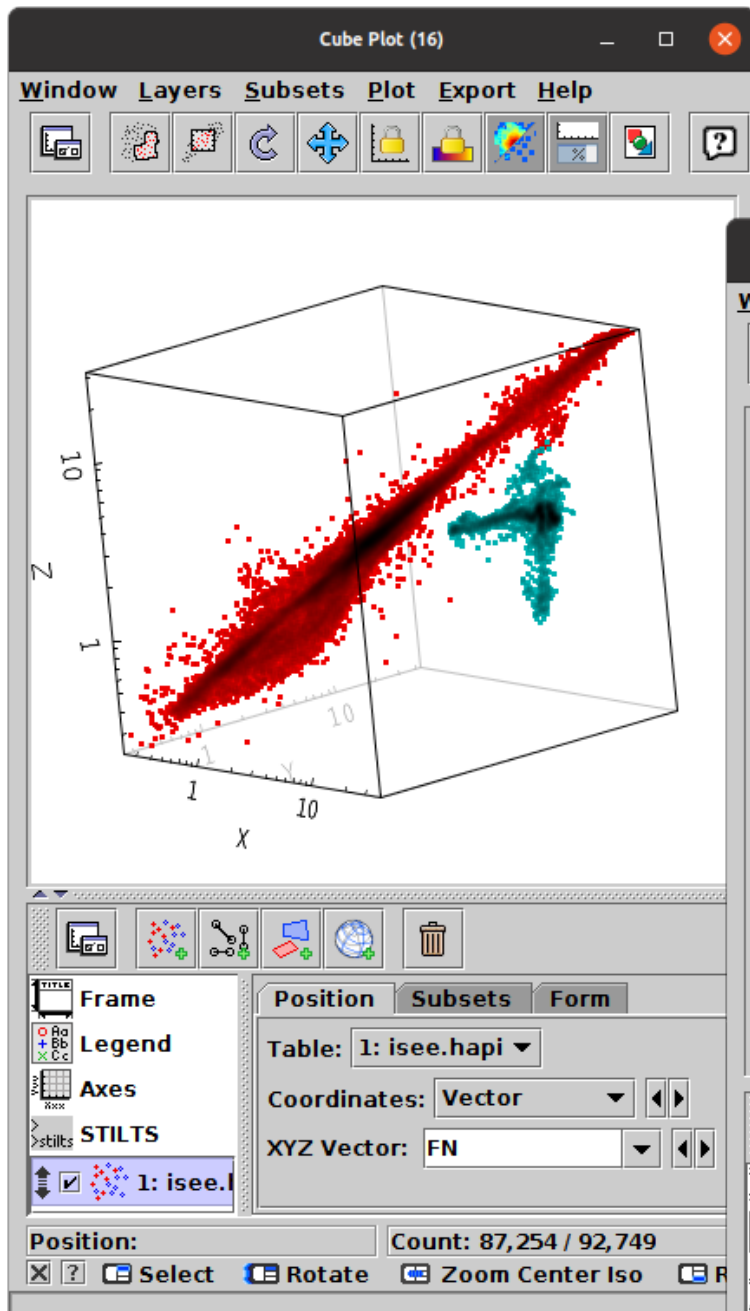
CDAWeb ISEE_H0_FE data

Example 3



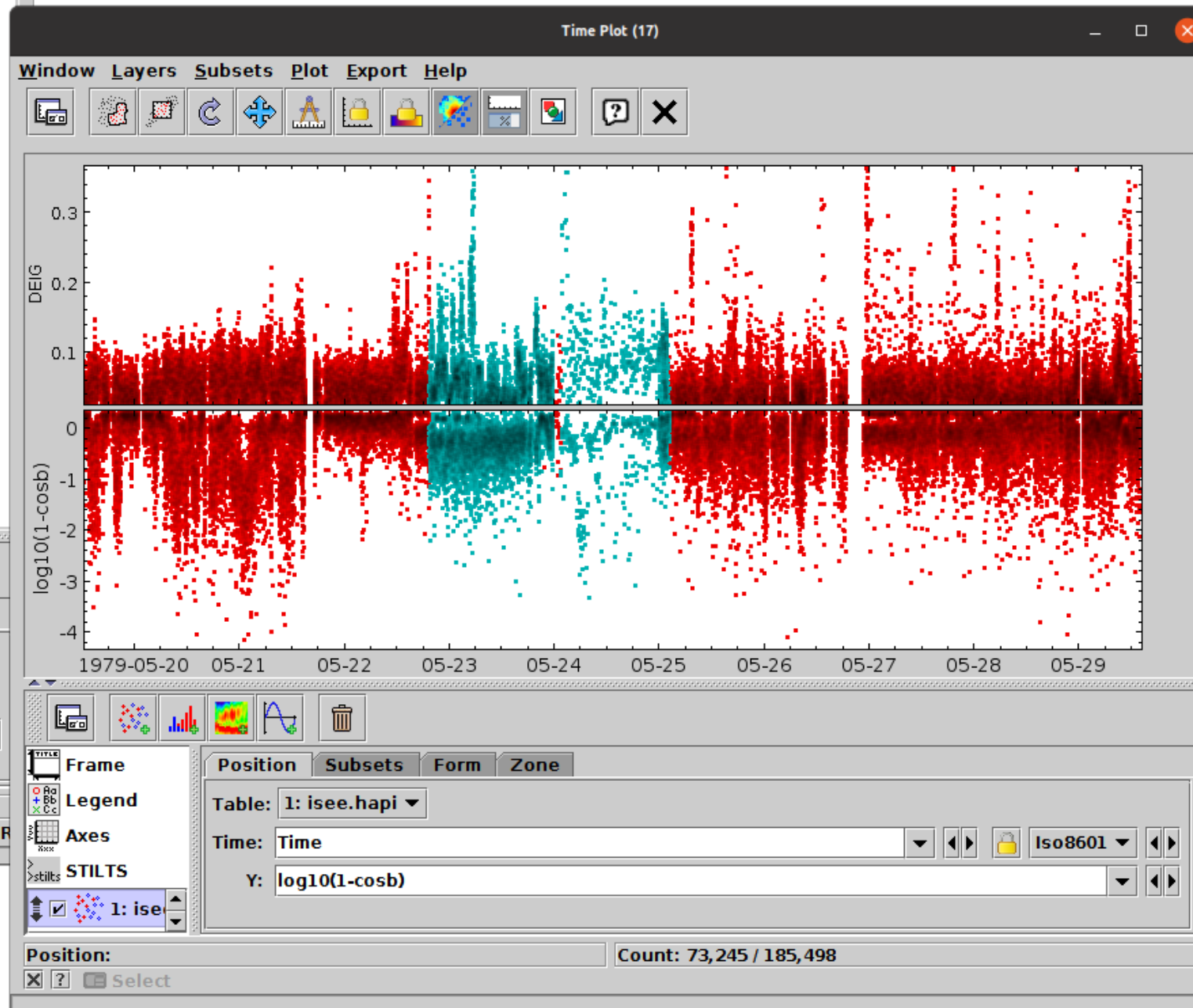
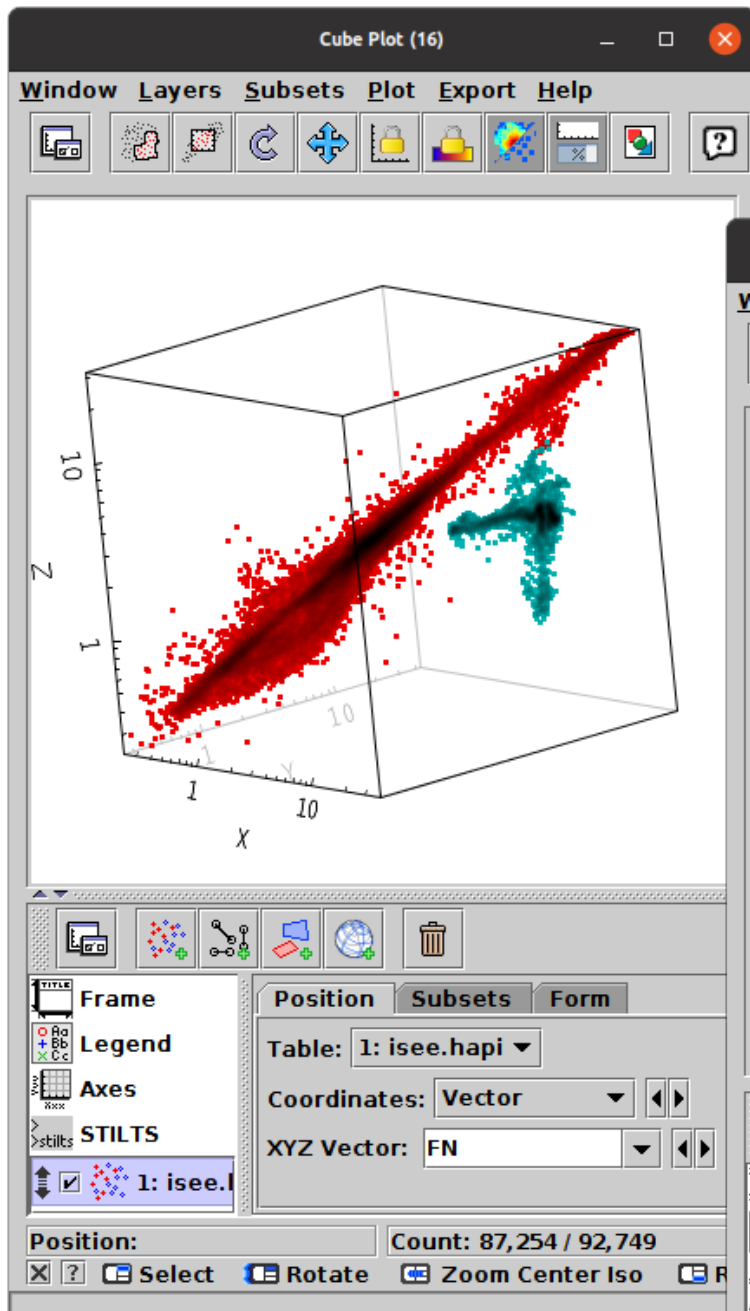
CDAWeb ISEE_H0_FE data

Example 3



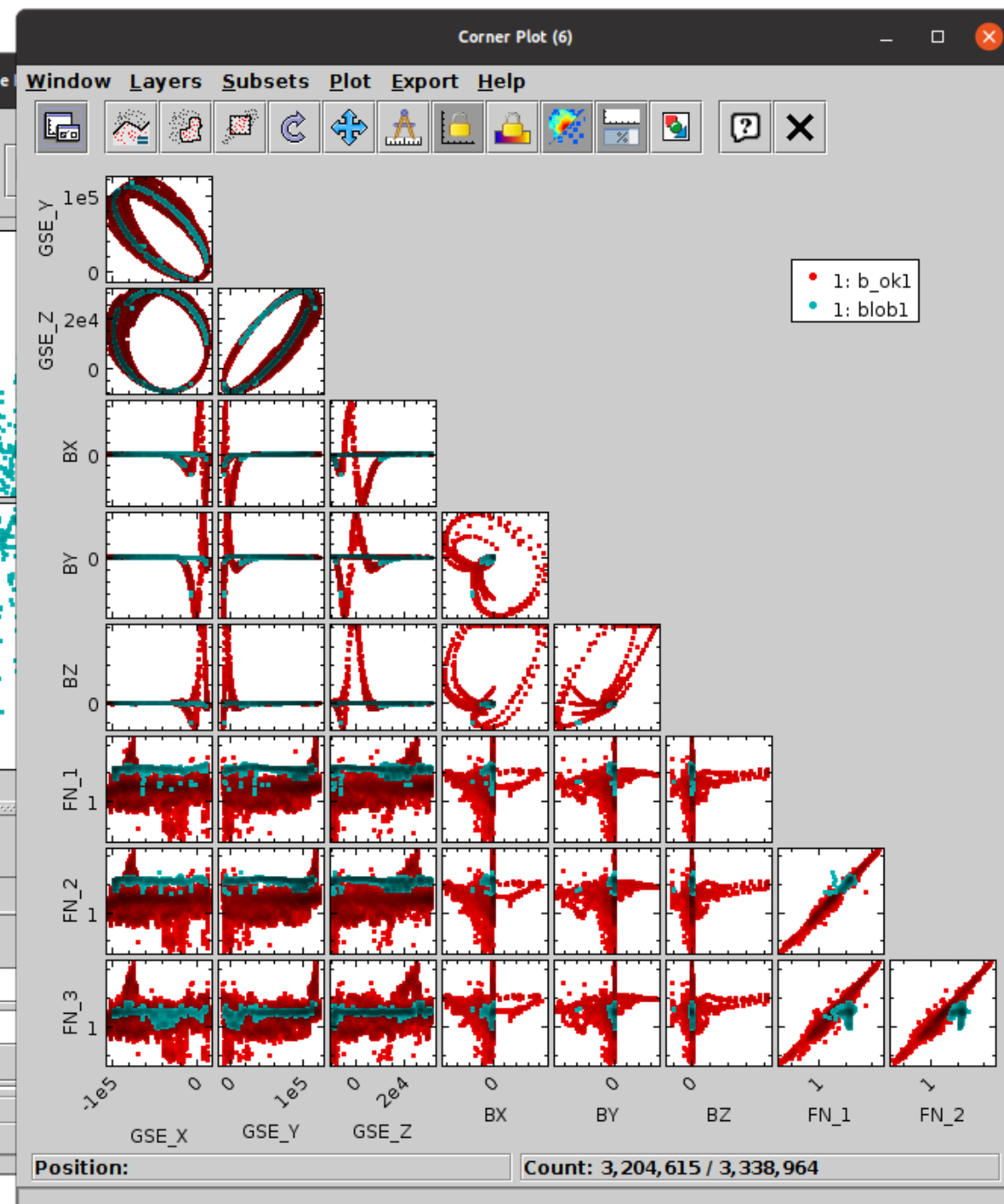
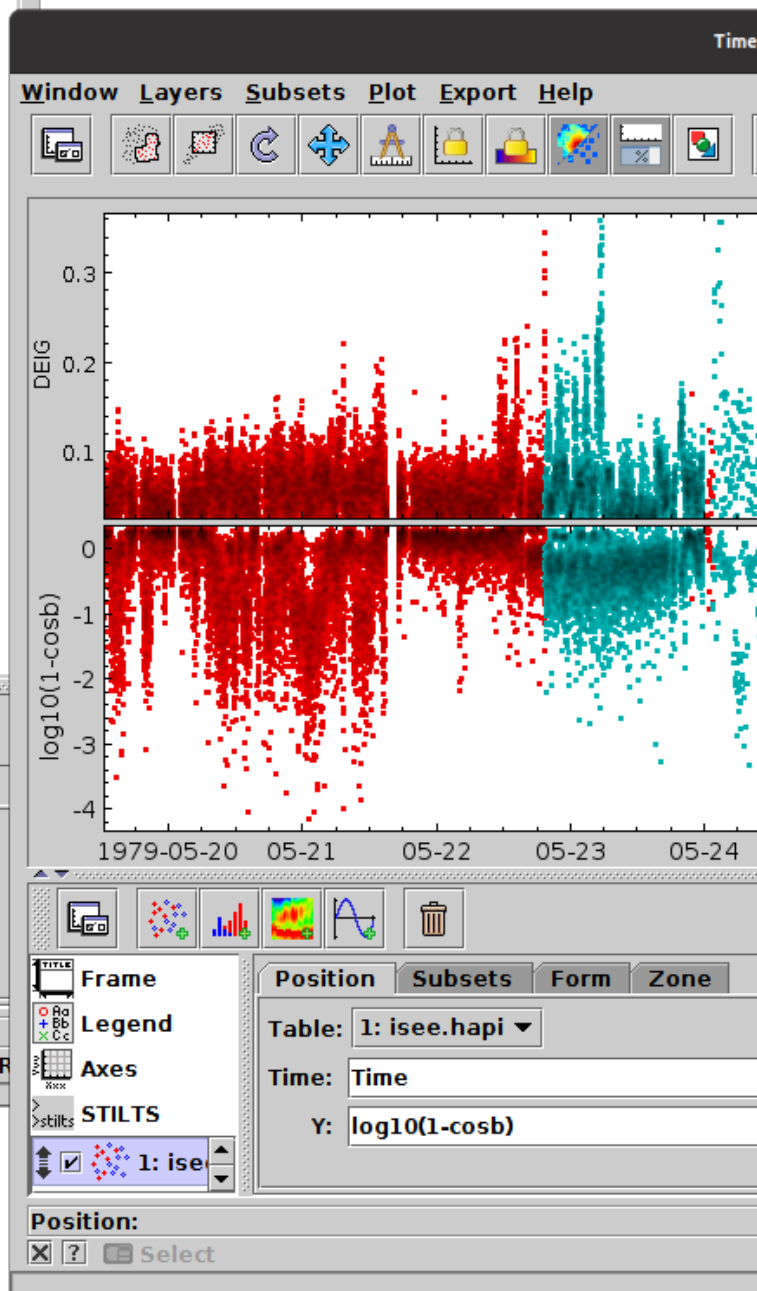
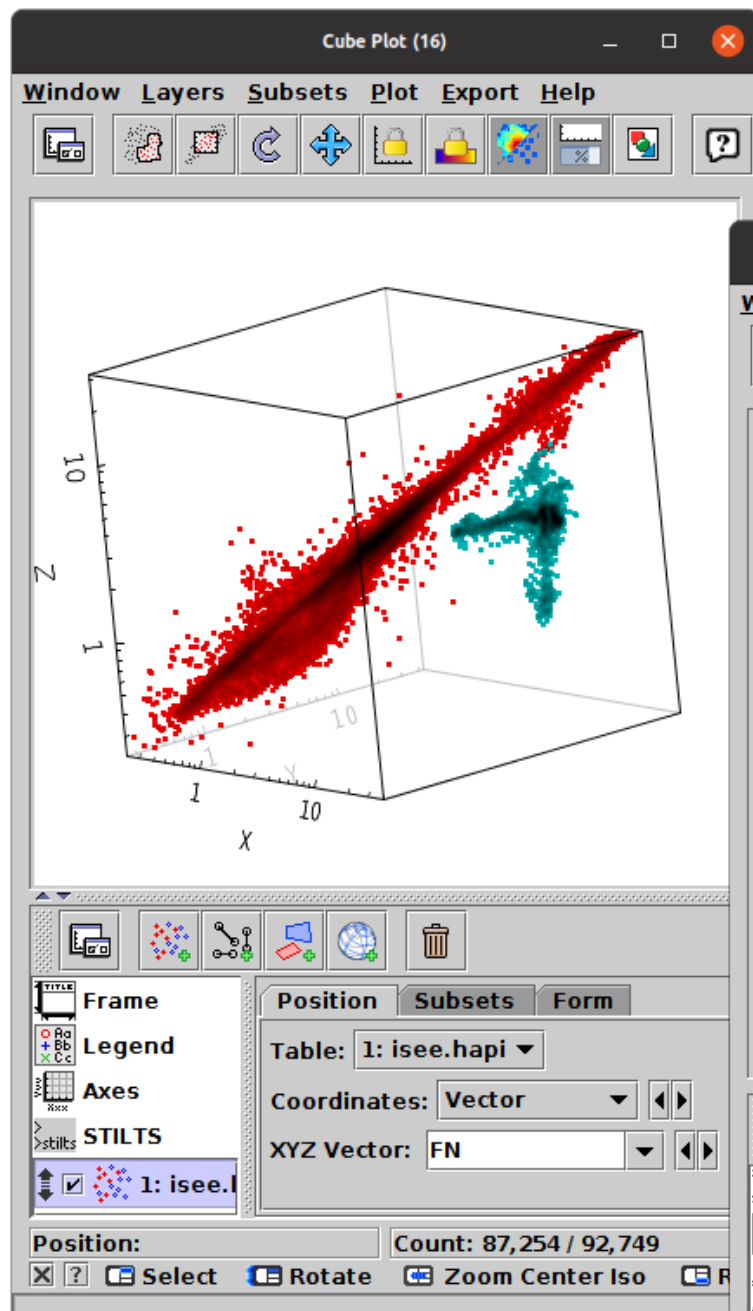
CDAWeb ISEE_H0_FE data

Example 3



CDAWeb ISEE_H0_FE data

Example 3



CDAWeb ISEE_H0_FE data

Summary

TOPCAT (and STILTS) can be useful for working with time series data

- Visualisation
- Format conversions
- HAPI client
- Large (multi-million sample) data sets

... but don't throw away your dedicated time series tools

<http://www.starlink.ac.uk/topcat/>
<http://www.starlink.ac.uk/stilts/>