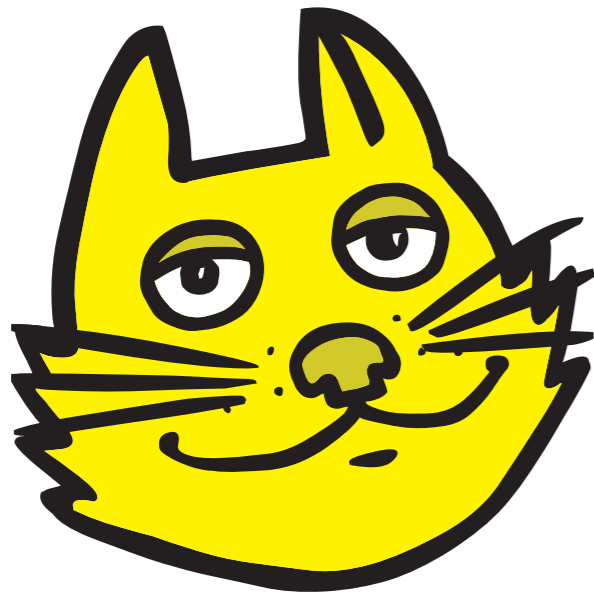


TOPCAT and Gaia XP Spectra



Mark Taylor (University of Bristol)

Applications WG
IVOA Interop
Online

20 October 2022



`$Id: tcxp.tex,v 1.13 2022/10/17 15:40:02 mbt Exp $`

Outline

Working with array-valued data:

- DataLink refresher, Gaia DR3 as example
- Using TOPCAT with DataLink services
 - ▷ Example: DR3 XP spectra using Activation Actions
- Using TOPCAT with array-valued columns
 - ▷ Example: DR3 XP spectra in table rows
- Summary of relevant TOPCAT/STILTS features

XP Sampled Spectra

Gaia XP Sampled Spectra data product, new in Gaia DR3

- Spectral data from BP + RP low-resolution spectrometry instruments
- Reconstructed from XP Continuous Spectra (coefficients)
- Available for 34M / 1.8G sources at DR3
- 343-row wavelength, flux, flux_error tables
- Wavelength values same for all sources

Access

- Delivered only via DataLink from ESA TAP service
- Available in other forms elsewhere

	wavelength <i>nm</i>	flux $Wm^{-2}nm^{-1}$	flux_error $Wm^{-2}nm^{-1}$
1	336.0	1.8571556E-17	9.309491E-18
2	338.0	1.0335697E-17	7.1697286E-18
3	340.0	8.157212E-18	5.6923542E-18
4	342.0	1.1108474E-17	5.036669E-18
5	344.0	1.3550346E-17	4.7585802E-18
6	346.0	1.1722847E-17	4.8270174E-18
7	348.0	8.0488636E-18	5.0007076E-18
8	350.0	7.61149E-18	5.4267143E-18
9	352.0	1.1499628E-17	6.0736378E-18
10	354.0	1.4324368E-17	6.5763125E-18
11	356.0	1.1296319E-17	6.1475095E-18
12	358.0	6.8084405E-18	5.7133638E-18
...
341	1016.0	4.218802E-16	5.3699563E-17
342	1018.0	4.2090065E-16	5.3001684E-17
343	1020.0	4.3125362E-16	5.3213895E-17

DataLink and Gaia DR3

Multiple “ancillary” data products are associated with each DR3 source

- These items are bulky (array-valued) and in general not available in the database (by direct ADQL query)
- Each source may have none, some or all of 6 items:
 - ▷ **XP sampled spectrum**, XP continuous spectrum, RVS spectrum, epoch photometry, MCMC gsphot, MCMC MSC
- There is a (DataLink) **Links Table** associated with each `gaia_source` table row
 - ▷ Each row describes one ancillary product
- How to find the Links Table?
 - ▷ *Either*: From service-specific documentation
 - Gaia DR3 links table URL is <https://gea.esac.esa.int/data-server/datalink/links?ID=<designation>>, where `<designation>` looks like `Gaia+DR3+30343944744320` (see DR3 docs)
 - ▷ *Or*: Use a (DataLink) **Service Descriptor**
 - Returned with result VOTable from suitable VO queries
 - Maps result table row to Links Table URL (using some ID value in the table)
 - For ESA Gaia DR3, query SELECT must include `designation` column (to use as ID)

ID	description	semantics	content_type	access_url
Gaia DR3 30343944744320	MCMC MSC, source Gaia DR3 30343944744320	#this	application/x-votable+xml	https://gea.esac.esa.int/data-server/data?ID=Gaia+DR3+30343944744320&RETRIEVAL_TYPE=MCMC_MSC
Gaia DR3 30343944744320	XP mean sampled spectra, source Gaia DR3 30343944744320	#this	application/x-votable+xml	https://gea.esac.esa.int/data-server/data?ID=Gaia+DR3+30343944744320&RETRIEVAL_TYPE=XP_SAMPLED
Gaia DR3 30343944744320	XP mean continuous spectra, source Gaia DR3 30343944744320	#this	application/x-votable+xml	https://gea.esac.esa.int/data-server/data?ID=Gaia+DR3+30343944744320&RETRIEVAL_TYPE=XP_CONTINUOUS
Gaia DR3 30343944744320	MCMC GSP-Phot, source Gaia DR3 30343944744320	#this	application/x-votable+xml	https://gea.esac.esa.int/data-server/data?ID=Gaia+DR3+30343944744320&RETRIEVAL_TYPE=MCMC_GSPPHOT
Gaia DR3 30343944744320	Epoch photometry, source Gaia DR3 30343944744320	#this	application/x-votable+xml	https://gea.esac.esa.int/data-server/data?ID=Gaia+DR3+30343944744320&RETRIEVAL_TYPE=EPOCH_PHOTOMETRY
Gaia DR3 30343944744320	RVS mean spectra, source Gaia DR3 30343944744320	#this	application/x-votable+xml	https://gea.esac.esa.int/data-server/data?ID=Gaia+DR3+30343944744320&RETRIEVAL_TYPE=RVS

Note: Gaia DR3 is just one (important) example — many other services use DataLink in the same way

TOPCAT and DataLink

TOPCAT features for working with DataLink services:

- Reports Service Descriptors in Parameters Window
- Provides Activation Actions to view/use Links Tables when parent table row is **activated**
 - ▷ **Invoke Service** action displays Links Table located by service descriptor
 - ▷ **View Datalink Table** action displays Links Table given explicit root URL
- Displayed Links Table has options to follow the links in it:
 - ▷ Select data product of interest
 - ▷ Specify an action on that data product (e.g. Load table into TOPCAT, Plot table columns, ...)
 - ▷ When next parent table row (source) is activated, the corresponding row is selected, and action can be auto-invoked

Example: DataLink and Activation Actions

View XP Sampled spectra for points in a plot of interest



Query gaia_source table to plot HR diagram of nearby stars:

```
SELECT designation, source_id, ra, dec, parallax, bp_rp, phot_g_mean_mag,  
       phot_g_mean_mag+5*log10(parallax/100) AS mag_g  
FROM gaiadr3.gaia_source  
WHERE parallax > 10  
      AND parallax_over_error > 10  
      AND phot_bp_mean_flux_over_error > 10  
      AND phot_rp_mean_flux_over_error > 10  
      AND astrometric_excess_noise < 1  
      AND has_xp_sampled = 'true'
```

- ▶ Select on `has_xp_sampled` to ensure spectra are available
- ▶ Must SELECT `designation` to get Service Descriptor

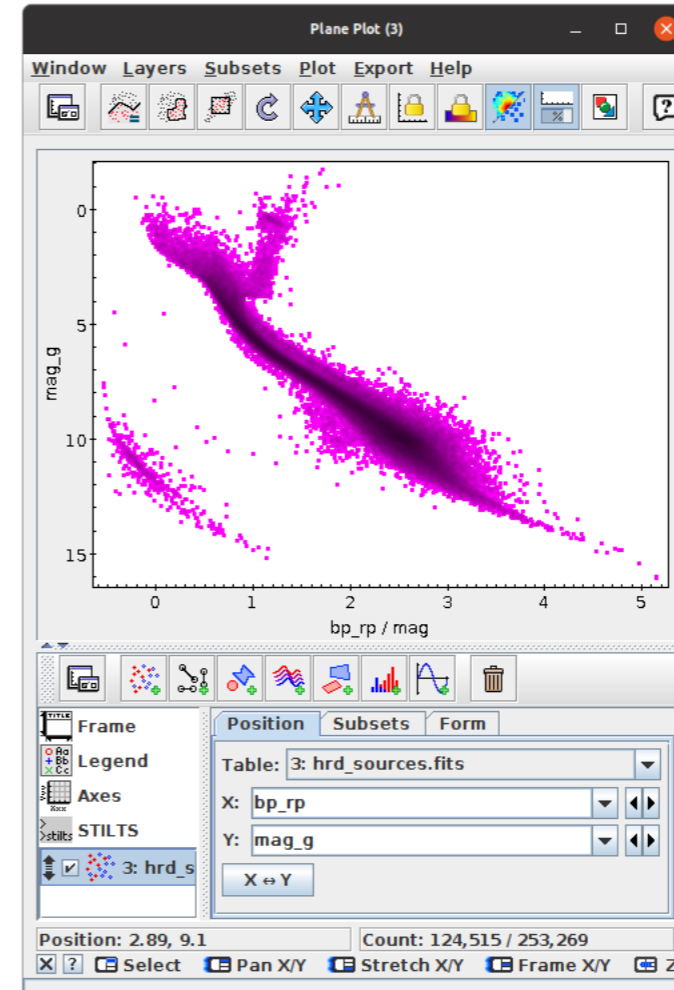


View Service Descriptor in **Parameters Window**



Set up **Activation Action**

- ▶ Select checkbox for **Invoke Service**
- ▶ Service **Action** is **View DataLink Table**
- ▶ Select **XP mean sampled spectra** row of DataLink table
- ▶ Configure to **Plot Table** on DataLink load and **Auto-Invoke**
- ▶ Set up plot to taste
 - clicking on point in plot displays spectrum
(works best with TOPCAT v4.8-6 or later)



Example: DataLink and Activation Actions

View XP Sampled spectra for points in a plot of interest



Query `gaiadr3.gaiadr3.gaia_source` table to plot HR diagram of nearby stars:

```
SELECT designation, source_id, ra, dec, parallax, bp_rp, phot_g_mean_mag,
       phot_g_mean_mag+5*log10(parallax/100) AS mag_g
FROM gaiadr3.gaiadr3.gaia_source
WHERE parallax > 10
      AND parallax_over_error > 10
      AND phot_bp_mean_flux_over_error > 10
      AND phot_rp_mean_flux_over_error > 10
      AND astrometric_excess_noise < 1
      AND has_xp_sampled = 'true'
```

- ▶ Select on `has_xp_sampled` to ensure spectra are available
- ▶ Must **SELECT** `designation` to get Service Descriptor



View Service Descriptor in **Parameters Window**



Set up **Activation Action**

- ▶ Select checkbox for **Invoke Service**
- ▶ Service **Action** is **View DataLink Table**
- ▶ Select **XP mean sampled spectra** row of DataLink table
- ▶ Configure to **Plot Table** on DataLink load and **Auto-Invoke**
- ▶ Set up plot to taste
→ clicking on point in plot displays spectrum
(works best with TOPCAT v4.8-6 or later)

The image shows two overlapping windows from the TOPCAT software. The background window is titled "Plane Plot (3)" and displays a scatter plot of stars. The vertical axis is labeled "mag_g" and ranges from 0 to 15. The horizontal axis is labeled "0" at the origin. The plot shows a dense sequence of purple points forming a curve, characteristic of a Hertzsprung-Russell diagram. The foreground window is titled "TOPCAT(3): Table Parameters" and shows the configuration for a table named "TAP_3_gaiadr3.gaia_source". It includes a table with columns for Name and Value, and a section for Service Descriptor configuration.

Name	Value
Name	sync
Column Count	8
Row Count	124515
QUERY_STATUS	OK
QUERY	SELECT designation, source_id, ra, dec, par...
CAPTION	How to cite and acknowledge Gaia: https://...
PAGE	
PAGE_SIZE	
JOBID	16655789168250
JOBNAME	16655789168250
Service_ancillary	accessURL: https://gea.esac.esa.int/data-s... Service Descriptor: Retrieve Data

Service Descriptor configuration:

Name: Service_ancillary
Class: ServiceDescriptor
Shape:
Units:
Description: Service Descriptor: Retrieve DataLink file containing ancillary data for source
UCD:
Utype:
Value:
accessURL: https://gea.esac.esa.int/data-server/datalink/links
standardId: ivo://ivoa.net/std/DataLink#links-1.0
Input parameters: ID (column=designation)

Example: DataLink and Activation Actions

View XP Sampled spectra for points in a plot of interest



Query gaia_source table to plot HR diagram of nearby stars:

```
SELECT designation, source_id, ra, dec, parallax, bp_rp, phot_g_mean_mag,  
       phot_g_mean_mag+5*log10(parallax/100) AS mag_g  
FROM gaiadr3.gaia_source  
WHERE parallax > 10  
      AND parallax_over_error > 10  
      AND phot_bp_mean_flux_over_error > 10  
      AND phot_rp_mean_flux_over_error > 10  
      AND astrometric_excess_noise < 1  
      AND has_xp_sampled = 'true'
```

- ▶ Select on `has_xp_sampled` to ensure spectra are available
- ▶ Must SELECT `designation` to get Service Descriptor

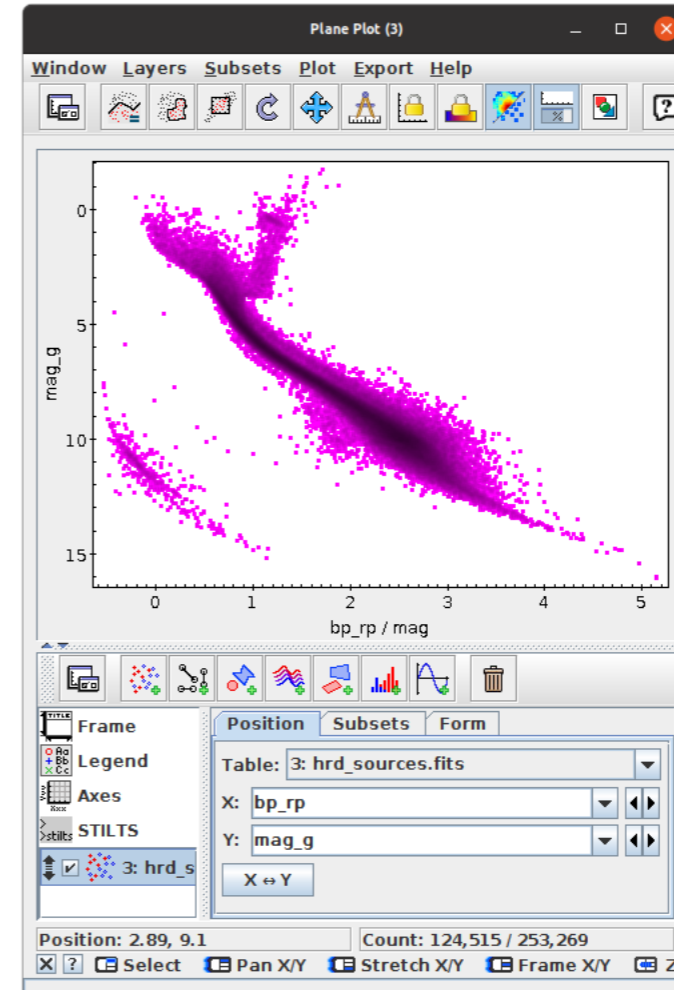


View Service Descriptor in **Parameters Window**



Set up **Activation Action**

- ▶ Select checkbox for **Invoke Service**
- ▶ Service **Action** is **View DataLink Table**
- ▶ Select **XP mean sampled spectra** row of DataLink table
- ▶ Configure to **Plot Table** on DataLink load and **Auto-Invoke**
- ▶ Set up plot to taste
 - clicking on point in plot displays spectrum
(works best with TOPCAT v4.8-6 or later)



Example: DataLink and Activation Actions

View XP Sampled spectra for points in a plot of interest



Query gaia_source table to plot HR diagram of nearby stars:

```
SELECT designation, source_id, ra, dec, parallax, bp_rp, phot_g_mean_mag,  
       phot_g_mean_mag+5*log10(parallax/100) AS mag_g  
FROM gaiadr3.gaia_source  
WHERE parallax > 10  
      AND parallax_over_error > 10  
      AND phot_bp_mean_flux_over_error > 10  
      AND phot_rp_mean_flux_over_error > 10  
      AND astrometric_excess_noise < 1  
      AND has_xp_sampled = 'true'
```

- ▶ Select on `has_xp_sampled` to ensure spectra are available
- ▶ Must SELECT `designation` to get Service Descriptor

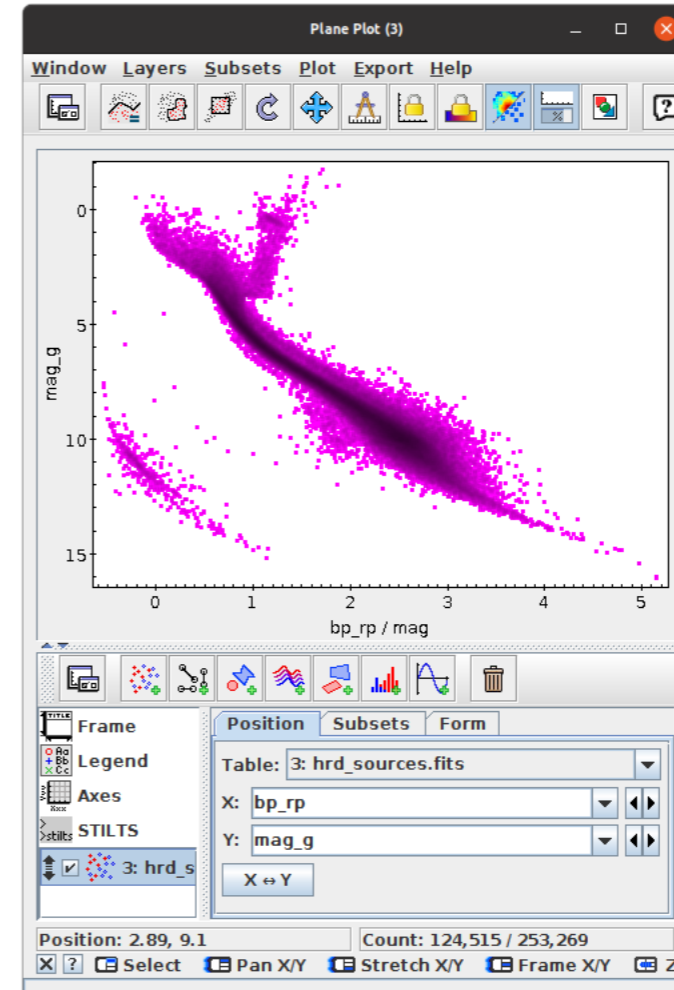


View Service Descriptor in **Parameters Window**



Set up **Activation Action**

- ▶ Select checkbox for **Invoke Service**
- ▶ Service **Action** is **View DataLink Table**
- ▶ Select **XP mean sampled spectra** row of DataLink table
- ▶ Configure to **Plot Table** on DataLink load and **Auto-Invoke**
- ▶ Set up plot to taste
 - clicking on point in plot displays spectrum
(works best with TOPCAT v4.8-6 or later)



Example: DataLink and Activation Actions

View XP Sampled spectra for points in a plot of interest



Query gaia_source table to plot HR diagram of nearby stars:

```
SELECT designation, source_id, ra, dec, parallax, bp_rp, phot_g_mean_mag,  
       phot_g_mean_mag+5*log10(parallax/100) AS mag_g  
FROM gaiadr3.gaia_source  
WHERE parallax > 10  
      AND parallax_over_error > 10  
      AND phot_bp_mean_flux_over_error > 10  
      AND phot_rp_mean_flux_over_error > 10  
      AND astrometric_excess_noise < 1  
      AND has_xp_sampled = 'true'
```

- ▶ Select on `has_xp_sampled` to ensure spectra are available
- ▶ Must SELECT `designation` to get Service Descriptor

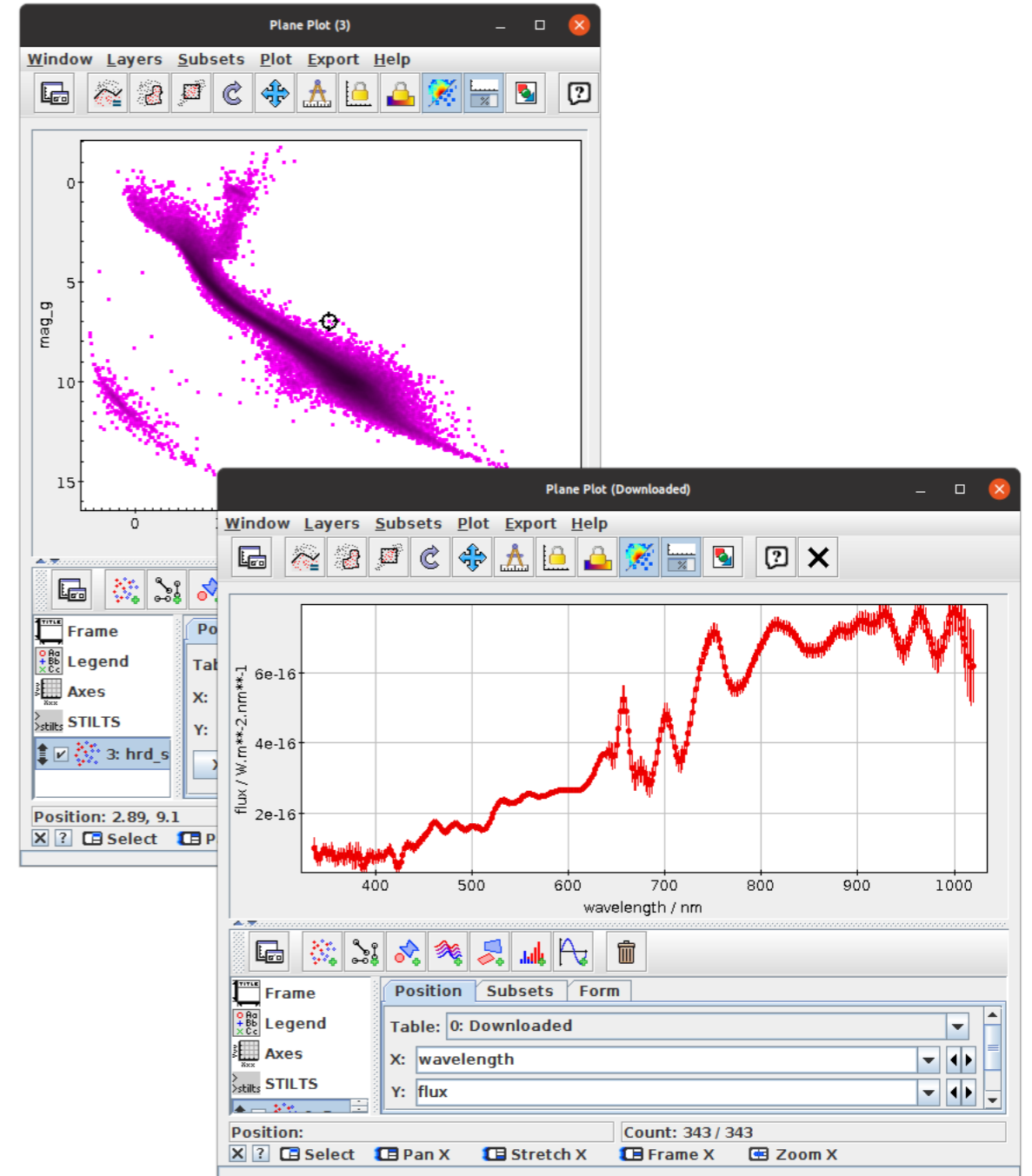


View Service Descriptor in **Parameters Window**



Set up **Activation Action**

- ▶ Select checkbox for **Invoke Service**
- ▶ Service **Action** is **View DataLink Table**
- ▶ Select **XP mean sampled spectra** row of DataLink table
- ▶ Configure to **Plot Table** on DataLink load and **Auto-Invoke**
- ▶ Set up plot to taste
 - clicking on point in plot displays spectrum
(works best with TOPCAT v4.8-6 or later)



Example: DataLink and Activation Actions

View XP Sampled spectra for points in a plot of interest



Query gaia_source table to plot HR diagram of nearby stars:

```
SELECT designation, source_id, ra, dec, parallax, bp_rp, phot_g_mean_mag,  
       phot_g_mean_mag+5*log10(parallax/100) AS mag_g  
FROM gaiadr3.gaia_source  
WHERE parallax > 10  
      AND parallax_over_error > 10  
      AND phot_bp_mean_flux_over_error > 10  
      AND phot_rp_mean_flux_over_error > 10  
      AND astrometric_excess_noise < 1  
      AND has_xp_sampled = 'true'
```

- ▶ Select on `has_xp_sampled` to ensure spectra are available
- ▶ Must SELECT `designation` to get Service Descriptor

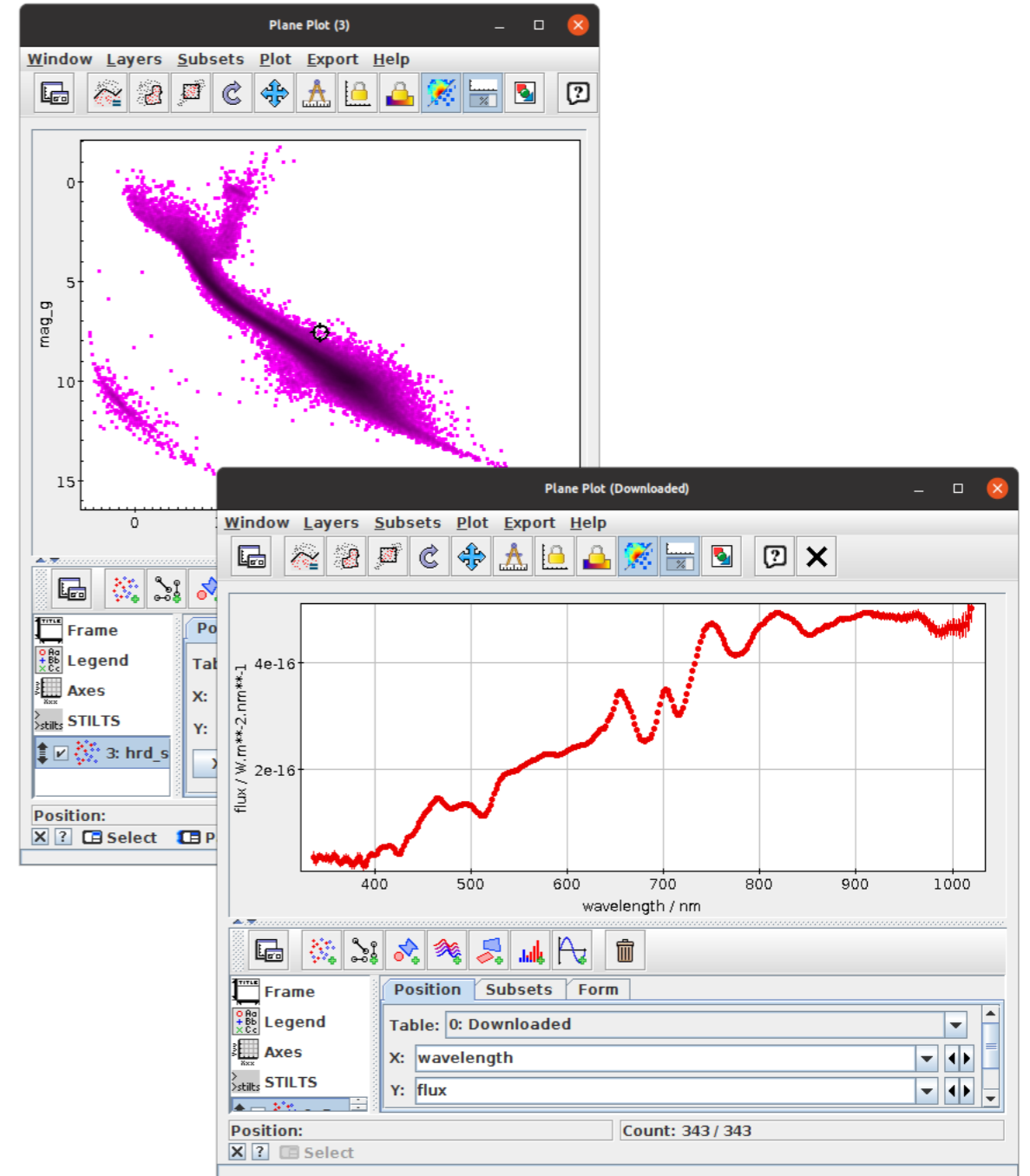


View Service Descriptor in **Parameters Window**



Set up **Activation Action**

- ▶ Select checkbox for **Invoke Service**
- ▶ Service **Action** is **View DataLink Table**
- ▶ Select **XP mean sampled spectra** row of DataLink table
- ▶ Configure to **Plot Table** on DataLink load and **Auto-Invoke**
- ▶ Set up plot to taste
 - clicking on point in plot displays spectrum
(works best with TOPCAT v4.8-6 or later)



Example: DataLink and Activation Actions

View XP Sampled spectra for points in a plot of interest



Query gaia_source table to plot HR diagram of nearby stars:

```
SELECT designation, source_id, ra, dec, parallax, bp_rp, phot_g_mean_mag,
       phot_g_mean_mag+5*log10(parallax/100) AS mag_g
FROM gaiadr3.gaia_source
WHERE parallax > 10
      AND parallax_over_error > 10
      AND phot_bp_mean_flux_over_error > 10
      AND phot_rp_mean_flux_over_error > 10
      AND astrometric_excess_noise < 1
      AND has_xp_sampled = 'true'
```

- ▶ Select on `has_xp_sampled` to ensure spectra are available
- ▶ Must SELECT `designation` to get Service Descriptor

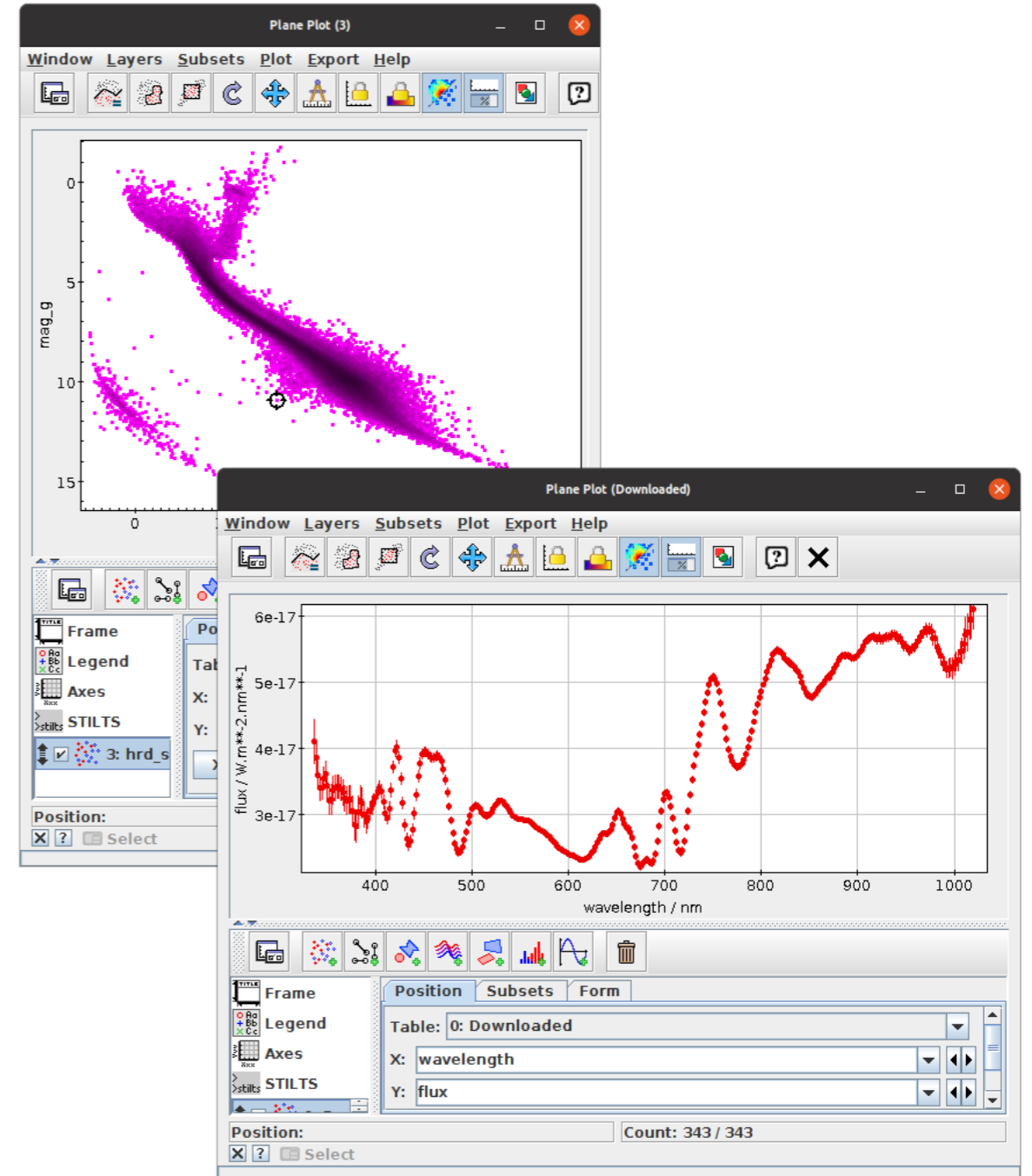


View Service Descriptor in **Parameters Window**



Set up **Activation Action**

- ▶ Select checkbox for **Invoke Service**
- ▶ Service **Action** is **View DataLink Table**
- ▶ Select **XP mean sampled spectra** row of DataLink table
- ▶ Configure to **Plot Table** on DataLink load and **Auto-Invoke**
- ▶ Set up plot to taste
 - clicking on point in plot displays spectrum
 - (works best with TOPCAT v4.8-6 or later)



Example: DataLink and Activation Actions

View XP Sampled spectra for points in a plot of interest



Query gaia_source table to plot HR diagram of nearby stars:

```
SELECT designation, source_id, ra, dec, parallax, bp_rp, phot_g_mean_mag,  
       phot_g_mean_mag+5*log10(parallax/100) AS mag_g  
FROM gaiadr3.gaia_source  
WHERE parallax > 10  
      AND parallax_over_error > 10  
      AND phot_bp_mean_flux_over_error > 10  
      AND phot_rp_mean_flux_over_error > 10  
      AND astrometric_excess_noise < 1  
      AND has_xp_sampled = 'true'
```

- ▶ Select on `has_xp_sampled` to ensure spectra are available
- ▶ Must SELECT `designation` to get Service Descriptor

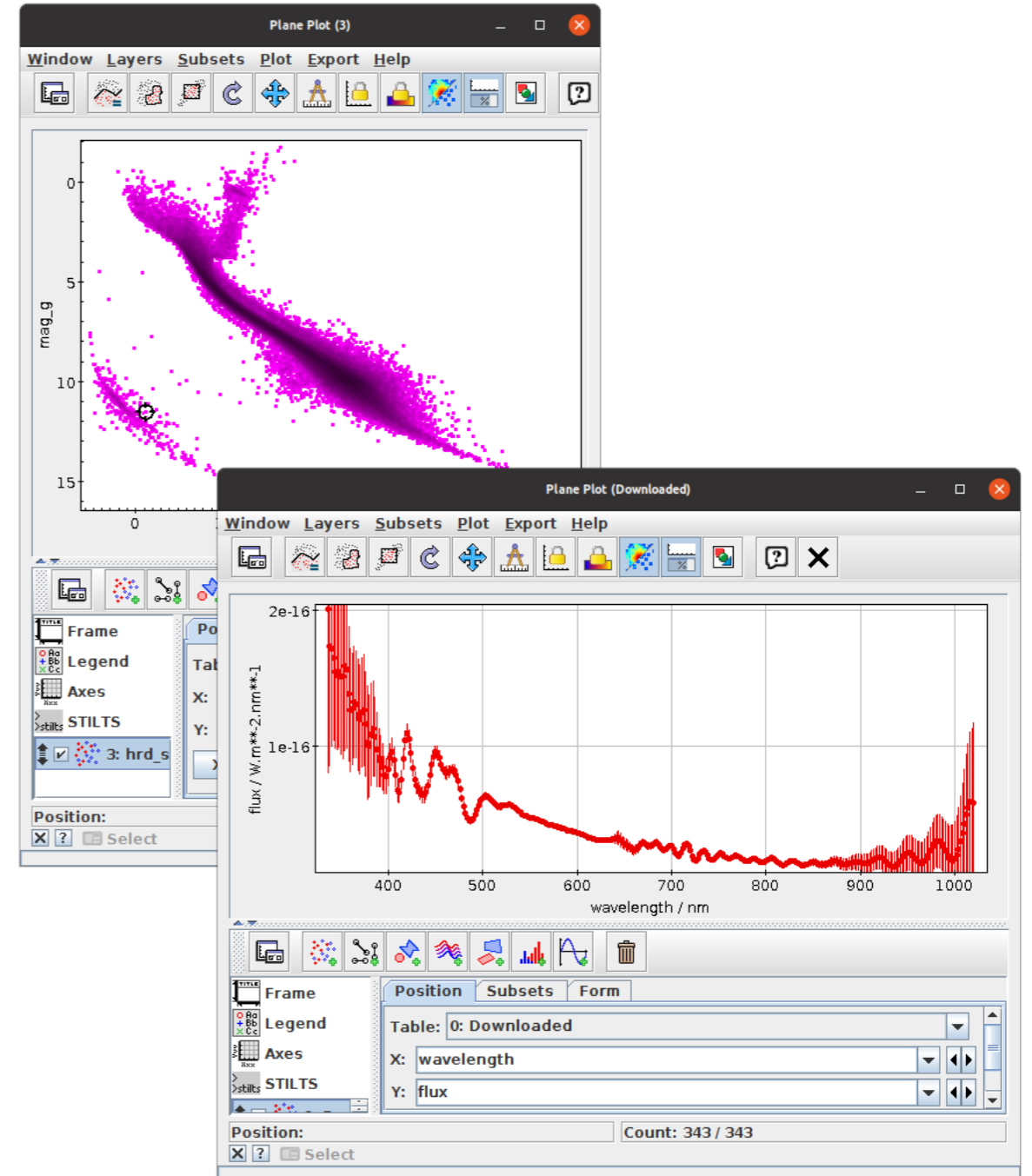


View Service Descriptor in **Parameters Window**



Set up **Activation Action**

- ▶ Select checkbox for **Invoke Service**
- ▶ Service **Action** is **View DataLink Table**
- ▶ Select **XP mean sampled spectra** row of DataLink table
- ▶ Configure to **Plot Table** on DataLink load and **Auto-Invoke**
- ▶ Set up plot to taste
 - clicking on point in plot displays spectrum
(works best with TOPCAT v4.8-6 or later)



Spectra as Arrays

Working with multiple spectra

- DataLink works fine for looking at one spectrum at a time
- Sometimes you want to manipulate (e.g. visualise) multiple spectra at once
- To do that in TOPCAT you need array-valued columns
 - ▷ One spectrum per row
 - ▷ `fluxes` column and maybe matching `wavelengths` and `flux_errors` columns (same number of elements in each array)

How to get tables with spectra as array columns? Options for Gaia DR3 XP spectra:

- Use STILTS `arrayjoin` command (form of spectrum URLs is from [ESA DataLink service docs](#)) — requires STILTS \geq v3.4-6
 - ▷ For each row, adds N -element array-valued columns `wavelength`, `flux`, `flux_error` from N -row downloaded XP table

```
stilts arrayjoin in=dr3-sources.vot \  
                atable="https://gea.esac.esa.int/data-server/data?RETRIEVAL_TYPE=XP_SAMPLED&RELEASE=Gaia+DR3&ID="+source_id' \  
                icmd=progress \  
                out=sources-with-xp.fits
```

- ARI-Gaia TAP service has table `gaiadr3.xp_sampled_mean_spectrum` (though ESA Gaia TAP service does not)

- ▷ Array-valued `flux` and `flux_error` columns are available in the database

```
SELECT source_id, ra, dec, parallax, flux, flux_error, ...  
FROM gaiadr3.xp_sampled_mean_spectrum  
NATURAL JOIN gaiadr3.gaia_source  
WHERE ...
```

- ▷ Can use expression `sequence(343,336.0,2)` for wavelength array

- See also `gedr3spec` tables in GAVO DC TAP service (lower resolution spectra, but for more sources)

Example: Spectra as Arrays



Get some White Dwarf spectra

```
SELECT source_id, bp_rp, phot_g_mean_mag+5*log10(parallax/100) AS g_abs
FROM gaiadr3.gaia_source
WHERE parallax > 10 AND parallax_over_error > 10
  AND phot_bp_mean_flux_over_error > 10 AND phot_rp_mean_flux_over_error > 10
  AND astrometric_excess_noise < 1
  AND has_xp_sampled = 'true'
  AND bp_rp BETWEEN -0.63 AND 1.21
  AND phot_g_mean_mag+5*log10(parallax/100) BETWEEN 7.4 AND 15.5

stilts arrayjoin in=wd_hrd.fits icmd=progress out=wd_spectra.fits \
  atable="https://gea.esac.esa.int/data-server/data?RETRIEVAL_TYPE=XP_SAMPLED&RELEASE=Gaia+DR3&ID="+source_id'
```



View them using the XYArray plot

- Use array functions to normalise them
 - If X Values are blank, array index is used instead
 - Plot mean spectra etc using **StatLine/StatMark** form
 - Linked views using subsets
 - To highlight activated row, use **Activated** subset
 - To select single/multiple rows from plot, use **Handles** layer
- (most of these features require recent versions)

Example: Spectra as Arrays



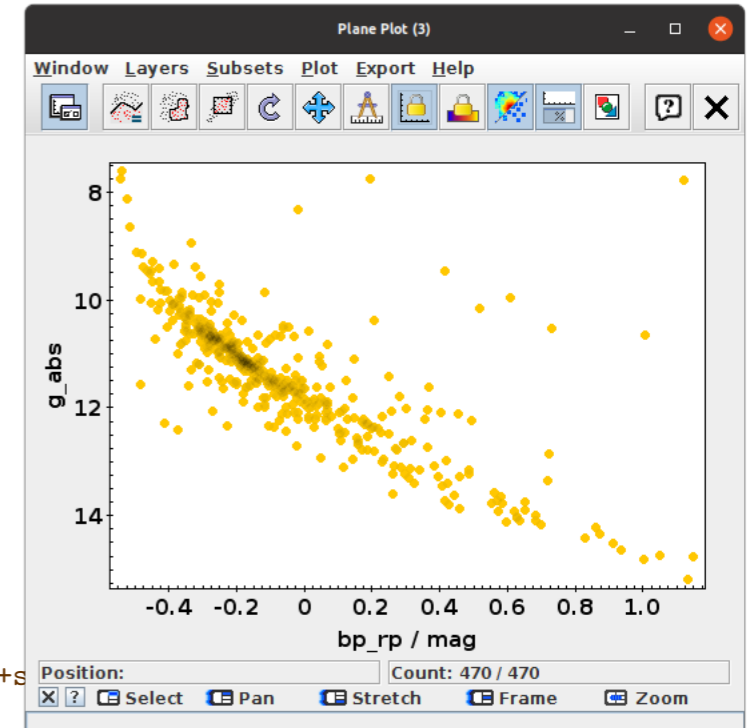
Get some White Dwarf spectra

```
SELECT source_id, bp_rp, phot_g_mean_mag+5*log10(parallax/100) AS g_abs
FROM gaiadr3.gaia_source
WHERE parallax > 10 AND parallax_over_error > 10
  AND phot_bp_mean_flux_over_error > 10 AND phot_rp_mean_flux_over_error > 10
  AND astrometric_excess_noise < 1
  AND has_xp_sampled = 'true'
  AND bp_rp BETWEEN -0.63 AND 1.21
  AND phot_g_mean_mag+5*log10(parallax/100) BETWEEN 7.4 AND 15.5
stilts arrayjoin in=wd_hrd.fits icmd=progress out=wd_spectra.fits \
  atable="https://gea.esac.esa.int/data-server/data?RETRIEVAL_TYPE=XP_SAMPLED&RELEASE=Gaia+DR3&ID="+s
```



View them using the XYArray plot

- Use array functions to normalise them
- If X Values are blank, array index is used instead
- Plot mean spectra etc using **StatLine/StatMark** form
- Linked views using subsets
- To highlight activated row, use **Activated** subset
- To select single/multiple rows from plot, use **Handles** layer
(most of these features require recent versions)



Example: Spectra as Arrays



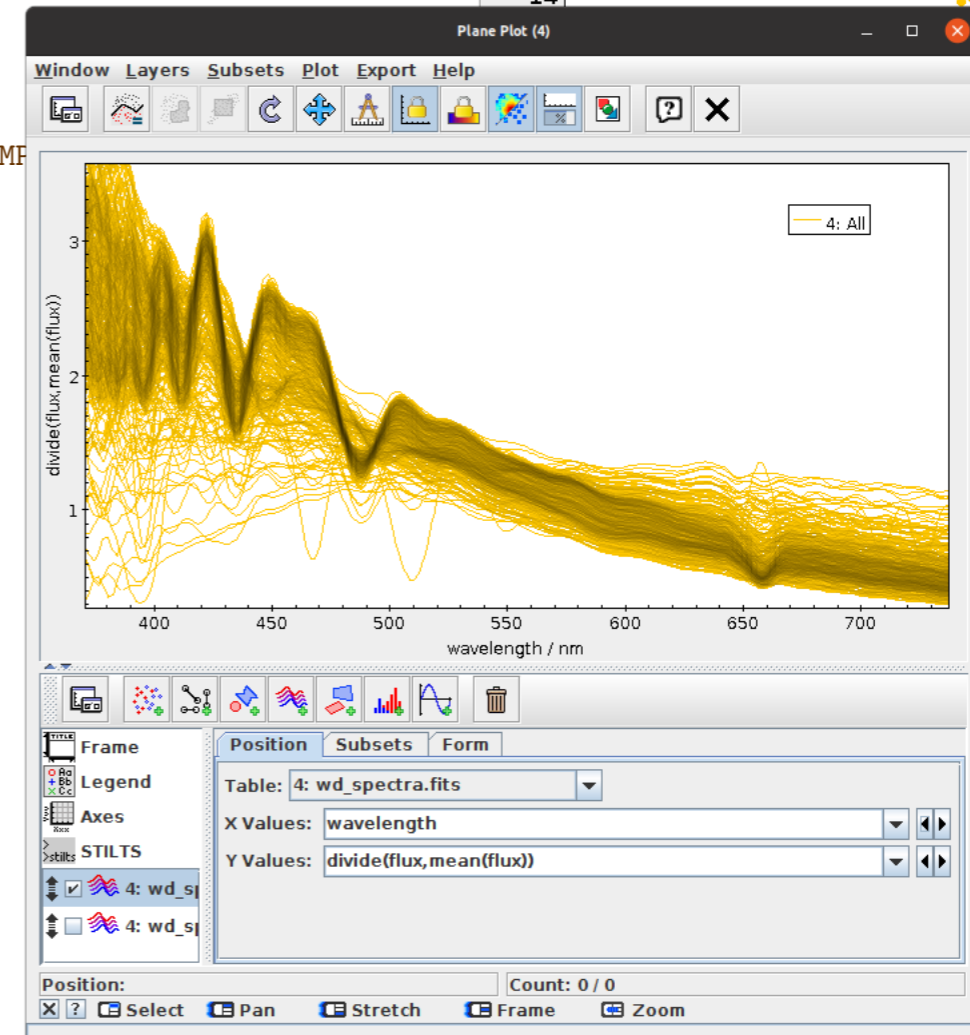
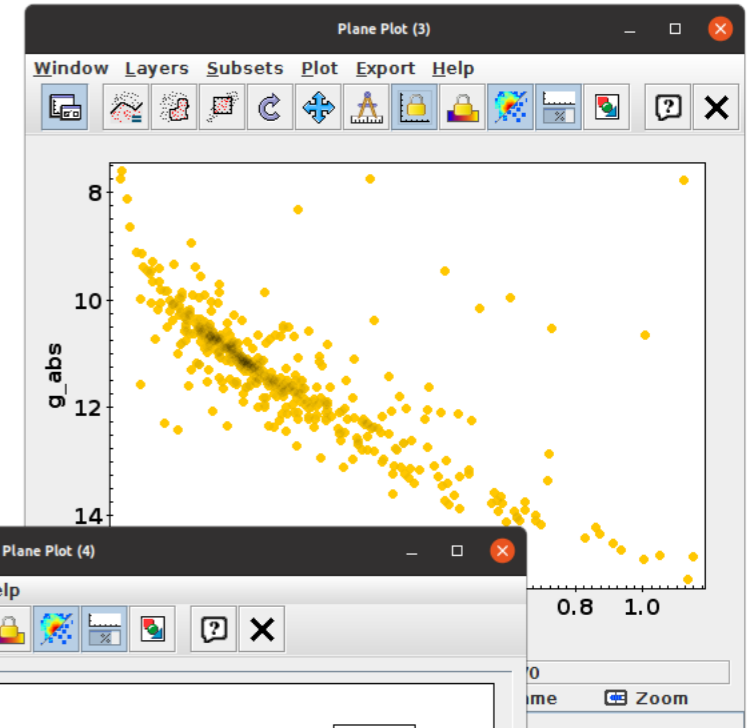
Get some White Dwarf spectra

```
SELECT source_id, bp_rp, phot_g_mean_mag+5*log10(parallax/100) AS g_abs
FROM gaiadr3.gaia_source
WHERE parallax > 10 AND parallax_over_error > 10
  AND phot_bp_mean_flux_over_error > 10 AND phot_rp_mean_flux_over_error > 10
  AND astrometric_excess_noise < 1
  AND has_xp_sampled = 'true'
  AND bp_rp BETWEEN -0.63 AND 1.21
  AND phot_g_mean_mag+5*log10(parallax/100) BETWEEN 7.4 AND 15.5
stilts arrayjoin in=wd_hrd.fits icmd=progress out=wd_spectra.fits \
  atable="https://gea.esac.esa.int/data-server/data?RETRIEVAL_TYPE=XP_SAMP
```



View them using the XYArray plot

- Use array functions to normalise them
 - If X Values are blank, array index is used instead
 - Plot mean spectra etc using **StatLine/StatMark** form
 - Linked views using subsets
 - To highlight activated row, use **Activated** subset
 - To select single/multiple rows from plot, use **Handles** layer
- (most of these features require recent versions)



Example: Spectra as Arrays



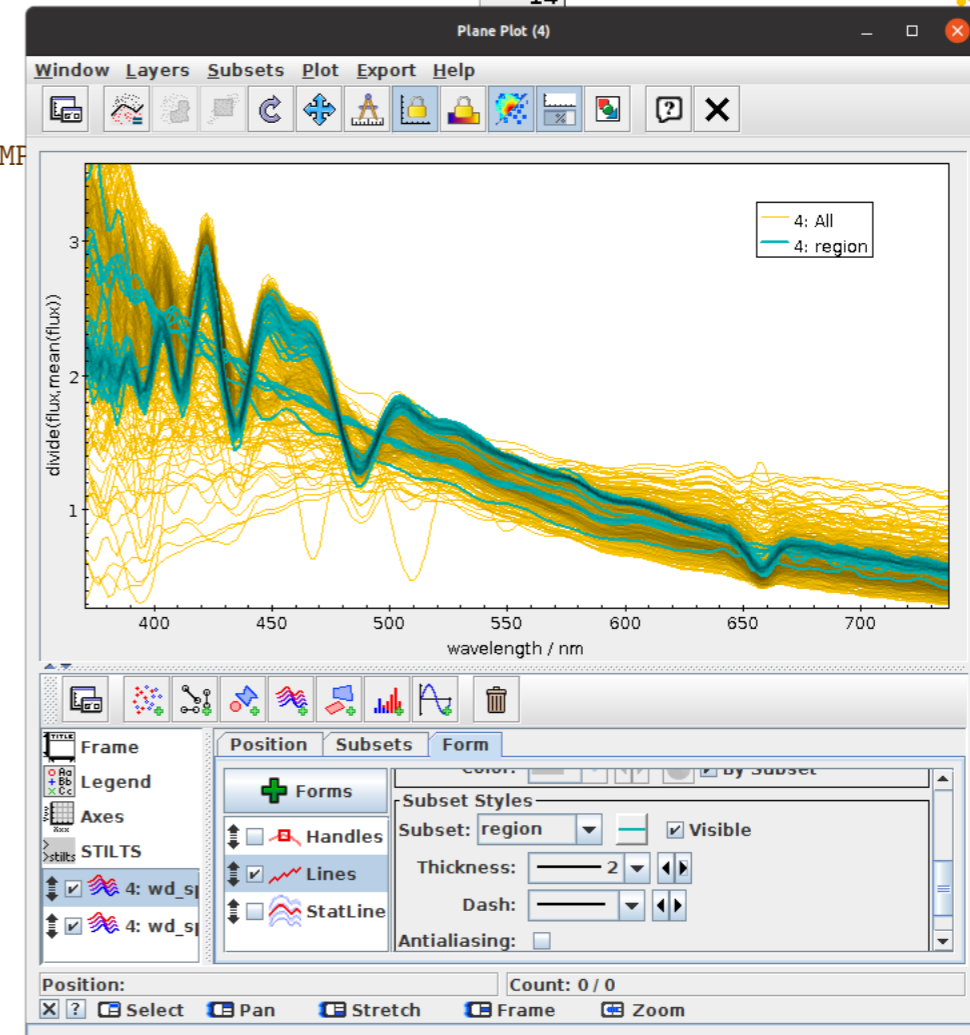
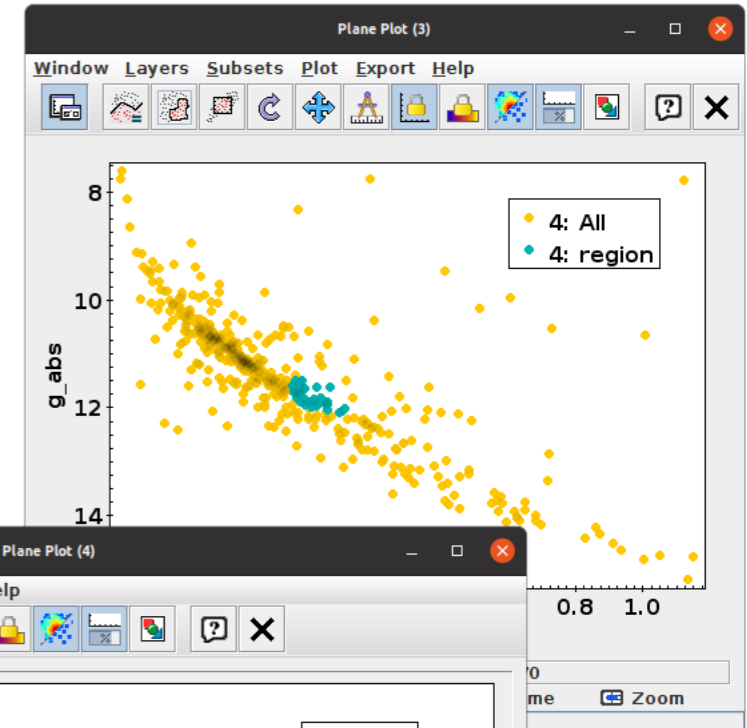
Get some White Dwarf spectra

```
SELECT source_id, bp_rp, phot_g_mean_mag+5*log10(parallax/100) AS g_abs
FROM gaiadr3.gaia_source
WHERE parallax > 10 AND parallax_over_error > 10
  AND phot_bp_mean_flux_over_error > 10 AND phot_rp_mean_flux_over_error > 10
  AND astrometric_excess_noise < 1
  AND has_xp_sampled = 'true'
  AND bp_rp BETWEEN -0.63 AND 1.21
  AND phot_g_mean_mag+5*log10(parallax/100) BETWEEN 7.4 AND 15.5
stilts arrayjoin in=wd_hrd.fits icmd=progress out=wd_spectra.fits \
  atable="https://gea.esac.esa.int/data-server/data?RETRIEVAL_TYPE=XP_SAMP
```



View them using the XYArray plot

- Use array functions to normalise them
 - If X Values are blank, array index is used instead
 - Plot mean spectra etc using **StatLine**/**StatMark** form
 - Linked views using subsets
 - To highlight activated row, use **Activated** subset
 - To select single/multiple rows from plot, use **Handles** layer
- (most of these features require recent versions)



Example: Spectra as Arrays



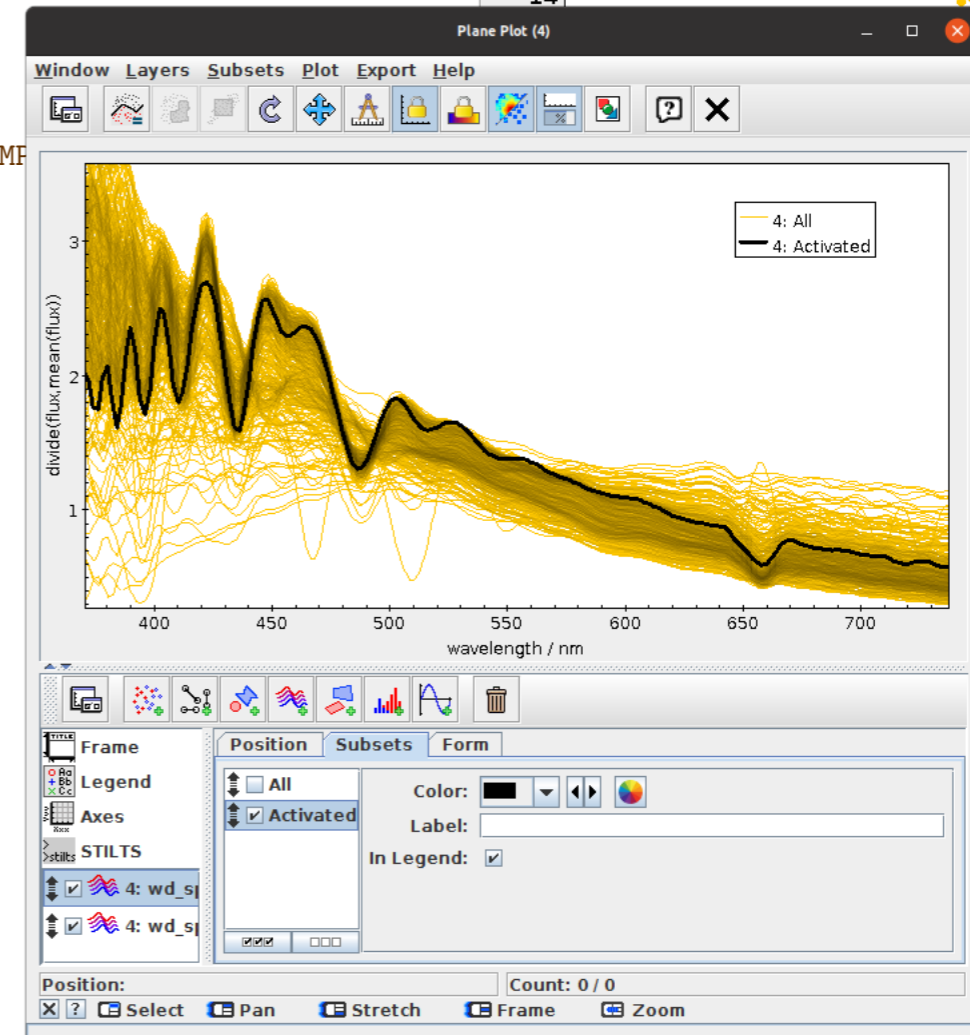
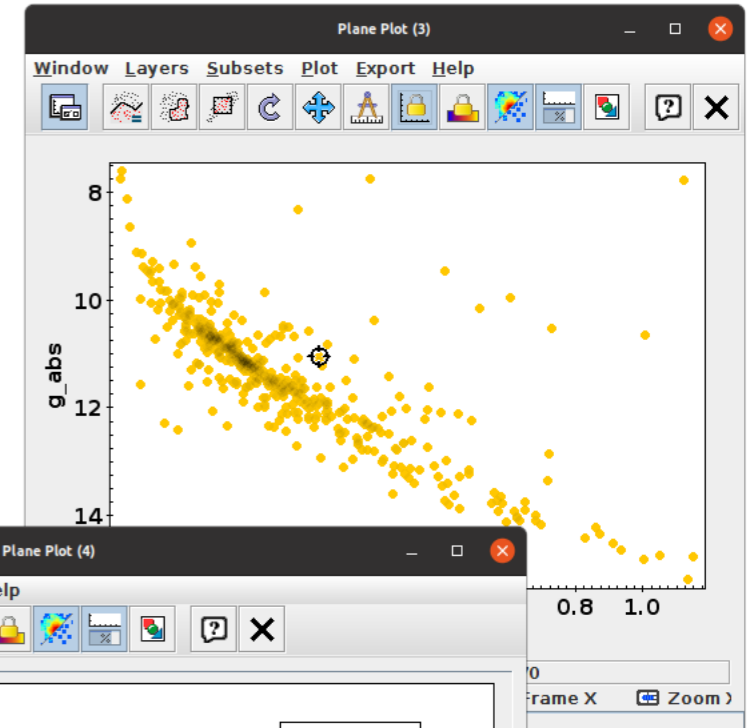
Get some White Dwarf spectra

```
SELECT source_id, bp_rp, phot_g_mean_mag+5*log10(parallax/100) AS g_abs
FROM gaiadr3.gaia_source
WHERE parallax > 10 AND parallax_over_error > 10
  AND phot_bp_mean_flux_over_error > 10 AND phot_rp_mean_flux_over_error > 10
  AND astrometric_excess_noise < 1
  AND has_xp_sampled = 'true'
  AND bp_rp BETWEEN -0.63 AND 1.21
  AND phot_g_mean_mag+5*log10(parallax/100) BETWEEN 7.4 AND 15.5
stilts arrayjoin in=wd_hrd.fits icmd=progress out=wd_spectra.fits \
  atable="https://gea.esac.esa.int/data-server/data?RETRIEVAL_TYPE=XP_SAMP
```



View them using the XYArray plot

- Use array functions to normalise them
 - If X Values are blank, array index is used instead
 - Plot mean spectra etc using **StatLine/StatMark** form
 - Linked views using subsets
 - To highlight activated row, use **Activated** subset
 - To select single/multiple rows from plot, use **Handles** layer
- (most of these features require recent versions)



Example: Spectra as Arrays



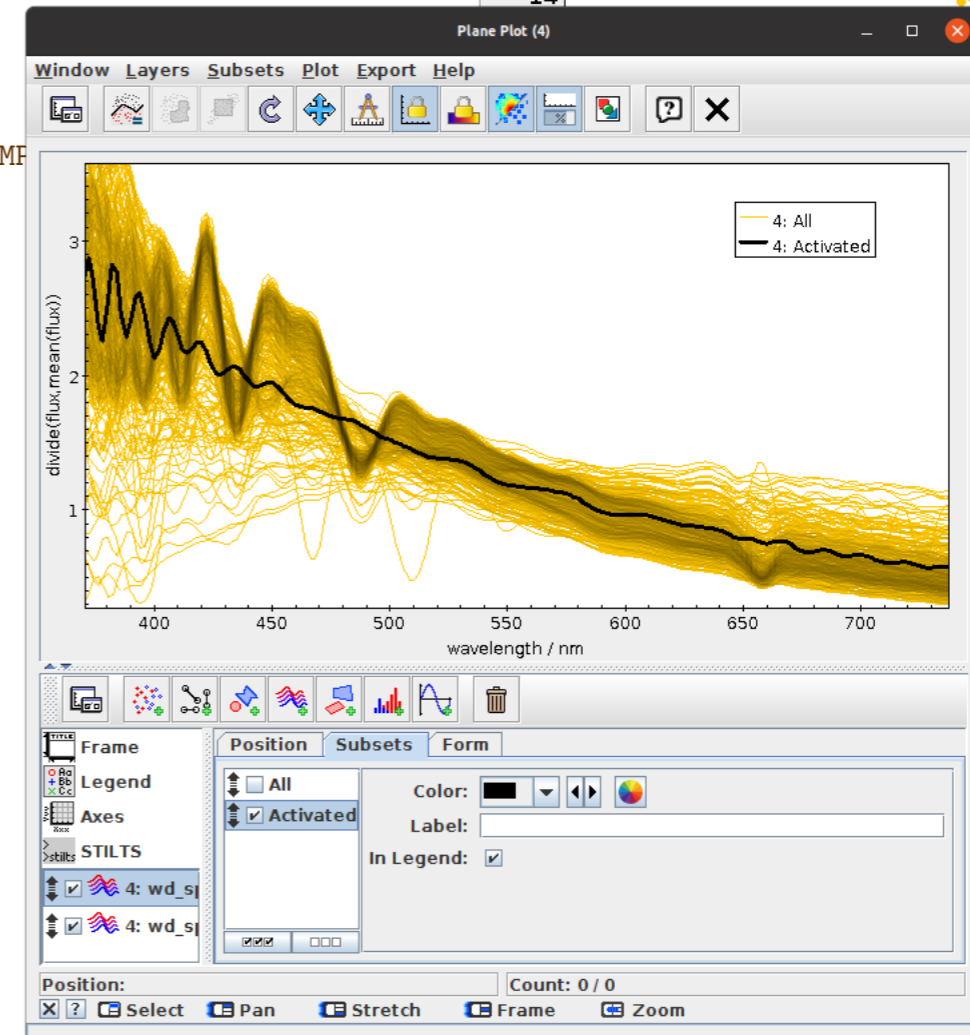
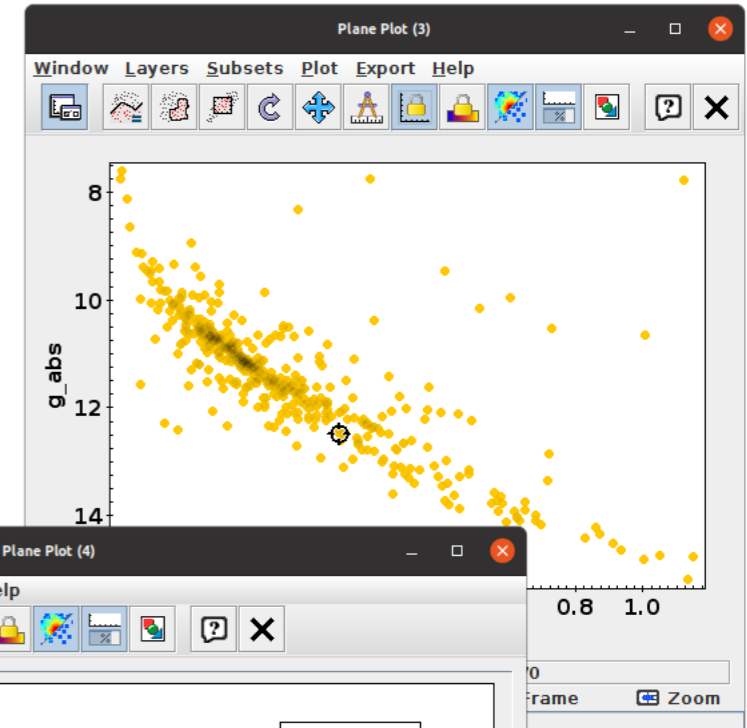
Get some White Dwarf spectra

```
SELECT source_id, bp_rp, phot_g_mean_mag+5*log10(parallax/100) AS g_abs
FROM gaiadr3.gaia_source
WHERE parallax > 10 AND parallax_over_error > 10
  AND phot_bp_mean_flux_over_error > 10 AND phot_rp_mean_flux_over_error > 10
  AND astrometric_excess_noise < 1
  AND has_xp_sampled = 'true'
  AND bp_rp BETWEEN -0.63 AND 1.21
  AND phot_g_mean_mag+5*log10(parallax/100) BETWEEN 7.4 AND 15.5
stilts arrayjoin in=wd_hrd.fits icmd=progress out=wd_spectra.fits \
  atable="https://gea.esac.esa.int/data-server/data?RETRIEVAL_TYPE=XP_SAMP
```



View them using the XYArray plot

- Use array functions to normalise them
 - If X Values are blank, array index is used instead
 - Plot mean spectra etc using **StatLine/StatMark** form
 - Linked views using subsets
 - To highlight activated row, use **Activated** subset
 - To select single/multiple rows from plot, use **Handles** layer
- (most of these features require recent versions)



Example: Spectra as Arrays



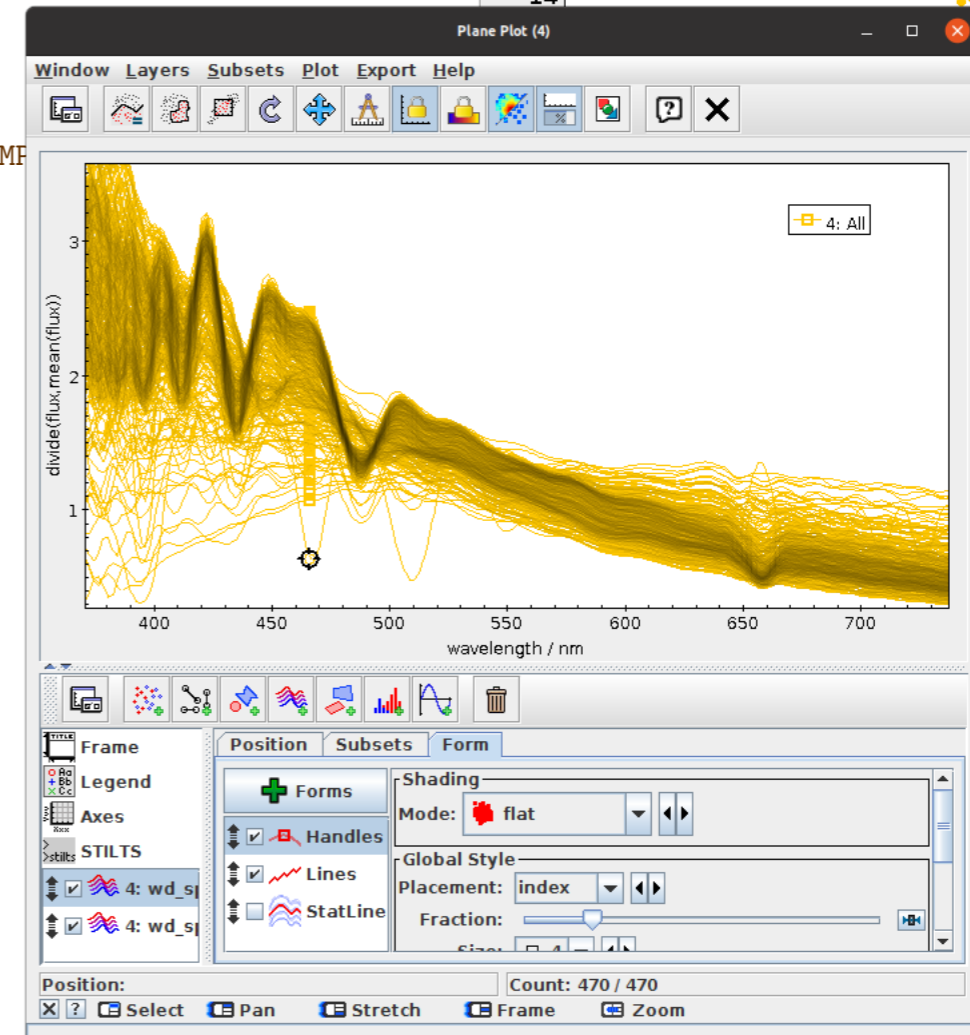
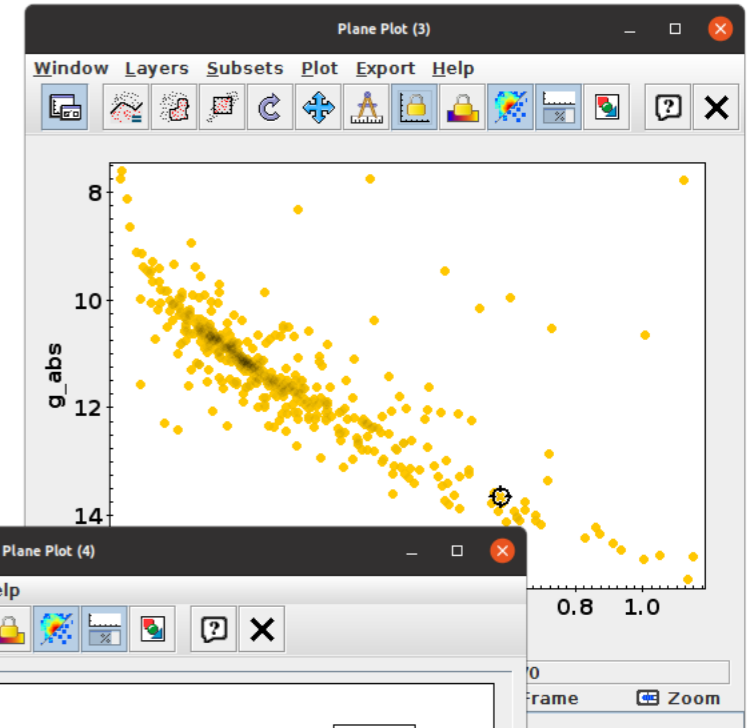
Get some White Dwarf spectra

```
SELECT source_id, bp_rp, phot_g_mean_mag+5*log10(parallax/100) AS g_abs
FROM gaiadr3.gaia_source
WHERE parallax > 10 AND parallax_over_error > 10
  AND phot_bp_mean_flux_over_error > 10 AND phot_rp_mean_flux_over_error > 10
  AND astrometric_excess_noise < 1
  AND has_xp_sampled = 'true'
  AND bp_rp BETWEEN -0.63 AND 1.21
  AND phot_g_mean_mag+5*log10(parallax/100) BETWEEN 7.4 AND 15.5
stilts arrayjoin in=wd_hrd.fits icmd=progress out=wd_spectra.fits \
  atable="https://gea.esac.esa.int/data-server/data?RETRIEVAL_TYPE=XP_SAMP
```



View them using the XYArray plot

- Use array functions to normalise them
- If X Values are blank, array index is used instead
- Plot mean spectra etc using **StatLine/StatMark** form
- Linked views using subsets
- To highlight activated row, use **Activated** subset
- To select single/multiple rows from plot, use **Handles** layer
(most of these features require recent versions)



Summary: TOPCAT Features for Array Data

Data Access:

- Activation Actions
 - ▷ **Invoke Service** understands `Service Descriptors`
 - ▷ **View Datalink Table** using `{links}` Endpoint and ID column — *New!*
- Auto-invoke row from DataLink table (Load, Plot, Send, ...)
- STILTS `arrayjoin` command — *New!*

Visualisation:

- XYArray plots
- Activation Subset — *New!*
- XYArray Handle plot layer — *New!*
- StatMark/StatLine and ArrayQuantile plot layers — *New!*

Array manipulation

- Array collapse functions: `mean`, `median`, `minimum`, `maximum`, `quantile`, ...
- Array combination functions: `multiply`, `divide`, `add`, `subtract`, ...
- Per-element functions: `condition`, `reciprocal`, `arrayFunc`, ...

Summary: TOPCAT Features for Array Data

Data Access:

- Activation Actions
 - ▷ **Invoke Service** understands [Service Descriptors](#)
 - ▷ **View Datalink Table** using `{links}` Endpoint and ID column — *New!*
- Auto-invoke row from DataLink table (Load, Plot, Send, ...)
- STILTS `arrayjoin` command — *New!*

Visualisation:

- XYArray plots
- Activation Subset — *New!*
- XYArray Handle plot layer — *New!*
- StatMark/StatLine and ArrayQuantile plot layers — *New!*

TOPCAT web page:

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

More examples at GAVO blog:

<https://blog.g-vo.org/>

Array manipulation

- Array collapse functions: `mean`, `median`, `minimum`, `maximum`, `quantile`, ...
- Array combination functions: `multiply`, `divide`, `add`, `subtract`, ...
- Per-element functions: `condition`, `reciprocal`, `arrayFunc`, ...