Data mining with TOPCAT and ADQL

Creating a target list

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Research workshop on evolved stars
02.09.2025

Overview

- Topcat
  - Basic overview
  - Table visualisation/manipulation
  - Visualisation tools
  - Crossmatching
- ADQL
  - Basic commands
- Exercise: ADQL query Gaia

TOPCAT

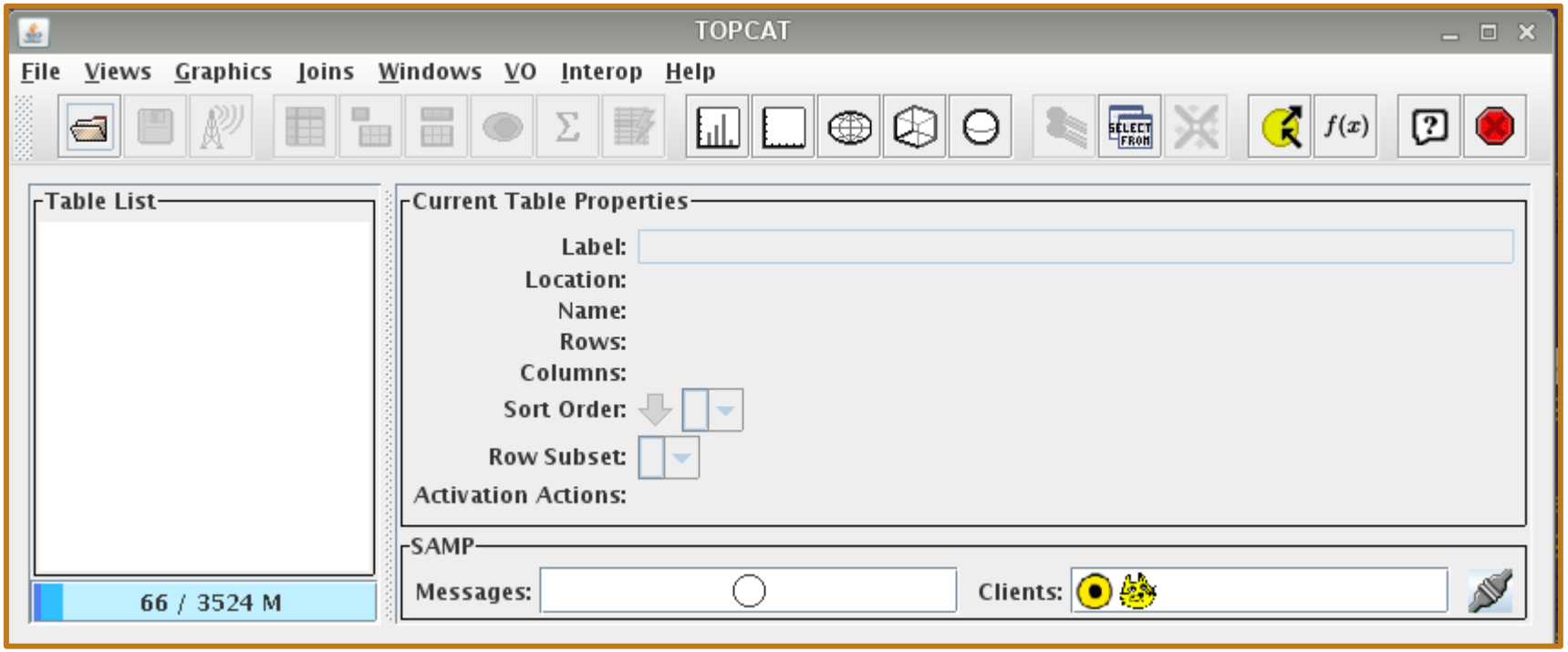
Tool for OPerations on Catalogues And Tables

Does what you want with tables

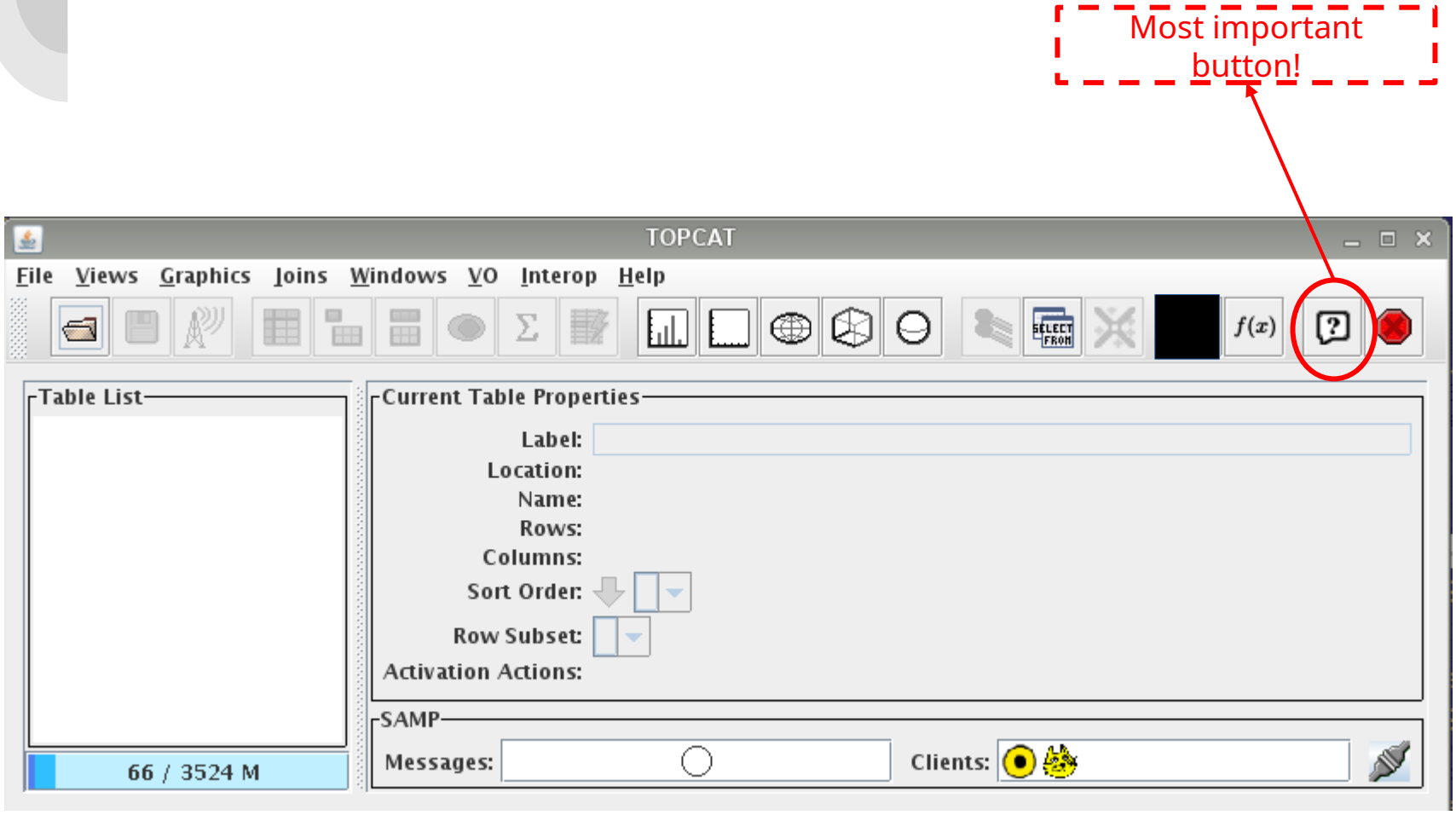
- Website: http://www.star.bristol.ac.uk/~mbt/topcat/
- Manual: http://www.starlink.ac.uk/topcat/sun253/
- Why TOPCAT?
  - Easy to use
  - Easy to learn
  - Easy to investigate data — good for exploratory analysis
  - Simple things obvious, complicated things documented
  - Easy to install and run
  - Fast
  - Copes with large data sets

- What can we do with TOPCAT?
  - Read/write tables in multiple formats
  - View/edit data
  - View/edit metadata
  - Plot data
  - Crossmatch — efficient and very flexible
  - (Simple) Calculations
  - Access Virtual Observatory (VO) services
- What can’t we do with TOPCAT?
  - Images and spectra (tables only!)
  - Do astronomy for you

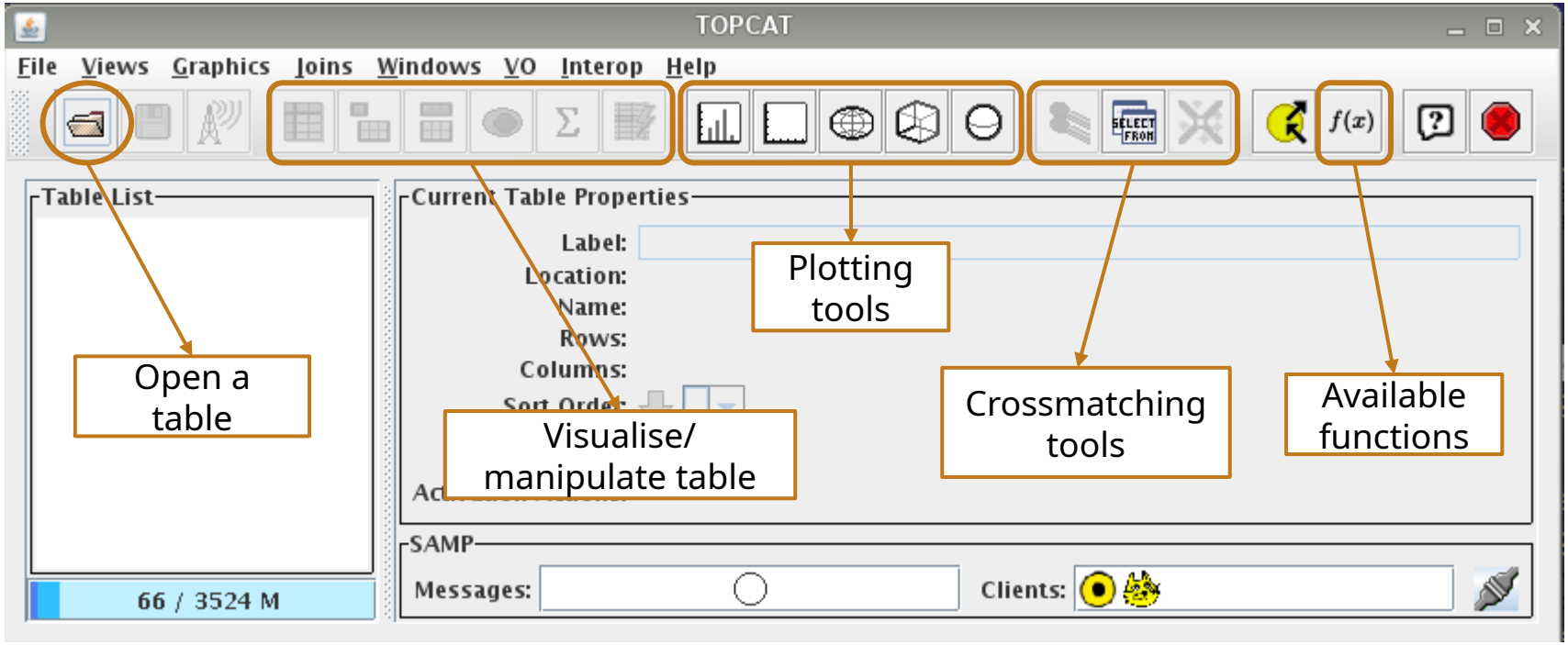
TOPCAT – start window



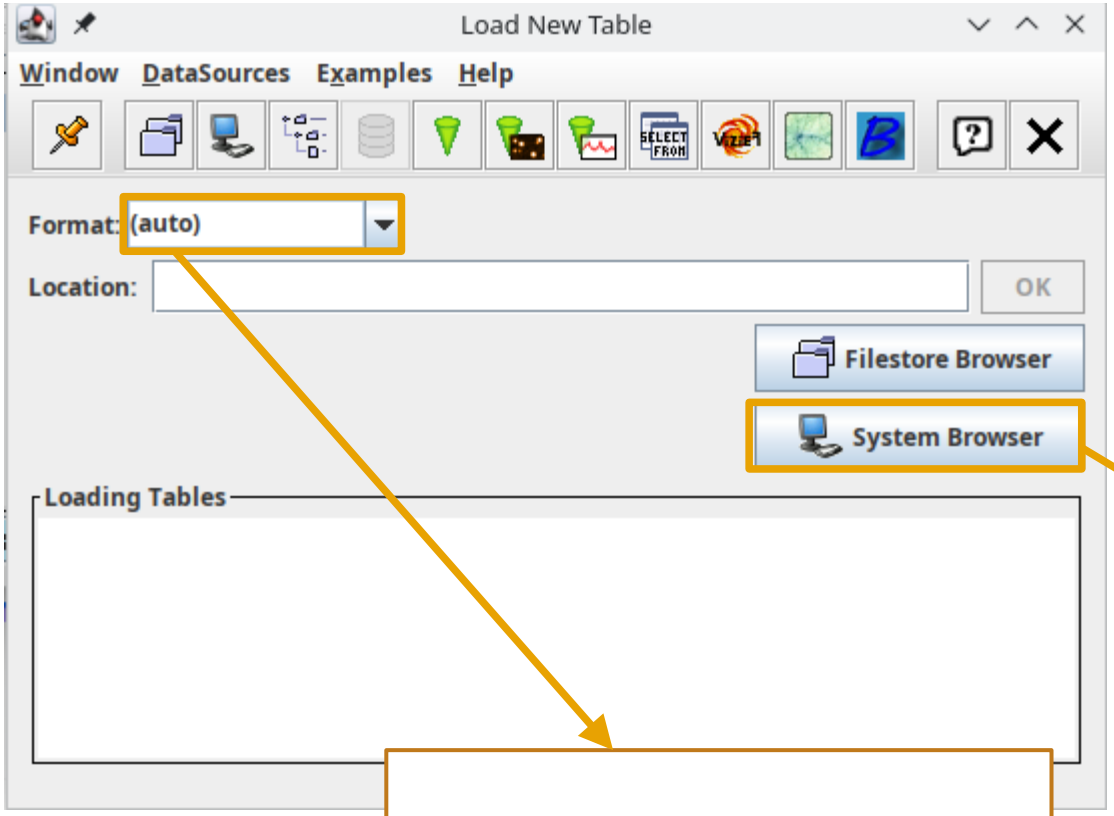
TOPCAT – start window



TOPCAT – start window



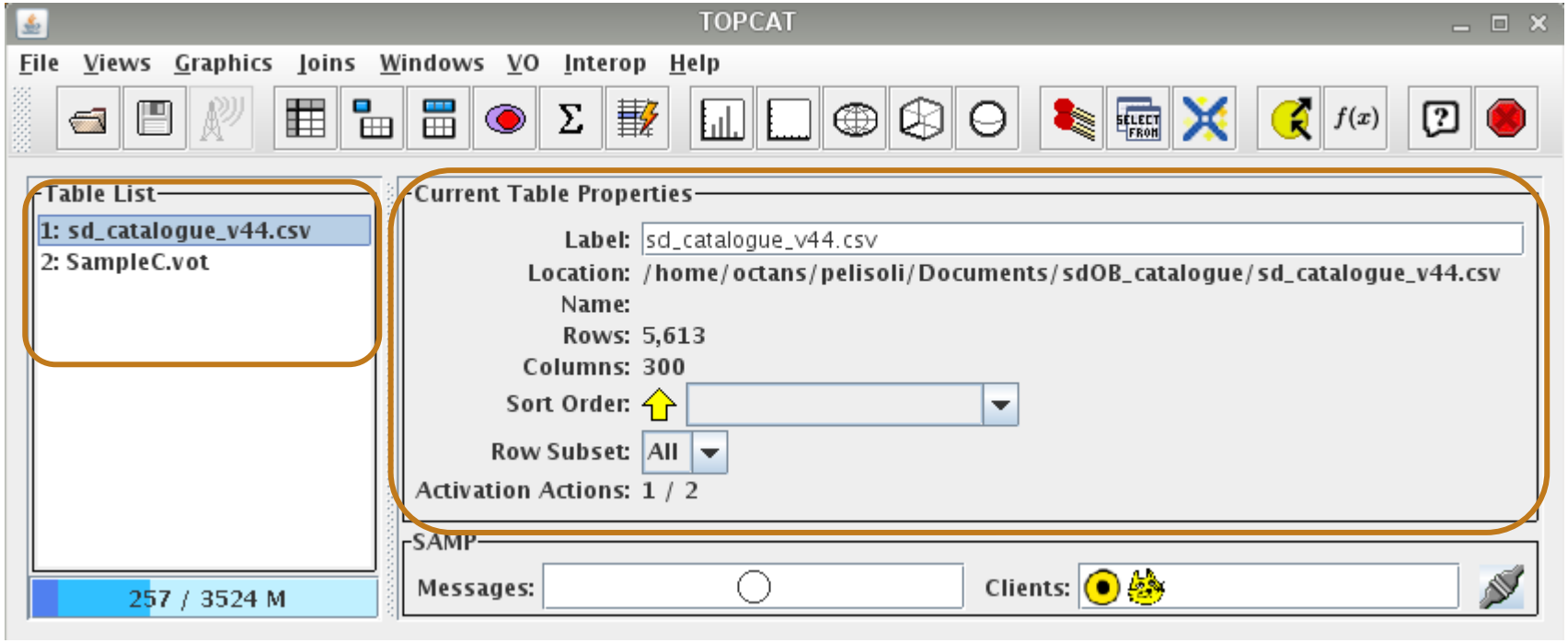
TOPCAT – open a table



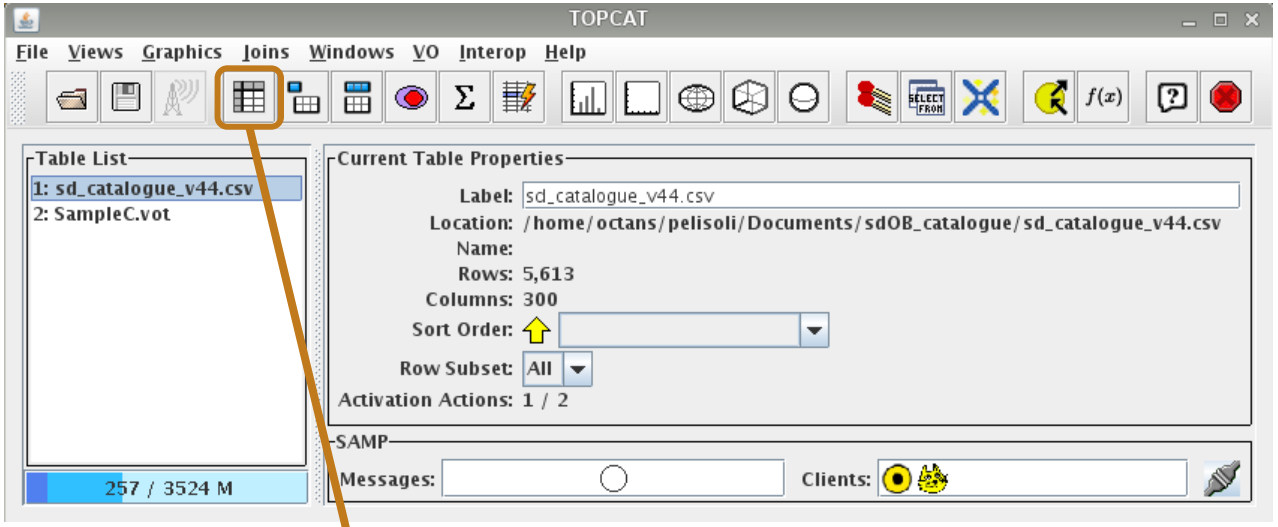
Select path where table is located, e.g. your share folder

You can keep “auto” here but it might fail sometimes and then you have to set the correct format of your table

TOPCAT – tables



TOPCAT – browse table entries



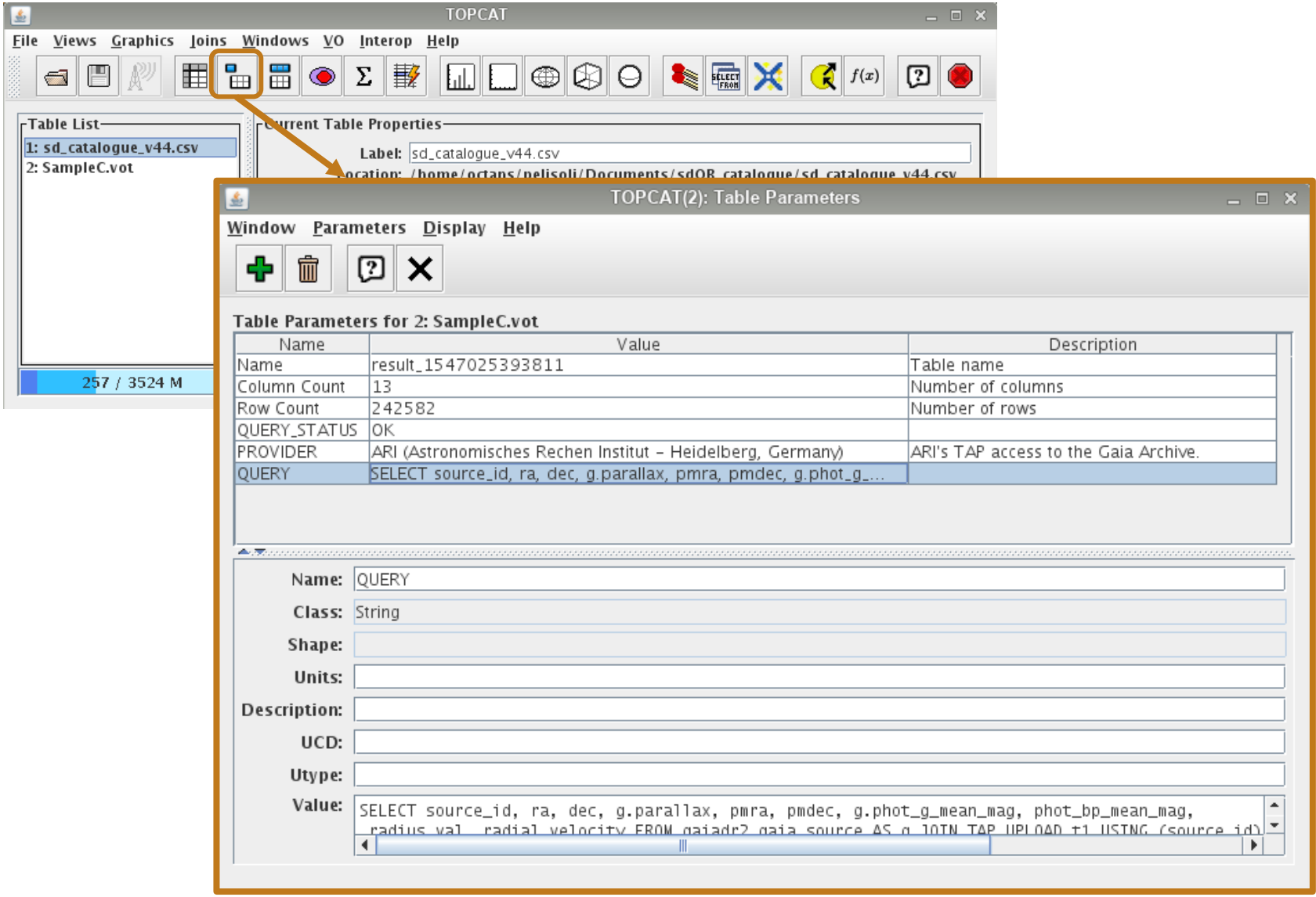
TOPCAT(2): Table Browser

Window Subsets Help

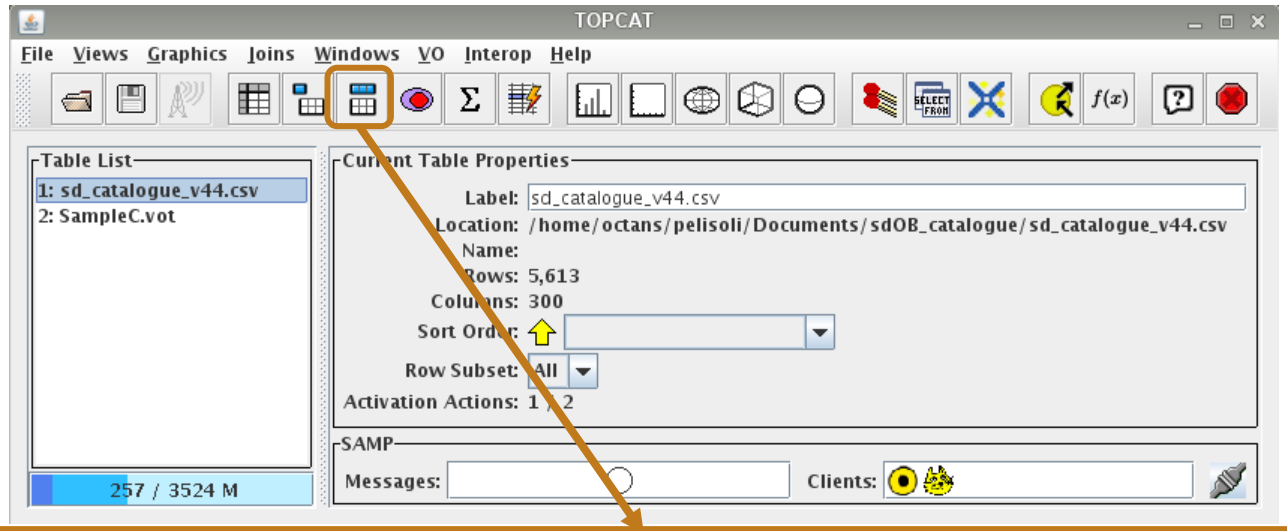
Table Browser for 2: SampleC.vot

	source_id	ra	dec	parallax	pmra	pmdec	phot_g_me...	phot_bp_m...	phot_rp_m...	bp_rp	teff_val	radius_val	radial_velocity
1	5256215443991096192	147.86761	-61.24324	14.45812	12.03787	-69.37827	15.9087	17.5931	14.6429	2.9502	4061.37		
2	5256330686560451584	151.56722	-60.97767	11.94937	-22.95639	71.97418	16.0123	17.8669	14.7033	3.16366	3719.83		
3	5256385455986316288	151.27972	-60.70641	12.54169	31.90794	80.67874	8.88798	9.19604	8.46277	0.733274	5956.	1.07332	-7.42609
4	5253416396637155072	153.5164	-61.03644	12.63063	-105.39727	-45.1931	15.137	16.5149	13.956	2.55884	3806.61		
5	5253387156502079744	152.8841	-61.23938	10.00575	-104.01756	50.83406	7.99488	8.28995	7.58982	0.700138	6150.75	1.89712	78.49139
6	5256366489408398336	150.23835	-60.96456	13.98831	-94.56353	119.33368	15.208	16.8438	13.9581	2.88572	3942.28		
7	5251098523021221376	144.83717	-61.32796	15.20927	-42.29215	19.4506	4.43662	4.46872	4.54535	-0.076632	9450.		
8	5257162462774509440	145.37644	-60.51155	19.26591	-186.61478	102.95347	11.6907	12.6408	10.7458	1.89492	4121.07	0.501863	15.92912
9	5258941648688757888	153.40699	-57.19364	13.69926	-19.40082	84.64139	15.0713	16.5366	13.8802	2.6564	3866.73		
10	5258898488554176384	151.62451	-57.25991	32.36492	48.46716	-62.36505	12.7897	14.1319	11.6591	2.47282	3764.82		
11	5259661897522690688	151.14651	-57.02871	11.71382	-114.0676	60.93288	14.3115	15.8704	13.0872	2.78321	3683.46		
12	5258429379357599232	152.07547	-58.19864	14.42705	-4.00739	-13.83841	6.47879	6.80914	6.04574	0.763399	6011.5	2.77469	-10.38242
13	5255092876977182976	153.85899	-59.60026	15.49247	-59.49346	11.34791	16.459	18.0891	15.1948	2.89426	4120.11		

TOPCAT – table metadata



TOPCAT – column metadata



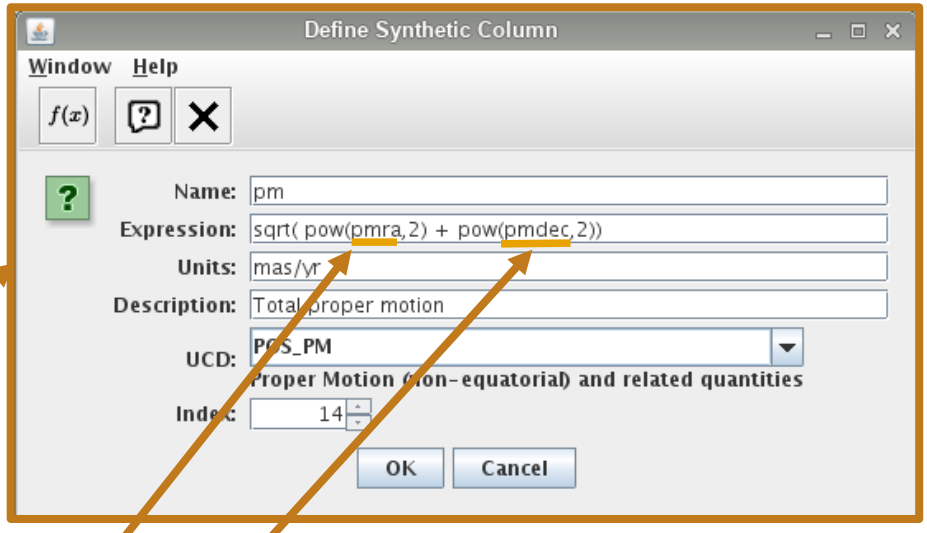
TOPCAT(2): Table Columns

Window Columns Display Help

Table Columns for 2: SampleC.vot

Δ	Index	Visible	Name	$ID	Class	Units	Description	UCD	Datatype	VOTable ID
0		☐	Index	$0	Long		Table row index			
1	1	☑	source_id	$1	Long				long	col_0
2	2	☑	ra	$2	Double	deg	Right ascension	pos.eq.ra;meta.main	double	col_1
3	3	☑	dec	$3	Double	deg	Declination	pos.eq.dec;meta.main	double	col_2
4	4	☑	parallax	$4	Double	mas	Parallax	pos.parallax	double	col_3
5	5	☑	pmra	$5	Double	mas/yr	Proper motion in right ascension direction	pos.pm;pos.eq.ra	double	col_4
6	6	☑	pmdec	$6	Double	mas/yr	Proper motion in declination direction	pos.pm;pos.eq.dec	double	col_5
7	7	☑	phot_g_mean_mag	$7	Float	mag	G-band mean magnitude	phot.mag;stat.mean;em.opt	float	col_6
8	8	☑	phot_bp_mean_mag	$8	Float	mag	Integrated BP mean magnitude	phot.mag;stat.mean	float	col_7
9	9	☑	phot_rp_mean_mag	$9	Float	mag	Integrated RP mean magnitude	phot.mag;stat.mean	float	col_8
10	10	☑	bp_rp	$10	Float	mag	BP – RP colour	phot.color	float	col_9
11	11	☑	teff_val	$11	Float	K	Stellar effective temperature	phys.temperature.effective	float	col_10
12	12	☑	radius_val	$12	Float	solRad	Stellar radius	phys.size.radius	float	col_11
13	13	☑	radial_velocity	$13	Double	km/s	Radial velocity	spect.dopplerVeloc.opt	double	col_12

TOPCAT – create new column



Column names become variables

Column names should not contain mathematical operators and spaces!

TOPCAT(2): Table Columns

Window Columns Display Help

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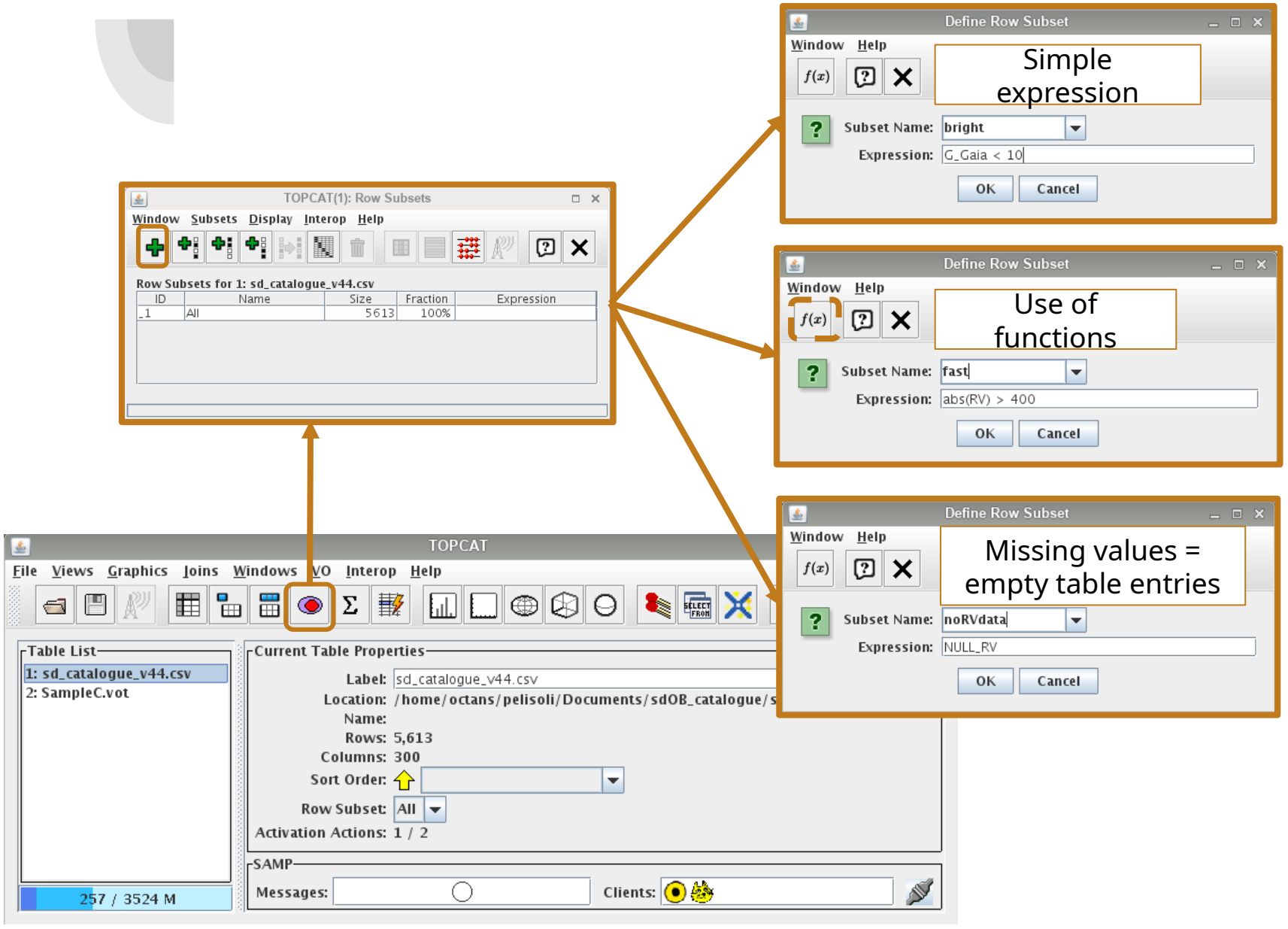
2	2	☑	ra	$2	Double	deg	Right ascension	pos.eq.ra;meta.main	double	col_1
3	3	☑	dec	$3	Double	deg	Declination	pos.eq.dec;meta.main	double	col_2
4	4	☑	parallax	$4	Double	mas	Parallax	pos.parallax	double	col_3
5	5	☑	pmra	$5	Double	mas/yr	Proper motion in right ascension direction	pos.pm;pos.eq.ra	double	col_4
6	6	☑	pmdec	$6	Double	mas/yr	Proper motion in declination direction	pos.pm;pos.eq.dec	double	col_5
7	7	☑	phot_g_mean_mag	$7	Float	mag	G-band mean magnitude	phot.mag;stat.mean;em.opt	float	col_6
8	8	☑	phot_bp_mean_mag	$8	Float	mag	Integrated BP mean magnitude	phot.mag;stat.mean	float	col_7
9	9	☑	phot_rp_mean_mag	$9	Float	mag	Integrated RP mean magnitude	phot.mag;stat.mean	float	col_8
10	10	☑	bp_rp	$10	Float	mag	BP – RP colour	phot.color	float	col_9
11	11	☑	teff_val	$11	Float	K	Stellar effective temperature	phys.temperature.effective	float	col_10
12	12	☑	radius_val	$12	Float	solRad	Stellar radius	phys.size.radius	float	col_11
13	13	☑	radial_velocity	$13	Double	km/s	Radial velocity	spect.dopplerVeloc.opt	double	col_12

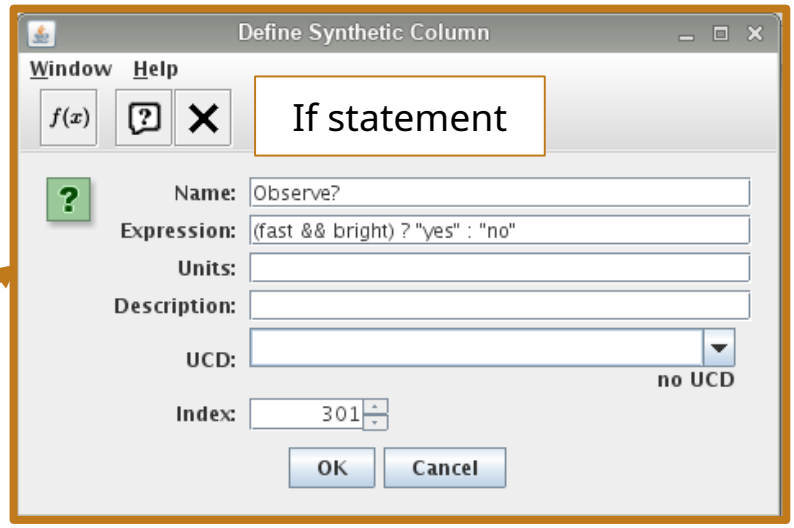
TOPCAT – most important math operators

Real	Expression in TOPCAT
+	+
-	-
*	*
/	/
log(5)	log10(5)
$\sqrt{5}$	sqrt(5)
10^5	pow(10,5)

TOPCAT – create subsets



TOPCAT – create column based on subset



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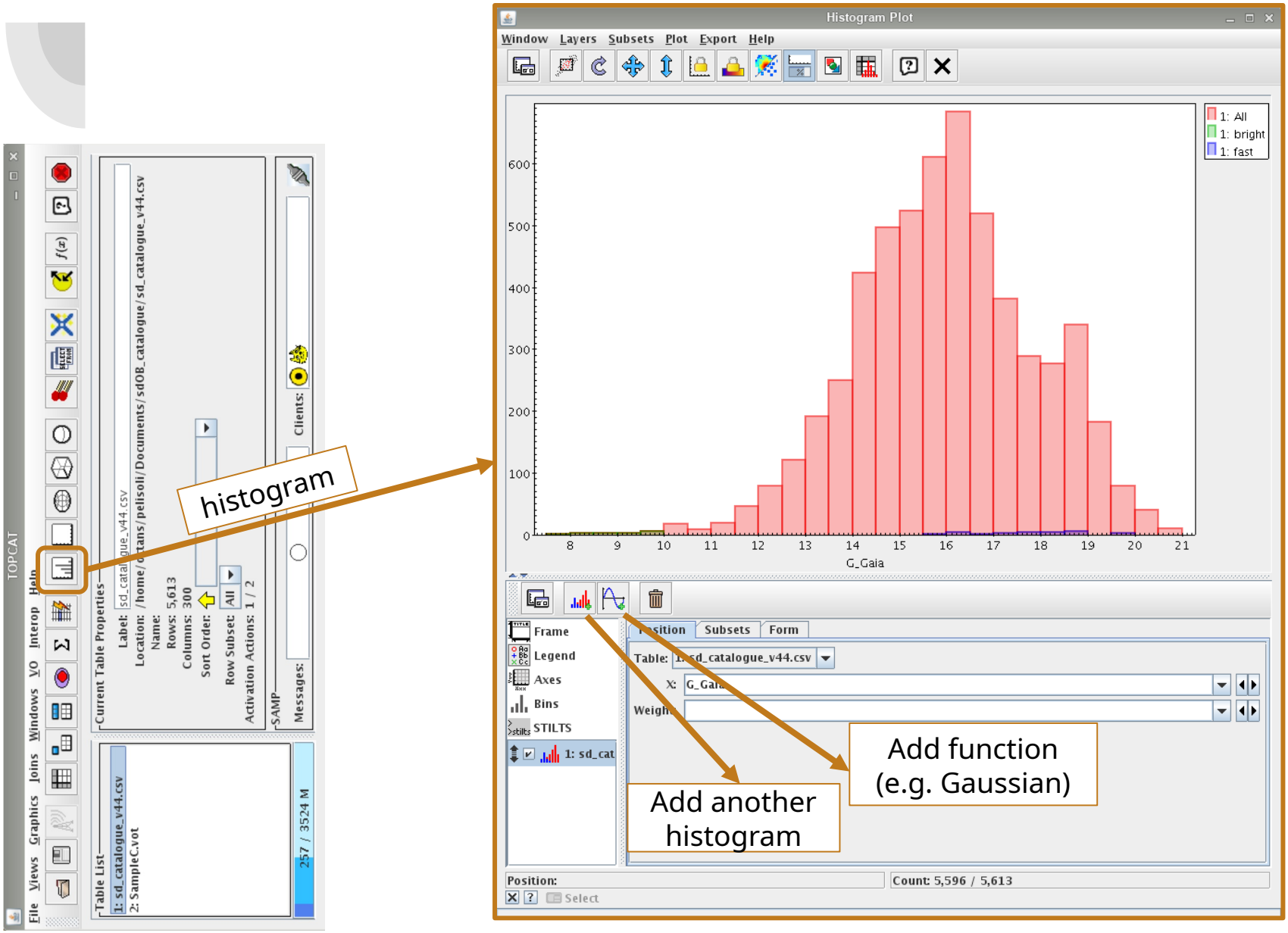
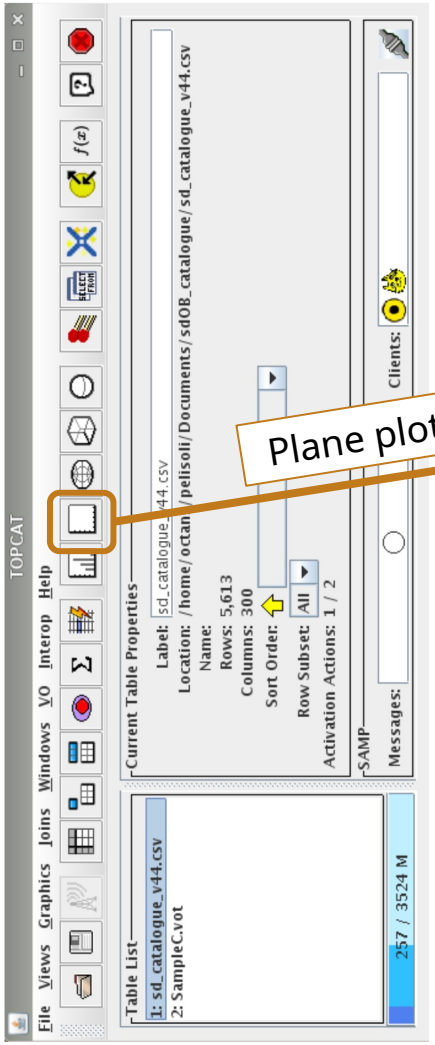
9	9	☑	phot_rp_mean_mag	$9	Float	mag	Integrated RP mean magnitude	phot.mag;stat.mean	float	col_8
10	10	☑	bp_rp	$10	Float	mag	BP – RP colour	phot.color	float	col_9
11	11	☑	teff_val	$11	Float	K	Stellar effective temperature	phys.temperature.effective	float	col_10
12	12	☑	radius_val	$12	Float	solRad	Stellar radius	phys.size.radius	float	col_11
13	13	☑	radial_velocity	$13	Double	km/s	Radial velocity	spect.dopplerVeloc.opt	double	col_12

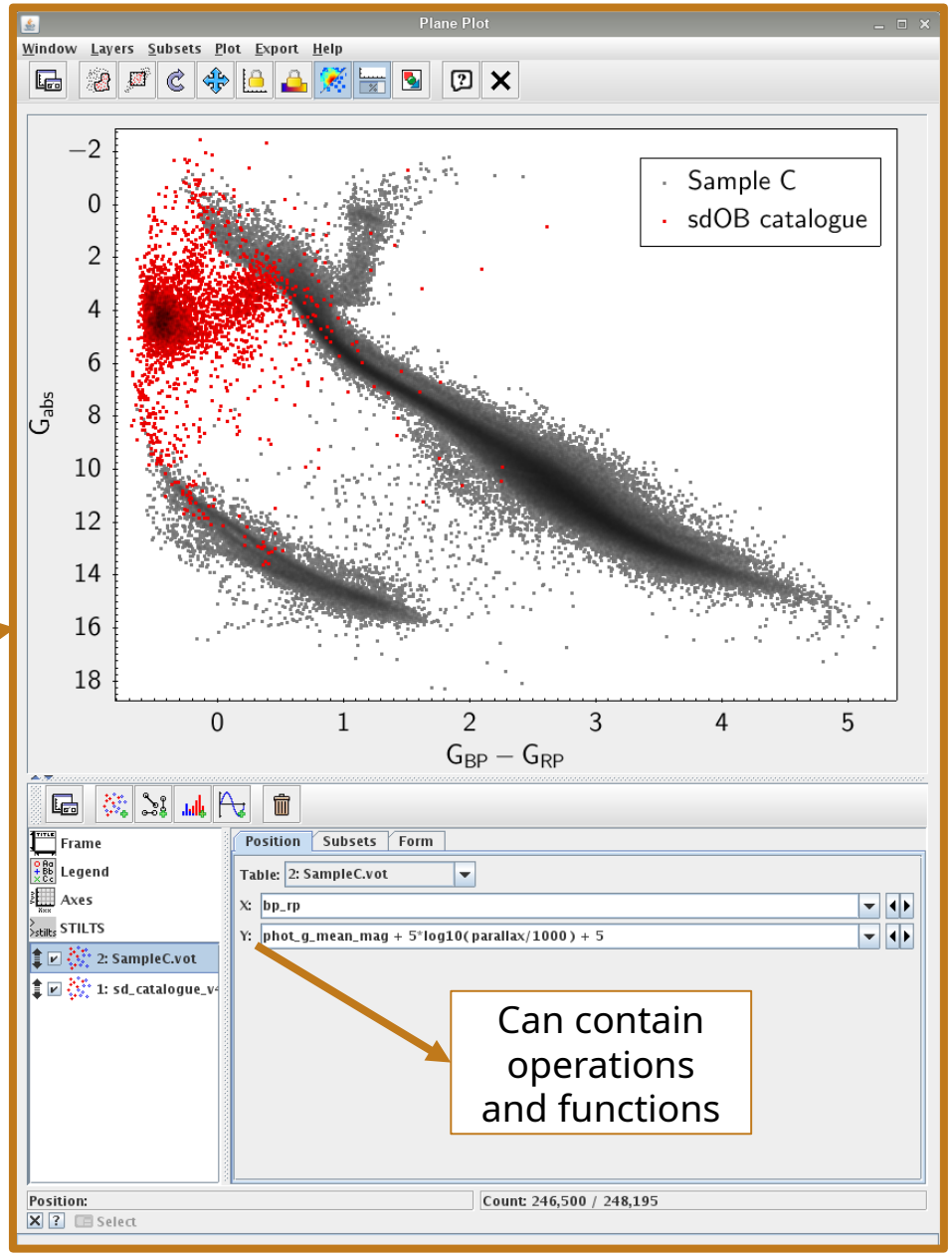
TOPCAT – Visualisation tools



TOPCAT – Visualisation tools

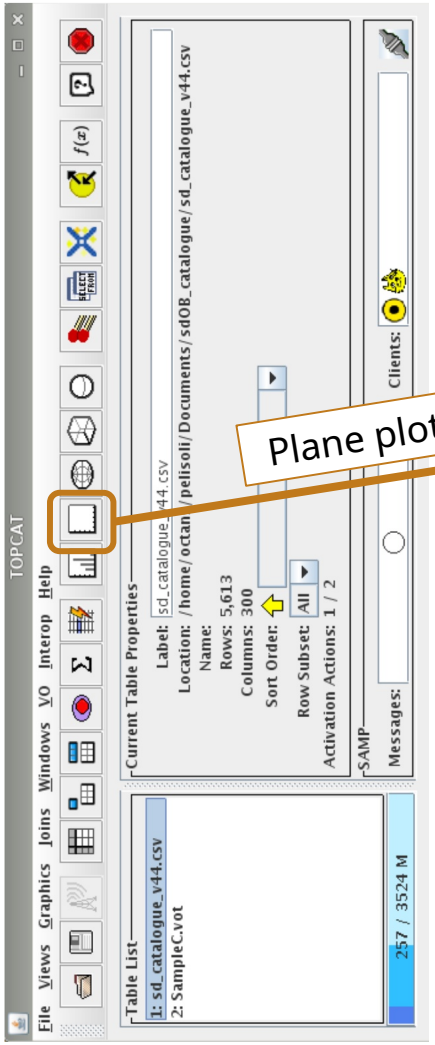


Plane plot

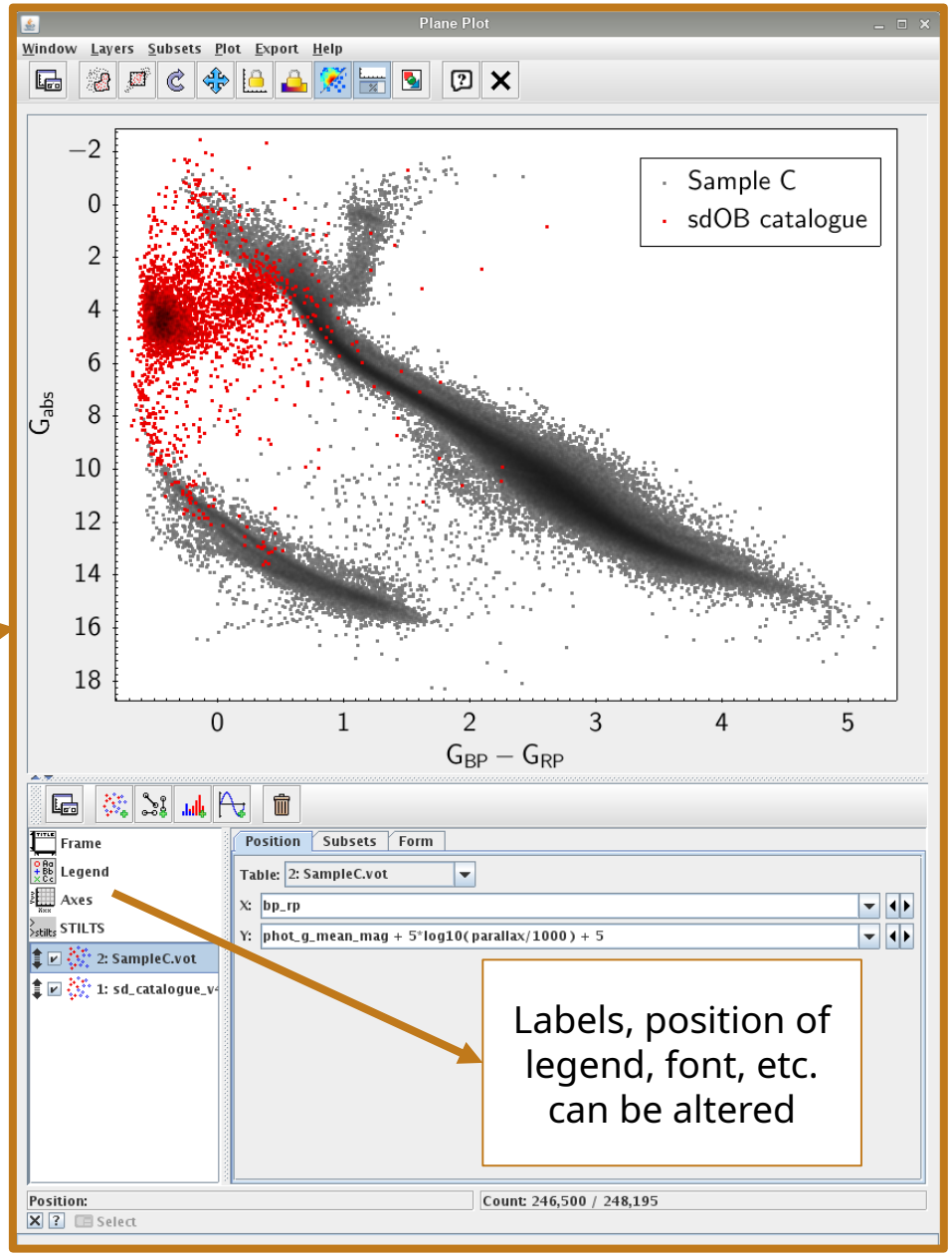


Can contain operations and functions

TOPCAT – Visualisation tools

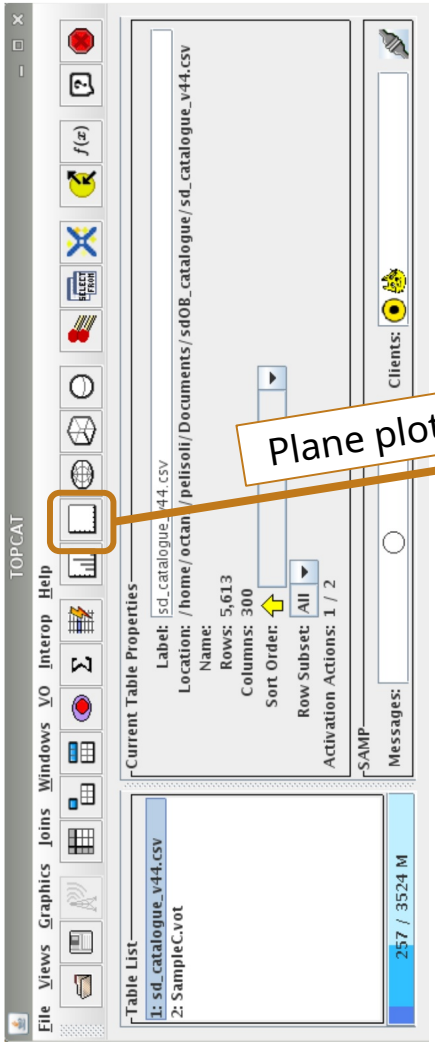


Plane plot

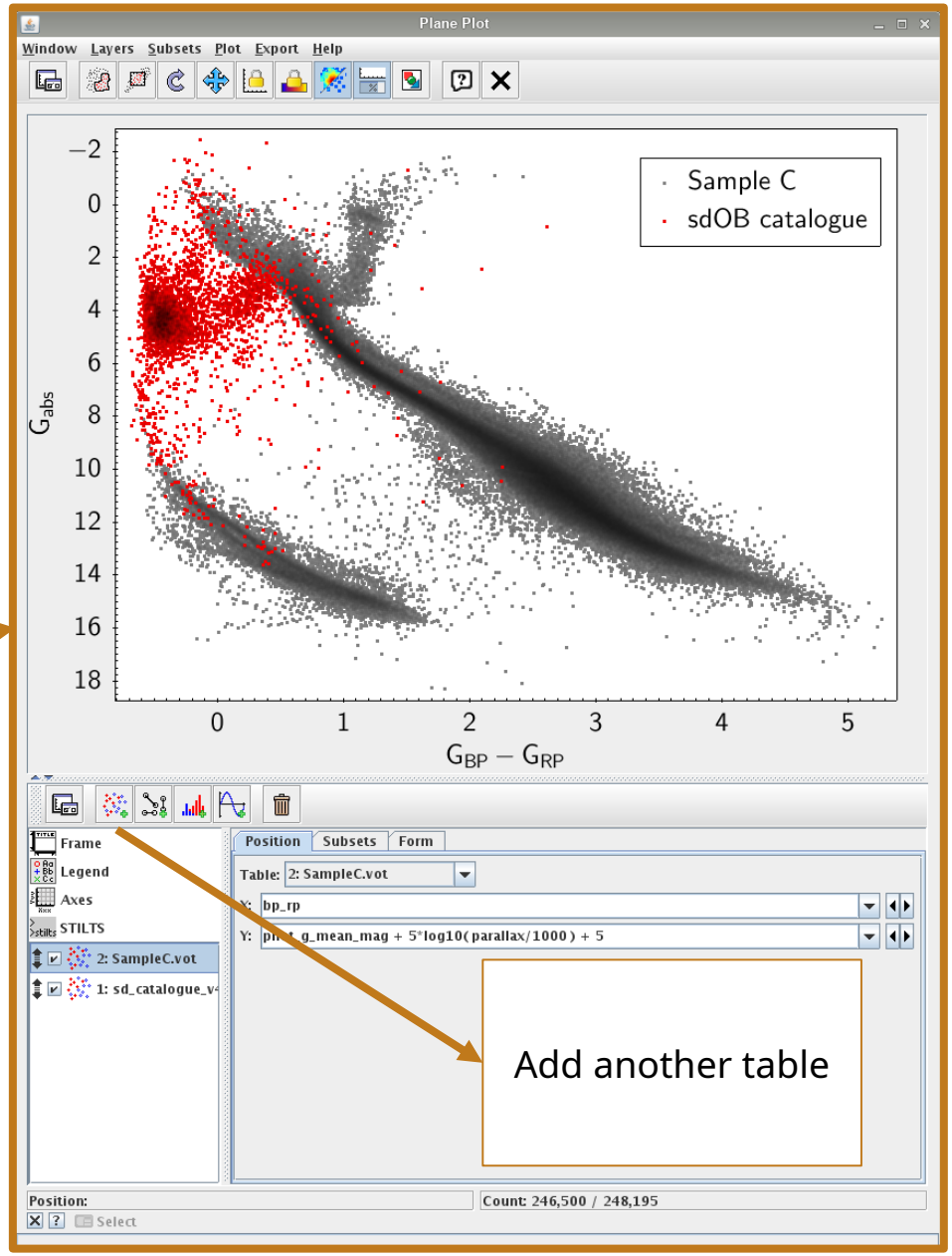


Labels, position of legend, font, etc. can be altered

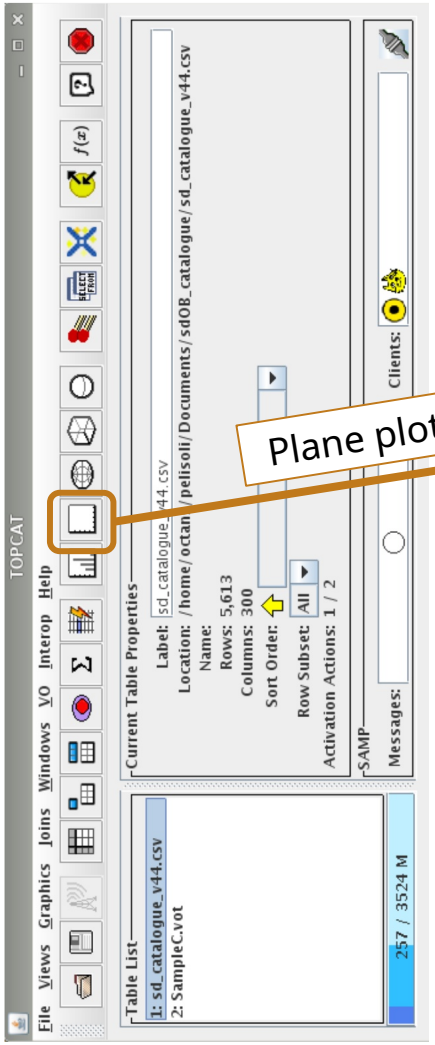
TOPCAT – Visualisation tools



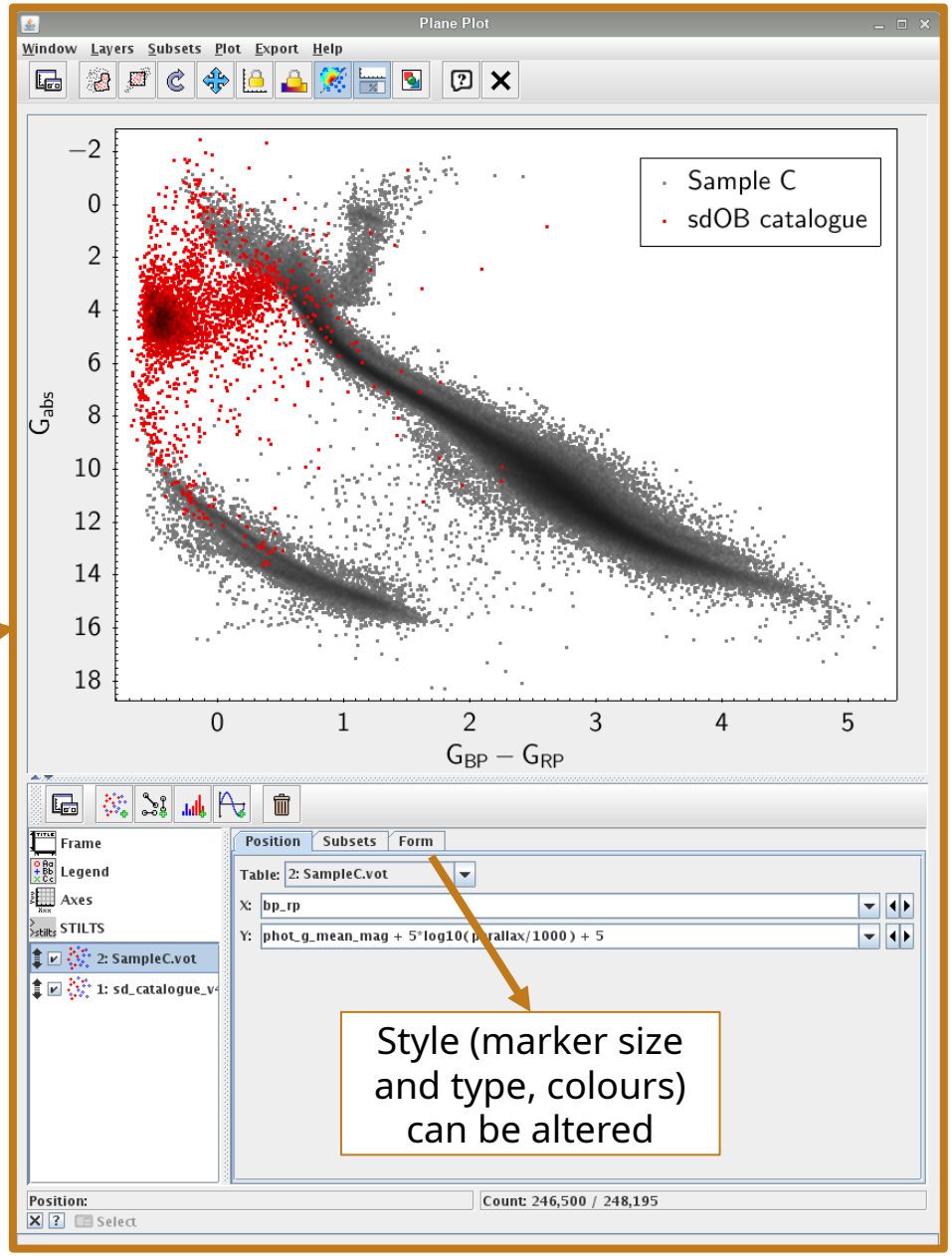
Plane plot



TOPCAT – Visualisation tools

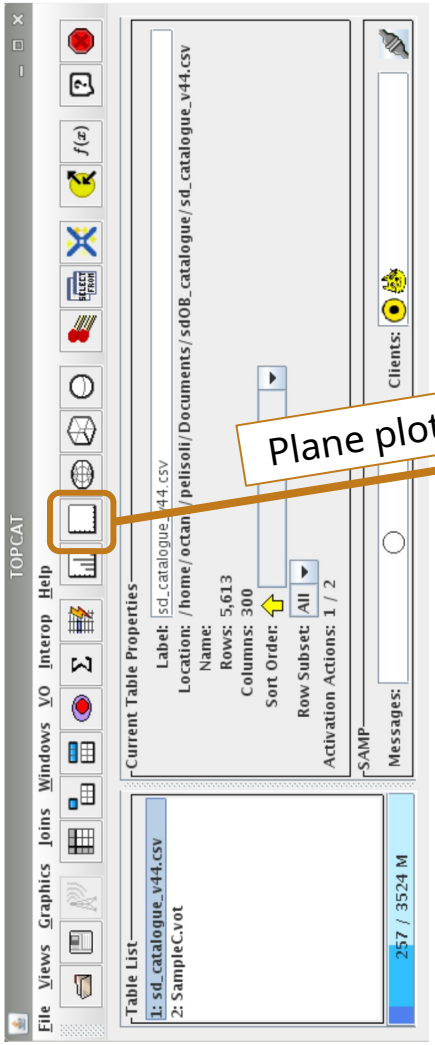


Plane plot

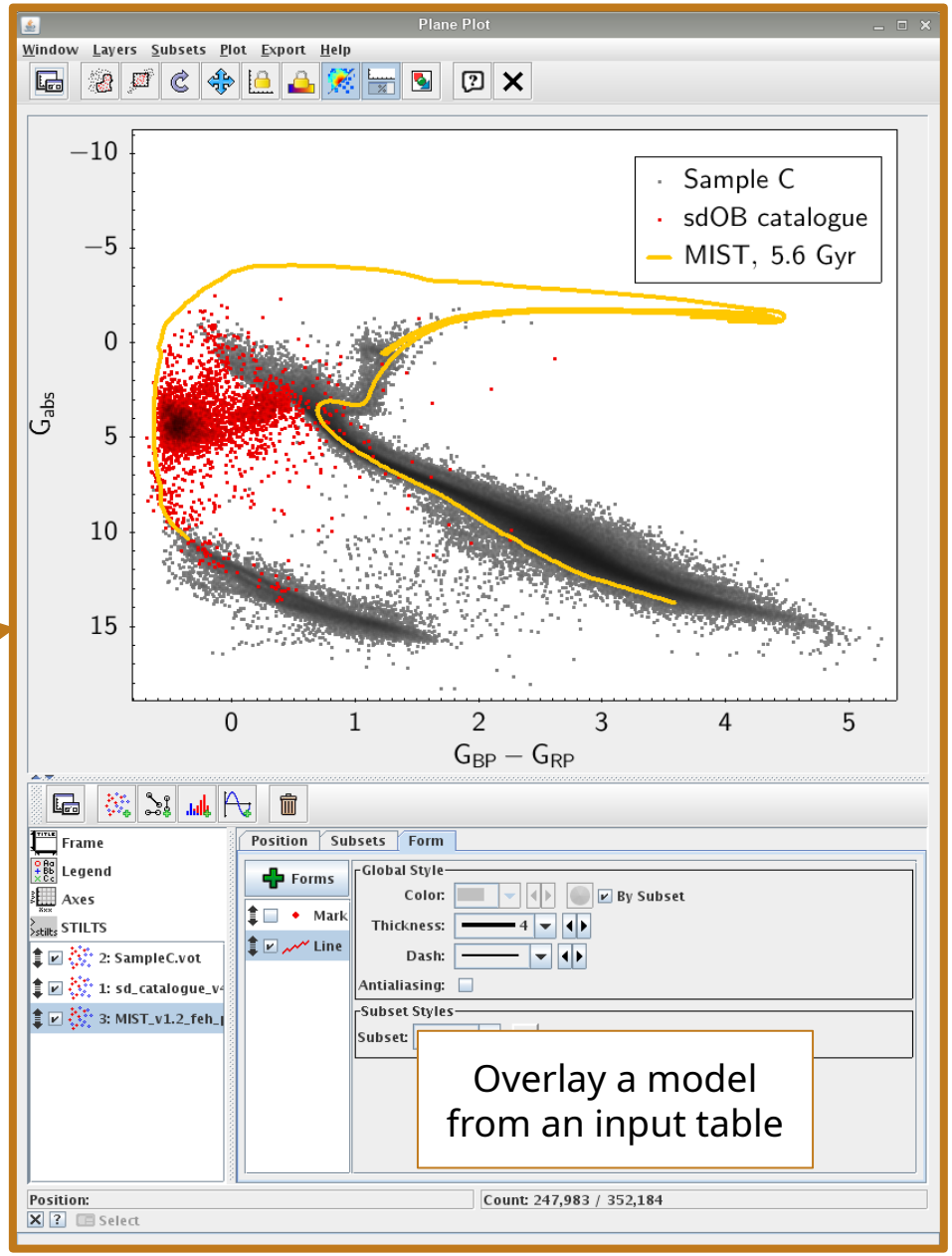


Style (marker size and type, colours) can be altered

TOPCAT – Visualisation tools

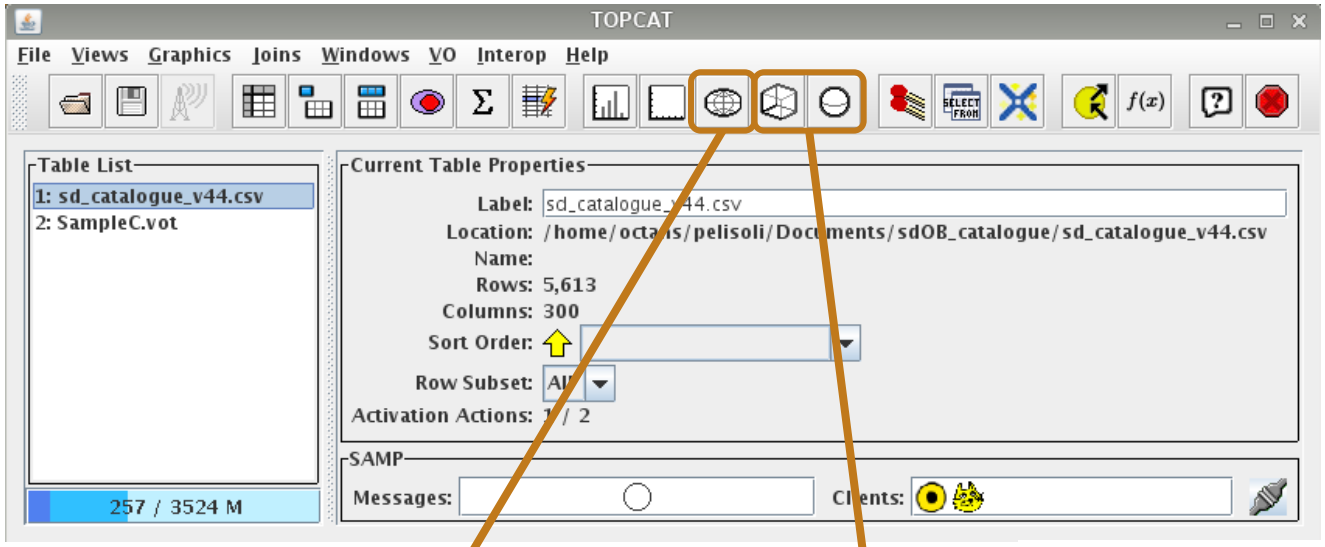


Plane plot

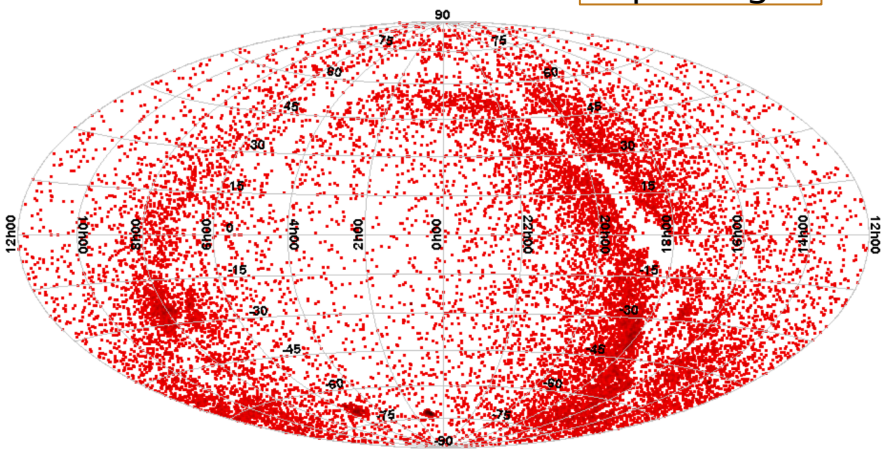


Overlay a model from an input table

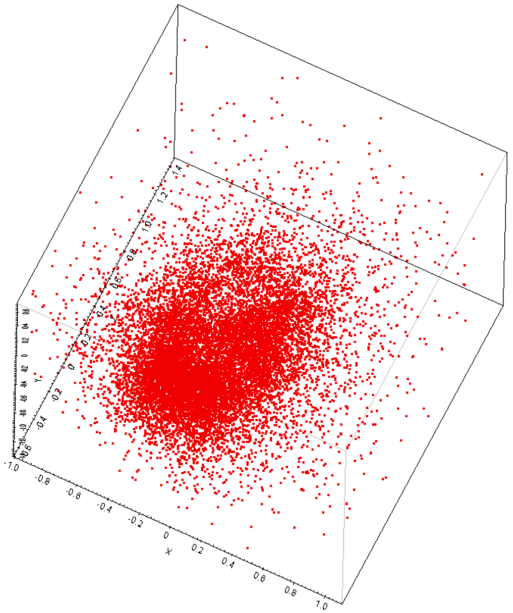
TOPCAT – Visualisation tools



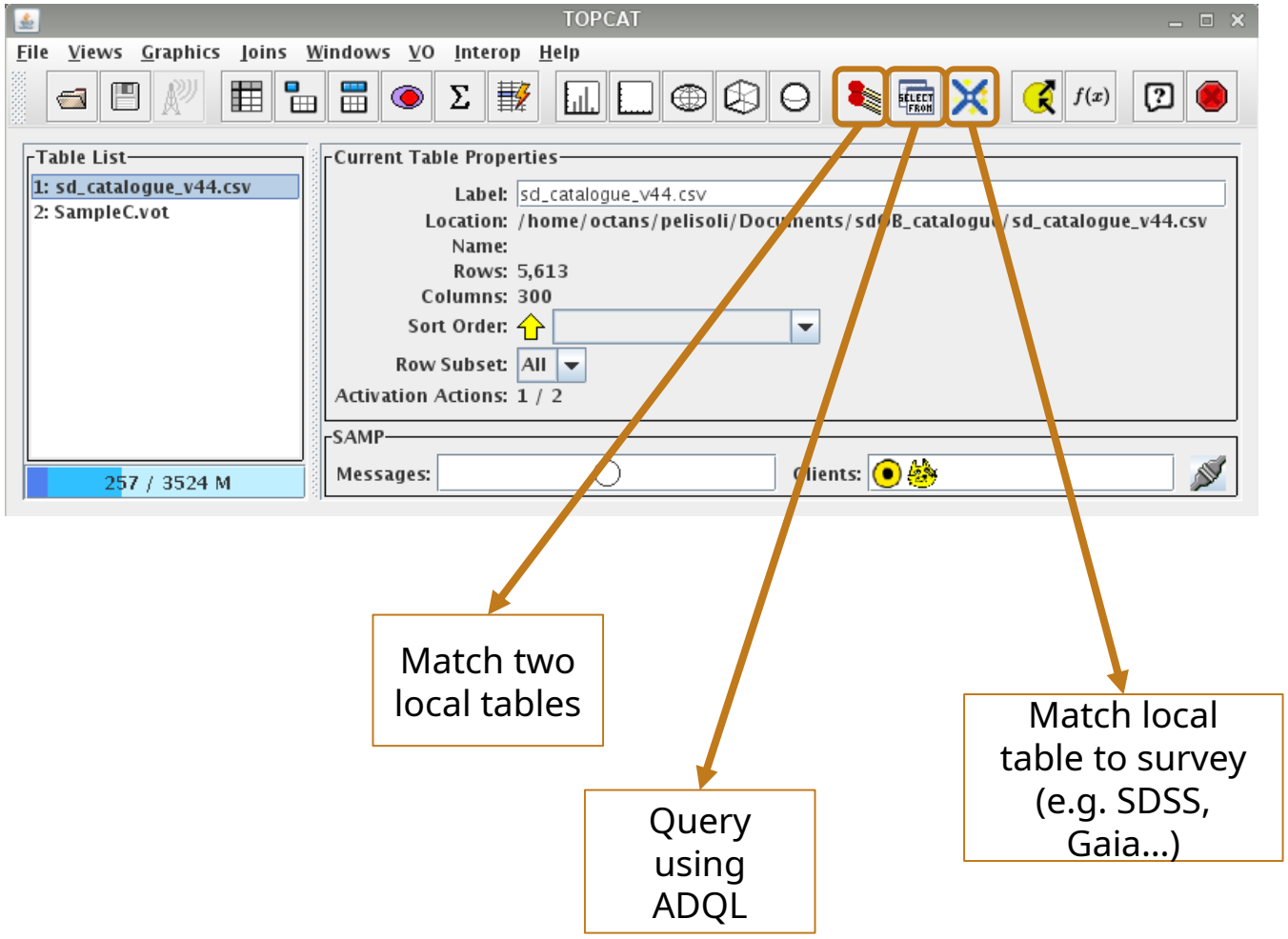
Sky plotting



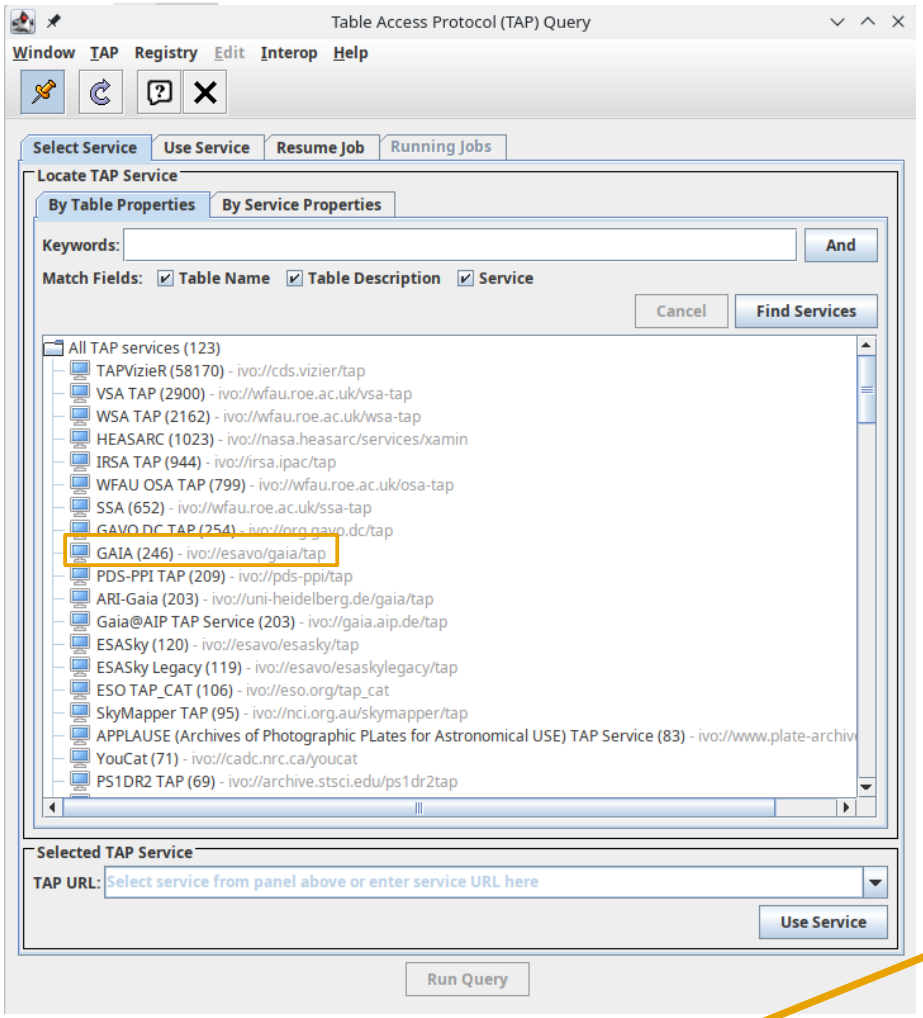
3D plotting

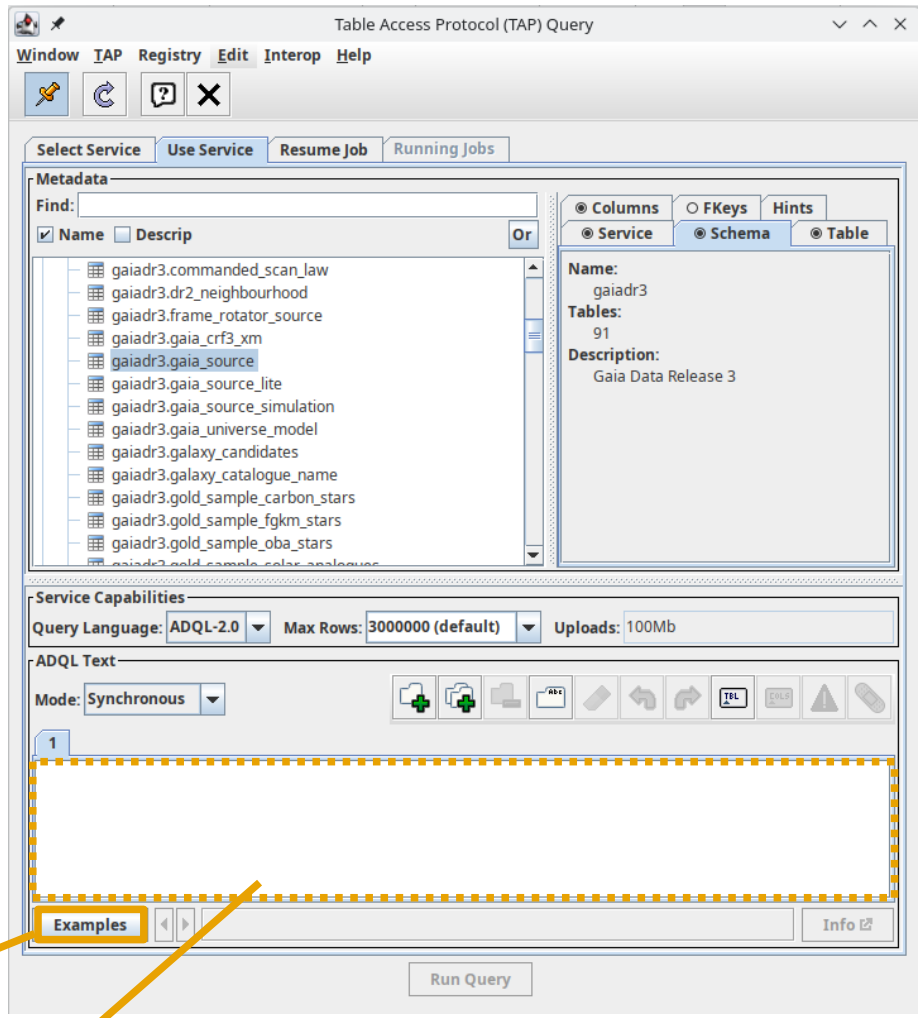


TOPCAT – Crossmatching



ADQL queries



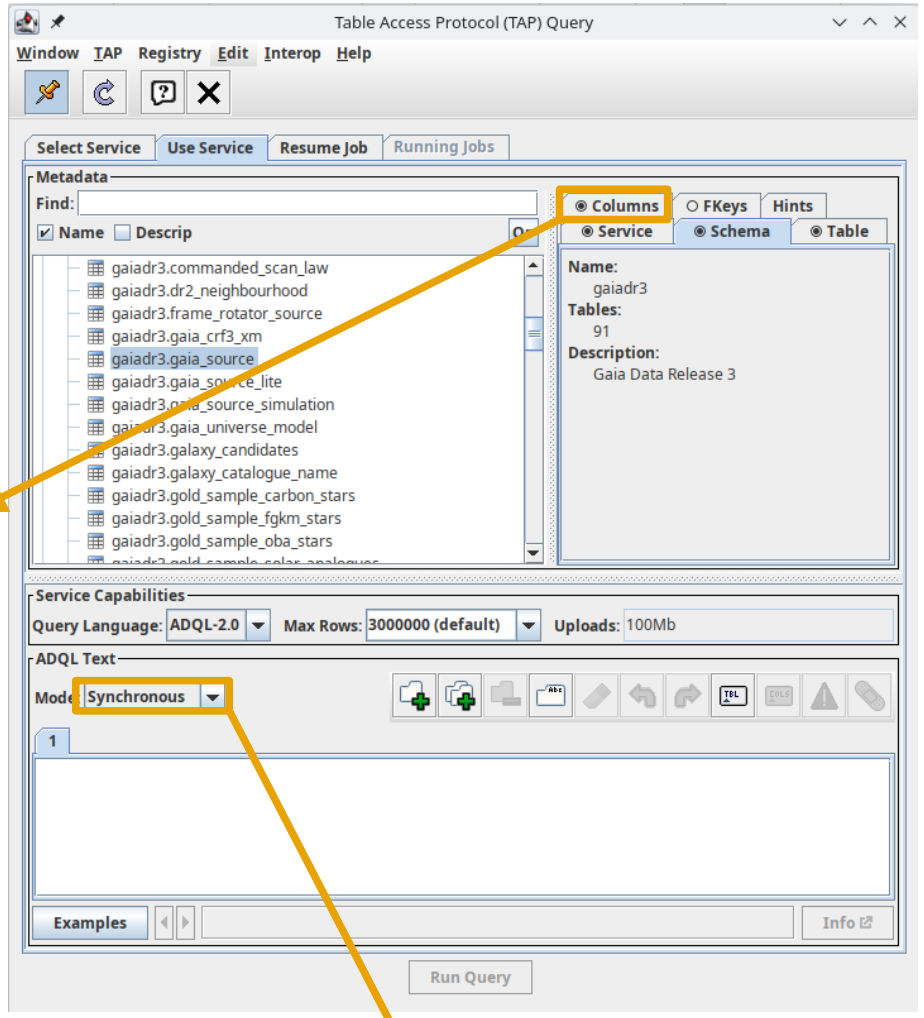


Provides simple queries that can be adapted

Here goes query

ADQL queries

Select this to see names of columns



Set to Asynchronus if query times out

ADQL queries

- ADQL = Astronomical Data Query Language
- Useful tutorial http://docs.g-vo.org/adql-gaia/html/
- A dialect of SQL

Column names

Very basic summary of a query:

```
SELECT [TOP (number of rows)] [source table index].(variables you need)
FROM (table you're querying) [AS (table index)]
[WHERE (condition 1) AND (condition 2) OR (condition 3)]
[ORDER BY (variable)]
```

[1]

[1] Instead of TOP a * can be used to select everything that fulfills criteria or until maximum number of entries is reached

ADQL queries – SELECT: ORDER BY

- Useful to select brightest, fastest, etc. from a table
- E.g.: 50 brightest stars in Gaia DR2

- E.g.: 20 highest proper motion stars in Tycho

ADQL queries – SELECT: ORDER BY

- Useful to select brightest, fastest, etc. from a table
- E.g.: 50 brightest stars in Gaia DR2

```
SELECT TOP 50 source_id, phot_g_mean_mag, parallax, bp_rp
FROM gaiadr3.gaia_source
ORDER BY phot_g_mean_mag
```

- E.g.: 20 highest proper motion stars in Tycho

```
SELECT TOP 20 source_id, parallax, phot_g_mean_mag,
              SQRT(POW(pmra,2)+POW(pmdec,2)) AS pm
FROM gaiadr1.tgas_source
ORDER BY pm DESC
```

ADQL queries – SELECT: WHERE clause

- WHERE introduces a logical expression, in a similar way to other languages, with operators AND and OR.
- E.g.: stars brighter than 12, closer than 50 pc.

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```
SELECT source_id, phot_g_mean_mag, parallax, bp_rp
FROM gaiadr3.gaia_source
WHERE phot_g_mean_mag < 12.0 AND parallax > 20.0
```

ADQL queries – SELECT: JOIN USING

- For joining two tables with a same column
- E.g.: get Gaia DR2 proper motions for stars with known `source_id`

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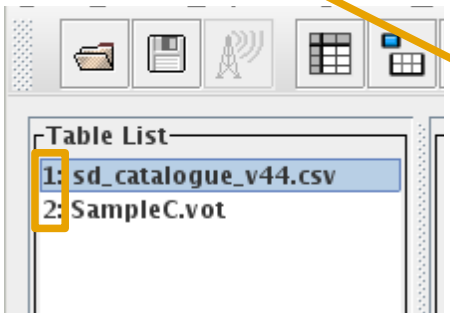
```
SELECT source_id, a.phot_g_mean_mag, a.parallax,
       a.bp_rp, b.pmra, b.pmdec
FROM TAP_UPLOAD.t6 AS a
JOIN gaiadr3.gaia_source AS b USING(source_id)
```

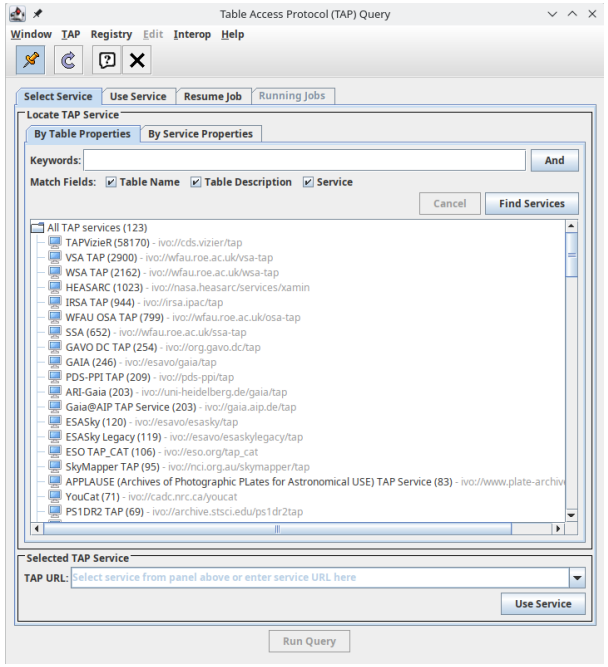


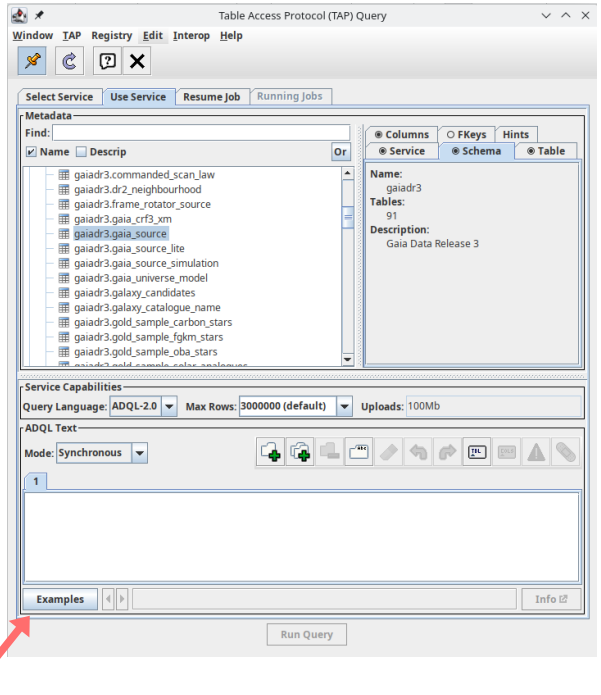
You can find this number in your table list

ADQL queries – Exercise: Select the top 1000 sources within 100 pc in Gaia

Select only sources where the parallax error is less than 10%.

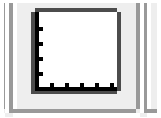
- Check the column parallax_over_error

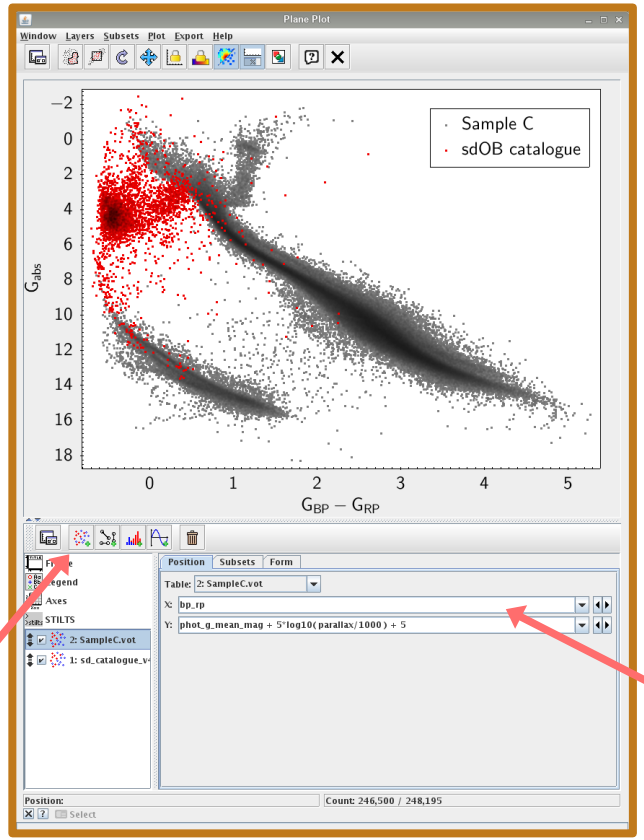




ADQL queries – Exercise: Load the table Hot_subdwarf_candidates_dereddening.csv from the photometry project directory into TOPCAT

Create a diagram where you plot Galactic longitude (l) against Galactic latitude (b) for both tables.





Add table

Select l and b

ADQL queries – Excersise: Color Magnitude Diagram (CMD)

Create a Colour Magnitude Diagram (CMD) of the stars in both tables. Use the columns bp_rp and phot_g_mean_mag

ADQL queries – Exercise: Identify variable sources

Calculate the variability index for the stars in Hot_subdwarf_candidates_dereddening.csv and plot the result over phot_g_mean_mag

- Variability index: $V_G = \frac{\sigma_G}{\langle G \rangle} \times \sqrt{n_{\mathrm{obs,G}}}$
- phot_g_mean_flux_error/phot_g_mean_flux*sqrt(phot_g_n_obs)

Now create the target lists for your projects