

# Exploring Gaia data with TOPCAT & STILTS

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# Outline

## Gaia

- Short introduction to mission and Data Release 1

## TOPCAT/STILTS

- Short introduction

## Hands-on exercises

- Pleiades distance determination (cone search, subsets, stats)
- Match Gaia and HST observations (CDS X-Match)
- TGAS-Hipparcos colour-magnitude diagram (TAP)
- TGAS density maps (all-sky visualisation)

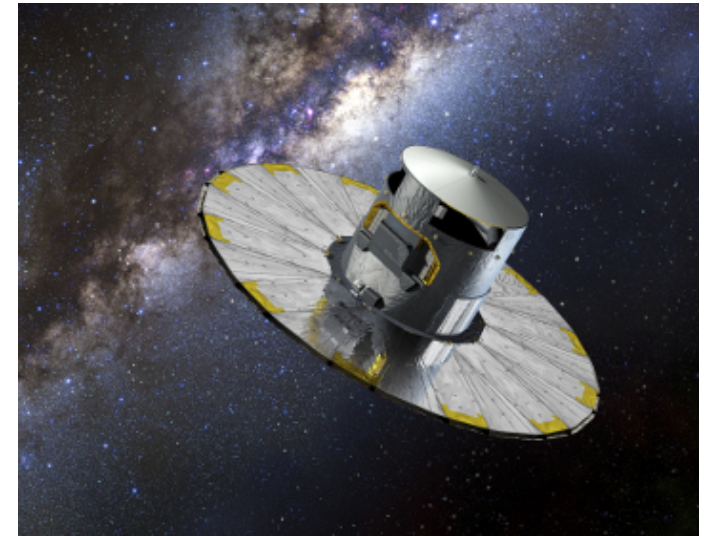
# Gaia Mission

## Satellite:

- Satellite at L2
- 5 year mission, launched 19 Dec 2013

## Aims (very approximately):

- Measure 1 billion point sources, complete to  $G \approx 20$ 
  - ▷ mostly milky way stars, also galaxies, QSOs, SSOs, ...
  - ▷ each source observed multiple times
- Astrometry: positions, parallaxes, proper motions ( $10^1$ – $10^3 \mu\text{as}$ )
- Photometry: G band (mmag)
- Spectrometry: radial velocities 1–15 km/s
- Spectro-Photometry: 20-band(?) in range 330–1050 nm



# Gaia DR1

## Data Release 1, 14 Sept 2016:

- “Secondary” data set
  - ▷ 1 billion objects
  - ▷ G magnitude and position only
- Tycho-Gaia Astrometric Solution (TGAS) (“primary” data set)
  - ▷ 2 million objects common with Tycho2/Hipparcos
  - ▷ G magnitude, position, parallax, proper motion
- ... plus some other things (light curves, errors, crossmatches, ...)
- Very useful dataset, but
  - ▷ various caveats for use
  - ▷ will be obsoleted by later data releases

Later data releases, much more and better data


# TOPCAT

## TOPCAT = Tool for OPerations on Catalogues And Tables

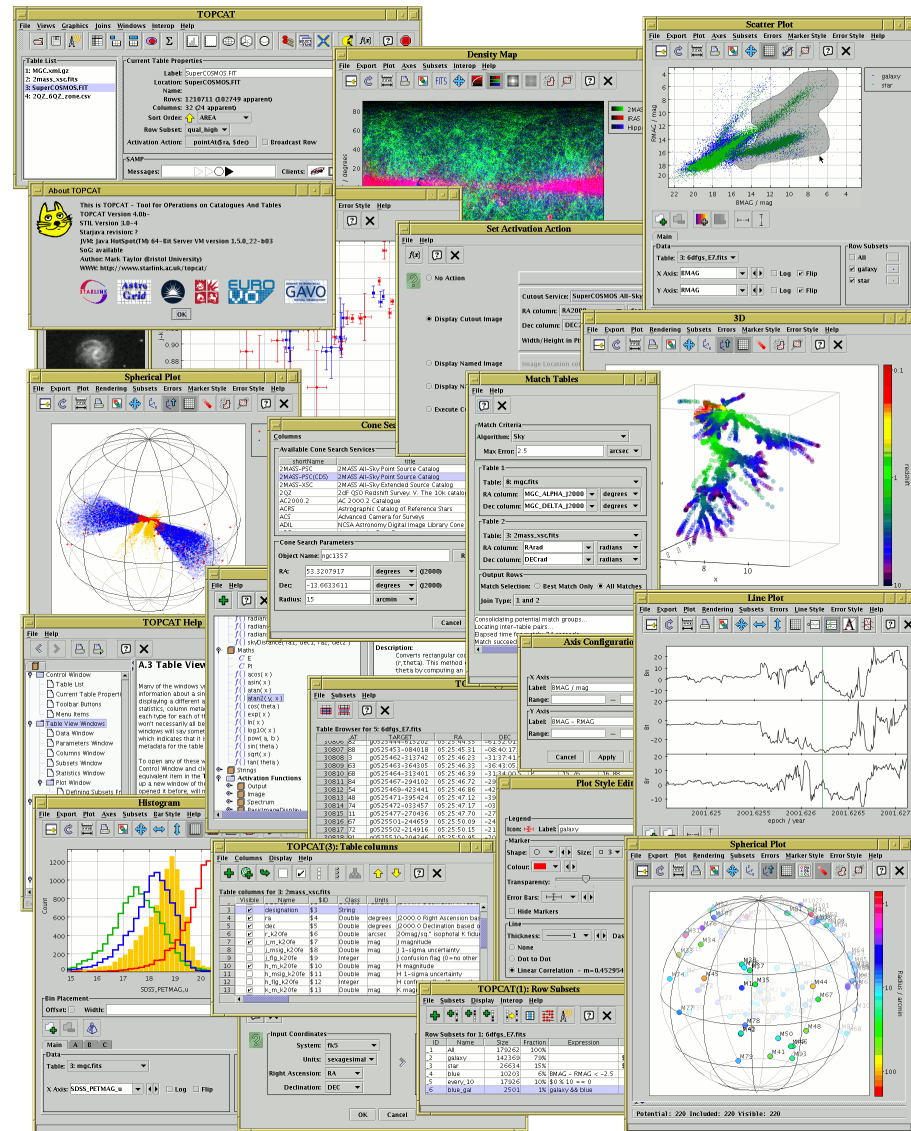
### Aims:

- Does stuff with tables
- Talks to the *Virtual Observatory*

### Help is available:

- Comprehensive [HTML](#) / [PDF](#) user manual
- **Help for Window**  button on every window
- Email support:
  - ▷ on list: [topcat-user@bristol.ac.uk](mailto:topcat-user@bristol.ac.uk)
  - ▷ in person: [m.b.taylor@bristol.ac.uk](mailto:m.b.taylor@bristol.ac.uk)
- Acknowledgement: 2005ASPC..347...29T

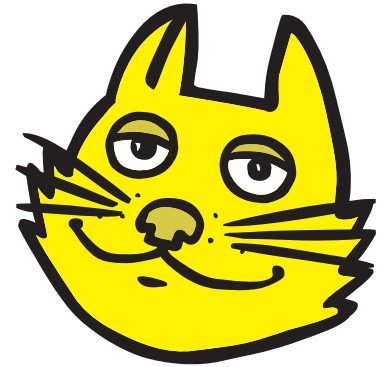
<http://www.starlink.ac.uk/topcat/>



# TOPCAT Capabilities

TOPCAT can:

- Read/write tables in multiple formats
- View/edit data
- View/edit metadata
- Calculations and statistics
- Visualisation
- Make/combine/display row selections in various ways (linked views)
- Crossmatching — efficient and very flexible
- Access external data services (VO and others)
- Trigger some event when a row is selected
- Talk to other astro tools (SAMP)



# STILTS

## STIL Tool Set (STIL = Starlink Tables Infrastructure Library)

- Has pretty much the same capabilities as TOPCAT
- but works from the command line (also **JyStilts** from Jython)

### TOPCAT



#### GUI

Interactive  
Easy to use  
Good for data exploration  
Exploratory phase  
few  $\times 10^6$  rows

### STILTS



#### Command line

Scriptable  
Reproducible  
Good for batch/programmed use  
Production phase  
Unlimited size (for most things)

## Typical usage:

- start off with TOPCAT
- maybe move on to STILTS for more specialised requirements

# Example 1: Pleiades distance determination

Determine parallax of Pleiades (following Gaia-DR1 paper)

- Cone search TGAS within  $5^\circ$  of Pleiades
- Plot `pmra` vs `pmdec`
- Identify comoving sources, create subset graphically
- Plot `parallax` histogram of comoving subset
- Restrict subset further to exclude parallax outliers
- Use Statistics window to determine cluster  $\mu_\varpi, \sigma_\varpi$
- Visualise cluster and non-cluster sources: in 3d space, showing proper motions



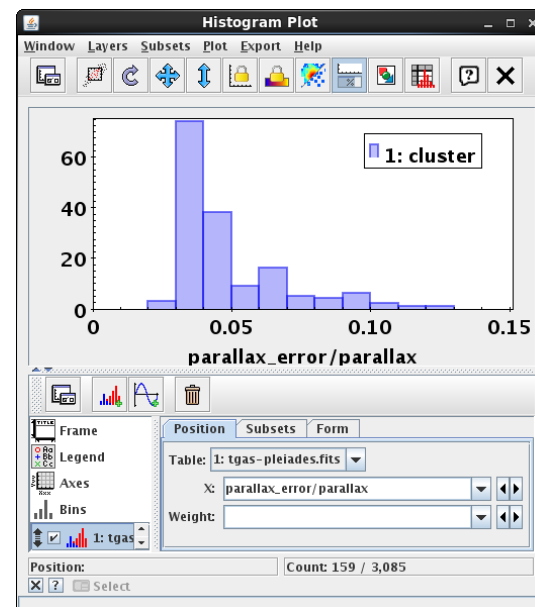
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## Result

- Pleiades  $\mu_\varpi \approx 7.5 \pm 0.4$  mas
  - ▶  $\Rightarrow \mu_D \approx 1000./7.5 \approx 133 \pm 7$  pc
  - ▶ ... but careful with priors
  - ▶ ... but  $\sigma_\varpi/\varpi < 0.15$



## 2: Match Gaia and HST observations

Match Gaia with Gouliermis et al. ([2006ApJS..166..549G](#))

- Find and download J/ApJS/166/549/table2 from VizieR load window
- Use CDS XMatch window to match with **GAIA DR1**
- Sky plot of Gouliermis and Gouliermis/Gaia matched pairs
- Plot  $\Delta\alpha$  vs.  $\Delta\delta$  and identify modal value
- Trace new subset to identify probable matches

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### Result

- Numbers:

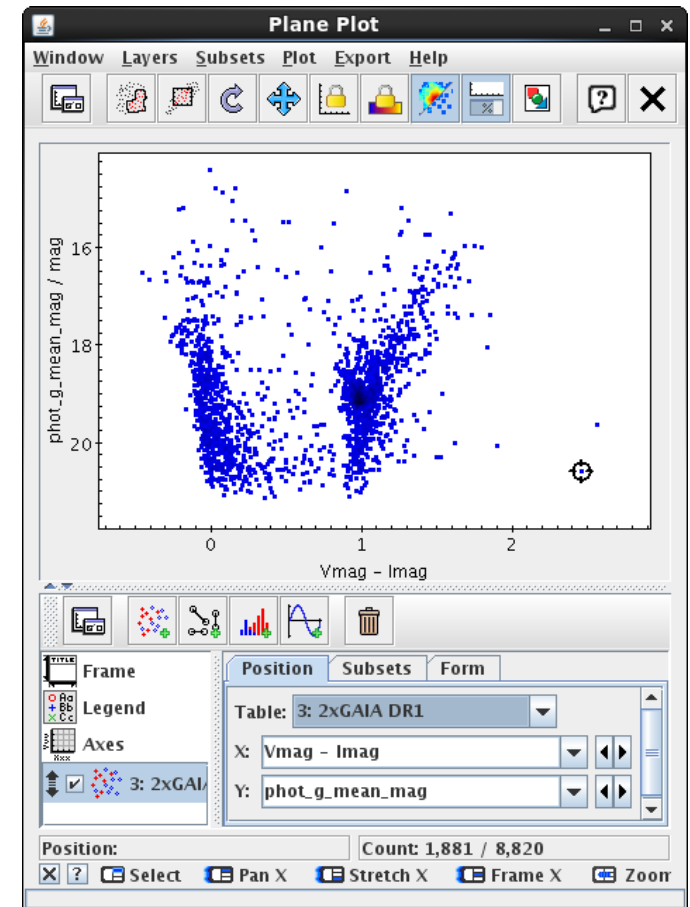
$$\overline{\Delta t} \approx 10.4 \text{ yr}$$

$$\overline{\cos \delta \Delta \alpha} \approx +210 \pm 20 \text{ mas}$$

$$\overline{\Delta \delta} \approx -284 \pm 15 \text{ mas}$$

- Conclusions:

- ▶ NGC346 proper motion (+20,-27) mas/yr?
- ▶ ... or maybe HST *absolute* astrometry errors ( $\sim 1$  arcsec)



## 3: TGAS-Hipparcos colour-magnitude diagram

Use ARI TAP **Example** query to generate fig 3 of Gaia DR1 paper

- Point TOPCAT TAP client at ARI-Gaia service
- Use **Examples|Service-Provided|Gaia DR1 Color and Magnitude** menu
- Plot Hipparcos  $B - V$  vs absolute Gaia  $G$
- Adjust TAP query to get more columns

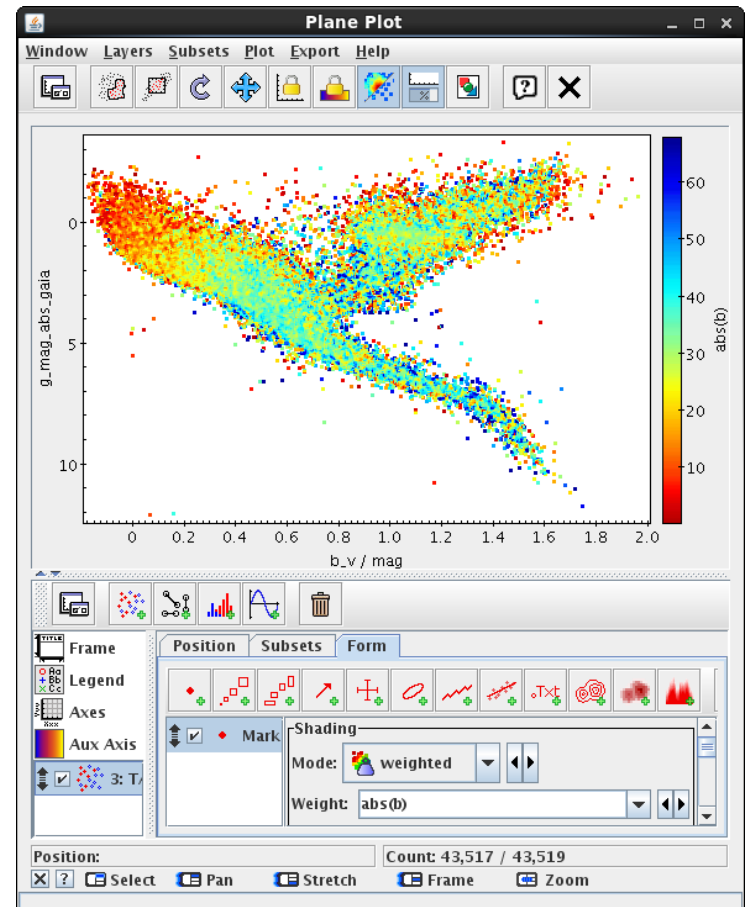
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## Result

- Weight points by `abs(b)`?



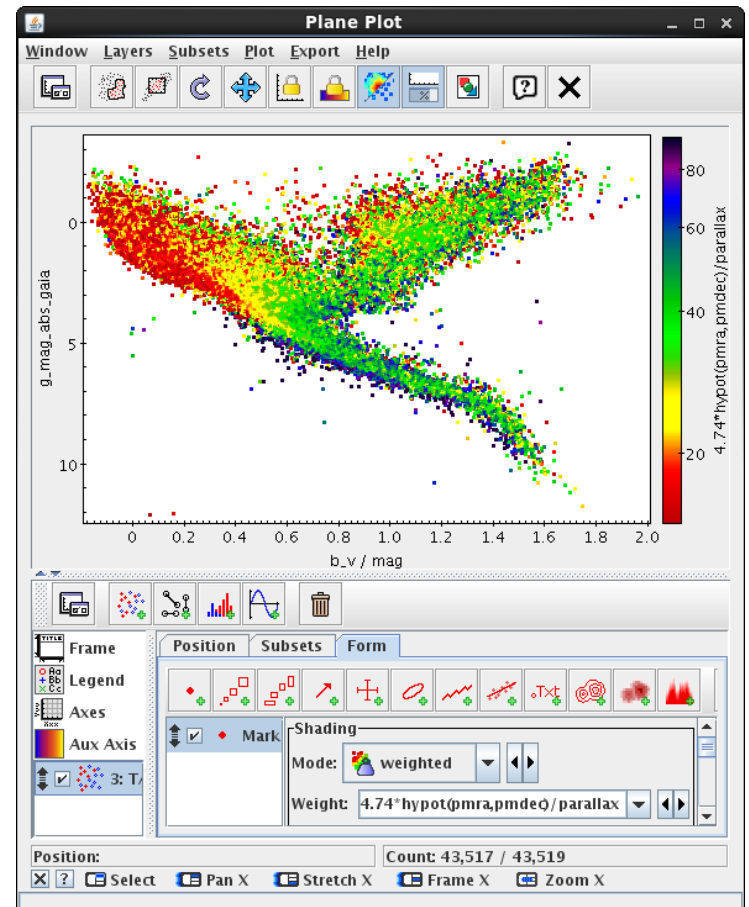
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## Result

- Weight points by `abs(b)`?
- Weight points by transverse velocity  
`4.74*hypot(pmra,pmdec)/parallax?`  
(Gaia DR1 paper fig 6)



## 4: Play with TGAS

### Acquire and use full TGAS sample

- Use STILTS
- Prepare full TGAS catalogue as monolithic FITS file
- Experiment with STILTS commands using TGAS

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**Well done!**