Tutorial #3: TOPCAT and STILTS

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Centro de Astrobiología,
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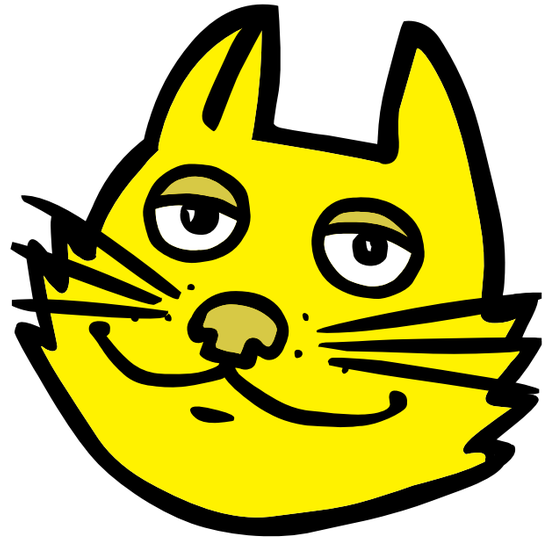

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TOPCAT/STILTS Installation

MacOS:

- If you have Homebrew:
  - ▷ `brew install --cask topcat --no-quarantine`
- Otherwise download DMG file (use `curl` *not* browser):
  - ▷ `curl -OL http://www.starlink.ac.uk/topcat/topcat-all.dmg`
  - ▷ `topcat -version`
  - ▷ `stilts -version`

Linux

- You need Java (JRE, any version)
  - ▷ Debian/Ubuntu: `sudo apt install openjdk-21-jre`, maybe `xwayland` too?
- Then download the JAR file and `stilts` script:
  - ▷ `curl -OL http://www.starlink.ac.uk/topcat/topcat-full.jar`
  - ▷ `curl -OL http://www.starlink.ac.uk/stilts/stilts`
  - ▷ `chmod +x stilts`
- Run TOPCAT:
  - ▷ `java -jar topcat-full.jar`
- Run STILTS:
  - ▷ `./stilts -version`

Windows

- You need Java (JRE, any version)
- Download `http://www.starlink.ac.uk/topcat/topcat-full.jar`
- ... click on it?

Not working? Ask!

Display problems on Ubuntu? maybe try
`https://github.com/RedChaosWolf92/TOPCAT_RESOURCES`

Debian astro installation is possible, but installs an older version (not everything will work):
`sudo apt install topcat stilts`

Outline

Introduction (10 mins)

- What is TOPCAT?
- What is STILTS?
- Gaia mission and data
- Examples overview

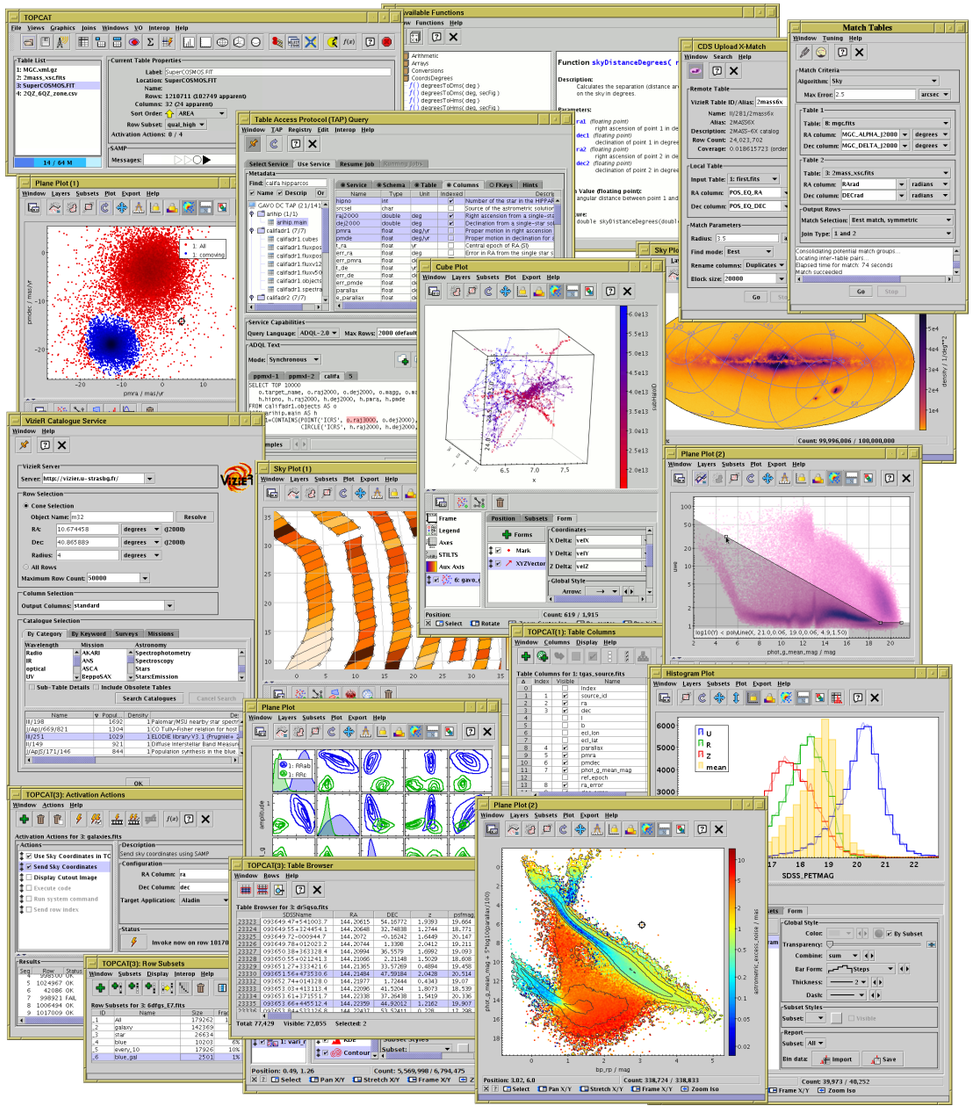
Hands-on examples:

1. Cluster identification #1: M4 in proper motion using Cone Search
2. Cluster identification #2: Hyades in 3-D velocity space using TAP
3. Match Gaia and HST observations
4. M4 in proper motion space using STILTS
5. Local Herzsprung-Russell Diagram

TOPCAT Overview

TOPCAT = Tool for OPerations on Catalogues And Tables

"Does what you want with tables"



Suitable for:

- Interactive exploration
- Quick look at unfamilar data
- In-depth analysis

Overall aim:

- Makes table manipulation easy,
  so users can concentrate on doing science

TOPCAT Aims

User-friendly

- Easy to install and run (pure Java — one download file, no library issues)
- Easy to get started
- Simple things fairly obvious
- Complicated things at least well-documented

  ... this does get harder as more functionality is added

High Performance

- Most things are fast
- Handles quite large tables: millions of rows, hundreds of columns easily (can be much more)
- ... even on modest hardware

Do the things that astronomers need

- Development is led by community input (mailing list, personal emails, tutorials, feature requests, bug reports...)
- Feedback always welcome!

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 	**STILTS** 
GUI	Command line
Interactive	Scriptable
Easy to use	Reproducible
Good for data exploration	Good for batch/programmed use
Exploratory phase	Production phase
$\lesssim 10^7$ rows	Unlimited size (for most things)

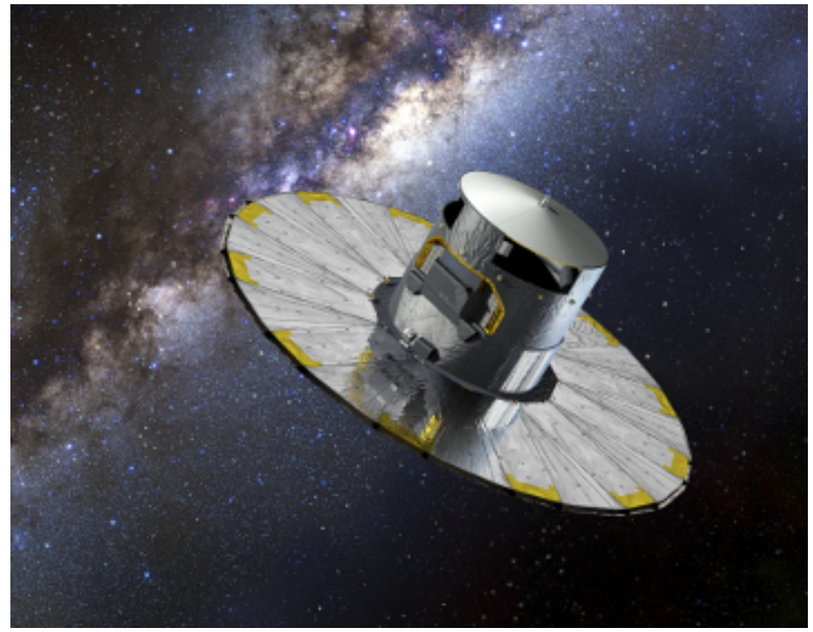
Typical usage:

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

Gaia Mission

ESA astrometry satellite:

- Satellite at L2
- ∼10 year mission, 2013–2025



Aims

- Measure ∼2 billion point sources, complete to G≈20
  - ▷ mostly milky way stars, also galaxies, QSOs, SSOs, ...
  - ▷ each source observed multiple times
- Astrometry: positions, parallaxes, proper motions (10^1–$10^3\mu$as accuracy)
- Photometry: G, RP, BP bands (mmag accuracy)
- Spectrometry: radial velocities (1–15 km/s accuracy)
- Spectro-Photometry: low-res spectra in range 330–1050 nm

Highly successful

- Thousands of published papers, impacts on all areas of astronomy

Data published primarily to the Virtual Observatory

- If you're using Gaia data, it's probably come through the VO

Hands-On Exercises: Instructions

For each exercise:

- I will quickly introduce it
- You work through the script; instructions are quite detailed, especially for the earlier exercises
- You will have 15–20 minutes for each one
- At the end, I'll talk through it

There's quite a lot there, people work at different speeds

- If you don't finish, don't worry!
- If you finish early, explore the software and data to see what else you can do
  (or go on to Exercise 5)
- The main thing is to get a flavour of what can be done and how to do it

Problems?

- We're here to help!
- You can also try the **Help Button**  in all TOPCAT windows — documentation is exhaustive!

Exercise #1

Cluster identification 1: Messier 4 in proper motion space

- Steps
  - ▷ Locate Gaia EDR3 Cone Search service
  - ▷ Query for sources in region of Messier 4
  - ▷ Plot positions on sky
  - ▷ Plot proper motions
  - ▷ Create subset of comoving objects
  - ▷ Create subset of background objects
  - ▷ Plot proper motion vectors
  - ▷ Histogram parallaxes of comoving and background objects
  - ▷ Infer distance to Messier 4
- TOPCAT features:
  - ▷ Cone search, Table data and metadata, Sky plot, Row Subsets, Histogram

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Distance to Pleiades: $1/0.535\,\mathrm{mas} \approx 1.8\,\mathrm{kpc}$

Exercise #2

Cluster identification 2: Hyades in 3-D velocity space

- Steps
  - ▷ Locate Gaia TAP service
  - ▷ Explore Gaia TAP service
  - ▷ Run toy TAP query
  - ▷ Run TAP query giving 6-d phase space information for nearby sources (cut'n'paste)
  - ▷ Create new columns with 3-d Cartesian velocity components
  - ▷ Plot sources in 3-d velocity space
  - ▷ Create subset of comoving sources (Hyades)
  - ▷ Examine Hyades *vs.* background sources on the sky
  - ▷ Plot colour-magnitude diagram of Hyades *vs.* background sources
  - ▷ Investigate outliers using linked views and activation actions
- TOPCAT features:
  - ▷ TAP, Expression language, 3D plot, Linked views, Activation Actions

Note: There will be much more on ADQL/TAP in Tutorial #4 this afternoon

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Distance to Hyades: $1000/21\,\mathrm{mas} \approx 46\,\mathrm{pc}$

Exercise #3

Match Gaia and HST observations for NGC 346

- Steps
  - ▷ Download J/ApJS/166/549 catalogue from VizieR
  - ▷ Crossmatch with Gaia EDR3 using CDS X-Match service
  - ▷ Plot the crossmatch results
  - ▷ Graphically find offset between HST and Gaia positions
  - ▷ Use this to make sense of cross-match results
  - ▷ Re-do crossmatch using TOPCAT internal match window
- TOPCAT features:
  - ▷ VizieR download, CDS X-Match, Multi-layer plots, Pair match

Exercise #4

Use STILTS for Messier 4 cluster identification

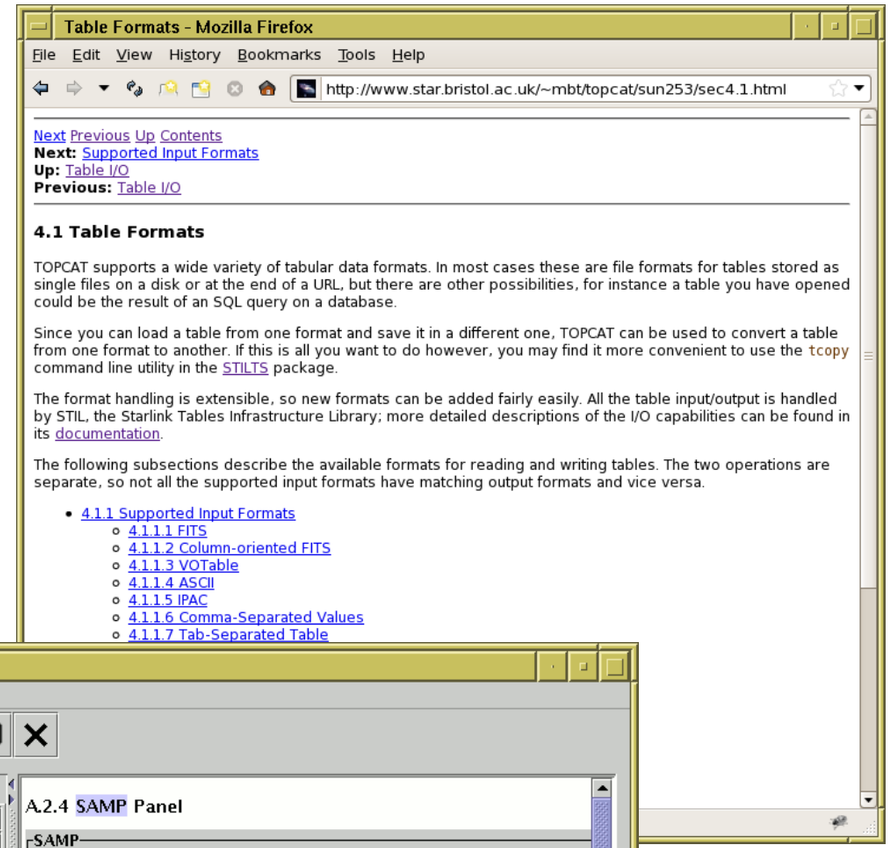
- Steps
  - ▷ Run a simple STILTS command (`calc`)
  - ▷ Download M4 data from a cone search service (`cone`)
  - ▷ Get used to table pipeline processing (`tpipe`)
  - ▷ Obtain mean parallax for comoving objects → distance to M4
  - ▷ Try some STILTS plotting (`plot2sky`)
- STILTS features
  - ▷ Running commands, help system, command documentation, pipeline filters, pipeline output modes, TOPCAT/STILTS interoperability

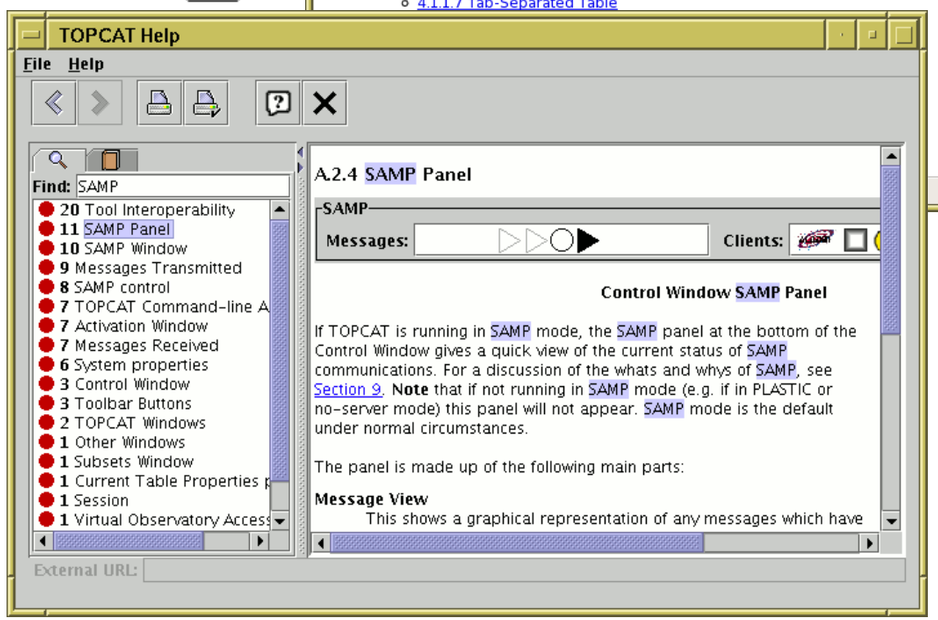
Further Information

- There are things I haven't mentioned!
- Full tutorial and reference documentation:
  - HTML/PDF manuals on web pages

    `http://www.starlink.ac.uk/topcat/`

    `http://www.starlink.ac.uk/stilts/` (or google them)
  - **Help for Window** button [?] on every window
  - Help browser includes search tool
  - More options in Help Menu (including **Help for Window in Browser** item [?])
  - Or print out the 600-page manual
- Support:
  - Talk to me here
  - Email me: m.b.taylor@bristol.ac.uk
  - Mailing list: topcat-user@jiscmail.ac.uk
  - All feedback and questions welcome!





Well done!