The positions of the constellation figures shown on the Farnese Atlas point to a date of 125 B.C., matching that of a long-lost star catalog by ancient Greek astronomer Hipparchus. (Gerry Picus, courtesy Griffith Observatory)
Present times in terms of Data....

- Digital data
- In depth study of individual objects
- Survey data of larger (or complete) sky
- ESO-VISTA 150TB/per year, LSST 500 TB/month
- Simulations TNG 300 +TNG 100 > PB data (2018 release)
- Data Centres
- Jupyter Notebooks
Types of Data

- Images
- Catalogs
- Spectra
- Polarization
- Time-series
Types of Data: Images

• 2-D array, pixel value-brightness
• RGB images
• Artificial colors
• (related to wavelength/energy)
Basics of Data: Images

- Point sources
- Extended sources
Figure 1.9. Willard S. Boyle (left) and George E. Smith, inventors of the charge-coupled device at the Bell Labs research center at Murray Hill, New Jersey in December 1974 when they received their patent for the CCD. Credit: Lucent Technologies Bell Labs.
CCDs

- Sensitivity (QE)
- dynamic range
- linearity.
- CCDs ~ 80% quantum efficiency

Digital is better than digitised!!!
Colors: Bayer filter (Eastman Kodak)

- Color filter array (CFA) for arranging RGB color filters on a square grid of photosensors. The filter pattern is 50% green, 25% red and 25% blue.
- Used in digital cameras, camcorders, and scanners to create a color image.
Astronomy Images

- Filters in succession
- Create RGB images
- Artificial colors

Figure 3: Two images of Westerlund 2. Image credit left: 2 m Faulkes Telescope operated by Las Cumbres Observatory at Siding Spring under license CC BY-2.0. Image on the right: NASA, ESA, the Hubble Heritage Team (STScI/AURA), A. Nota (ESA/STScI), and the Westerlund 2 Science Team.
Flexible Image Transport System (FITS) is an open standard defining a digital file format useful for storage, transmission and processing of data: formatted as multi-dimensional arrays (for example a 2D image), or tables.

FITS was designed specifically for astronomical data.

Includes provisions such as describing photometric and spatial calibration information, together with image origin metadata.

FITS is also often used to store non-image data, such as spectra, photon lists, data cubes, or structured data such as multi-table databases. A FITS file may contain several extensions, and each of these may contain a data object. For example, it is possible to store x-ray and infrared exposures in the same file.
$2^{16} = 65536$

Figure 4: Part of the Westlund 2 image taken through an R (red) filter in April 2017 with the 2 m Faulkes Telescope operated by Las Cumbres Observatory at Siding Spring in Australia with different scaling. Left: Linear scaling from 0 to 65536. Center: Linear scaling from 4572 to 6002. Right: Square scaling from 4572 to 6002.
NGC 281
(3.6 µm) Spitzer image of NGC 281 from the Warm Spitzer image. The large blue square is the Chandra ACIS field and the cyan box is the Spitzer cyro data.
NGC 281 by Chandra
Types of Data: Spectra

- 1D data
- Energy distribution among different wavelengths
- Contribution of light from that particular wavelength region
Types of Data: Data Cubes

- 3D data
- For example, Integral Field Spectroscopy (IFS)
- Each pixel has a whole spectrum received from the pixel
Types of Data: Catalog Data

<table>
<thead>
<tr>
<th>Cluster</th>
<th>RAJ2000</th>
<th>DEJ2000</th>
<th>GLON</th>
<th>GLAT</th>
<th>r50</th>
<th>Nstars</th>
<th>pmRA</th>
<th>pmDE</th>
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<td>51.87</td>
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### Time series data

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<th>$S_t$ ($p=4$)</th>
<th>$N_t$</th>
<th>$Y_t$</th>
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</tbody>
</table>

![Example Time Series](image)
Tools:

- Image Visualization: ds9
- Catalogs: TOPCAT
- Programming Languages: Python ....modules, libraries
- Not to be used as black boxes
Meta-Data

- Descriptive information about the data
- Images: Telescope, exposure time....
- Simulations
- Spectra
What is an Astronomy Archive?

Organised, systematic information about the sky above us, we will call as an astronomy archive.

Today's archives are many terabytes and sometimes even petabytes in size
Astronomy Archives

- Hipparchus (190 – c. 120 BC)
  850 stars, 1-6 mag

- Tycho Brahe (1546 – 1601)
  positions of the naked eye planets as a function of time
- Used by Kepler (first example of archival data!!)
• 1603, Bayer, compiled his star catalogue, labeling every star in a constellation by its brightness.

• 1771, Charles Messier catalogue of nebulous objects ~ 100

• 1888, Dreyer: NGC catalogue > 7,000

Organised data!!!
Palomar sky survey

1950-1957, Oschin Schmidt Telescope at the Palomar Observatory, California, USA.

2,000 photographic plates of the night sky (14-inch (35.5-cm) square photographic plates, each covering 36 square degrees of sky)

1990s: DPOSS
And then Technology...

Digital data, QE, linear response

Citizen science projects
In other wavelengths too.....

- Similar growth in radio, Xray, etc
Technology goes hand-in-hand....
Astronomy Archives

• In the true spirit of science
• Available to all
  (ex instrument groups, proprietary period, etc)
• Citizen Science projects: SETI, Galaxy Zoo,
Data Archives

VizieR: access to the most complete library of published astronomical catalogues and online data tables

Simbad: Astronomical database which provides basic data, cross-identifications, bibliography

NED The NASA/IPAC Extragalactic Database (NED): multi-wavelength fusion of data for millions of objects outside the Milky Way galaxy.
SDSS DR15 Sloan Digital Sky Survey: systematic map of a quarter of the sky, producing new catalogues for deep-sky.

2MASS Two Micron All Sky Survey (2MASS): map of the entire sky in near-infrared.

ESO data archive: ESO observational data
MAST The Multimission Archive at STScI: scientifically related data sets in the optical, ultraviolet, and near-infrared parts of the spectrum.

2dFGRS The 2dF Galaxy Redshift Survey (2dFGRS) is a spectroscopic survey and spectra is obtained for 245591 objects, mainly galaxies.
IPAC/IRSA: NASA’s infrared and sub-millimeter astronomy projects and missions.

HLA The Hubble Legacy Archive (HLA): optimize science from the HST providing online, enhanced Hubble products and advanced browsing capabilities.
Hubble MAST

- MAST Observations: Millions of observations from Hubble, Kepler, GALEX, IUE, FUSE, and more.
- Virtual Observatory: Search thousands of astronomical data archives from around the world for images, spectra, and catalogs.
- Hubble Source Catalog: A master catalog with a hundred million measurements of objects in Hubble images.
- MAST Catalogs: Access to catalog data such as Gaia and TESS Input Catalog, with more coming soon.
GAIA: 6D revolution
RA, Dec, parallax, RV, pmra, pmdec

Two identical, three-mirror anastigmatic (TMA) telescopes, with apertures of 1.45 m × 0.50 m pointing in directions separated by the basic angle (Γ = 106 ° .5)
Accuracy of 24 microarcsec = 42 kpc, 0.06 arcsec pixels

Galactic Archealogy!!! Imagine!!!
Welcome to the Chandra Data Archive

The Chandra Data Archive (CDA) plays a central role in the operation of the Chandra X-ray Center (CXC) by providing support to the astronomical community in accessing Chandra data. The CDA offers access to digital archives through powerful query engines, including VO-compliant interfaces and also serves as a permanent storage repository of contributed data products by authors who have processed images or other pertinent and valuable datasets that are essential to their publications.

Access the Chandra Data Archive

- **ChaseR**: Search & Retrieval interface for scientists, allowing specification of detailed selection criteria. Chandra Fast Image is a simplified quick search tool for Chandra X-ray images and other data for the general public.
- **FTP**: Direct FTP access to the primary and secondary data products for all observations that are publicly released.
- **Cool Chandra Targets** (formerly known as CATS): the list of approved Cool Chandra Targets (CCTs) programs, including the PI names, titles and abstracts.
- **Footprint Service**: A search by position or object name overlays the footprints of Chandra Observations on Digital Sky Survey images, allowing further selection and retrieval of observations.
- **Chandra MOCs**: Multi-Order Coverage maps (MOCs) for public Chandra observations, that can be used to visualize and analyze the global Chandra footprint.
- **Chandra Source Catalog**: The most comprehensive catalog of sources detected in public Chandra Observations. The catalog can be accessed through CSCview.
- **CIAO Tools**: There are command-line scripts for finding and downloading publicly-available...
The Sloan Digital Sky Survey has created the most detailed three-dimensional maps of the Universe ever made, with deep multi-color images of one third of the sky, and spectra for more than three million astronomical objects. Learn and explore all phases and surveys—past, present, and future—of the SDSS.
Literature Survey

https://vizier.u-strasbg.fr/viz-bin/VizieR

Vizier Demo....