Scientific Use of Astronomical Databases

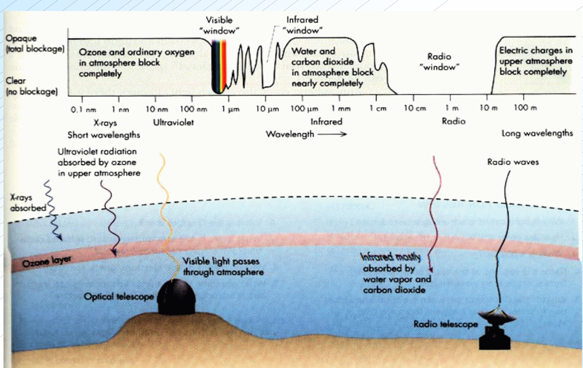
Jacobus Kapteyn (1851-1922)

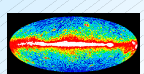
Contents:

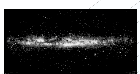
1. The Electromagnetic Spectrum

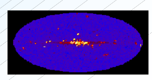
Until the Second World War Astronomy was an Optical Science: all observations were made with instruments working in the visible (with usually the eye as a detector). As a result of modern technology, this has changed enormously.

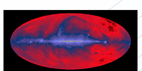
Type Of Radiation	Characteristic Temperature	Objects Emitting This Type of Radiation
Gamma rays	more than 10^8 Kelvin (K)	* Interstellar clouds where cosmic rays collide with hydrogen nuclei * Accretion disks around black holes * Pulsars or Neutron Stars
X-rays	10^6-10^8 K	* Regions of hot, shocked gas * Gas in clusters of galaxies * Neutron stars * Supernova remnants * Stellar corona
Ultraviolet	10^4-10^6 K	* Supernova remnants * Very hot stars * Quasars
Visible	10^3-10^4 K	* Planets * Stars * Galaxies * Reflection nebulae * Emission nebulae
Infrared	10-10^3 K	* Cool stars * Star Forming Regions * Interstellar dust warmed by starlight * Planets * Comets * Asteroids
Radio	less than 10 K	* Cosmic Background Radiation * Scattering of free electrons in interstellar plasmas * Cold interstellar medium * Regions near neutron stars * Regions near white dwarfs * Supernova remnants * Dense regions of interstellar space (e.g. near the galactic center) * Cold, dense parts of the interstellar medium - concentrated in the spiral arms of galaxies in molecular clouds (often the site of star formation). * Cold molecular clouds



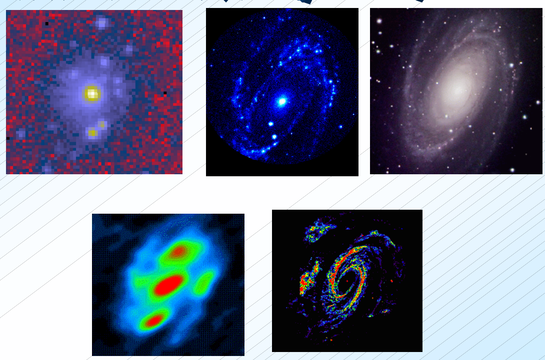


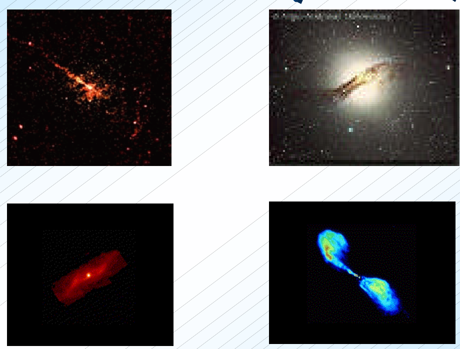






Gamma-Ray (CGRO) Infrared (IRAS) Visual (Lund)





Available Databases

1. Bibliographic

Journals in Astronomy: all on NASA ADS (http://adswww.harvard.edu/inde
This site has several mirrors across the world.

Preprints: http://arXiv.org/ also with several mirrors

Makes libraries redundant!

The NASA Astrophysical Data System

http://adswww.harvard.edu

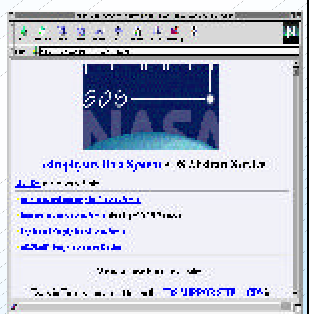
Some History:

1980's	System developed to connect databases for NASA space missions
1993	Abstracts from NASA's Scientific & Technical Information Office added
1994	Web developed--abstract service moved to web environment--usage triples within one month
post-1994	Web allows more linking to more databases, e.g. SIMBAD, NED

Searching the Database

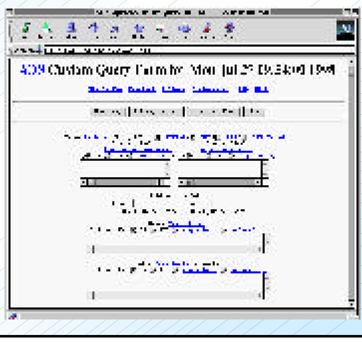
Select a Database:

- Astronomy/Astrophysics abstracts
- Instrumentation
- Physics and Geophysics
- ADS/astro-ph preprints

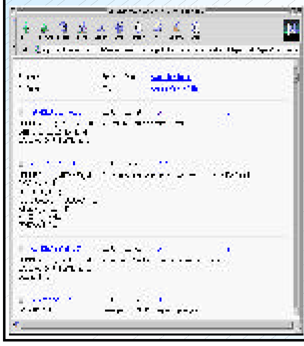


Creating the Query:

- •Title
- •Author
- •Object
- •Keyword



Information provided about links:



O: Original Author Abstract
E: Online E-Journal at site of publisher
F: Full article available from ADS
S: Link to SIMBAD
N: Link to NED
C: Citations

Available Databases: Observations

Available at present:

- Satellites (HST, Chandra, IUE, IRAS, etc.)
  see MAST (Multimission Archive) http://archive.stsci.edu
- Ground-based telescopes
  - Survey Telescopes (2MASS, POSS, SDSS, etc.)
  - General Observer Telescopes
    (ESO, La Palma, UKIRT, CFHT/CADC, JCMT, VLA)
- Object-oriented
  - Galaxies: NASA Extragalactic Database (NED); LEDA
  - Nearby Galaxies: Hypercat (specialised)
  - Stars: SIMBAD

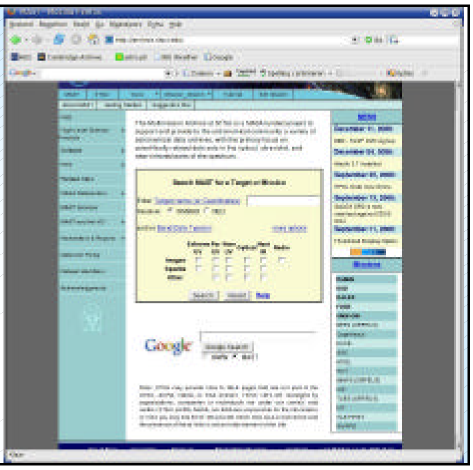
References:

The electromagnetic spectrum: http://www.ipac.caltech.edu/Outreach/Multiwa
(at IPAC)
Data Archives:
Satellites: reachable through STScI (http://archive.stsci.edu/)
ESO: http://archive.eso.org/
La Palma: http://archive.ast.cam.ac.uk/ingarch/
UKIRT: http://archive.ast.cam.ac.uk/ukirt_arch/
CFHT: at CADC (http://cadcwww.dao.nrc.ca/) together with a lot of Other archives
VLA: http://www.aoc.nrao.edu/vla/vladb/
Etc.

Object oriented:
Simbad (stars): http://simbad.u-strasbg.fr/Simbad
LEDA (nearby galaxies): http://leda.univ-lyon1.fr/
Hypercat (nearby galaxies): http://www-obs.univ-lyon1.fr/hypercat/

MAST

Database similar to the HST archive with lots of space missions

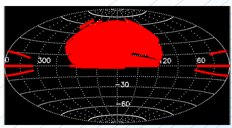


SDSS

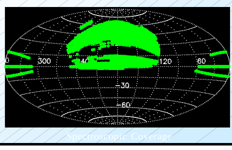
Imaging and Spectroscopy Megasite

The Sloan Digital Sky Survey
(Princeton, JHU, etc.)

Dedicated survey of 8000 degree^2

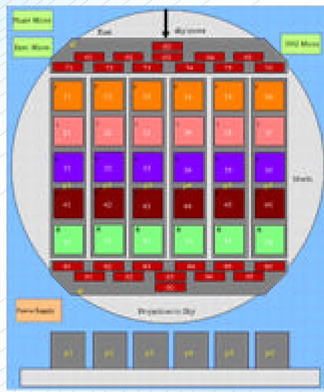


Imaging in ugriz
Spectroscopy from 3800-9200 A

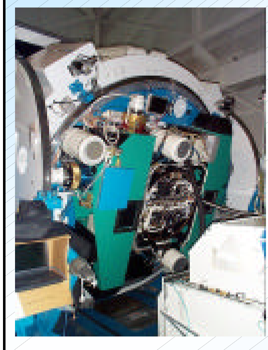


Derivation of age from spectra

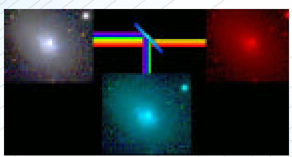
The SDSS imaging
camera



The SDSS Spectrographs

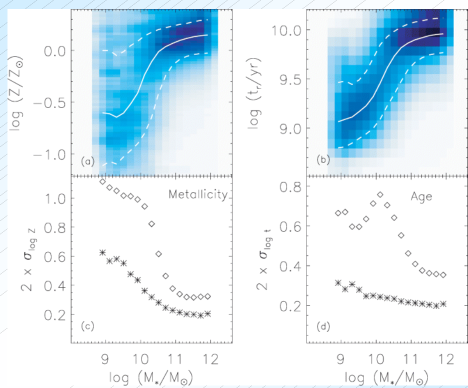


Dichroics



Plug-plates (640 fibers/plate)

200000 spectra from the SDSS survey



Age

Larger galaxies are older (Gallazzi et al. 2005)!

CADC

Site comparable to the CDS with many archives and mirrors

Has CFHT, JCMT, Gemini archives

NASA´s Extragalactic Database (NED)

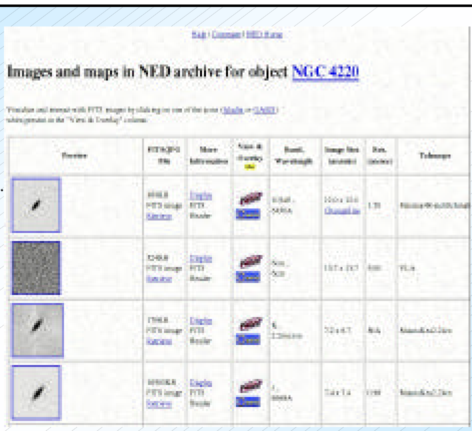
Database of literature parameters of extragalactic objects

Similar to SIMBAD for Galactic objects

NED Gives:

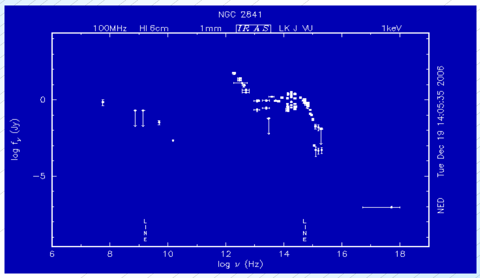
- Object names
- Coordinates (different systems)
- Classification
- Basic RC3 and other Atlas parameters
- References where this object is discussed
- Photometric datapoints
- Diameter datapoints
- Image database
- Several useful links

Has functionality of Alladin, but also includes images from individual papers.



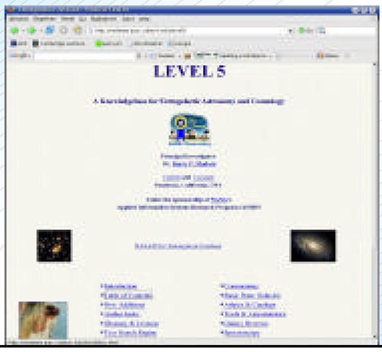
Other Functionalities of NED:

- Gives references where the object is used
- Gives database of photometric datapoints



Other Functionalities of NED:

Level 5 Database: Database of important articles



Very often used:

- Data Reduction and Analysis: AIPS, ESO-MIDAS, IDL, IRAF, PROS, STARLINK, STSDAS
- Document Preparation: LaTeX, TeX
- Modelling: NEMO, CLOUDY, DUSTY, TINYTIM
- Subroutine Libraries: FITSIO, NAG, Numerical Recipes, Python
- Math Routines: Maple, StatCodes
- Utilities: …

3. Caveats when using databases

- Documentation might be wrong or incomplete
- Data quality varying (seeing, photometric conditions)
- Varying depth in data (difficult to calculate statistically complete samples)
- Instrumental settings might be varying without the user knowing this.
- All this is worse for ground-based than for space-based archives.

4. How to produce science with databases

Process:

1. Ask scientific questions
2. Find suitable scientific databases
3. Select sample using one database
4. Extract sample from image using a VO-tool to determine a catalog
5. Do the same for other bands
6. Cross-correlate catalogs with each other and with existing data
   Here is important that the extracted image sizes are the same
   (PSF matching!)
7. Do analysis on the common sample.

An example, the Star Formation History in the Universe
(Cimatti, de Young)

Scientific Questions:

1. When did the first objects form?
2. What are the progenitors of present-day giant ellipticals?
3. What types of galaxies are there at z> 1, 2, 4?
4. How many massive galaxies were already assembled at z=1,2,4?
5. How does the star formation and galaxy stellar mass density evolve?
6. What is the evolution of the metallicity in the Universe with redshift?

The GOODS imprint on the Hubble UDF

Data available for the GOODS survey

- HST/ACS imaging in bviz
- Ground-based imaging in UBVRIZJHK
- Optical Spectroscopy (ESO-VLT etc.)
- Radio data Merlin, GMRT, VLA, Atca
- Chandra/XMM-Newton X-ray data
- Spitzer MIR imaging (3.6, 4.5, ..., 24 micron)
- GALEX UV imaging

Sample Selection:

- Using deep red passband (e.g. K-band at 2.2 micron)

Why?

Young stars generally shine most of their light in the blue, while old stars are brighter in the red. Young stars generally have high L/M ratios (Luminosities for a given mass), so the mass of a galaxy is generally determined by the red stars.
So: to find the mass, a red band is required.
Redshift moves the light towards redder wavelengths:
wavelength $l_{obs} = l_{rest}$ (1+z). This means that observed R-band for z=4 corresponds to l=1200A !

So, need to go to very red bands.

2. Find the sources and extract their photometric parameters
   (e.g. Using SEXtractor)
   (or using WESIX http://nvogre.phyast.pitt.edu:8080/wesix/)

3. Do this also for other bands and cross-correlate the catalogs
   (see e.g. http://openskyquery.org)

(Sites above are links from the US NVO (http://www.us-vo.org)

4. Determine redshifts
   - spectroscopic redshifts (from telescope, difficult)
   - photometric redshifts

5. Determine morphological information
   - concentration, asymmetry, clumpiness parameters (CAS)
   (Abraham et al., Conselice et al.) or surface brightness fits
   (GALFIT, GIM2D). This should be done on *thumbnail images*, preferably
   to be able to check and refine the results.

6. Compare with theoretical predictions (or simulations).
   If these are simulations, one could treat them the same as the observations.

Photometric Redshifts:

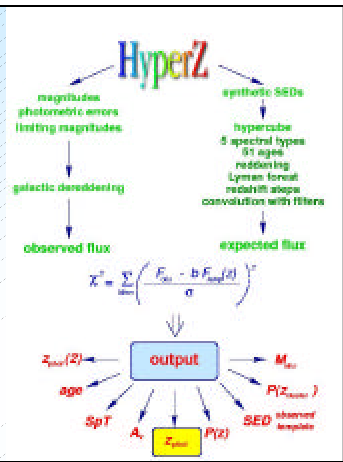
Determining redshifts from photometric data

Determine the most likely redshift of an object by fitting the spectral energy distribution to redshifted model spectral energy distributions of different types of astronomical objects, where galactic reddening is taken into account.

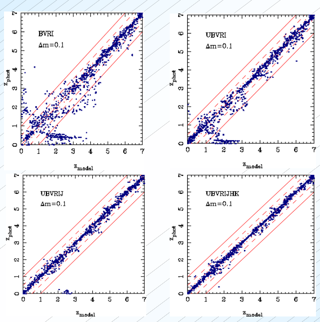
Minimizing:

$$\chi^2(z) = \sum_{i=1}^{N_{filters}} \left[\frac{F_{obs,i} - b \times F_{temp,i}(z)}{\sigma_i}\right]^2, \quad (1)$$

where $F_{obs,i}$, $F_{temp,i}$ and σ_i are the observed and template fluxes and their uncertainty in filter i, respectively, and b is a normalization constant.

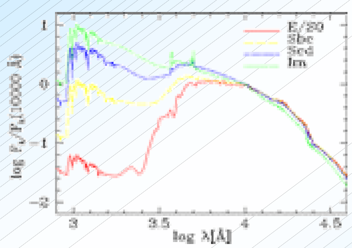


How does hyperz work?



Hyperz uses the fact that a galaxy spectrum has distinct features, such as the Balmer jump. With redshift these features slowly shift into different passbands. Since the variety in galaxy spectra is limited, one can disentangle the effects of spectral shape and redshift.

Some template spectrum for typical galaxies



From stellar library of Bruzual & Charlot (2003) Important: large wavelength coverage.

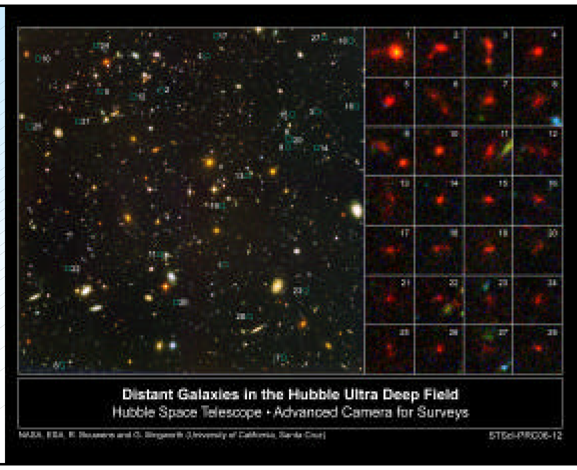
- More passbands – more accurate photometric redshifts
- Accuracies (when including K) often as good as Delta_z=0.02

The dropout method: find the reddest galaxies

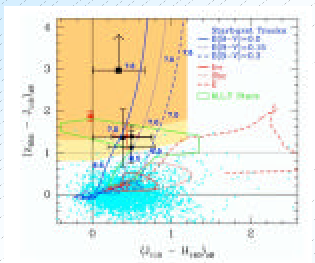
- by selecting the objects that are not detected in the bluest band (or bands) the reddest objects are found, which often are the objects at the highest redshift.

By-products from using hyperz:

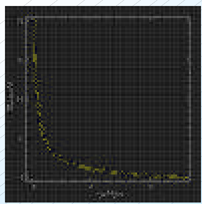
- One obtains reddening, galaxy type and intrinsic luminosity
- This can be converted into reddening, star formation rate and galaxy mass



Using NICMOS and ACS:
z-band dropouts ($l_{z,eff}$=850 nm)



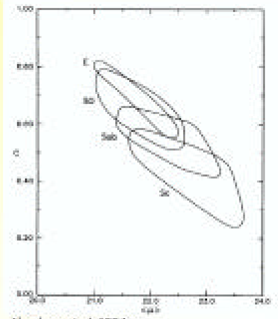
Several galaxies are found at z=7.
Very luminous galaxies are rare beyond redshift 7
(Bouwens & Illingworth 06)



From a talk by Ignacio Ferreras:

Is it possible to develop QUANTITATIVE MORPHOLOGY ?

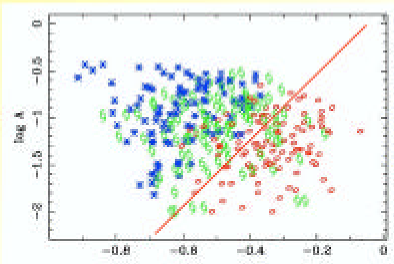
Distribution of light
- Concentration
- M_{20} (2nd order moment)
- Gini Coefficient
- Asymmetry (rotate & compare)
- Clumpiness (filter & compare)
- PCA, ANNs, …



Abraham et al. 1994

Nevertheless, a visual inspection is necessary !!
No clear cut region in parameter space between E/S0 and later types

The eye beats the computer !!
(So far, anyway…)



Menanteau et al. 2004

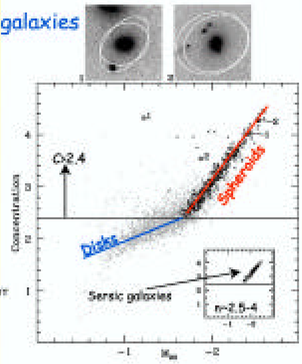
Selecting early-type galaxies

All galaxies in GOODS/CDFS
160 arcmin²
i_{AB}<24
N ~ 2,800 galaxies
C-M_{20} knee used to pre-select

C=5log(r_{80}/r_{20})

M_{20}=log [μ(0.2)/μ(1)],

μ(x) = Σf_i(x_i^2+y_i^2), while Σf_i < xf_{TOT}



Result: the History of Star Formation in the Universe
(Feulner et al. 2004)