Whittle : EXTRAGALACTIC ASTRONOMY

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3. SURVEYS, CATALOGS, & GLOBAL PARAMETERS

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(1) Introduction

Extragalactic research often relies on making use of preexisting data. Knowing whats out there, how to access it, what it means, and what its limitations are, is an important aspect of your astronomical "competence". This topic aims to give a brief overview of the growing databases and catalogues which you may need in the future.

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(2) Major WEB Resources

Rather than describe these in detail, it is best to simply try them out to see what's available.

- NASA/IPAC Extragalactic Database (NED)
  This has a remarkably wide coverage and set of tools : object search; images; SEDs; catalogues; literature. Check out the "knowledge base - level 5" which gives routes into many topics via review articles and books.
- Astronomical Data Center (ADC)
  A NASA site for astronomical data and catalogues from the literature.
- Centre de Donees astronomique de Strasburg (CDS)
  European center for astronomical data and bibliography. Routes to a variety of other sites.
- Space Science Data Systems (SSDS)
  Links to many other data systems
- SIMBAD
  Gives basic data on objects, with references to all papers which include the object.
- Digital Sky Survey (DSS)

Easy way to view (and/or download) images from the many Schmidt sky surveys.

- SkyView
  created by HEASARC, allows you to access images of a region of sky from many of the all sky multiwavelength surveys.
- Aladin
  Ability to view the sky and superimpose many images and source lists at different wavelengths, and access information and references on these sources
- VizieR
  Great way to find catalogues of interest and download them

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(3) WEB Literature Resources

- "Astrophysics Data System Abstract Service" (ADS)
  Gives access to on-line Journals, Conference Proceedings, and Abstracts.
- E-Preprint service of LANL astro-ph
  Contains preprints submitted by authors, a good way of keeping up with the most recent literature.
- Annual Reviews of Astronomy and Astrophysics, with a subset on galaxies to be found here.
- Encyclopedia of Astronomy and Astrophysics

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(4) Optical Galaxy Catalogs

(a) Important, Currently Used Catalogs

RC3 : "Third Reference Catalogue of Bright Galaxies" 1991 deVaucouleurs et al.

This superceeds the RC1 (1964) and RC2 (1976). Gathers and reduces to common system : positions, classifications, magnitudes, colors, radial velocities and other information for ~23000 galaxies. A definitive and impressive work.

UGC : "Uppsala General Catalog of Galaxies" by Nilsen using PSS (1973)

Data on ~13000 galaxies north of -2.5deg, diameter 1 arcmin or more, or brighter than 14.5. Morphology and descriptions good. Commonly used. A related ESO/Uppsala survey of the ESO(B) plates extends the UGC to the south (1982, Lauberts), with densitometry by Lauberts and Valentijn (1989).

RSA : "Revised Shapley Ames" (1987) by Sandage and Tammann

Based on the original 1932 Harvard catalog. Positions, morphology, magnitudes, velocities for ~1200 galaxies brighter than m~13.2 (complete to m=12, but only 50% at m=12.7). Images illustrate the luminosity classes. Related catalogs/atlases from Sandage include the Hubble Atlas (1961), the Carnegie Atlas of Galaxies (1994), the Atlas of Galaxies Useful for Measuring the Cosmic Distance Scale (NASA 1988). These all have wonderful large format images.

PGC : "Principal Galaxy Catalogue" 1989 Paturel et al

A gargantuan list of ~73000 galaxies with cross-references, morphologies, sizes, magnitudes and velocities. The RC3 uses the PGC number as primary ID.

(b) Previously Important or Less Used Catalogs

NGC : "New(!) General Catalog" originally from Dreyer (1880s), revised 1973 (RNGC) by Sulentic and Tifft

Contains star clusters, galaxies, HII regions, planetary nebulae. The catalog itself is not much used now, though the names obviously are. Closely associated is the IC (Index Catalog) of Dreyer which added ~7000 objects. Both are combined in the NGC 2000 catalog.

MCG : "Morphological Catalog of Galaxies" 1964, Vorontsov-Velyaminov and Arhipova (Moscow)

Coded descriptions and rough magnitudes for ~29000 galaxies above m=15 and north of -33. Not much used except for names if no others apply. Careful with names : MCG 8-11-11 is a different galaxy from MCG -8-11-11.

CGCG : "Catalog of Galaxies and Clusters of Galaxies" Zwicky (1961-1968) generated from PSS

N hemisphere. Positions and relatively reliable magnitudes (using defocussed images) for ~31000 galaxies. Nearly complete to m_{pg}=15.5; limit is 15.7. Also identifies 10000 galaxy clusters. Long used to define galaxy samples (magnitude limited) and for reasonable photometry.

Arp : "Atlas of Peculiar Galaxies" Arps famous 1966 atlas

About 340 peculiar galaxies, grouped by type of peculiarity. Excellent deep Palomar images. Extended to the south in "A Catalogue of Southern Peculiar Galaxies and Associations" by Arp and Madore (1987). Older related catalogs include : "Atlas and Catalog of Interacting Galaxies" (1959, 1977, Verontsov-Velyaminov) and "Catalog of Selected Compact Galaxies and of Post-Eruptive Galaxies" (CGPG) by Zwicky (1971).

NBG : "Nearby Bright Galaxies" 1988 by Tully.

A catalog specifically devoted to the three dimensional distribution of nearby galaxies.

Further lists of the major catalogs are given : here, and here, and here.

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(5) All Sky Surveys

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(6) Selection Effects in Surveys and Catalogs

The principal criteria which exclude galaxies from surveys and/or catalogs are :

- Apparent magnitude : usually some limit, (eg m=15.7 for CGCG)
- Angular size : either explicitly (eg UGC is ~1 arcmin; star/galaxy confusion can exclude compact galaxies)
- Surface Brightness : Low Surface Brightness (LSB) galaxies might be invisible below the sky.

These can be summarized with a figure, showing how these limits bracket the galaxies in the RC2 (from Keel).

While spectroscopic surveys suggest luminous compact galaxies aren't common,
the frequency of undetected LSB galaxies is still unknown.

(a) LSB galaxies

- Many LSB *dwarfs* are known (eg Local Group dSph and dIrr), but probably still missing some.
- LSB *giant* galaxies have recently been discovered (eg Malin 1) which can have M_B~-22 !
  note that these galaxies can have *central* SB ~ 27 mag/ss

There is an ongoing debate whether LSB galaxies are a significant (even dominant) galaxian population.
Under this view, the galaxies we know and study are simply the "tip of the iceberg".

(b) Malmquist Bias

- Flux (apparent magnitude) limited samples over-represent high luminosity objects.
- High luminosity objects can be detected to larger distances and therefore a larger volume is included in the sample.
- The observed distribution of lumiosities is artificially skewed to high luminosity.
- This figure (from Keel) illustrates the effect for the simple case of
  (a) uniform spatial distribution, *and*
  (b) Gaussian distribution of absolute magnitude
  A line of constant (limiting) magnitude is shown.
  Only objects above the line are included in the sample.
- Similar kinds of bias result from other selection effects (eg diameter, SB), and in general are very widespread in astronomy.
- In general "selection functions" must be applid to correct the bias. These can be difficult and uncertain (see Topic 4 on Luminosity Functions). To illustrate, Trimble (1994, PASP 108 1073) remarks : "Any large gathering of observational cosmologists today will include at least one person who thinks that someone else in the room does not understand the Malmquist effect".

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(7) Global Parameters

There are a number of standard global parameters which galaxy catalogues often list.
It can be quite complex to convert/reduce to a standard system (eg the RC3 introduction is long and detailed !)
Lets briefly review these, using the RC3 as example.

(a) Positions

- RA, Dec : epochs B1950 & J2000, note that changing epoch can alter the order of catalogued objects (eg NGC ordered by RA-1855; while PGC number is ordered by RA-2000)
- Galactic Longitude & Latitude : (G-Center at 17 42.4, -28 55 & G-Pole at 12 49, +27 24; both 1950)
- Supergalactic Longitude & Latitude : corresponds to the flattened distribution of galaxies within 10 Mpc (see picture of nearest 10 Mpc in SG coordinates)

(b) Angular Sizes

- D_{25} : angular diameter to 25th B mag/ss ispohote (major axis)
  this is ~few % of sky and is about the size you would guess from the PSS
  Note : older parameter r_H (Holmberg radius) is to 26.5 pg mag/ss but is too faint to yield reliable sizes
- R_{25} : major/minor axis ratio at the 25th B mag/ss isophote

Note that conversion to inclination is not simply inverse sine (several prescriptions are used)
- A_e : "Effective" (circular) aperture diameter which would enclose half the total light (see below)
- D_0 : same as D_{25} but corrected for galactic extinction and galaxy inclination (ie corrected to "face on")

(c) Extinctions

- A_g : Galactic extinction in B band. After a complex history, RC3 uses the reddening maps of Burstein & Heiles (1978) derived from HI maps and faint galaxy counts. Since then, improved (by factor 2) maps have been derived from HI maps and FIR maps of COBE/DIRBE and IRAS. Here is an all sky map of the dust, while here is a calculator to estimate the extinction at any coordinate.
- A_i : Internal Extinction in the B band - ie extinction due to dust in the galaxy itself. This is much less well known, but is clearly a function of (a) the Hubble type and (b) the inclination. After a complex history, RC3 gives a prescription.
  Note that RC3 estimates extinction to "face on", while RSA estimates extinction to "no dust" (and therefore much higher values, particularly for later Hubble types)
- A_{21} : HI line self absorption. Somewhat debatable, but RC3 gives an HI absorption which is a function of inclination and Hubble type.

(d) Magnitudes

- B_T : Total photoelectric B magnitude, derived either from aperture photometry or surface photometry (CCD or calibrated photographic). Requires fitting aperture data to "growth curves" (standard curves of cumulative magnitude vs aperture/A_e) allowing extrapolation to "infinite" aperture, or "Total" magnitude. B_T is a very standard, relatively well defined, quantity, usually of higher quality than m_B.
- m_B : Total photographic B magnitude. Since many sources of magnitudes (eg Zwicky's 31000 CGCG galaxies) are photographic, RC3 includes them but separately from the photoelectric magnitudes. They all need to be reduced to the standard system.
- m_{FIR} : a Far IR magnitude, defined using the IRAS 60 and 100 micron fluxes.
- B_T^o : Total B magnitude, corrected for galactic absorption, internal absorption (to face on) and for redshift. The first two corrections are simply A_g and A_i defined above. The so-called "K" correction recognizes that the object's redshift has brought a bluer part of its spectrum into the B band. K corrections are a function of z and Hubble type (since the spectral energy distribution depends on type).

(e) Colors

- $(U-B)_T$; $(B-V)_T$; $(U-B)_e$; $(B-V)_e$: are colors for Total galaxy light, and effective (half light) apertures. They are also corrected for galactic and internal extinction and redshift, yielding $(U-B)_T^o$ etc.

(f) HI Fluxes and Kinematics

- m_{21} : HI "magnitude" is a measure of the integrated HI 21cm line flux. This is corrected for internal self-absorption (A_{21}) and a redshift (1+z) to yield m_{21}^o. The quantity m_{21}^o - B_T^o then represents an HI/L_B ratio, which is a standard parameter of galaxies (and increases along the Hubble sequence).
- W_{20}; W_{50} : The width of the integrated 21cm HI line profile, measured at the 20% and 50% height levels. This measures the (projected) galaxy rotation velocity, and is an important parameter in, for example, the Tully-Fisher relation.

(g) Redshifts

- V_{opt}; V_{21} : Optical and 21cm systemic heliocentric velocities (*always* given as cz). Usually, these agree well.
- V_{GSR} : velocity (cz, wt mean of opt & 21cm)) referred to the Galactic Standard of Rest (the center of the galaxy). This combines a transformation from HC to LSR (16.5 km/s towards l=53, b=+25) with a further transformation to the galactic center (220 km/s towards l=90, b=0). This can be used for distance estimates using the Hubble constant.
- V_{3K} : velocity referred to the frame of the CMB (microwave background) : a tranformation from HC by 360 km/s towards RA=11 15, dec= -5.6 (1950). This may be better for distance estimates. Note, for cz within ~5000 km/s people sometimes use a "Virgocentric Infall" model to correct both our and the galaxy's redshifts for large scale flows before applying the Hubble law.

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