Galaxy Surface Photometry

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- Demo — IRAF and Surface Photometry

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- Demo — IRAF and Surface Photometry

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Surface photometry is a technique to measure the surface brightness distribution of extended objects (galaxies, HII regions etc.).

Surface photometry: distribution of light (mass), global structure of galaxies, geometrical characteristics of galaxies, spatial orientation, stellar populations, characteristics of dust...

Surface photometry and spectroscopic observations – two major observational methods of extragalactic astronomy.

Definitions

Surface brightness (SB) – radiative flux per unit solid angle of the image ($I \propto f/\Delta\Omega$).

To a first approximation, the **SB** of an extended object is independent of its distance from us since f and $\Delta\Omega$ are proportional to $1/r^2$ (flat, static Universe).

Optical astronomers measure **SB** in magnitudes per square arcsecond [$mag/arcsec^2$]:

$\mu = -2.5 \log I + ZeroPoint$

where I = Counts per $sec/arcsec^2$ for each isophote

Definitions

Surface brightness (SB) – radiative flux per unit solid angle of the image ($I \propto f/\Delta\Omega$).

Solid Angle $\Delta\Omega$ — is the area on the unit sphere that an object covers. Since a unit sphere has an area of 4π, there are 4π steradian on the sky.

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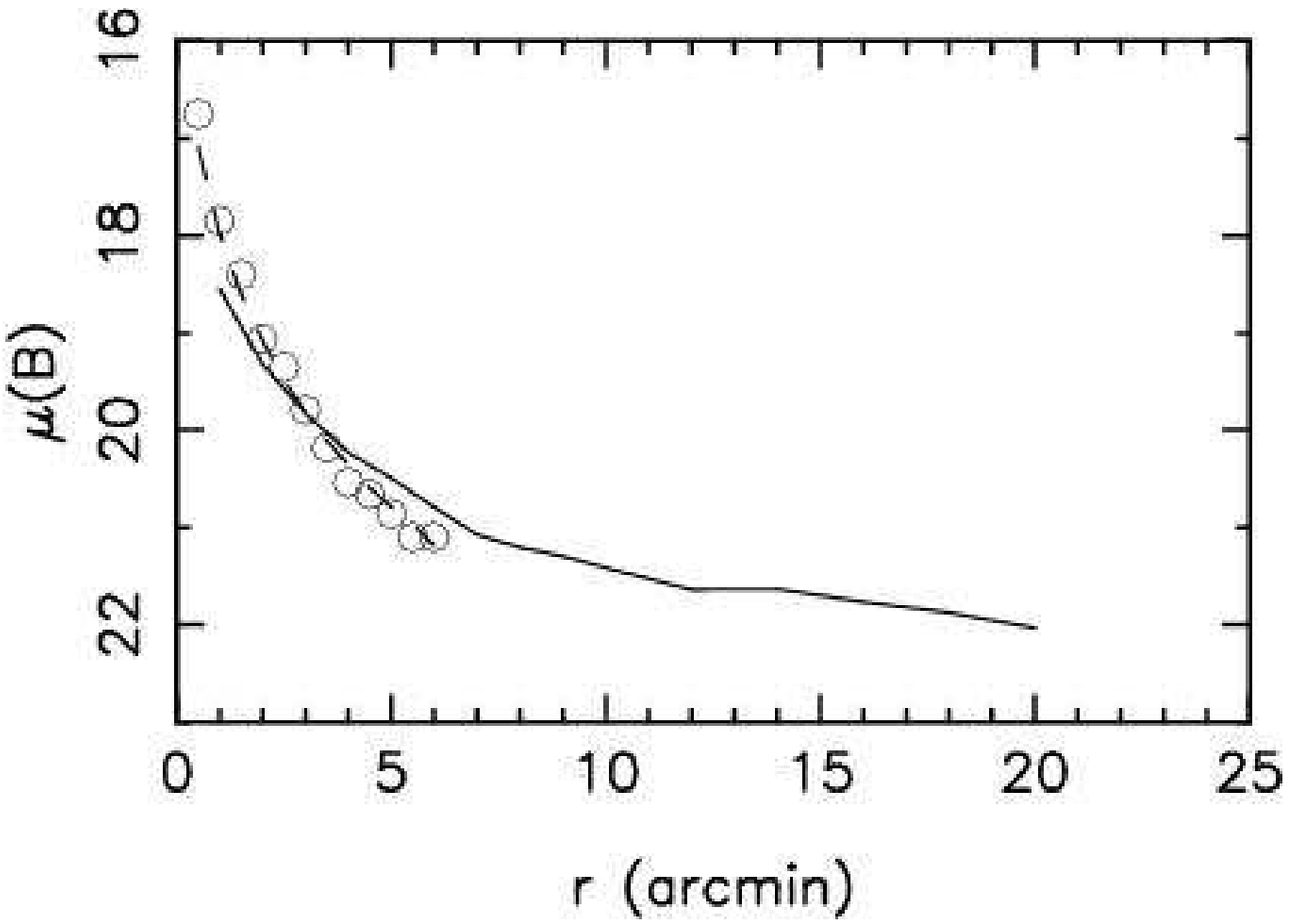
Short history

One of the oldest techniques in modern astronomy. The first attempt at surface photometry of galaxies dates back to Reynolds (1913) of M31. It was based on photographic exposures of up to 100 minutes on a 28–inch reflector.



circles — Reynolds (1913)

solid line — Walterbos & Kennicutt (1987)

Short history

Hubble (1930) – first systematic study of the light distribution in ellipticals. He showed that the elliptical galaxies —

1) have no definite edge,

2) have all the same standard luminosity profile $I(r) = I(0) / (r+a)^2$

3) are relaxed self-gravitating systems in equilibrium.

Redman & Shirley (1936–1938) – first systematic discussion of some of the technical difficulties of the photographic surface photometry. In particular they discussed the effect of the point spread function (PSF) on the apparent luminosity distribution.

Oort (1940) – joint photometric and dynamical analysis of NGC 3115 and NGC 4494.

Short history

Seyfert (1940) – first quantitative study of optical color distribution in the disks of 7 spirals.

Patterson (1940) – surface brightness in the disk of M 33 decays exponentially with distance from the center; first detailed intensity matrix maps of 14 spiral and irregular galaxies.

Lindblad (1941-42) – detailed studies on the luminosity and color distributions in several large spirals; detection of reddening in the dust lanes between spiral arms; luminosity–color asymmetry along the minor axis of the image.

G. de Vaucouleurs (1948) – “de Vaucouleurs law” for elliptical galaxies.

Main steps of surface photometry

Surface photometry is currently done using CCDs (charge-coupled devices).

When a photon hits the detector, it sets free electrons, generating a current. This current is collected and amplified, and the signal produced should be linearly proportional to the number of incident photons.

The surface of a CCD is divided into individual picture elements, or **pixels**. It is possible to do **photometry** (the image recorded is then a portion of the sky/star/galaxy) or **spectroscopy** (the light is dispersed by using a grating into its colors).

Main steps of surface photometry

There are some common problems with CCDs, which need to be taken into account in every observational program —

– **read-out noise** (random fluctuations in the count rate: 3–10 e/pixel)

– **dark counts** (failure to respond to currents, or electrons without an incident signal → cooled down to 100–200 K)

– **cosmic rays** (energetic particles hit the detector and produce a signal which is not related to the astronomical object under study). They appear as “stars”, but if the same portion of the sky is imaged more than once, it’s unlikely a cosmic-ray will fall in the same pixel. Hence they can be corrected for.

Main steps of surface photometry

Flat-fielding — Pixels do not respond uniformly. Need to measu- re the individual response of the pixels by observing a diffuse screen or black twilight sky.

Sky background subtraction — The background local sky level I_S (x, y) is determined and subtracted from I_{G+S} (x, y), leaving I_G(x, y), the intensity distribution of only the galaxy. This is the most important step in surface photometry.

Stack of frames

Photometric calibration — Need to observe some standard stars of known brightness to determine how many counts correspond to a given flux or magnitude.

Surface Photometry i.e. fit ellipses

Presentation of surface photometric data

Detailed interpretation, modelling

Standard packages

IRAF (http://iraf.noao.edu/)
Image Reduction and Analysis Facility

IRAF includes a good selection of programs for general image processing and graphics applications, plus a large number of programs for the reduction and analysis of optical astronomy data. Some packages are also available for the analysis of HST, XRAY and EUV data.

IRAF Tutorial

http://mips.as.arizona.edu/~khainline/intro_to_IRAF.html

Standard packages

ESO-MIDAS (http://www.eso.org/midas/)
European Southern Observatory - Munich Image Data Analysis System

The MIDAS system provides general tools for image processing and data reductions with emphasis on astronomical applications including special reduction packages for ESO instruments at La Silla and the VLT at Paranal. In addition it contains application packages for stellar and surface photometry, image sharpening and decomposition, statistics and various others.

ESO-MIDAS and IRAF are freely available on many platforms (VMS, UNIX...). Both systems include a complete programming environment for scientific applications, which includes a programmable Command Language scripting facility.

Standard packages

IDL (http://idlastro.gsfc.nasa.gov/)

Interactive Data Language (commercial package)
The IDL Astronomy Users Library – repository for low-level astronomy software written in the commercial language IDL. Not an integrated package, but a collection of procedures from which users can pick and choose for their own use.

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But Python can do all these.. learn Python

Do Surface Photometry yourself

- Each group has given three galaxies - elliptical, S0 and Spiral
- Use IRAF to do Surface Photometry i.e. use ellipse task in STSDAS package to fit ellipses
- Plot Surface Brightness, Position angle, ellipticity as well as a4, b4 profiles for each morphological type
- Compare these profiles and come up with interpretation

Demo