Next week...

First part of assignment

During this class, you will give a presentation on how to derive stellar masses from SDSS data.

The assignment for this week is to review three papers:

- Test et al. (2010) which presents common methodologies for deriving stellar masses from photometric data
- Review by Chapman (2010), which presents the code most commonly used for the SDSS fitting
- Fink et al. (2007) which describes the incorporation of GALAXI UV derived SFRs associated with the public stellar mass catalog from the IBM/ESO group.

Please review the papers and come prepared to discuss the methodologies, results, and conclusions, especially so that you can follow the presentation given by Shan.

Second part of assignment

Part of this class will be dedicated to reports on projects built on accessing the SDSS SQL server and analysis of groups of participants. These reports should take about 10 minutes each. Please email Ann (Martin) at astro.cverted@gmail.com a PDF version of your presentation by 11:59 on Wednesday so that she can post them in advance of class.

Here is the list of topics and the assignments:

- Finding massive early type galaxies in SDSS
  - Ann, Carl, Drew

Your task is to explore how to find the most massive galaxies using the SDSS SQL server.

Dawson et al. (2002) (AJ 123, 2491) need to identify the most massive galaxies by querying the SDSS database to find the objects with the highest velocity dispersions. They find ~100 galaxies with v > 300 km/s, about half of which are supergalaxies, and a study of 500 mass, try to construct their results by running your own query on the SDSS database. Your task is to explore how to find these galaxies by running your own query on the SDSS database.

- Finding dwarf galaxies in a nearby group
  - Ann, Betty, Martha

Your task is to explore how to find dwarf galaxies in a nearby group using the SDSS SQL server.

Vogt & Ivanov (2005) (astro-ph/0504179) provided a list of dwarf galaxies in the region of two groups of galaxies, the NGC 20562 group and the NGC 20565 group. You are expected to search for dwarf galaxies in nearby groups.

Note: We assume here that Martha will be flying back from LA overnight, and that Shan is making a presentation on deriving stellar masses from SDSS.

So: Ann will "be Martha" (in case my flight is delayed)
SDSS access tools


SDSS database tables

Structured Query Language

http://dev.mysql.com/docs/refman/5.0/en/tutorial.html
Read the docs on the SDSS Sky Server


Example:

```
SELECT
  p.ra, p.dec, s.z, p.petroMag_r,
  p.petroR90_r, p.lnLEX_r, p.lnLDev_r, p.expAB_r, p.isoPhi_r
FROM PhotoObj p, SpecObj s, SpecLine \l
WHERE
  p.SpecObjID = s.SpecObjID AND
  p.SpecObjID = l.specObjID AND
  l.lineID = dbo.TSpecLineNames('CIV_1549') AND
  p.ra >> 120 AND p.ra <= 150 AND
  p.dec >= 5 AND p.dec <= 10 AND
  s.z >> 5.0
order by p.ra
```

Finds QSOs with \( z > 5.0 \) in a region of the sky via their CIV lines
Common emission features in optical spectra

<table>
<thead>
<tr>
<th>λ (Å)</th>
<th>Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>3726, 3729</td>
<td>[O II]</td>
</tr>
<tr>
<td>3869</td>
<td>[Ne III]</td>
</tr>
<tr>
<td>3889</td>
<td>He I</td>
</tr>
<tr>
<td>3970</td>
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<td>Hδ</td>
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<tr>
<td>4340</td>
<td>Hγ</td>
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<td>4363</td>
<td>[O III]</td>
</tr>
<tr>
<td>4861</td>
<td>Hβ</td>
</tr>
<tr>
<td>4959, 5007</td>
<td>[O III]</td>
</tr>
<tr>
<td>5875</td>
<td>He I</td>
</tr>
<tr>
<td>6548, 6584</td>
<td>[N II]</td>
</tr>
<tr>
<td>6563</td>
<td>Hα</td>
</tr>
<tr>
<td>6717, 6731</td>
<td>[S II]</td>
</tr>
</tbody>
</table>
AGN diagnostics

- See Osterbrock's book
- Red circles: AGN
- Blue triangles: Star forming galaxies

"BPT diagram"
- Carl will talk about this on March 10th
# Selecting by line ID


Note: the SDSS folks use "weird" wavelength units.

- Go to the Schema Browser
- Search for "wavelength"
- Click on Columns, table SpecLineAll, Line rest wavelength
- Scroll down to "lineID" and click there on "i":

<table>
<thead>
<tr>
<th>lineID</th>
<th>wavelength</th>
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</thead>
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<tr>
<td>CIII_4963</td>
<td>4960.00</td>
</tr>
<tr>
<td>CIII_5008</td>
<td>5008.24</td>
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<tr>
<td>Mg_5177</td>
<td>5176.79</td>
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<tr>
<td>Nb_5895</td>
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<tr>
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<td>CI_6563</td>
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<tr>
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<tr>
<td>Ni_6554</td>
<td>6554.66</td>
</tr>
<tr>
<td>Hs_6563</td>
<td>6563.81</td>
</tr>
</tbody>
</table>

## Line ID list

Example:

Find all galaxies with H-alpha in a box and redshift range

```
SELECT
  p.ra, p.dec, s.z, s.err, p.petroR90_r, p.petroR50_r, p.expAB_r,
  p.petroMag_u, p.petroMag_g, p.petroMag_r, p.petroMag_i, p.petroMag_z,
  p.lnExp_r, p.lnDev_r, p.isoPhi_r, l.sigma, l.sigmaErr,
  l.ew, l.ewErr, l.chisq, l.nu, s.zWarning, p.objID
FROM PhotoObj p, SpecObj s, SpecLine l
WHERE
  p.SpecObjID = s.SpecObjID AND
  p.SpecObjID = l.specobjID AND
  s.specClass=2 AND
  l.linelID = dbo.SpecLineNames('Ha_6565') AND
  p.ra >= 287.95 AND p.ra <= 214.15 AND
  p.dec >= 5.86 AND p.dec <= 12.15 AND
  s.z <= 0.061
ORDER BY p.ra
```

Example:

**************
Select a set of inclined disk galaxies by H-alpha redshift

```
SELECT
  p.ra, p.dec, s.z, p.expAB_r, p.fiberMag_r, p.petroMag_r,
  p.petroR90_r, p.lnExp_r, p.lnDev_r, l.sigma, l.sigmaErr,
  l.ew, l.ewErr, l.chisq, l.nu, s.zWarning, p.isoPhi_u,
  p.isoPhi_g, p.isoPhi_r, p.isoPhi_i, p.isoPhi_z
FROM PhotoObj p, SpecObj s, SpecLine l
WHERE
  p.SpecObjID = s.SpecObjID AND
  p.SpecObjID = l.specobjID AND
  s.specClass=2 AND
  l.sigma >= 2.1897 AND l.sigma <= 15.3280 AND
  p.lnExp_r > (13.81+p.lnDev_r) AND
  l.lineID = dbo.SpecLineNames('Ha_6565') AND
  (p.ra >= 345 OR p.ra <= 45 ) AND
  p.dec >= 5 AND p.dec <=35 AND
  s.z <= 0.063
ORDER BY p.lnExp_r desc
```
Example:

Select by velocity dispersion:

```sql
SELECT p.ra, p.dec, s.i, p.p.expAB_r, p.petroMag_r,
p.petroR90_r, p.p.lnExp_r, p.p.lnDev_r, l.sigma, l.sigmaErr,
l.ew, l.ewErr, l.chisq, l.nu, s.zWarning, p.isophi_r, p.isophi_l
FROM PhotoObj p, SpecObj s, SpecLine l
WHERE p.SpecObjID = s.SpecObjID AND
  p.SpecObjID = l.specobjID AND
  s.eclass < 8 AND
  p.fracDev_r > 0.8 AND
  l.lineID = dbo.SpecLineNames('H_3970') AND
  l.sigma*360000/b.wave > 350 AND
  (p.ra >= 170 AND p.ra <= 210 ) AND
  p.dec >= 5 AND p.dec <=15 AND
  s.z < 0.83
order by p.ra
```

Notice that sigma is expressed in weird units. To convert to km/s you multiply by c and divide by the rest wavelength. See the expression above.

SDSS magnitudes:

SDSS Data Release 7: Sloan Digital Sky Survey

Measures of flux and magnitudes

This page provides descriptions of various magnitudes and related output of the photometry pipelines. We also provide descriptions of some methodologies for details of the Photo.p query processing please read the corresponding EDR query similar. There are a separate page describing the output of the MZRedD sources and the photometry for color.

- The (SDSS) zero point magnitude (kin/s2)
- The (SDSS) zero point magnitude (kin/s2)
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The SDSS zero point magnitude system

Magnitudes within the SDSS are expressed in the so-called "SDSS" magnitudes, described in detail by Szalay, Coe & Sheth (2008). They are calculated as a weighted average of aperture magnitudes. The transformation from aperture magnitudes to galaxy magnitudes is designed to make them consistent with the Sloan Digital Sky Survey (SDSS) pipeline. The aperture corrections are derived from artificial objects and are very accurate for typical observations. The SDSS data are obtained from the First Data Release of the Sloan Digital Sky Survey. The magnitudes are measured for galaxies, stars, and other astronomical objects.

The aperture magnitudes are characterized by a set of parameters, including the SDSS zero point magnitude, the typical 1-sigma noise of the sky, and the effective size of the aperture. The relation between the aperture and the SDSS zero point magnitude can be expressed as:

$$ m = m_{0} + 2.5 \log_{10}(D/0.5)-5 \log(D/0.5) + 5.5 $$

Here, $m_{0}$ is the SDSS zero point magnitude for the given object, $D$ is the effective diameter of the aperture, and $m$ is the aperture magnitude. The quantity $2.5 \log_{10}(D/0.5)-5 \log(D/0.5)$ is the correction to the aperture magnitude associated with the size of the aperture. The term 5.5 accounts for the flux corresponding to the aperture. These effects are determined by the SDSS pipeline. If these corrections are applied to other flux measures, the SDSS zero point magnitude is recovered.

Fiber magnitudes

The flux contained within the aperture of a spectrally fiber (2") is calculated in each band.
SDSS magnitudes:

Petrosian magnitudes

Determined as petroPhot FOR galaxy photometry, measuring flux in a circular aperture profile, and have no sharp edges. In order to avoid biases, we wish to measure a constant fraction of the total light independent of the galaxy's shape and orientation. To satisfy these requirements, the section of a constant surface brightness within a petroPhot aperture (aperture) has been defined as the “Petrosian flux” (Fp). It is a factor from the center of the object to the radius of the circle surface brightness in an annulus of the mean surface brightness, s, as described by

\[ F_p = \frac{\int_{r_p}^{r_f} 2\pi r s(r) dr}{\int_{r_p}^{r_f} 2\pi r s(r) dr} \]

where Fp is the petroPhot surface brightness profile.

The Petrosian radius r_p is defined as the radius at which Petrosian magnitude (M_p) becomes measurable at a certain number of S/N. As a result of this definition, the Petrosian flux is an integrated value over the entire Petrosian aperture.

In practice, there are a number of complications associated with this definition, including shape variations, photometric errors, and line-of-sight effects. The Petrosian magnitude is given by

\[ M_p = -2.5 \log_{10}(F_p) - 5 \]

where Fp is the Petrosian flux. The Petrosian magnitude is usually defined as the magnitude at the radius of the first peak, which is the radius at which the flux is half of the maximum flux.

Model magnitudes

The computation of model magnitudes in the DR1 and EDR processing has been a significant improvement that should be used for scientific analysis. The imaging data have all been processed through a new version of the SDSS imaging pipeline, that most importantly fixes an error in the model fits to each object. The result is that the model magnitudes are now a good proxy for point spread function (PSF) magnitudes for point sources, and Petrosian magnitudes (which have larger errors than model magnitudes) for extended sources.

Just as the PSF magnitudes are optimal measures of the fluxes of stars, the optimal measure of the flux of a galaxy would use a matched galaxy model. With this in mind, the code fits two models to the two-dimensional image of each object in each band:

1. A pure deVaucouleurs profile
   \[ I(r) = I_0 \exp\left(-r^2/r_0^2\right) \]

   (truncated beyond 7r_0 to smoothly go to zero at 8r_0, with some softening within \(r/\sigma<50\)).

2. A pure exponential profile
   \[ I(r) = \exp(-r/\sigma) \]

   (truncated beyond 3\sigma to smoothly go to zero at 4\sigma).

Each model has an arbitrary axis ratio and position angle. Although for large objects it is possible and even desirable to fit more complicated models (e.g., bulge plus disk), the computational expense to compute them is not justified for the majority of the detected objects. The models are convolved with a double-Gaussian fit to the PSF, which is provided by pyPSF. Residuals between the double-Gaussian and the full PSF model are added on for just the central PSF component of the image. These fitting procedures yield the quantities:

- r_deV and r_exp, the effective radii of the models;
- a_b deV and a_b exp, the axis ratio of the best-fit models;
- p_90 deV and p_90 exp, the position angles of the ellipse (in degrees East of North);
- deV I and exp I, the likelihoods associated with each model from the chi-squared fit;
- deV M and exp M, the total magnitudes associated with each fit.

Note that these quantities correctly model the effects of the PSF. Errors for each of the last two quantities (which are based on the chi-square statistics) are also reported. We apply aperture corrections to make these model magnitudes equal the PSF magnitudes in the case of an unresolved object.
SDSS magnitudes:

Cmodel magnitudes

The code now also takes the best fit exponential and de Vaucouleurs fits in each band and asks for the linear combination of the two that best fits the image. The coefficient (defined between zero and one) of the de Vaucouleurs term is fit in the quantity $F_{\text{def}}$, while $F_{\text{ex}}$ is fixed. (In the fits of the $Kc$-bands, this parameter is maximally allowed. This allows us to define a composite flux

$$F_{\text{comp}} = \frac{\text{frac} \times F_{\text{def}}}{F_{\text{ex}} + (1 - \text{frac}) \times F_{\text{def}}}$$

where $F_{\text{def}}$ and $F_{\text{ex}}$ are the de Vaucouleurs and exponential fluxes (not magnitudes) of the object in question. The magnitude derived from $F_{\text{comp}}$ is referred to below as the cmodel magnitude (as distinct from the model magnitude, which is based on the better-fitting of the exponential and de Vaucouleurs models in the $r$-band).

In order to measure unbiased colors of galaxies, we measure their flux through equivalent apertures in all bands. We choose the model (exponential or de Vaucouleurs) of highest likelihood in the filter, and apply that model (i.e., allowing only the amplitude to vary) in the other bands after convolving with the appropriate PSF in each band. The resulting fluxes are then $F_{\text{def}}$ (Mag). The resulting estimate of galactic color will be unbiased in the absence of color gradients. Systematic differences between Petrosian colors are in fact often seen due to color gradients, in which case the concept of a global galaxy color is somewhat ambiguous. For faint galaxies, the model colors have appreciably higher signal-to-noise ratio than do the Petrosian colors.

There is now excellent agreement between cmodel and Petrosian magnitudes of galaxies, and cmodel and PSF magnitudes of stars. Cmodel and Petrosian magnitudes are not expected to be identical, of course, as Shupe et al. (2003) describe. The Petrosian aperture excludes the outer parts of galaxy profiles, especially for elliptical galaxies. As a consequence, there is an offset of 0.05–0.1 mag between cmodel and Petrosian magnitudes of bright galaxies, depending on the photometric bandpass and the type of galaxy. The rms scatter between model and Petrosian magnitudes at the bright end is now between 0.06 and 0.08 magnitudes, depending on bandpass; the scatter between cmodel and Petrosian magnitudes for galaxies is smaller, 0.03 to 0.05 magnitudes. For comparison, the code that was used in the EDR and DR1 had scatter of 0.1 mag and greater, with much more significant offsets. The cmodel and PSF magnitudes of stars are in good agreement (they are forced to be identical in the mean by aperture corrections, as was true in earlier versions of the pipeline), the rms scatter between model and PSF magnitudes for stars is much reduced, going from 0.03 mag to 0.02 magnitudes, the exact values depending on bandpass. In the SDSS and DR1, new-galaxy reprocessing was based on the difference between model and PSF magnitudes. We now do size-galaxy separation using the difference between cmodel and PSF magnitudes, with the threshold at the screen value (0.15 magnitudes).

Due to the way in which model fits are carried out, there is some weak discretization of model parameters, especially $r_{\text{exp}}$ and $r_{\text{de}}$. This is yet to be fixed. Two other issues (negative axes ratios, and bad model maps for bright objects) have been fixed since the EDR.

SDSS magnitudes:

The reddening correction in magnitudes at the position of each object, $\text{reddening}$, is computed following Schlegel, Finkbeiner & Davis (1998). These corrections are not applied to the magnitudes in the database. Corrections from ESGDR1 to total DE-90 fluxes, assuming a 2–3 elliptical galaxy spectral energy distribution, are tabulated in Table 22 of the EDR Paper.

Which Magnitude should I use?

Facing this array of different magnitude measurements to choose from, which one is appropriate in which circumstances? We cannot give any guarantees of what is appropriate for the science you want to do, and here we present some examples where we use the general guidelines that are usually the most effective in determining the best signal-to-noise ratio, fraction of the total flux included, and freedom from systematic variations with observing conditions and distance.

Given the excellent agreement between cmodel magnitudes (see Cmodel magnitudes above) and PSF magnitudes for point sources, and between cmodel magnitudes and Petrosian magnitudes (subject to intrinsic color aperture corrections) for galaxies, the cmodel magnitude is now an adequate proxy to use as a universal magnitude for all types of objects. As it is approximately a matched aperture for a galaxy, it has the great advantage over Petrosian magnitudes, in particular, of having closer to optimal noise properties.

Example magnitude usage

- **Photometry of Bright Stars**: If the objects are bright enough, add up all the flux from the profile photometry and generate a larger aperture magnitude, for example using the first 7 arcmin.
- **Photometry of Distant Quasars**: These will be unresolved, and therefore have image consistent with the PSF. For this reason, psMag is unbiased and optimal.
- **Colors of Elliptical Galaxies**: Objects that are bright enough to be included in our spectroscopic sample have relatively high signal-to-noise ratio measurements of their Petrosian magnitudes. Since these magnitudes are model-independent and yield a larger fraction of the total flux, roughly constant with reddening, psMag is the measurement of choice for such objects. In fact, the entire properties of Petrosian magnitudes converge to $m0$ or so.
- **Photometry of Galaxies**: Under these conditions, the cmodel magnitude is a reliable estimate of the galaxy flux. In addition, this magnitude corrects for the effects of local seeing and is less dependent on local seeing variations.
- **Colors of Elliptical Galaxies**: The colors of galaxies are almost completely unafflicted by the PSF software error. The model magnitude is calculated using the best parameters in the $r$-band, and applied to it all other bands; the light is therefore measured consistently through the same aperture in all bands.

Of course, it would not be appropriate to study the evolution of galaxies and their colors by using Petrosian magnitudes for bright galaxies, and model magnitudes for faint galaxies.

Finally, we note that minimally-averaged radial profiles are also provided, as described above, and can easily be used to create circular aperture magnitudes of any desired type. For instance, in order to study a larger dynamic range of galaxy fluxes, one could create intermediate Petrosian magnitudes with parameters tuned such that the Petrosian flux includes a small fraction of the total flux, but yields higher signal-to-noise ratio measurements at faint magnitudes.
SDSS magnitudes:

Radial Profiles

The Frames pipeline extracts an azimuthally-averaged radial surface brightness profile. In the catalogs, it is given as the average surface brightness in a series of concentric annuli. The units are milliabert (magnitudes) per square arcsec; where a magnitude is a linear measure of flux, one magnitude has an AB magnitude of 0 (thus a surface brightness of 29 mag/square arcsec corresponds to 10⁻³ magnitudes per square arcsec). The number of annuli for which there is a measurable signal is listed as annNum, the mean surface brightness is listed as profMean, and the error is listed as profErr. This error includes both photon noise, and the small-scale “bumpiness” in the counts as a function of azimuthal angle.

When converting the profMean values to a local surface brightness, it is not the best approach to assign the mean surface brightness to some radius within the annuli and then linearly interpolate between radial bins. Do not use smoothing splines, as they will not go through the points in the cumulative profile and thus (obviously) will not conserve flux. What Frames does, e.g., in determining the Petrosian radius, is to fit a local spline to the cumulative profile and then differentiate that spline, to get the slope, and then integrating the slope to zero.

The annuli used are:

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<thead>
<tr>
<th>Aperture Radius (pixels)</th>
<th>Radius (arcsec)</th>
<th>Area (pixels)</th>
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</thead>
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back top