Point Spread Function of Spitzer IRAC Mosaics for 2-D Decomposition of Lenticular Galaxy Images

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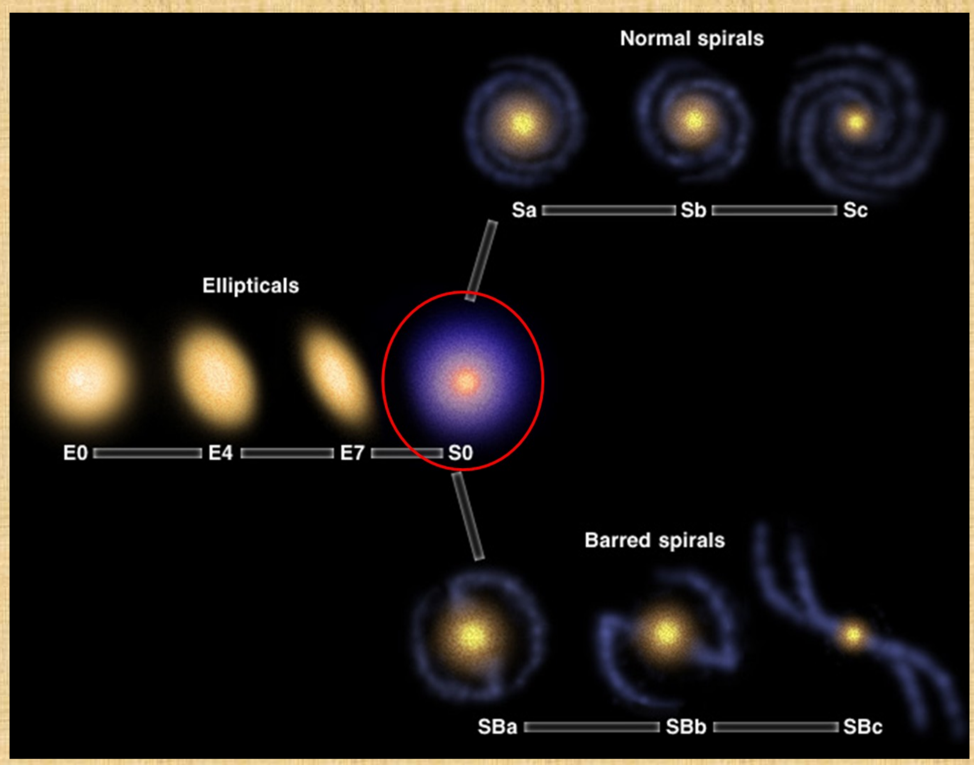
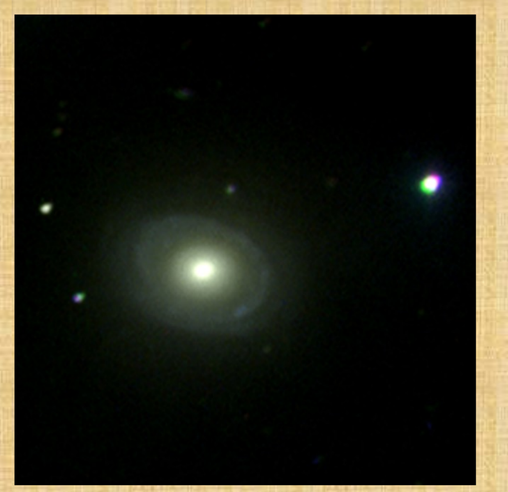


Are the lenticular galaxies simply an intermediate stage between elliptical and spiral galaxies as the Hubble classification diagram above depicts?
Or are they special objects in their own right with a diversified morphology depending on their environment and formation history?

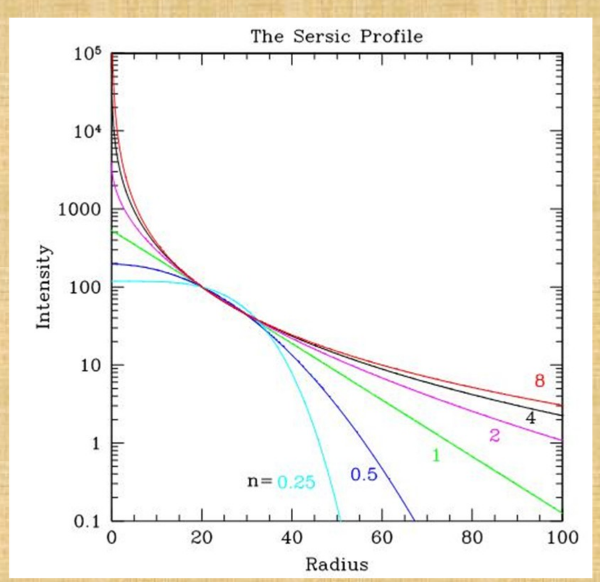


Recent studies indicate that the properties of lenticular galaxies have a possible luminosity and environment dependence. Bright and faint galaxies follow different correlations such as Kormendy relation, photometric plane, etc . It has been further established that bar fraction is also different for faint and bright lenticular galaxies, being larger among the bright lenticular galaxies. All these findings hint at lenticular galaxies being complex objects with varied morphological features and a signficant dependence on their environment and evolution history. We have undertaken a multi-wavelength study of lenticular galaxies. As a part of this study, we wish to determine the photometric properties of the bulges using images from the Spitzer Space Telescope's IRAC (Infra Red Array Camera) at a wavelength of 3.6 microns.

Decomposition Technique

The technique involves fitting the light distribution in the images of the galaxy using analytical profiles such as the Sersic profile.

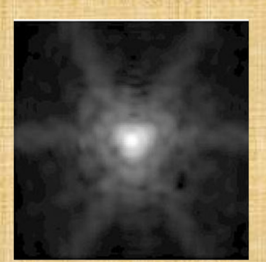
$$\Sigma(r) = \Sigma_e \exp\left[-K\left(\left(\frac{r}{r_e}\right)^{1/n}\right)-1\right]$$

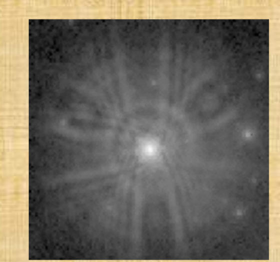


n = 1—Exponential profile; n = 0.5—Gaussian Profile

- The procedure involves construction of a model image using some initial parameters.
- The model image must then be convolved with the point spread function in order to account for atmospheric/instrumental effects.
- A χ^2 function is constructed which is a measure of the disagreement between model and observed image.
- This function is minimized to find the parameters that best describe our galaxy.

The Point Spread Function has the effect of flattening the light distribution especially at the centre of the galaxy where the bulge is most dominant. Thus, in order to recover the parameters of the bulge accurately, the PSF must be accurately determined. (Spitzer and HST WPFC's PSFs shown below)





The Spitzer Space Telescope

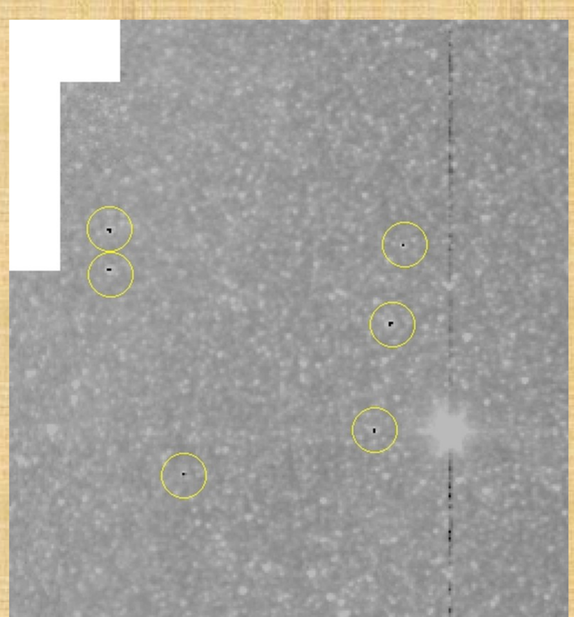
The Spitzer Space Telescope was launched in 2003 as a part of the NASA Great Observatories Program. It is a space based dedicated Infra-Red telescope. On board the Spitzer are 3 major instruments, namely the IRAC (Infra Red Array Camera), MIPS (Multiband Imaging Photometer for Spitzer) and IRS (Infra Red Spectrograph), covering altogether wavelengths from 3.6 microns to 150 microns).

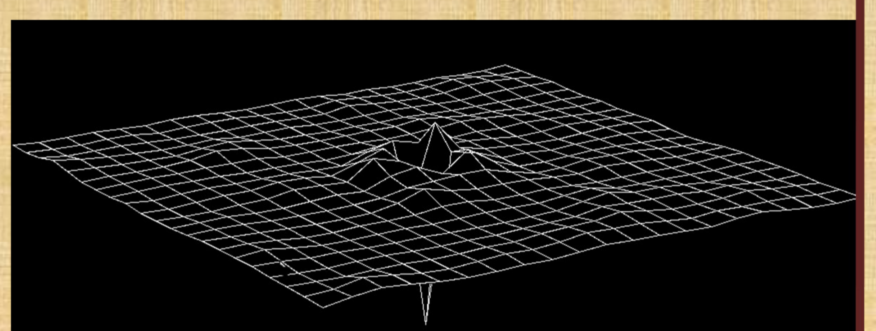
We use the images from IRAC at 3.6 microns. At this wavelength, the total light from a galaxy includes the contribution from the low mass stars and hence is a better representative of the dynamical mass content of the galaxy. Further, dust effects can be ignored. The images captured by IRAC can have flat fielding errors of ~10% and also optical distortions. Thus, one needs to take dithered exposures of the galaxy and construct a suitable mosaic to overcome these problems.

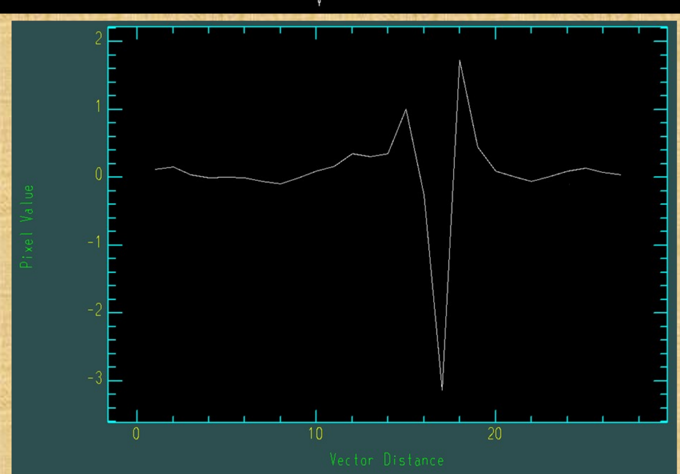
Testing The PSF

Spitzer is a space based telescope and hence free from the atmospheric seeing effects. The IRAC CCD comprising of 256 X 256 pixels is placed such that the pixel scale is about 1.22 arc sec. This results in FWHM of the IRAC PSF to be 1.7 pixels i.e. it is under-sampled. Thus conventional methods cannot be used for PSF extraction. When one uses the 5 times fine sampled PSFs provided by the Spitzer Science Center to fit stars, one finds central negative residues as shown below.

Left: A residue image grey scaled suitably to make the central negative residue stand out.
Top Right: A surface plot of the region near the residue of a star.
Bottom Right: A vector plot of the same star again indicating the negative residue at the centre.



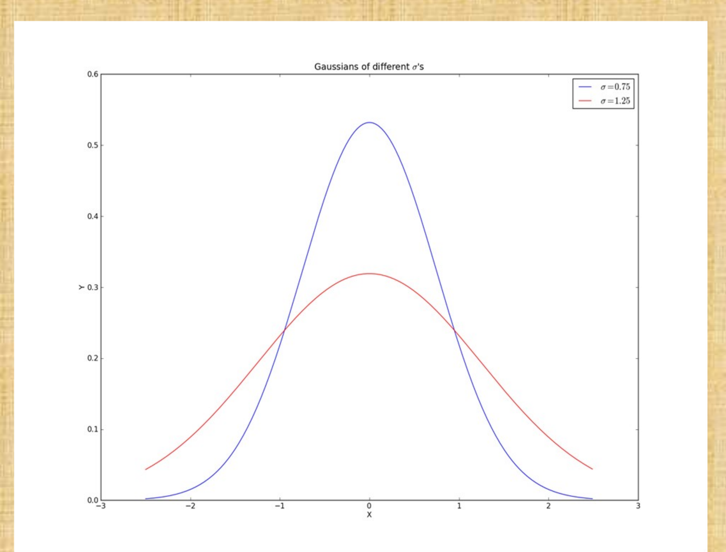




The above analysis showed that on an average there was a negative central residue of ~ 13%. In the wings, the residue was positive and was again ~ 13%. This clearly showed that PSF model was not suitable for decomposition of IRAC mosaicked images.

Making a New PSF

From the two plots and the comparison of the residue in both centre and wings of the residues, it is clear that the intensity in the central region is overestimated by ~13% and in the wings, underestimated by more or less the same amount within the fluctuation levels in the background. This indicates that the FWHM of the "right" PSF for the mosaic is greater than that of the PSFs provided for individual CCD images as can be understood from the adjoining graph.



The construction of the mosaic involves projecting images onto a grid and interpolating. This process is known to dilute or broaden the Point Spread Function. Thus the FWHM of the PSF suitable for a mosaic is greater than that of the PSF meant for the actual CCD image.

- The convolution of the PSF with a Gaussian has the effect of broadening it. Since the FWHM brings in 1st order effects in determining the photometric parameters as opposed to extended features, it is essential to correct for this.
- To determine the right parameters of the Gaussian, bright but unsaturated field stars where chosen and a Gaussian convolved with a PSF was fit with a constraint that all stars have the same Gaussian properties.
- An image was constructed by convolving a Gaussian of these found parameters with the original PSF. This was used as the new PSF.
- Tests indicate that the residue improved from an average of ~13% to ~4%, within the fluctuations of the background.