PHOTOMETRY
Point Spread Function (PSF)

BRIEF

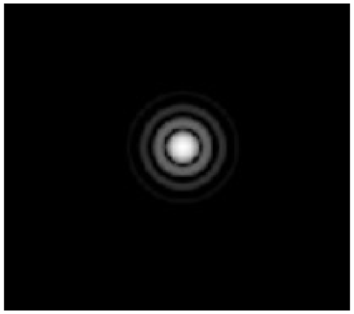
Overview

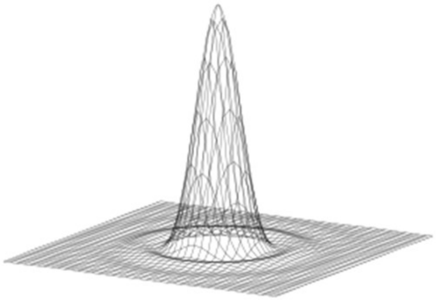
PSF stands for Point Spread Function which describes how an imaging system (ex. Telescope and CCD camera) image a singular point source such as a star.

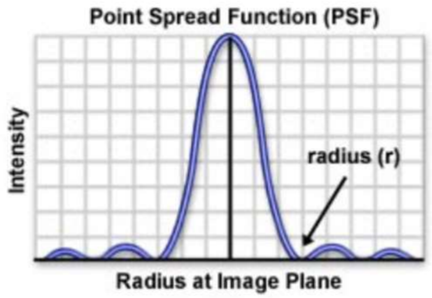
When a CCD image the object is divided into discrete point objects of varying intensity, each object is computed as a sum of the PSF of each point.

The PSF is typically determined entirely by the imaging system and thus the entire image can be described by knowing the optical properties of the system.

Understanding this, any CCD image can be studied through PSF applications.







Crowded Field Photometry

In very crowded fields, say a globular cluster or dense star field, the star images become so close together that it is not possible to use aperture photometry with its sky annulus, as there would always be many stars in the sky annulus preventing a good sky value.

Photometry in globular clusters or similar crowded fields makes use of specialized software programs measuring the stars one by one, starting with the brightest, then digitally subtracting each star from the image as it is measured.

The result are fewer stars to mess up the sky annulus which could cause contamination for the fainter stars.

In crowded field photometry, with so many objects packed close together, PSF is a leading solution.

Tale of Two Stars in an Image

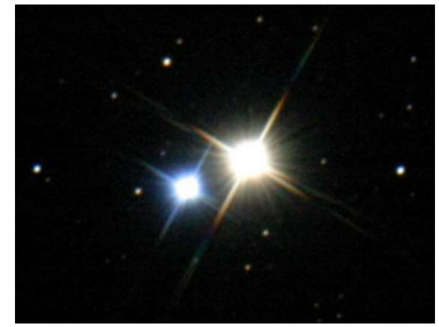
In any given image of the sky, stars appear to have different sizes: bright stars are big and faint stars are very small.

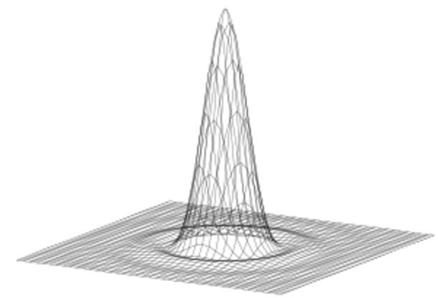
This is an illusion. In a perfect optical system (i.e. no aberrations or other distortions), all stars across the entire image are the same size at the focal plane.

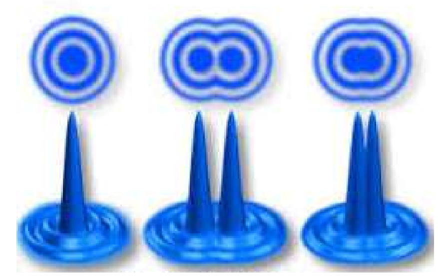
A closer examination of two bright stars on an image, when viewing their full-width, half-maximum (FWHM) values show almost identical and general shapes of the two profiles.

The fainter star only appears smaller because there are fewer pixels above a given level than with the brighter star.

Therefore, every star can be considered a point source, since it has this specific shape and size at the focal plane and is called the point spread function (PSF).

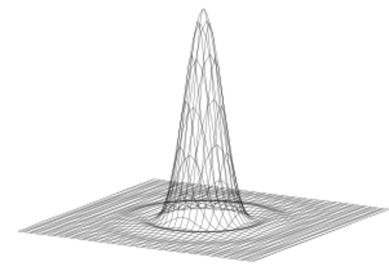




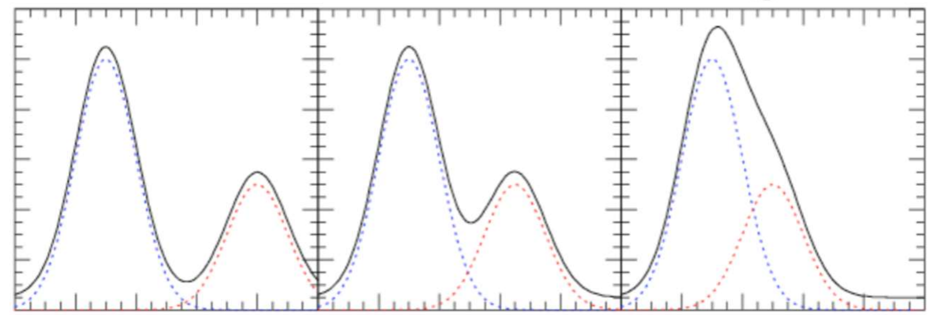


PHOTOMETRY - PSF

PSF - Process



The PSF should be circularly symmetric and can be plotted as the flux vs. radius in a star image.



The angular size can be characterized by the full width at half maximum (FWHM) which is the diameter where the flux falls to half its central value.

PSF uses these properties to its advantage to model how individual stars are displayed on an CCD image.

These models can overlap. Thus, the PSF process basically subtracts “levels” of the profiles reducing the image complexity.

PSF: Modeling, Advantages, and Disadvantages

The stellar profile mode should come from:

1. The best, most luminous, and most isolated stars
2. Multiple stars (to reduce noise), well spread within the frame (to measure PSF spatial variations).

Advantages:

- Works in crowded fields
- Areas in the image with the best SNR (Signal to Noise Ratio) determine the best PSF fit
- Background is included as a parameter

Disadvantages:

- PSF is not perfectly fit in all profiles
- PSF varies across the CCD image (chip)
- PSF can be affected by seeing, the “smearing” of a perfect optical image due to turbulence and temperature differences in the atmosphere.

NOTE: The disadvantages can be mitigated by analyzing multiple PSF models and an interpolation and modeling

Summary

PSF uses known optical behaviors of both the stellar light and imaging system to decrease complexity of an image and create “separation” between objects for more accurate study.

This technique is beneficial when studying: closely spaced double stars, stars in globular clusters, and stars in high density areas.

PSF is not perfect, however, as it depends on good models, low impact from atmospheric seeing, flattened CCD chip, and good telescope/mount tracking.

Questions?