Extracting Point Spread Function (PSF) using PyRAF

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1. Preface

Download and install PyRAF (Python wrapper version of IRAF) and DS9 (FITS image viewer) using Anaconda (www.anaconda.com/download)

2. Getting basic parameters of the image

bash-3.2$ mkiraf
(only if this is first time of running pyraf; set xgterm for terminal type)

bash-3.2$ pyraf
(run PyRAF or IRAF in the directory where your input image is)

--> daophot
(load IRAF/DAOPHOT Package)

--> !ds9 &
(run DS9 program)

Load the image that you want to extract PSF from onto DS9. Here, we use g.fits as an example.

--> daoedit g > g.sky
(run DAOEDIT task with an image g.fits and save the result in a file g.sky)

Notice, if you move your mouse cursor onto the DS9, the usual arrow cursor is now has been changed into ring shape. Move the cursor to a star and press 'r' key. The xgterm screen with a count profile and some information on top will be open. Select a star which is isolated and bright but not with spikes by pressing 'a' key. Select >10 isolated stars. >15 negligible difference. Exit by pressing 'q' key.

--> !more g.sky

# XCENTER	YCENTER	SKY	SKYSIGMA	FWHM	COUNTS	MAG
1322.21	1760.12	0.0	0.02	2.80	291.7	-6.162
1281.74	1529.70	0.0	0.02	2.89	82.8	-4.795
1657.07	1584.32	0.1	0.02	2.79	305.6	-6.213
1839.96	1779.63	0.0	0.02	2.92	42.4	-4.067
1895.98	1828.58	0.0	0.02	2.99	17.0	-3.073
2011.80	1705.87	0.0	0.02	2.77	58.4	-4.417

1881.36	1307.53	0.4	0.19	4.86	803.4	-7.262
1663.72	1466.33	0.1	0.02	2.89	37.4	-3.932
1471.79	1348.69	0.1	0.02	2.85	28.1	-3.620
1067.23	1368.83	0.0	0.02	2.66	15.3	-2.963

(see the result)

I would pick values of 0.0, 0.02, and 2.80 for SKY, SKYSIGMA, and FWHM (because bright stars are more reliable and FWHMs of them are around 2.80).

3. Setting the parameters for DAOPHOT

--> datapars
: update '(fwhmpsf)' with a value of FWHM (2.8) and '(sigma)' with a value of SKYSIGMA (0.02)

--> centerpars
: update '(cbox)' with the bigger value of 5 or 2*FWHM (5.6); whichever is bigger, which is 5.6 in this case

--> fitskypars
: update '(annulus)' with a value of 4*FWHM (11.2), '(skyvalue)' with a value of SKY (0.0), and '(dannulus)' with a value of 3*FWHM (8.4)

--> epar photpars
: update '(apertures)' with the bigger value of FWHM (2.8) and 3.0, which is 3.0 in this case

--> epar daopars
: update '(psfrad)' with a value of 30 (size of PSF; we decided to use 30x30 size of PSF after in-depth analysis) and '(fitrad)' with a value of FWHM (2.8)

4. Finding the Stars

--> daofind
Input image(s) ('abc') : g ↲
: write the name of input image without '.fits' and press Enter.

Output coordinate file(s) (default: image.coo.?) ('default') : ↲
: if you leave 'output' with 'default', the file with a name of 'g.coo.1' will be created that contains coordinates of the stars found.

FWHM of features in scale units (2.8) (CR or value) : ↲
Standard deviation of background in counts (0.02) (CR or value) : ↲
: leave the values of FWHM and SKYSIGMA values as it is because we already updated in the section 3.

Detection threshold in sigma (4.) (CR or value) : 3.5 ↲
: how bright sources do you want to be detected as stars? 2~4 x SKYSIGMA is about right. I put 3.5 x SKYSIGMA as an initial value. If there are too many stars after DAOFIND, increase the threshold below (can go to up to 50 in case of SDSS mosaic data)
Minimum good data value (INDEF) (CR or value) : ↲
Maximum good data value (INDEF) (CR or value) : ↲
: leave as it is

--> epar phot
: edit parameter of PHOT task

image	=	g	Input image(s)
coords	=	default	Input coordinate list(s) (default : image.coo.?)
output	=	default	Output photometry file(s) (default : image.mag.?)

: input image is again 'g.fits', coordinate list is 'g.coo.1' that we created just before with DAOFIND task, output file will be 'g.mag.1'.

--> phot
: execute PHOT task, and press Enter for all the options asked because we already updated. You can execute PHOT task also by pushing 'Execute' button after you're done with editing parameters of PHOT task.

5. Extracting PSF

--> epar psf

image :	g	Input image(s) for which to build PSF
photfile :	g.mag.1	Input photometry file(s) (default: image.mag.?)
pstfile :		Input psf star list(s) (default: image.pst.?)
psfimage :	g.psf.1	Output PSF image(s) (default: image.psf.?)
opstfile :	g.pst.1	Output PSF star list(s) (default: image.pst.?)
groupfile :	g.psg.1	Output PSF star group file(s) (default: image.psg.?)

: we're using 'g.mag.1' from PHOT task running. leave 'pstfile' BLANK because we're running PSF task first time here, but 'g.pst.1' will be used for saving a list of stars used for making PSF image. 'g.psg.1' file is the list of the PSF stars and the stars around the PSF stars, the purpose of this file is to clean out neighboring stars and extract pure PSF.

--> psf

Analytic psf function(s) (gauss) : auto↲

: by selecting auto it will fit through all the functions and use best-fit function.
(for more information, please refer to IRAF Tutorial - A reference Guide to the IRAF/DAOPHOT package by Lindsay E. Davis p.50)

: select default values for remaining questions.

- Move your mouse cursor to ds9. Put cursor onto a star isolated and bright but without spikes, and press 'a' key.
- Meshed plot will be drawn for the star on seperate xgterm screen. Scrutinize the star by using contour plot by pressing 'c', radial plot by pressing 'r', and meshed plot by pressing 'm'. Press 'e', 's', and 'n' to rotate mesh graph. Press 't' for more information about graph. Press 'p' for information (coords, mag) of star.
- Contour graph (c) should be circular.
- Checking whether intensity in the center is reduced in half at 'Half width half-maximum' vertical line in the radial plots might be helpful.
- If you want to select the star to create PSF press 'a' key again, if not press 'd' key.
- With same method, select total around 15 stars.
- Bright star will have more weight when PSF is generated.
- Once you're done with selecting stars, press 'f' key to finish and do fitting.
- If the value of 'norm scatter' should be ~ 0.1.
- Once fitting is done, press 'w' to write the results.
- Once the result is written, press 'q' to quit.

In order to check the psf, type:
--> seepsf
psfimage : g.psf.1
image : g_psf

--> !ds9 g_psf.fits &
(& will run ds9 on the background so you can still work on command line while ds9 is running.)

6. Subtract the stars neighboring the PSF stars

--> epar allstar

image :	g	Image corresponding to photometry
photfile :	g.psg.1	Input photometry file (default: image.mag.?)
psfimage :	g.psf.1	PSF image (default: image.psf.?)
allstarf :	g.als.1	Output photometry file (default: image.als.?)
rejfile :	g.arj.1	Output rejections file (default: image.arj.?)
subimage :	g.sub.1	Subtracted image (default: image.sub.?)

Excecute allstar command

: 'g.psg.1' is a list of a group of stars PSF+neighbor. Photometry result of them will be saved in 'g.als.1'.

--> epar substar

image :	g	Image corresponding to photometry file
photfile :	g.als.1	Input photometry file (default: image.nst.?)
exfile :	g.pst.1	Input exclude file (default: image.pst.?)
psfimage :	g.psf.1	PSF image (default: image.psf.?)
subimage :	g.sub.11	Subtracted image (default: image.sub.?)

Excecute substar command

: Subtract 'g.als.1' (photometry result of PSF and neighbor stars) but not the PSF stars in exclude file 'g.pst.1', and save the image in 'g.sub.11.fits'.

7. Extract PSF again using neighbor-star-subtracted-image

--> epar psf

image :	g.sub.11	Input image(s) for which to build PSF
photfile :	g.mag.1	Input photometry file(s) (default: image.mag.?)
pstfile :	g.pst.1	Input psf star list(s) (default: image.pst.?)
psfimage :	g.psf.2	Output PSF image(s) (default: image.psf.?)
opstfile :	g.pst.2	Output PSF star list(s) (default: image.pst.?)
groupfile :	g.psg.2	Output PSF star group file(s) (default: image.psg.?)

Execute psf command

: Only different things are 'g.sub.11' and 'g.pst.1', and increasing numbers for output files. If you run IRAF PSF task, the stars you picked will show up one by one on xterm window. If you still want to use the star, select the star by pressing 'a', if not press 'd' to get rid of. After going over all candidates from 'g.pst.1', you can add more stars by move the cursor onto the star and pressing 'a' for checking and pressing 'a' one more time to select. The newer list will be updated in 'g.pst.2'.

press 'f' to fit, then 'w' to write, then 'q' to quit. Or you can press 'w' to fit & write and 'q' to quit.

8. Doing it again

--> epar allstar

image :	g	Image corresponding to photometry
photfile :	g.psg.2	Input photometry file (default: image.mag.?)
psfimage :	g.psf.2	PSF image (default: image.psf.?)

allstarf :	g.als.2	Output photometry file (default: image.als.?)
rejfile :	g.arj.2	Output rejections file (default: image.arj.?)
subimage :	g.sub.2	Subtracted image (default: image.sub.?)

Execute allstar command

: We are using updated list of PSF+neighbor star 'g.psg.2' and new PSF 'g.psf.2', and save the photometry result in 'g.als.2'

--> epar substar

image :	g	Image corresponding to photometry file
photfile :	g.als.2	Input photometry file (default: image.nst.?)
exfile :	g.pst.2	Input exclude file (default: image.pst.?)
psfimage :	g.psf.2	PSF image (default: image.psf.?)
subimage :	g.sub.22	Subtracted image (default: image.sub.?)

Execute substar command

--> epar psf

image :	g.sub.22	Input image(s) for which to build PSF
photfile :	g.mag.1	Input photometry file(s) (default: image.mag.?)
pstfile :	g.pst.2	Input psf star list(s) (default: image.pst.?)
psfimage :	g.psf.3	Output PSF image(s) (default: image.psf.?)
opstfile :	g.pst.3	Output PSF star list(s) (default: image.pst.?)
groupfile :	g.psg.3	Output PSF star group file(s) (default: image.psg.?)

: Repeating the process about 2-4 times while checking how well PSF subtraction is done (You can check by opening 'g.sub.?.fits' or 'g.sub.??.fits' images using DS9) (** Tab key blinks between images on ds9)

Reference

DAOPHOT 을 이용한 PSF 측광 (황호성, 이명균 2006)