Introduction to Skymaker and the STEP1 simulations

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Stuff and skymaker form an image simulation package to mimic multi-colour surveys. They were written by E. Bertin (TERAPIX)

What is skymaker?

Skymaker makes realistic sky simulations with the
main emphasis on reproducing observational effects:

- telescope aperture
- Optical defects (e.g. astigmatism, coma, tracking errors)
- detector and sky characteristics (gain, sky brightness, saturation effects)
- halos around bright stars (star aureole)

!! Skymaker uses galaxy catalogues generated by stuff !!

What is stuff?

The program is optimised to reproduce 'photometric‘ properties of real galaxies (lensing could be introduced at this stage)

galaxy distribution:
- galaxies are placed in space in a Poisson distributed way (from z=10 to z=0)
- galaxies of different types (E, S0, Sab, Sbc, Scd, Sdm) are mimicked by the superposition of a de Vaucouleurs and elliptical profile in varying ratios.
- galaxies have random orientation and ellipticity (unless lensing is applied).

photometric properties:
- galaxy absolute luminosities are chosen according to a Schechter LF
- apparent magnitudes are calculated by taking into account internal extinction of the disk, distance modulus, K-correction (galaxy templates from Coleman are used by default but the user can change this)

Where to download skymaker & stuff?
Versions used for STEP1 and space simulations:

Stuff 1.05:

http://terapix.iap.fr/cplt/oldSite/soft/stuff/index.html

Skymaker 2.3.4:

http://terapix.iap.fr/cplt/oldSite/soft/skymaker/

More recent Stuff 1.11 (2005) available here:

ftp://ftp.iap.fr/pub/from_users/bertin

Stuff packaging:

stuff1.05/source
stuff1.05/config/dust stuff1.05/config/extinct stuff1.05/config/filters stuff1.05/config/seds
stuff1.05/config/default.stuff

Usage: stuff [-c <configuration_file>] [-<keyword> <value>]

Output: CATALOG_NAME b.list,v.list,i.list # output catalog file name(s)

Stuff catalogue format:

200 155.598 1954.978 20.3004 0.191 0.252 0.798 84.68 0.704 0.761 79.03 0.61757

(bulge: de vaucouleur
disk: exp(-sqrt(x^2+y^2)/rg) cut at 4rg)

200: code (200 is galaxy, 100 is star)
155.598 1954.978: X and Y
20.3004: total mag
0.191: bulge to total flux ratio
0.252: bulge length scale (arcsec)
0.798: bulge projected axis ratio
84.68: bulge position angle
0.704: disk length scale (arcsec)
0.761: disk projected axis ratio
79.03: disk position angle
0.61757: redshift

Critical keywords in Stuff configuration file (default.stuff):

```
CATALOG_NAME    b.list,v.list,i.list    # output catalog file name(s)
IMAGE_WIDTH     4096            # width of the simulated frame
IMAGE_HEIGHT    4096            # height of the simulated frame
MAG_LIMITS      15.0,25.0       # allowed range of apparent magnitudes
PIXEL_SIZE      0.2             # pixel size (arcsec)
```

Secondary keywords in config file:

```
H0              65.0            # Hubble constant (km.s-1.Mpc-1)
OMEGA_M         0.3             # matter density in units of critical density
OMEGA_LAMBDA    0.7             # cosmo constant in units of critical density
```

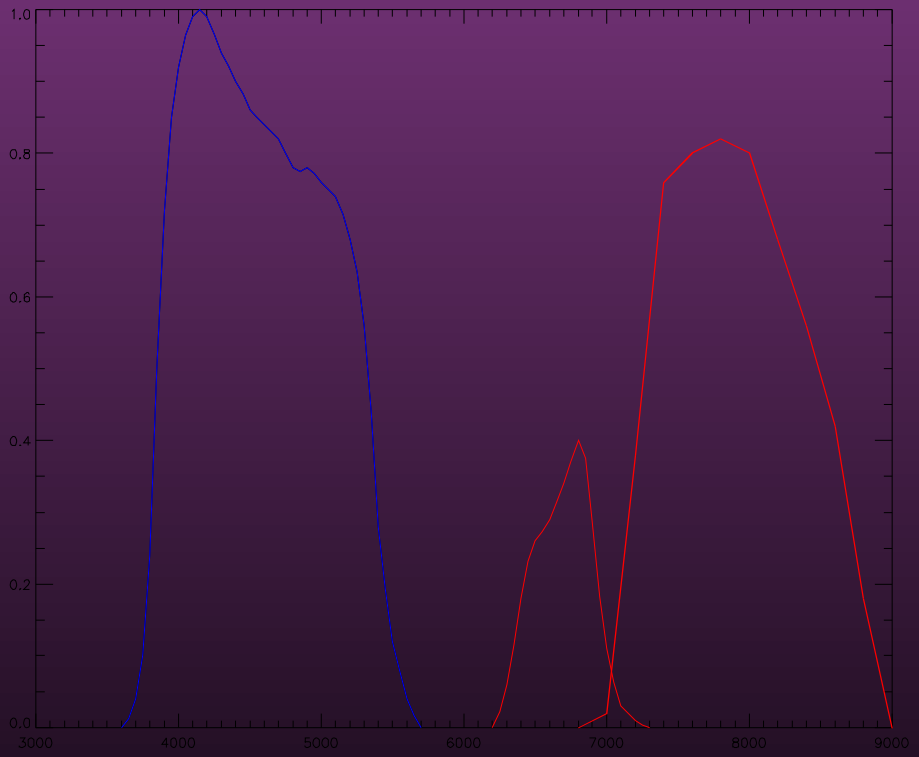
Does not work yet: `INCLUDE_STARS   N               # allow addition of a stellar field?`
`GALACTIC_COORDS 270,30.0       # galactic coordinates`

Things you should NOT change unless you know what you are doing:

SED, galaxy types, luminosity functions
Stuff uses a non-evolving Schechter function

Passbands (used to generate b.list,v.list,i.list):

PASSBAND_OBS config/filters/Bj_couch, config/filters/Rf_couch, config/filters/I_bessell



PASSBAND_REF config/filters/Bj_couch : is the reference filter where the M of the Schechter function Is computed

Skymaker packaging:

skymaker2.3.4/source
skymaker2.3.4/config
skymaker2.3.4/config/param.sky

Usage: skymaker [<list_file>] [-c <configuration_file>] [-<keyword> <value>]

Output(s): IMAGE_NAME Test.fits # name of the output frame

A new output catalogue is generated, Test.list, which contains the stuff list catalogue and the stars added by Skymaker (if any) with code 100. ex:

100 30.000 30.000 21.9672

Critical keywords in Skymaker configuration file (param.sky):

```
IMAGE_NAME      Test.fits       # name of the output frame
IMAGE_WIDTH     2048            # width of the output frame
IMAGE_HEIGHT    2048            # height of the output frame
PIXEL_SIZE      0.2             # pixel size in arcsec.
```

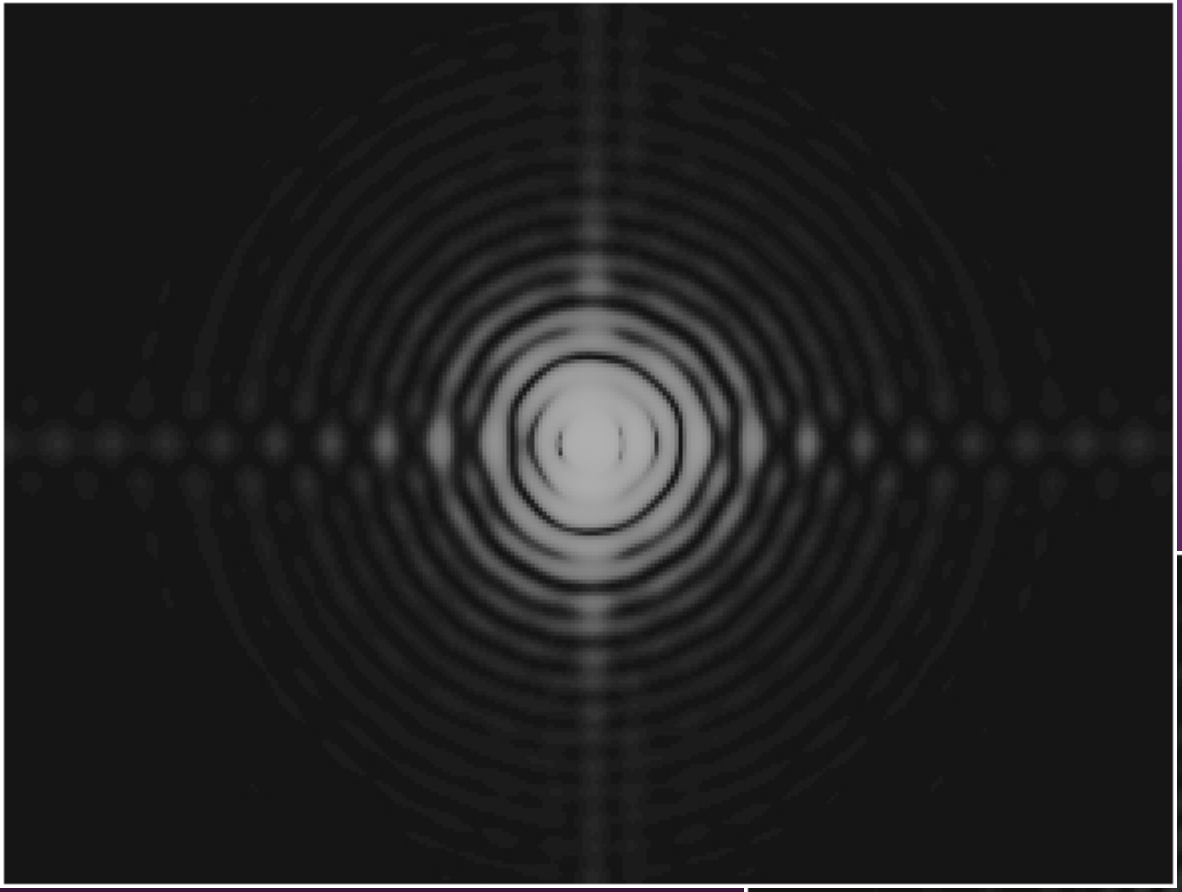
!!!YOU CANNOT MAKE A SKYMAKER FROM A STUFF CATALOGUE USING TWO DIFFERENT PIXEL_SIZE!!!

Simulation type: `IMAGE_TYPE  SKY  # type of image`

SKY: normal mode
SKY_NONOISE: noise free simulation

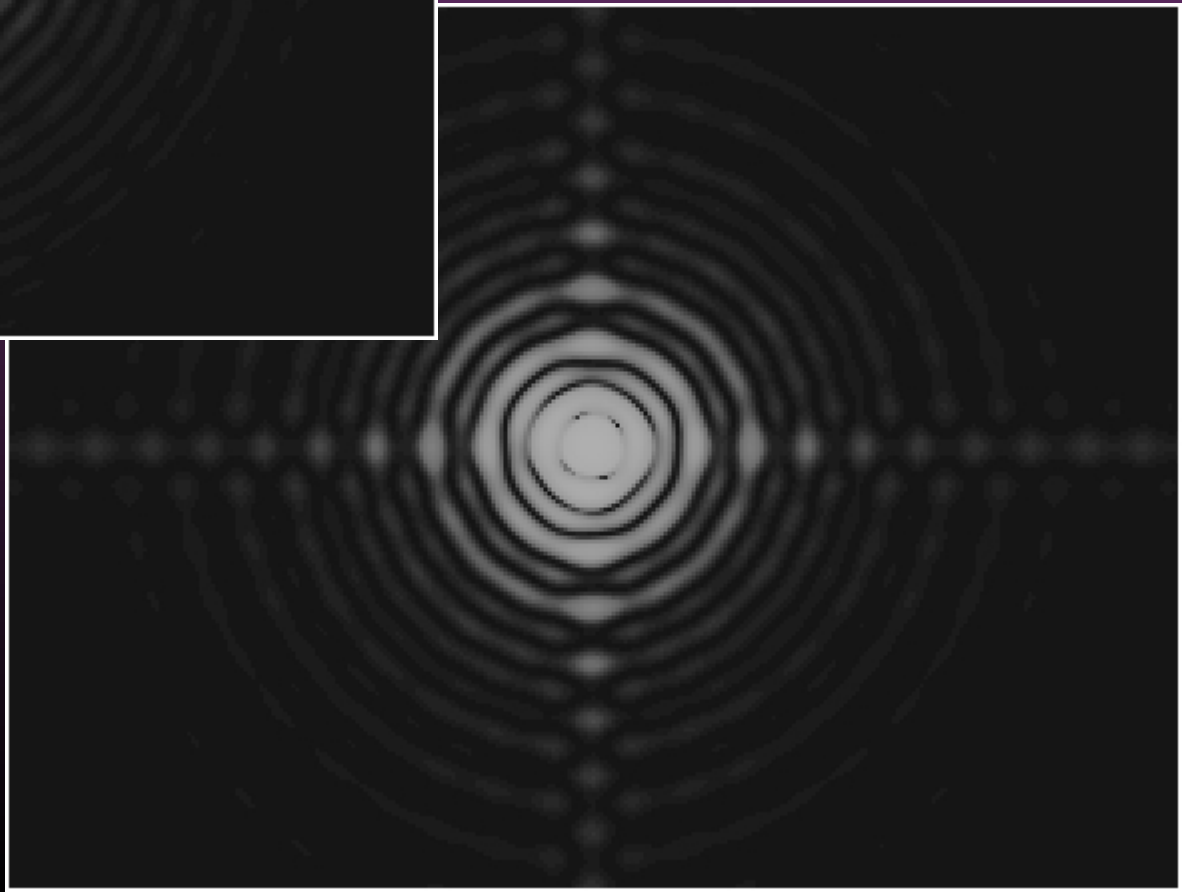
PUPIL_REAL
PUPIL_IMAG
PUPIL_MODULUS
PUPIL_PHASE: shows the different components of the pupil

PSF_FULLRES: oversampled PSF
PSF_FNALRES: user-defined resolution PSF



<- WFPC2

ACS ->



Critical keywords in Skymaker configuration file (param.sky):

Detector/magnitude calibration:

```
READOUT_NOISE   0.8             # read-out noise (e-)  (negligible for long exposures)
GAIN            2.              # gain (e-/ADU)

EXPOSURE_TIME   600             # total exposure time (s)
MAG_ZEROPOINT   25.65             # magnitude zero-point ("ADU per second")
BACK_MAG        19.9            # background surface brightness (mag/arcsec2)
```

MAG_ZEROPOINT the magnitude zeropoint in ADU per sec., i.e. for an image that is normalised to 1s (WARNING: The result of skymaker is normalised to the provided EXPOSURE_TIME t, i.e. the magnitude zeropoint (mag) to be used in SExtractor for your simulation is:

mag = MAG_ZEROPOINT + 2.5*log(t))

Subtlety for object S/N: if (exp time) X (GAIN) is constant then S/N is the same Everywhere (ex: 600 sec GAIN=12 is the same as 3600 sec with GAIN=2) -> useful in order to avoid saturation with long single exposure.

```
SATUR_LEVEL     65535           # saturation level (ADU)
```

PSF characterisation:

```
SEEING_TYPE     LONG_EXPOSURE   # (NONE, LONG_EXPOSURE or SHORT_EXPOSURE)
SEEING_FWHM     0.7             # FWHM of seeing in arcsec (incl. motion).
```

NONE: diffraction limited simulation
LONG and SHORT exposures: atmospheric seeing added
SEEING_FWHM not used if SEEING_TYPE is NONE

```
AUREOLE_RADIUS  200             # Range covered by aureole (pix) 0 = no aureole
AUREOLE_SB      16.0            # SB (mag/arcsec2) at 1' from a 0-mag star

PSF_OVERSAMP    5               # oversampling factor / final resolution
PSF_MAPSIZE     1024            # PSF mask size (pixels): must be a power of 2
```

PSF anisotropy

```
TRACKERROR_TYPE DRIFT          # (NONE, DRIFT or JITTER)
TRACKERROR_MAJ  0.0            # tracking RMS error (major axis) (in arcsec)
TRACKERROR_MIN  0.0            # tracking RMS error (minor axis) (in arcsec)
TRACKERROR_ANG  0.0            # tracking angle (in deg, CC/horizontal)

M1_DIAMETER     3.5            # diameter of the primary mirror (in meters)
M2_DIAMETER     1.0            # obstruction diam. from the 2nd mirror in m.
ARM_COUNT       4              # number of spider arms (0 = none)
ARM_THICKNESS   10.0           # thickness of the spider arms (in mm)
ARM_POSANGLE    30.0           # pos. angle of the spider pattern / horizontal
DEFOC_D80       0.07           # d80% diameter induced by defocusing (arcsec)
SPHER_D80       0.0            # d80% diameter induced by spherical (arcsec)
COMAX_D80       0.0            # d80% diameter induced by coma along x (arcsec)
COMAY_D80       0.0            # d80% diameter induced by coma along y (arcsec)
AST00_D80       0.0            # d80% diameter induced by astigmatism at 0 deg. (arcsec)
AST45_D80       0.0            # d80% diameter induced by astigmatism at 45 deg. (arcsec)
TRI00_D80       0.07           # d80% diameter induced by triangular at 0 deg. (arcsec)
TRI30_D80       0.1            # d80% diameter induced by triangular at 30 deg. (arcsec)
QUA00_D80       0.0            # d80% diameter induced by quadratic at 0 deg. (arcsec)
QUA22_D80       0.0            # d80% diameter induced by quadratic at 22.5 deg. (arcsec)
```

Check at http://mathworld.wolfram.com/ZernikePolynomial.html

WFPC2 type space simulation (space STEP skymaker)

Stars could be added by skymaker, if absent in the stuff catalogues:

```
STARCOUNT_ZP    42000.0        # nb of stars /deg2 brighter than MAG_LIMITS
STARCOUNT_SLOPE 0.3            # slope of differential star counts (dexp/mag)
MAG_LIMITS      15.0,26.0      # stellar magnitude range allowed
```

Skymaker has an excellent interface to control sky, detector and telescope features. The PSF module is particularly good because it is very realistic and flexible.

Skymaker's weakness is the galaxy profiles which are too simplistic (in particular for space Simulations).
The lensing implementation (lensed ellipticities) is too simplistic, ultimately we want to be able to simulate all lensing features (SL, high order moments).

Erben & LVW are working on a modified skymaker which implements the shapelets:

Faster FFT algorithm

Will include realistic galaxy profiles (machine learning from UDF, COSMOS,…), this will replace stuff.

Will include full lensing features (pixel mapping)