CatSim hands-on

What do I need to put in my simulation mocks to use them with catsim/phosim?

Debbie Bard
SLAC National Accelerator Laboratory

DESC Collaboration Meeting
Pittsburgh, Dec 2013

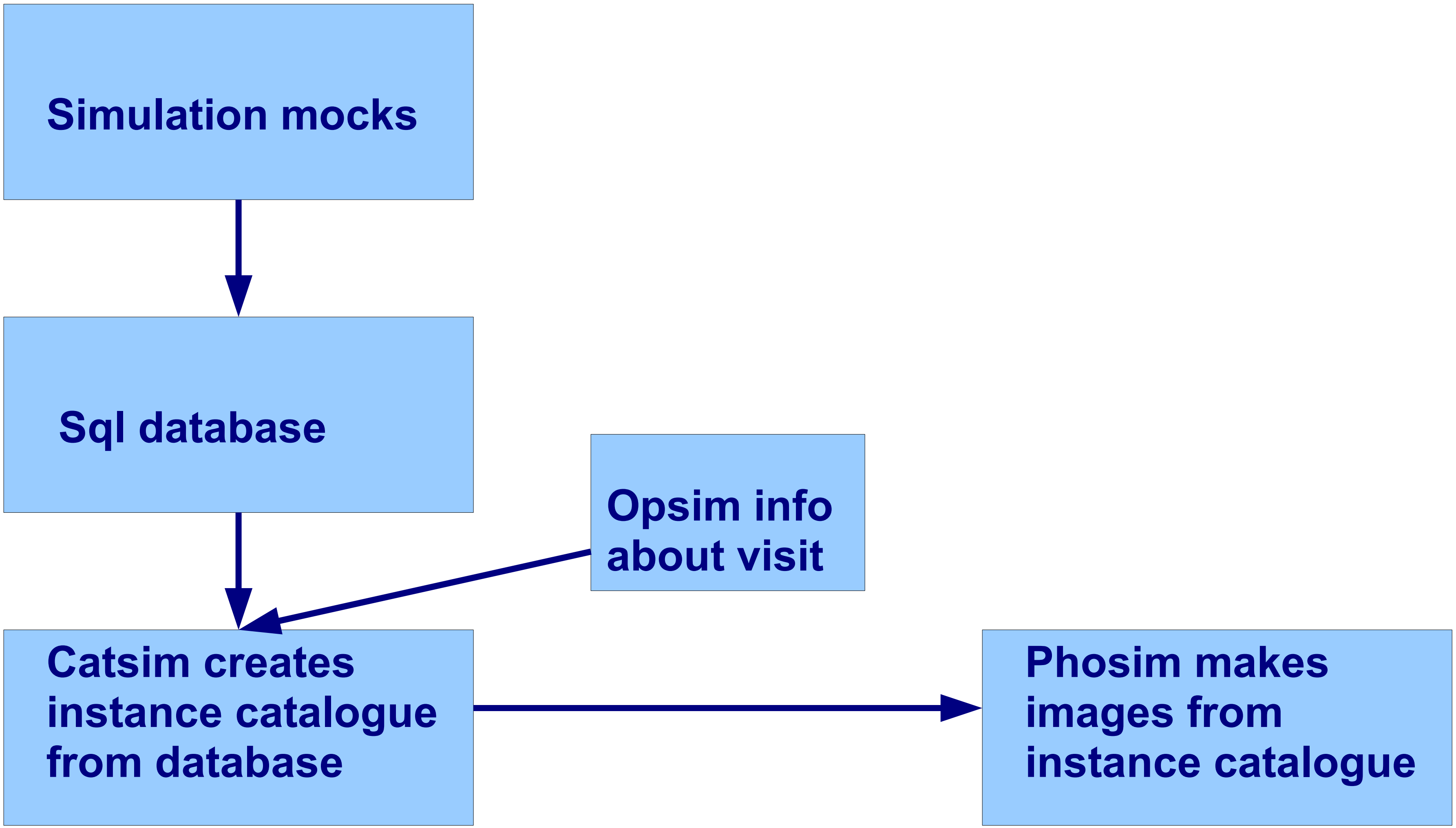
LSST DESC Dark Energy Science Collaboration

SLAC NATIONAL ACCELERATOR LABORATORY

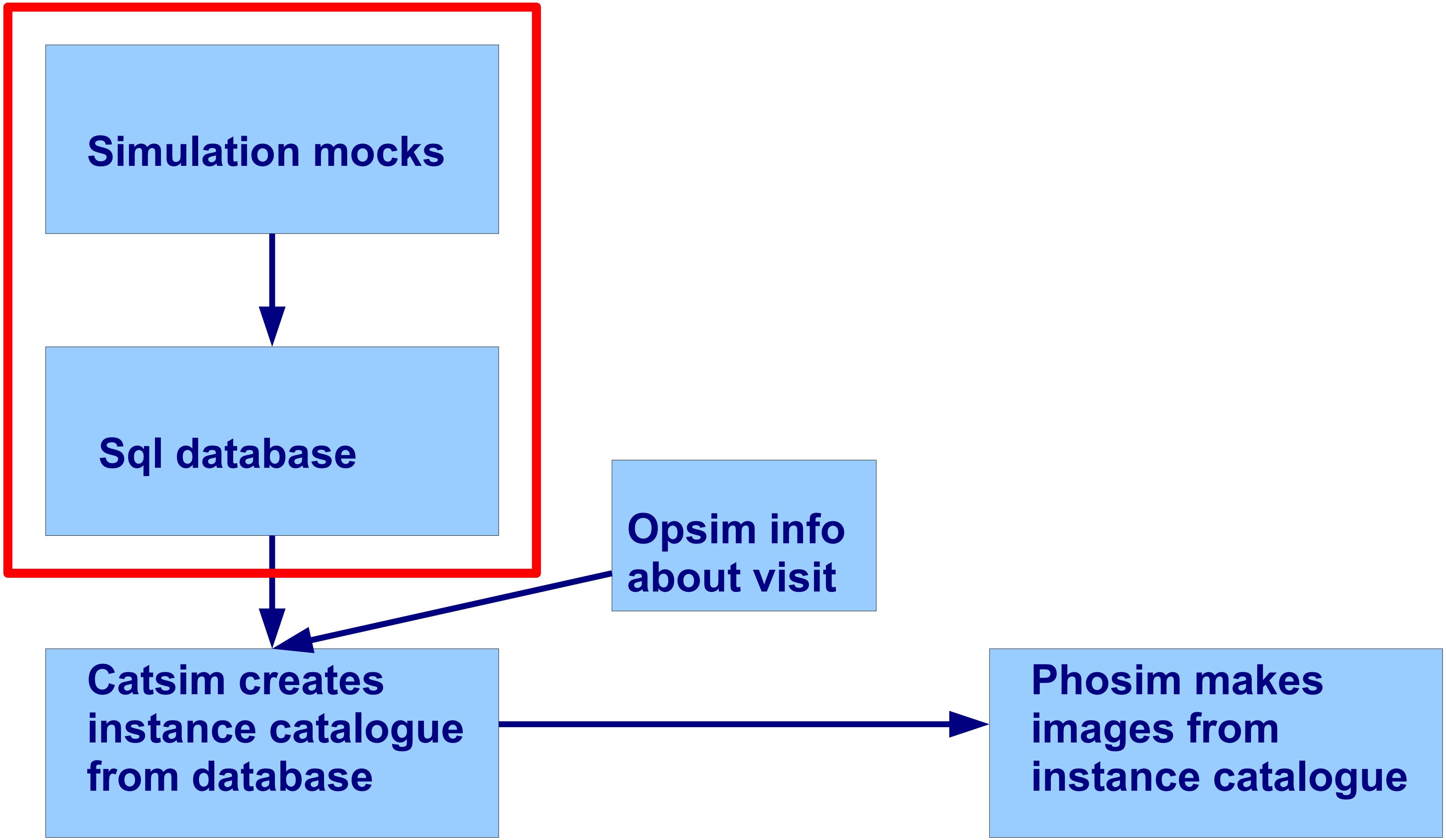
Outline

- Overview of simulation framework
- What goes into an instance catalogue?
  - Examples
- How I've made catalogues out of DES mocks, and run phosim over them.

How the sims work



How the sims work

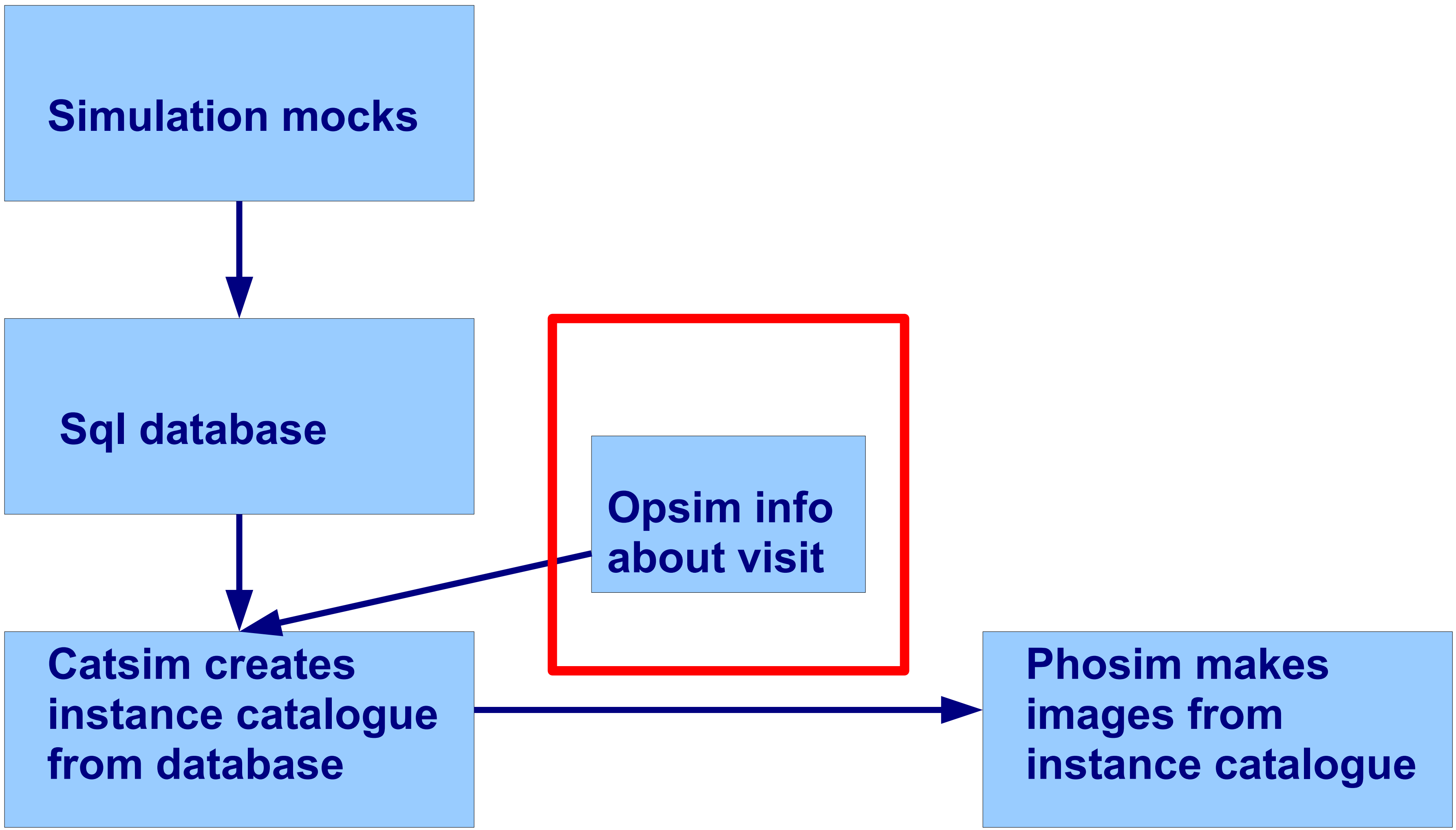


Galaxy database

- Simple mysql routine (+ example data) you can download from the DESC guithub:
- https://github.com/DarkEnergyScienceCollaboration/ImageSimulationRecipes

- In principal, it doesn't matter where you put the database. You can query from wherever using the catsim code.

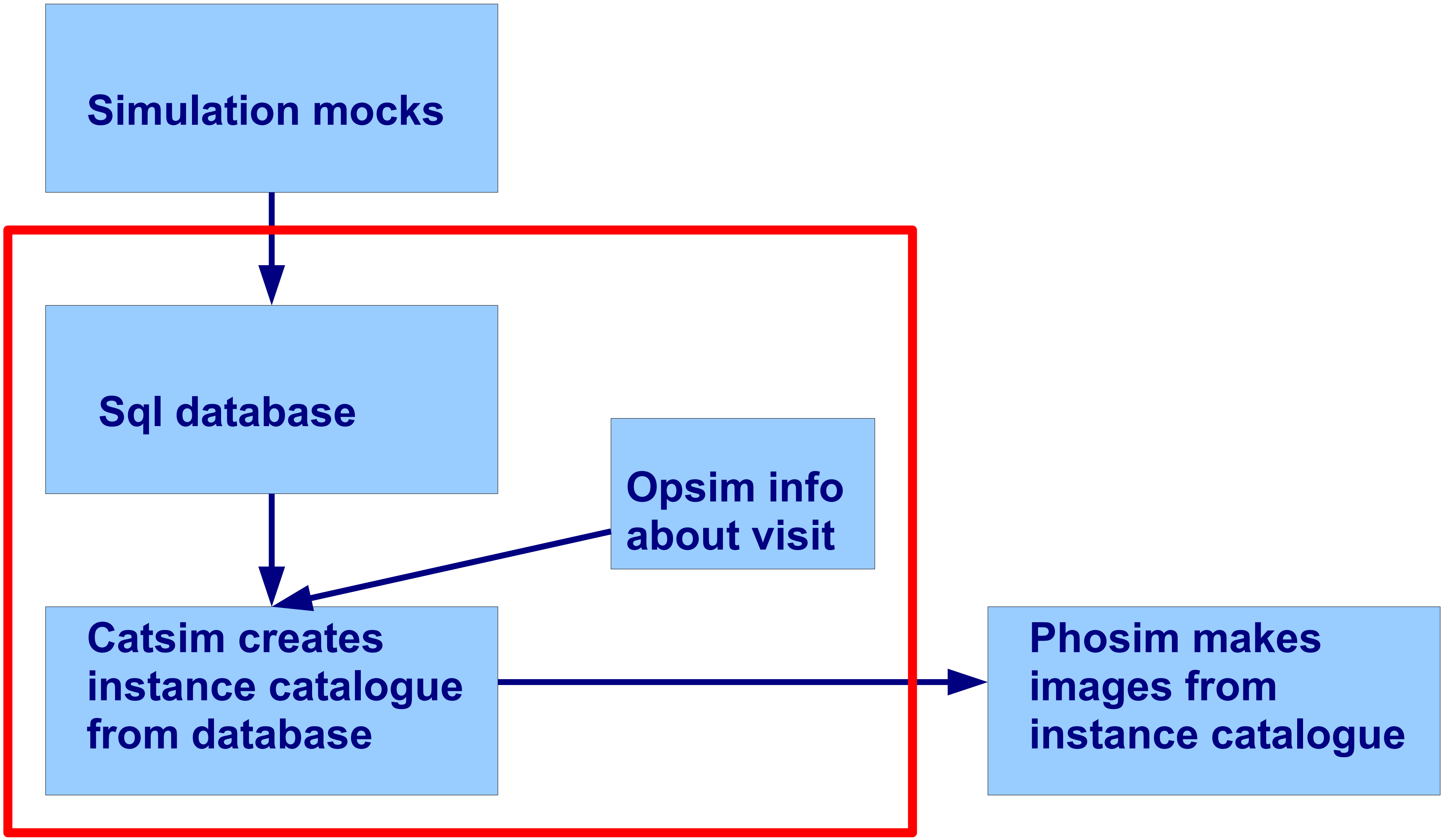
How the sims work



Opsim

- You can download the opsim DB from here (about 1.5GB):
  - http://opsimcvs.tuc.noao.edu/runs/opsim3.61/opsim3.61.html
  - http://opsimcvs.tuc.noao.edu/runs/opsim3.61/output_opsim3_61.sql.gz
- Use 2nd link (unzipped) to create opsim db using:
  - mysql -p databasename < output_opsim3_61.sql
- or, if you're logged onto a remote mysql server (e.g. at ncsa):
  - create database MyUsername_opsim;
  - use MyUsername_opsim;
  - source output_opsim3_61.sql;
- Use this to query db to find visits:
  - select obsHistID from output_opsim3_61 where fieldRA between 1.18 and 1.20 and fieldDEC between -0.7 and -0.67 and filter="r" and airmass between 1 and 1.1 and seeing between 0.6 and 0.7;

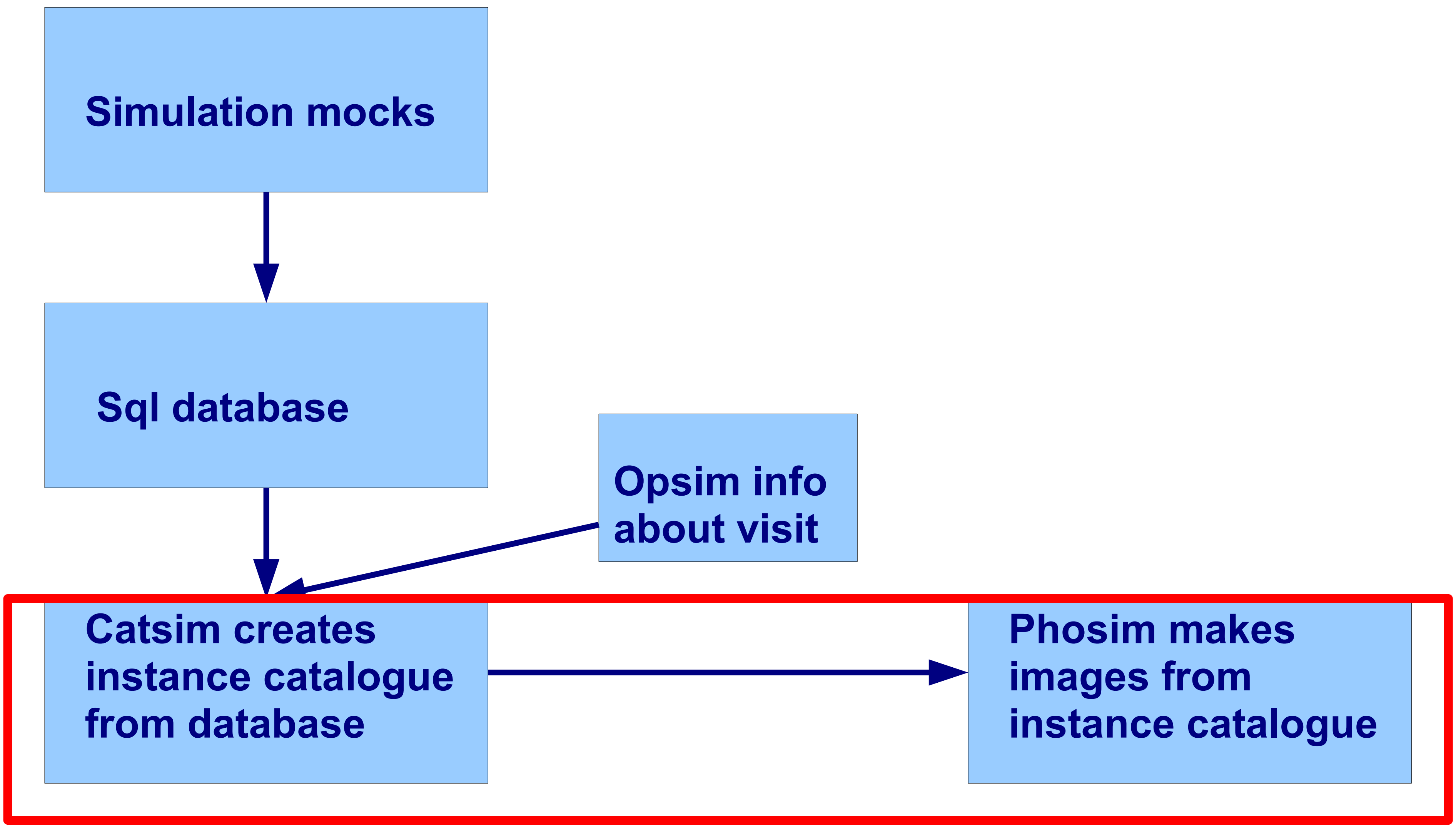
How the sims work



catsim

- Catsim has easy interface to the sims database (and your own), which you can use to make catalogues for input to phosim, or for your own edification.
- This is somewhat more involved, I can give a demo if you want...
- measures/test/runCat.py gives instance catalogues that have the correct format for using as input to phosim...

How the sims work



phosim instance catalogue

- OpSim observation information:

Last modified 5 mont

From https://dev.lsstcorp.org/trac/wiki/IS_instance_catalog

ıstance Catalog Formats

There are two parts to the instance catalog: the observation parameters and the astrophysical inputs.

bservation Parameters

The following are the observational numbers required by phoSim. Normally, the first set of these are set by opSim, but it can be useful to modify these for an individual simulation. These values are normally decided by a telesc operator in a real telescope, but note these parameters can be made inconsistent with one another. In fact, many of the pointing parameters could be condensed into just 4 independent variables: an observation time, alt, az, a camera rotation angle. This is intentional to allow flexibility in the simulations, but note that the telescope could be looking through the Earth or simulating a scenerio that would not ever occur.

	Time, implied pointing, Sun & Moon positions
Opsim_expmjd X	X= MJD of observation (e.g. 49552.3)
Slalib_date X	X= Date of observation in format: 1994/7/19/0.298822999997
Unrefracted_RA_deg X	X= Unrefracted Right Ascension in decimal degrees
Unrefracted_Dec_deg X	X = Unrefracted Declination in decimal degrees
Opsim_rotskypos X	X = Angle of sky relative to camera coordinates
Opsim_moondec X	X = Declination of moon in decimal degrees
Opsim_moonra X	X = Right Ascension of moon in decimal degrees
Opsim_moonalt X	X= Altitude of moon in decimal degrees
Opsim_dist2moon X	X = distance to moon in degrees
Opsim_moonphase X	X = phase of moon from 0 to 100
Opsim_sunalt X	X= Altitude of the sun in decimal degrees
	Environmental
Opsim_rawseeing X	X= seeing at zenith at 500 nm (set to -1 for random)
	Telescope Operator
Unrefracted_Azimuth X	X= Unrefracted Azimuth in decimal degrees
Unrefracted_Altitude X	X = Unrefracted Altitude in decimal degrees
Opsim_rottelpos X	X= Angle of sky relative to telescope
Opsim_filter X	X= filter (0=u,1=g,2=r,3=i,4=z,5=y)
SIM_TELCONFIG X	X=telescope configuration (0=dome open/dome light off ; 1=dome closed/dome light off; 2=dome closed/dome light high ; 3=dome closed/dome light low
SIM_CAMCONFIG X	X=camera configuration (bitmask where first bit is science sensors on; second bit is wavefront sensors on; third bit is guiders on)
SIM_VISTIME X	X= total exposure time in seconds of observations (including read out times between exposures)
SIM_NSNAP X	X= number of exposures in a sequence
	Simulation bookkeeping
Opsim_obshistid X	X = observation identifier (names files)
SIM_SEED X	X= random number seed
SIM_MINSOURCE X	X=minimum number of source on chip to bother to simulate it

phosim instance catalogue

- Object information:

strophysical inputs

From https://dev.lsstcorp.org/trac/wiki/IS_instance_catalog

For every object the following line is implemented at the end of the instance catalog file. Note an astrophysical object could be composed of more than one line (e.g. a bulge and disk of a galaxy).

object ID RA DEC MAG_NORM SED_NAME REDSHIFT GAMMA1 GAMMA2 MU DELTA_RA DELTA_DEC SOURCE_TYPE source_pars DUST_REST_NAME dust_pars_1 DUST_LAB_NAME dust_pars_1

ID	A floating point number to keep track of the object, which is unused by phoSim
RA	The right ascension of the center of the object or image in decimal degrees.
DEC	The declination of the center of the object in decimal degrees
MAG_NORM	The normalization of the flux of the object. We use AB magnitudes at (500 nm)/(1+z) (which is roughly equivalent to V (AB) or g (AB)).
SED_NAME	The name of the SED file relative to the data directory
REDSHIFT	The redshift (or blueshift) of the object. The SED does not need to be redshifted if using this
GAMMA1	The value of the shear parameter gamma1 used in weak lensing.
GAMMA2	The value of the shear parameter gamma2 used in weak lensing.
MU	The value of the magnification parameter given in magnitudes.
DELTA_RA	The value of the declination offset in radians. This can be used either for weak lensing or objects that moved from another exposure if you do not want to change the source position in the first two columns.
DELTA_DEC	The value of the declination offset in radians. This can be used either for weak lensing or objects that moved from another exposure if you do not want to change the source position in the first two columns.
SOURCE_TYPE	The name of the spatial model to be used as defined below.

We have currently implemented the following spatial models:

point	No parameters	This is a model primarily used for stars, but also unresolved objects.
gaussian	1 parameter: sigma in arcseconds	This is a model for a gaussian-shaped object.
movingpoint	2 parameters: the derivative of the velocity arcseconds per second along the ra direction, the derivative of the velocity in arcseconds per second along the dec direction	Moving object (e.g. asteroid)
sersic2D	4 parameters: (half-light radius of semi-major axis in arcseconds, half-light radius of semi-minor axis in arcseconds, position angle in radians, sersic index	2-D elliptical Sersic model
sersic	6 parameters: size of axis 1 in arcseconds, size of axis 2 in arcseconds, size of axis 3 in arcseconds, sersic index, polar angle in radians, position angle in radians	3-D ellipsoidal Sesric model
If the SOURCE_TYPE contains fits or fit	2 parameters: pixel size (in arcseconds) and rotation angle (in degrees).	Complex morphology spatial truth images

spatial_pars	The associated parameters for each spatial model.There could be none or many. While the parser is reading the model it looks for more parameters based on the name of the model.
DUST_REST_NAME	Dust model name in the object's rest frame. This is either the ccm for the CCM model, or calzetti for the calzetti model. If no dust model is desired, then put none *for this field.*
dust_pars_1	The parameters for both the calzetti and CCM are the A_v followed by the R_v value. If no dust model is used, do not use parameters
DUST_LAB_NAME	Dust model name in the lab frame. This is either the ccm for the CCM model, or calzetti for the calzetti model. If no dust model is desired, then putnone *for this field.*
dust_pars_2	The parameters for both the calzetti and CCM are the A_v followed by the R_v value. If no dust model is used, do not use parameters

phosim instance catalogue

- example:

File Edit Options Buffers Tools Help

```
Opsim_obshistid 87393588
SIM_SEED 97895167
Unrefracted_RA 81.1760879
Unrefracted_Dec -12.2103036
Opsim_moonra 313.898938
Opsim_moondec -12.7605726
Opsim_rotskypos 184.222551
Opsim_rottelpos 0
Opsim_filter 2
Opsim_rawseeing 0.514460981
Opsim_sunalt -18.1759974
Opsim_moonalt -25.2607921
Opsim_dist2moon 122.048036
Opsim_moonphase 0.394149005
Opsim_expmjd 50486.0469
Opsim_altitude 72.4911951
Opsim_azimuth 355.249313
object 8796393441277.10 81.2108221 -11.6323995 16.3084 galaxySED/Exp.32E09.04Z.spec.gz 0.0289583 3.50177e-06 3.50177e-06 -5.24508e-05 0 0 SERSIC2 5.35761595 3.12147927 344.482849 1 CCM 0.1 3.1 none 0.3 3.1
object 8796403897331.10 81.2835226 -11.6139993 27.4603 galaxySED/Inst.50E09.002Z.spec.gz 0.0287281 2.33203e-06 2.33203e-06 -5.24842e-05 0 0 SERSIC2 13.751585 7.10892057 308.114746 1 CCM 0.1 3.1 none 0.3 3.1
object 8796534352082.10 81.2784262 -11.6226997 17.9969 galaxySED/Exp.32E09.02Z.spec.gz 0.0293501 1.3411e-06 1.3411e-06 -5.2501e-05 0 0 SERSIC2 6.1322732 3.02417946 320.518188 1 CCM 0.1 3.1 none 0.4 3.1
object 8797160154087.10 81.1979208 -11.6355991 18.257 galaxySED/Exp.40E09.02Z.spec.gz 0.0293398 4.4927e-06 4.4927e-06 -5.24332e-05 0 0 SERSIC2 7.09667015 4.0055933 89.9593048 1 CCM 0.1 3.1 none 0.3 3.1
object 8799887945150.10 81.2798223 -11.5966997 18.7994 galaxySED/Inst.25E09.02Z.spec.gz 0.029686 3.8743e-06 3.8743e-06 -5.2515e-05 0 0 SERSIC2 1.52350485 0.436195195 163.246765 1 CCM 0.1 3.1 none 0.7 3.1
object 8800070150795.10 81.2996282 -11.5818996 20.9188 galaxySED/Const.20E09.002Z.spec.gz 0.0298588 3.97116e-06 3.97116e-06 -5.247e-05 0 0 SERSIC2 8.84360027 8.32420635 301.687439 1 CCM 0.1 3.1 none 0 3.1
object 8800383680182.10 81.2294225 -11.5748997 18.0333 galaxySED/Const.10E10.02Z.spec.gz 0.0294581 9.53674e-06 9.53674e-06 -5.24505e-05 0 0 SERSIC2 5.09084368 3.46244931 8.32006741 1 CCM 0.1 3.1 none 0.2 3.1
object 12644457299698.10 81.2262182 -11.6434994 17.7217 galaxySED/Exp.20E09.02Z.spec.gz 0.0292513 4.32134e-07 4.32134e-07 -5.24324e-05 0 0 SERSIC2 3.25808382 1.74044859 160.216278 1 CCM 0.1 3.1 none 0.3 3.1
object 12644471692087.10 81.3008184 -11.6462002 19.8307 galaxySED/Exp.25E09.02Z.spec.gz 0.029389 4.47035e-08 4.47035e-08 -5.24464e-05 0 0 SERSIC2 3.77889156 3.7383039 199.545746 1 CCM 0.1 3.1 none 0 3.1
object 12644485355332.10 81.2123174 -11.6837997 16.9662 galaxySED/Const.12E10.02Z.spec.gz 0.0296298 -3.68059e-06 -3.68059e-06 -5.24478e-05 0 0 SERSIC2 8.42547417 3.37985229 48.0801506 1 CCM 0.1 3.1 none 0.5 3.1
object 12644516590726.10 81.2159185 -11.6563997 27.3708 galaxySED/Exp.62E09.002Z.spec.gz 0.02978 8.9407e-08 8.9407e-08 -5.24915e-05 0 0 SERSIC2 15.4554195 8.4504652 296.12442 1 CCM 0.1 3.1 none 0.3 3.1
object 12644561573483.10 81.268218 -11.6385994 17.7868 galaxySED/Exp.25E09.02Z.spec.gz 0.0292602 -1.19209e-06 -1.19209e-06 -5.24737e-05 0 0 SERSIC2 4.82559443 1.96054626 87.5157394 1 CCM 0.1 3.1 none 0.5 3.1
object 12644833080735.10 81.3127279 -11.6413002 17.2339 galaxySED/Burst.20E09.02Z.spec.gz 0.0298534 2.27988e-06 2.27988e-06 -5.24953e-05 0 0 SERSIC2 10.219286 7.06785822 231.364548 1 CCM 0.1 3.1 none 0.2 3.1
object 12645053829279.10 81.283225 -11.6068001 18.6756 galaxySED/Exp.32E09.02Z.spec.gz 0.0294505 2.98768e-06 2.98768e-06 -5.2398e-05 0 0 SERSIC2 5.79870129 3.39096165 247.467346 1 CCM 0.1 3.1 none 0.3 3.1
object 12645063833510.10 81.1748266 -11.6462993 18.257 galaxySED/Exp.40E09.02Z.spec.gz 0.029184 6.60121e-06 6.60121e-06 -5.24726e-05 0 0 SERSIC2 7.09667015 4.0055933 89.9593048 1 CCM 0.1 3.1 none 0.3 3.1
object 12645064330943.10 81.271224 -11.6704998 19.1561 galaxySED/Inst.64E08.02Z.spec.gz 0.0299003 -9.26852e-06 -9.26852e-06 -5.24833e-05 0 0 SERSIC2 4.23225975 4.12281752 296.74292 1 CCM 0.1 3.1 none 0 3.1
object 12645066355465.10 81.2800207 -11.5767002 18.365 galaxySED/Exp.32E09.02Z.spec.gz 0.0294985 5.1707e-06 5.1707e-06 -5.25369e-05 0 0 SERSIC2 25.9062195 18.3850994 190.63446 1 CCM 0.1 3.1 none 0.1 3.1
object 12645111138539.10 81.1484213 -11.6083994 18.5101 galaxySED/Exp.25E09.02Z.spec.gz 0.0299545 5.99027e-06 5.99027e-06 -5.25605e-05 0 0 SERSIC2 4.78244257 4.59284925 185.382355 1 CCM 0.1 3.1 none 0 3.1
object 12645119253193.10 81.3079214 -11.6838999 18.9729 galaxySED/Burst.25E09.02Z.spec.gz 0.0295492 -8.60542e-06 -8.60542e-06 -5.24167e-05 0 0 SERSIC2 4.89894915 2.25433302 294.901276 1 CCM 0.1 3.1 none 0.4 3.1
```

Galaxy parameterisation

- Galaxy location
- Mag normalisation (AB magnitudes at (500 nm)/(1+z))
- SED
- Redshift
- Shear params (if any)
- Object type (Gaussian, Sersic2D, sersic3D, fits image)
- Dust model
- Old document detailing this:
  - http://basov.physics.purdue.edu/lsst_sims/inputoutput.pdf

Simulating galaxies

- Draws photons randomly over time from source
  - Extended source (gaussain/sersic): chose r/theta randomly from PDF.
  - 'truth' fits image of galaxy: 2d PDF of finding a photon in a given pixel. Allows for arbitrary rotation and scaling
- Wavelength chosen by randomly sampling the wavelength probability constructed from the SED.
- Flux is based on 500nm AB mag: total # photons calculated by prob. (from SED) of finding a photon at that wavelength, modulated by poisson sampler.
- Shear applied by distorting photon positions.
- Magnification is (currently) just an addition, not cosmological magnification from shear params.

http://basov.physics.purdue.edu/lsst_sims/phosim_peterson_080213.pdf

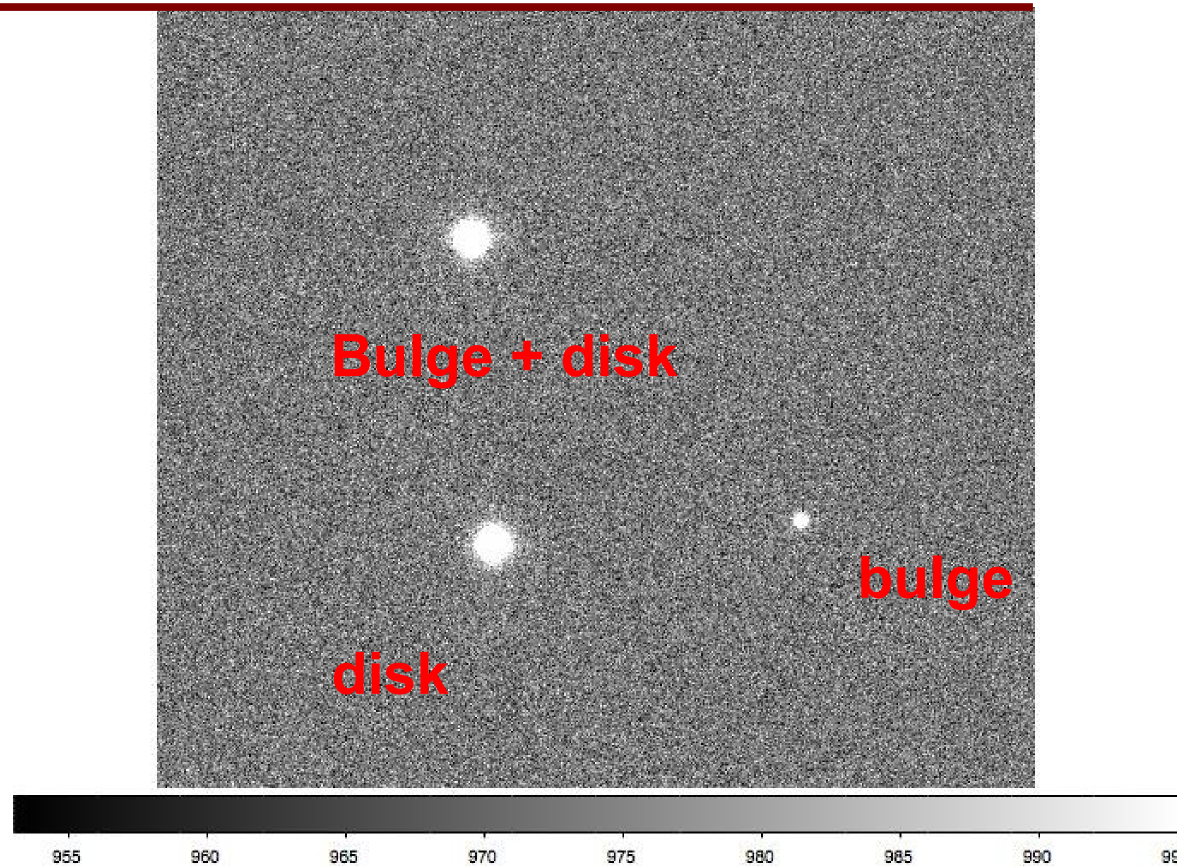
SEDs

- SED file: flux units (ergs cm^{-2} s^{-1} A^{-1} per wavelength bin.
- I don't see any reason why you should not supply your own SED files, if they comply with this format.
- It would be harder to use a different format, but a conversion could be incorporated into the phosim framework with some work.
- Currently have 960 zipped galaxy SED files: 37 MB.
  - If it gets much larger, this causes real problems for running phosim (disk I/O)

Example instance catalogues

- Gaussian

```
Opsim_obshistid 87393588
SIM_SEED 97895167
Unrefracted_RA 81.1760879
Unrefracted_Dec -12.2103036
Opsim_moonra 313.898938
Opsim_moondec -12.7605726
Opsim_rotskypos 184.222551
Opsim_rottelpos 0
Opsim_filter 2
Opsim_rawseeing 0.514460981
Opsim_sunalt -18.1759974
Opsim_moonalt -25.2607921
Opsim_dist2moon 122.048036
Opsim_moonphase 0.394149005
Opsim_expmjd 50486.0469
Opsim_altitude 72.4911951
Opsim_azimuth 355.249313
```



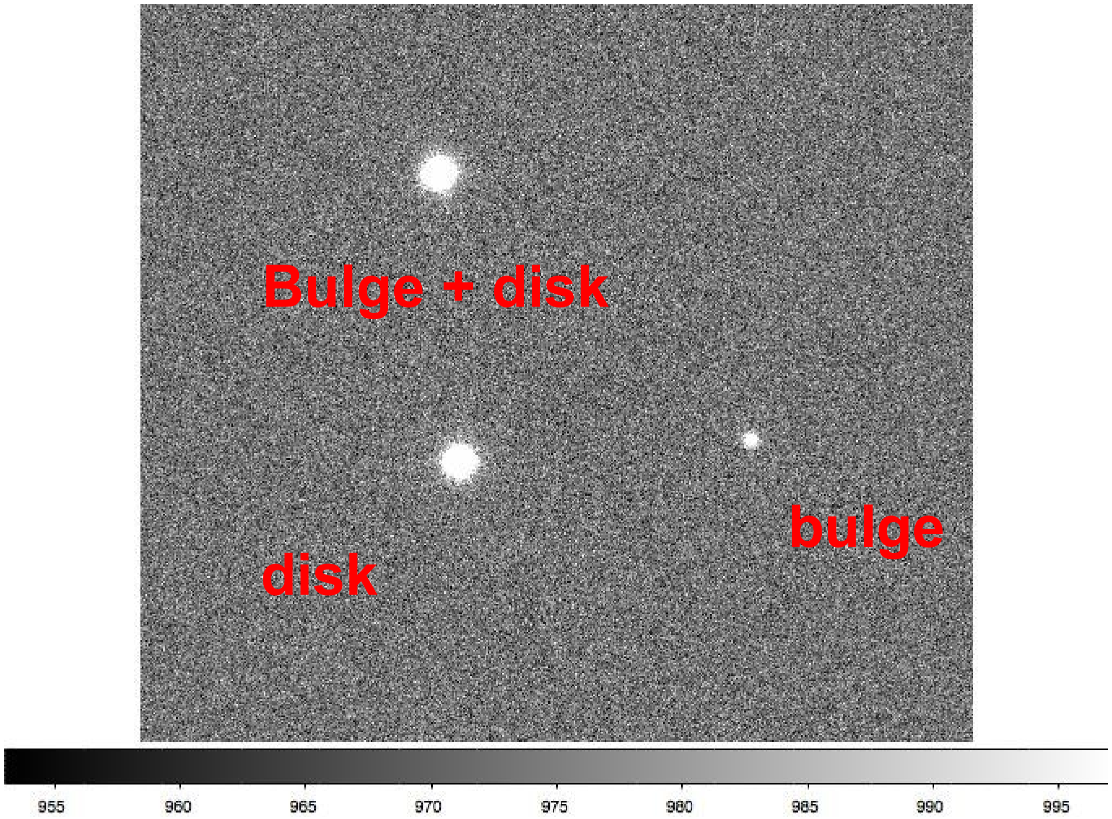

```
object 8796393441277.10 81.2108221 -11.6323995 16.3084 galaxySED/Exp.32E09.04Z.spec.gz 0.0289583 3.50177e-06 3.50177e-06 0.0 0 0 GAUSSIAN 6 CCM 0.1 3.1 none
 0.3 3.1
object 8796393441277.10 81.2108221 -11.6323995 19.9704 galaxySED/Burst.40E09.002Z.spec.gz 0.0289583 3.50177e-06 3.50177e-06 0.0 0 0 GAUSSIAN 1 CCM 0.1 3.1 n
one 0.6 3.1

object 8796393441277.10 81.2208221 -11.6323995 16.3084 galaxySED/Exp.32E09.04Z.spec.gz 0.0289583 3.50177e-06 3.50177e-06 0.0 0 0 GAUSSIAN 6 CCM 0.1 3.1 none
 0.3 3.1
object 8796393441277.10 81.2208221 -11.6423995 19.9704 galaxySED/Burst.40E09.002Z.spec.gz 0.0289583 3.50177e-06 3.50177e-06 0.0 0 0 GAUSSIAN 1 CCM 0.1 3.1 n
one 0.6 3.1
```

Example instance catalogues

- Sersic 2D

```
Opsim_obshistid 87393588
SIM_SEED 97895167
Unrefracted_RA 81.1760879
Unrefracted_Dec -12.2103036
Opsim_moonra 313.898938
Opsim_moondec -12.7605726
Opsim_rotskypos 184.222551
Opsim_rottelpos 0
Opsim_filter 2
Opsim_rawseeing 0.514460981
Opsim_sunalt -18.1759974
Opsim_moonalt -25.2607921
Opsim_dist2moon 122.048036
Opsim_moonphase 0.394149005
Opsim_expmjd 50486.0469
Opsim_altitude 72.4911951
Opsim_azimuth 355.249313
```



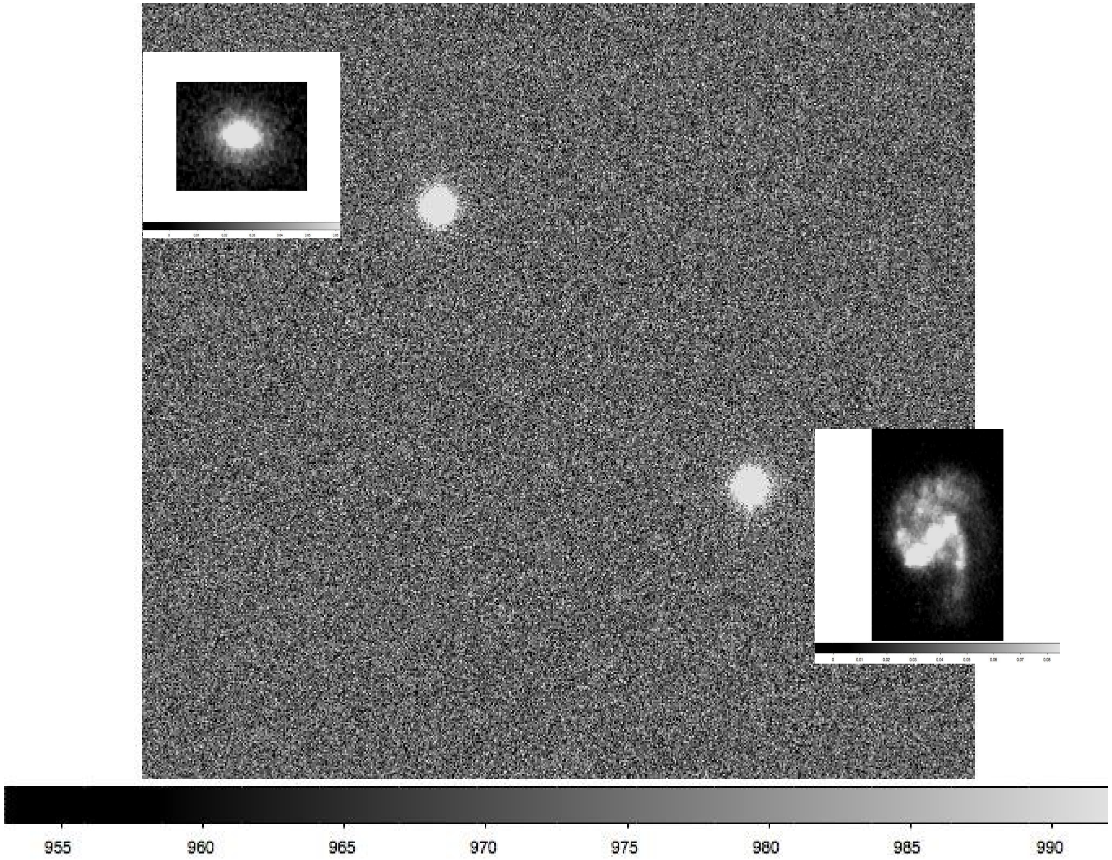

```
object 8796393441277.10 81.2108221 -11.6323995 16.3084 galaxySED/Exp.32E09.04Z.spec.gz 0.0289583 3.50177e-06 3.50177e-06 0.0 0 0 SERSIC2 5.35761595 3.121479
27 344.482849 1 CCM 0.1 3.1 none 0.3 3.1
object 8796393441277.10 81.2108221 -11.6323995 19.9704 galaxySED/Burst.40E09.002Z.spec.gz 0.0289583 3.50177e-06 3.50177e-06 0.0 0 0 SERSIC2 0.578801513 0.34
9905312 344.482849 4 CCM 0.1 3.1 none 0.6 3.1

object 8796393441277.10 81.2208221 -11.6323995 16.3084 galaxySED/Exp.32E09.04Z.spec.gz 0.0289583 3.50177e-06 3.50177e-06 0.0 0 0 SERSIC2 5.35761595 3.121479
27 344.482849 1 CCM 0.1 3.1 none 0.3 3.1
object 8796393441277.10 81.2208221 -11.6423995 19.9704 galaxySED/Burst.40E09.002Z.spec.gz 0.0289583 3.50177e-06 3.50177e-06 0.0 0 0 SERSIC2 0.578801513 0.34
9905312 344.482849 4 CCM 0.1 3.1 none 0.6 3.1
```

Example instance catalogues

- Fits file

```
Save current buffer to its file
Opsim_obshistid 8
SIM_SEED 97895167
Unrefracted_RA 81.1760879
Unrefracted_Dec -12.2103036
Opsim_moonra 313.898938
Opsim_moondec -12.7605726
Opsim_rotskypos 184.222551
Opsim_rottelpos 0
Opsim_filter 2
Opsim_rawseeing 0.514460981
Opsim_sunalt -18.1759974
Opsim_moonalt -25.2607921
Opsim_dist2moon 122.048036
Opsim_moonphase 0.394149005
Opsim_expmjd 50486.0469
Opsim_altitude 72.4911951
Opsim_azimuth 355.249313
```




```
object 8796393441277.10 81.2108221 -11.6323995 16.3084 galaxySED/Exp.32E09.04Z.spec.gz 0.0289583 3.50177e-06 3.50177e-06 0.0 0 0 onegal.fits   0.2   65 CCM
0.1 3.1 none 0.3 3.1

object 8796393441277.10 81.2208221 -11.6423995 16.3084 galaxySED/Burst.40E09.002Z.spec.gz 0.0289583 3.50177e-06 3.50177e-06 0.0 0 0 onegal2.fits   0.2   65
CCM 0.1 3.1 none 0.3 3.1
```

My new galaxy catalogue

- Using DES mocks from Risa Wechsler
  - contains both galaxy clustering and lensing parameters.
  - single-exposure depth (i-mag~23.5)
- Take cosmology from these catalogues
  - i.e. galaxy locations and shear parameters
- Take other quantities from existing galaxy database, based on Millenium mocks (See Simon's presentation for validation details).

In a phosim instance catalogue, I need:

- Galaxy location
- Mag normalisation (AB magnitudes at (500 nm)/(1+z))
- SED
- Redshift
- Shear params (if any)
- Object type: I've used Sersic2D
- Dust model

In a phosim instance catalogue, I need:

- Galaxy location
- Mag normalisation (AB magnitudes at (500 nm)/(1+z))
- SED
- Redshift
- Shear params (if any)
- Object type: I've used Sersic2D
- Dust model

From DES catalogues

Other quantities I take from existing galaxy Millenium mocks. Magnitude is the obvious missing element.

In a phosim instance catalogue, I need:

- $\boxed{\text{Galaxy location}}$
- Mag normalisation (AB magnitudes at (500 nm)/(1+z))
- SED
- Redshift
- Shear params (if any)
- Object type: I've used Sersic2D
- Dust model

From DES catalogues

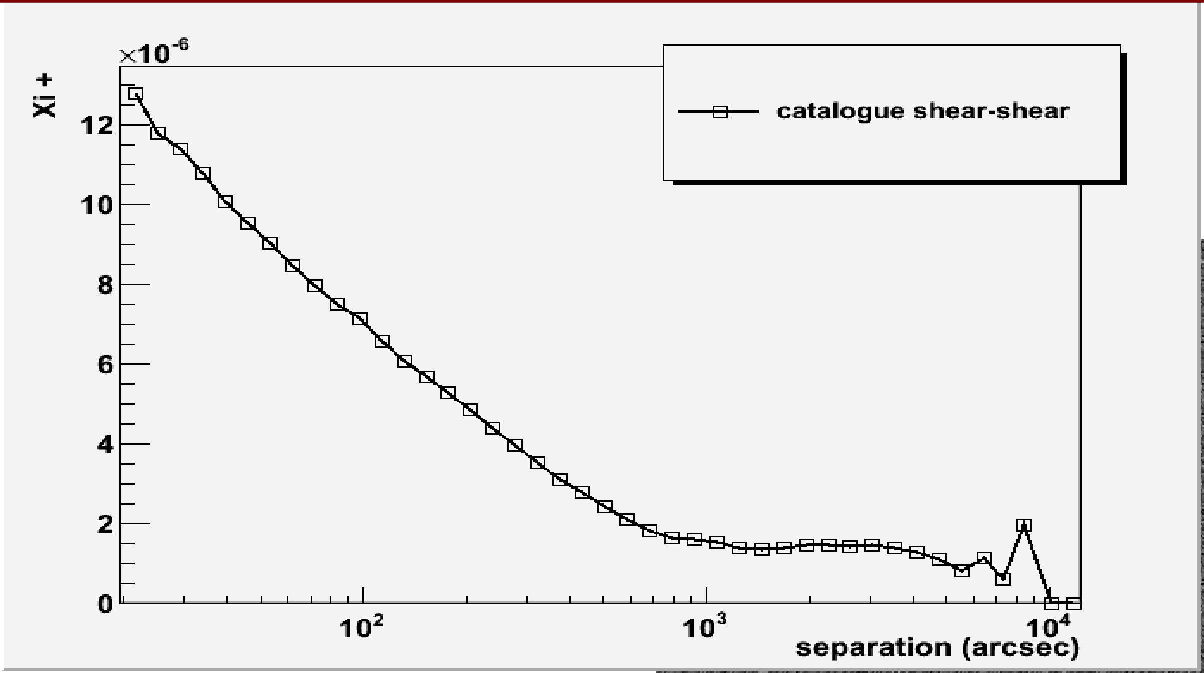
This requires two entries in instance catalogue, one for bulge, one for disk. Complications for matching magnitudes from mocks!

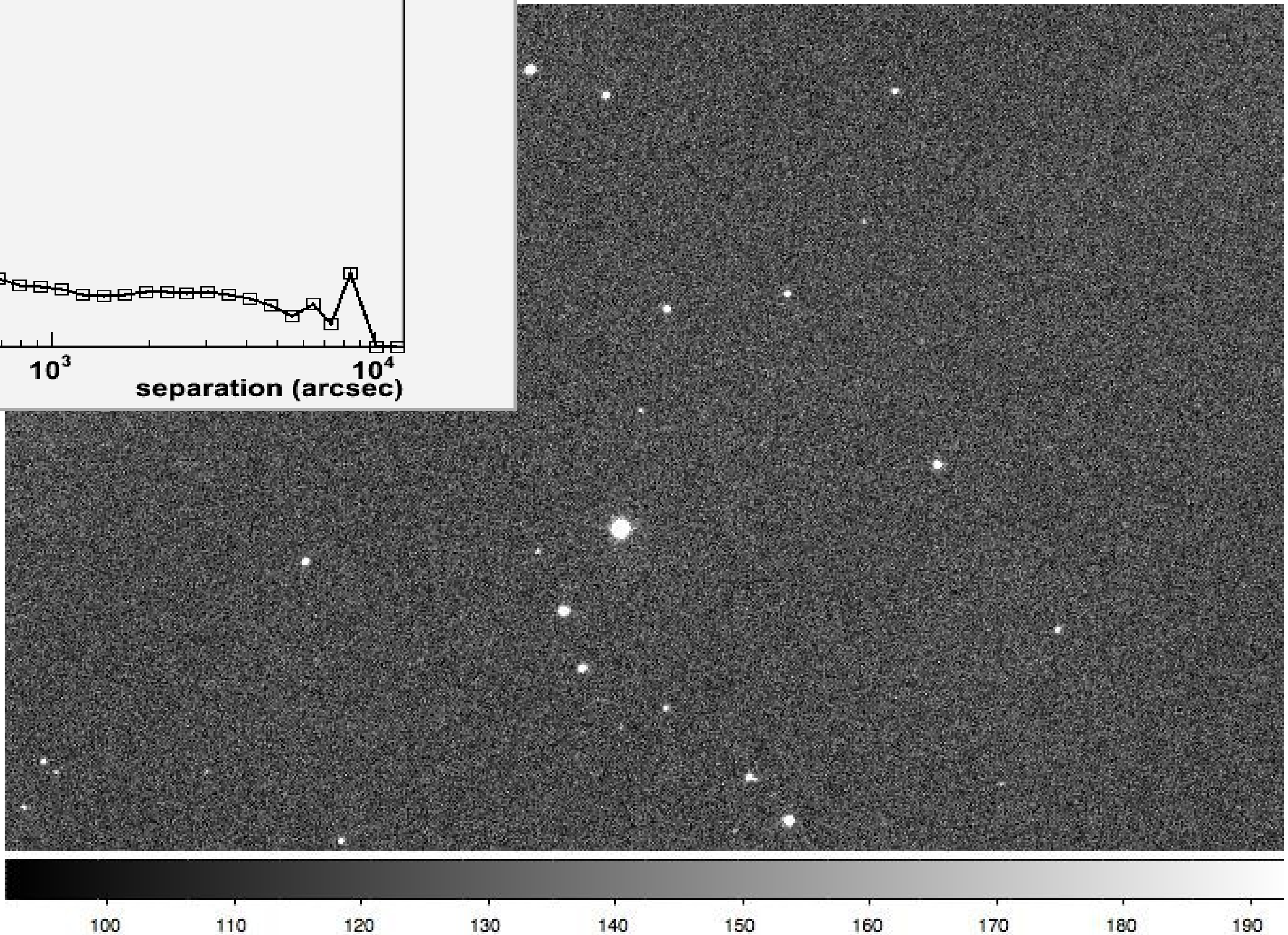
Other quantities I take from existing galaxy Millenium mocks. Magnitude is the obvious missing element.

Procedure

- Bin DES and Millenium mocks in redshift
- Take one galaxy from DES mocks
- Chose a galaxy from Millenium mocks in the same redshift bin, at random.
  - Use bulge+disk components, or disk only.
- Write out new catalogue entry containing ra/dec/z/shear from DES mocks, other params from millenium mock.
- Upload that catalogue to a database.
- Draw an instance catalogue using catsim.
- Run it through phosim.

Looks pretty good:





Potential difficulties:

- SEDs I presume would be easy enough to generate
  - Given infinite disk space...
- Galaxy morphology
  - Bulge+disk colours?
  - Dust reddening parameters?
- Longer-term:
  - how to incorporate realistic galaxy morphologies (blobby)?
  - Galaxy colour gradients?