



PhoSim: An Introduction



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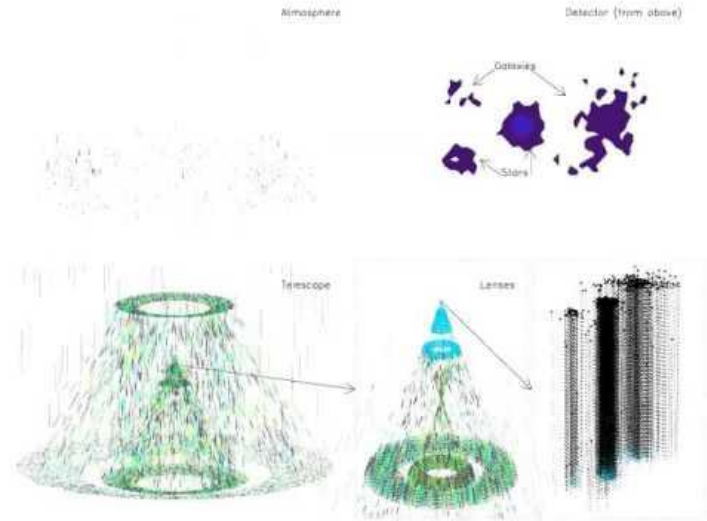


What is PhoSim?

- Photon Simulator
- “a set of extremely fast photon Monte Carlo codes used to calculate the physics of the atmosphere and a telescope & camera”
- Creates simulated astronomical images based on an input file

How does PhoSim work?

- Simulates optical/infrared astronomical images
- Applies numerical techniques to behavior of photons and electrons to simulate effects of atmosphere, telescope, and camera.
- Generates images by collecting electrons into pixels.



Video Credit: LSST Project/NSF/AURA



Modelling Details: Physics

- Photon sampling from galaxy/asteroid/star SEDs & spatial distribution
- Dust absorption at source and in Milky Way
- Airglow, moonlight, twilight
- Von Karman frozen turbulence
- Atmospheric dispersion
- Atmospheric molecular opacity and scattering
- Cloud absorption
- Reflection/refraction/diffraction of mirrors, lenses, sensors
- Interference reflection/transmission/absorption of coatings
- Photo-electric conversion (incl. fringing, field free regions)
- Charge diffusion (incl. lateral fields, charge sharing)
- Saturation & blooming
- Readout: read noise, dark current, gain, pre-over scans, bias, CTE
- Hot pixels/columns, dead pixels, lithography errors



Modelling Details: Instrument and Site

- Site Properties: wind, turbulence intensity, outer scale
- Optical design
- Focal plane layout
- Obstructions (spider)
- Tracking system
- Surface perturbation & alignment errors of all optics & sensors
- Mirror, lens, filter, detector coating details
- Dome seeing
- Cosmic ray properties



How do you use PhoSim?

- Install set of files
- Create or find premade text file input
 - Input catalog specifying photon sources
 - Input commands specifying operating conditions
- Control from command line
 - Specify override commands
 - Specify text file input
- Run PhoSim
- Collect simulated images from output folder



Instance Catalog

- The input file PhoSim uses to run the simulation
- At least one command or object must be specified
- Two parts:
 - List of operational settings
 - List of photon sources



Unrefracted_RA 112
Unrefracted_Dec -35
Opsim_rotskypos 112
Opsim_rottelpos 0.559023062
Opsim_filter 1
Opsim_altitude 22.3365589
Opsim_azimuth 118.659768
Opsim_moonphase 0
Opsim_expnmjd 58484

object	31045209446404	112.127152	-35.1095775	25.9733482	starSED/mlt/m2.3Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.97022901	3.28717208	none	
object	31849541430276	112.124094	-35.112892	25.9551262	starSED/mlt/m4.0Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.97473641	3.29123981	none	
object	31042887425028	112.126817	-35.1118198	27.6748117	starSED/mlt/m4.1Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.97135586	3.28275049	none	
object	32162734262276	112.128266	-35.1123254	22.6155855	starSED/kurucz/km50.6500.fits	q40	6580	.gz	0	0	0	0	0	0	0	point	CCM	0.97360956	3.28797006	none
object	31042891484164	112.119928	-35.1186206	28.5439105	starSED/mlt/m6.2Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.97811696	3.28248074	none	
object	31566730173444	112.119487	-35.1185658	26.6469104	starSED/mlt/m6.2Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.92290069	3.09748087	none	
object	31849543072772	112.123334	-35.1183126	17.9740613	starSED/kurucz/km10.5750.fits	g20	5910	.gz	0	0	0	0	0	0	0	point	CCM	0.97811696	3.28253904	none
object	31849542270980	112.123702	-35.115723	26.5565209	starSED/mlt/m2.9Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.97699011	3.28835487	none	
object	31042898974724	112.133375	-35.1200781	26.3345151	starSED/mlt/m4.2Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.97473641	3.27232186	none	
object	31849544301572	112.132255	-35.1181975	26.1450654	starSED/mlt/m2.1Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.97360956	3.27722997	none	
object	31849543708676	112.127642	-35.1182749	18.5820581	starSED/kurucz/km25.5750.fits	g15	5830	.gz	0	0	0	0	0	0	0	point	CCM	0.97586326	3.28660009	none
object	31042894464004	112.126966	-35.1183734	20.4050844	starSED/kurucz/km10.4750.fits	g00	4870	.gz	0	0	0	0	0	0	0	point	CCM	0.97586326	3.28643268	none
object	31566731260932	112.131329	-35.116017	24.4428428	starSED/mlt/m5.0Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.88346063	2.97028356	none	
object	31045210012676	112.1242	-35.1152698	28.5824533	starSED/mlt/m6.6Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.96346791	3.24429804	none	
object	31042889419780	112.124157	-35.114861	17.6986871	starSED/kurucz/km15.5500.fits	g10	5600	.gz	0	0	0	0	0	0	0	point	CCM	0.97360956	3.279906	none
object	31849542528004	112.127453	-35.1149435	20.4029818	starSED/mlt/m1.1Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.78880399	2.65624156	none	
object	31042894524420	112.127964	-35.1180299	18.4420846	starSED/kurucz/km10.4750.fits	g00	4870	.gz	0	0	0	0	0	0	0	point	CCM	0.9544528	3.21542011	none
object	32056255396868	112.117077	-35.1322807	26.3581264	starSED/mlt/m4.0Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.98825892	3.26912872	none	
object	32056255513604	112.119351	-35.1318365	25.8449133	starSED/mlt/m4.5Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.98487837	3.25923655	none	
object	31045210231812	112.116027	-35.1205407	25.1747996	starSED/mlt/m4.9Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.96234106	3.236387	none	
object	31849543332868	112.11396	-35.1229764	17.1129759	starSED/kurucz/km20.6000.fits	g25	6240	.gz	0	0	0	0	0	0	0	point	CCM	0.98375121	3.29808663	none
object	32162735580164	112.117153	-35.1243503	26.8619892	starSED/kurucz/km10.5000.fits	g15	5060	.gz	0	0	0	0	0	0	0	point	CCM	0.98825892	3.30535486	none
object	32162735499268	112.116816	-35.1241564	22.0537753	starSED/kurucz/km15.5750.fits	g25	5870	.gz	0	0	0	0	0	0	0	point	CCM	0.98375121	3.29133427	none
object	32056253365252	112.116346	-35.1238715	25.6783465	starSED/mlt/m3.9Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.98262436	3.28897915	none	
object	31849543464964	112.115726	-35.1225789	27.1605156	starSED/mlt/m4.2Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.98375121	3.29916727	none	
object	31042899346436	112.116626	-35.1274509	23.639065	starSED/mlt/m2.1Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.98487837	3.27992224	none	
object	32257739009028	112.114012	-35.1264774	28.2685984	starSED/mlt/m0.3Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.98600522	3.28932219	none	
object	32162735992836	112.115802	-35.127033	25.2545521	starSED/kurucz/km10.5250.fits	g15	5350	.gz	0	0	0	0	0	0	0	point	CCM	0.98825892	3.29353031	none
object	31042915185668	112.135634	-35.1343663	26.1516356	starSED/mlt/m6.0Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.91839329	3.02611375	none	
object	31849550613508	112.138646	-35.1349828	27.2824903	starSED/mlt/m2.4Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.98149751	3.23089583	none	
object	31042906251268	112.13073	-35.1279383	22.641648	starSED/kurucz/km40.4250.fits	g00	4250	.gz	0	0	0	0	0	0	0	point	CCM	0.98037066	3.25801176	none
object	31849548090372	112.135872	-35.1282728	25.3748941	starSED/mlt/m3.1Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.97924381	3.25149827	none	
object	31849548571652	112.134651	-35.1303916	19.3301816	starSED/kurucz/km20.5750.fits	g15	5790	.gz	0	0	0	0	0	0	0	point	CCM	0.98037066	3.2466737	none
object	31042909026308	112.124363	-35.1332087	24.5725986	starSED/mlt/m0.3Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.98600522	3.25563507	none	
object	31566736768004	112.128208	-35.1296531	25.9265317	starSED/mlt/m3.6Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.98375121	3.26254076	none	
object	31849547653124	112.127443	-35.1305076	26.7708942	starSED/mlt/m3.1Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.98375121	3.25910383	none	
object	32162738117636	112.128292	-35.1334865	26.6314315	starSED/mlt/m2.0Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.98487837	3.24992683	none	
object	31849548729348	112.133797	-35.1312138	28.472474	starSED/mlt/m5.5Full.dat.gz	0	0	0	0	0	0	0	0	0	point	CCM	0.98149751	3.24709206	none	
object	32162737380356	112.123874	-35.1314105	25.8659499	starSED/kurucz/km50.3750.fits	g20	3910	.gz	0	0	0	0	0	0	0	point	CCM	0.98600522	3.26365777	none



Creating an Instance Catalog: Settings

- PhoSim uses numbers for:
 - Time
 - Pointing
 - Temperature, pressure
 - Operator decisions (visit time, number of snaps per visit)
 - Simulation bookkeeping choices



Creating an Instance Catalog: Photon Sources

For each object, the following items must be designated, in order, with whitespace between each value:

- ID number (not used by PhoSim, but used by you to distinguish between objects)
- Right ascension
- Declination
- G-filter magnitude
- **Spectral Energy Distribution file (full path)**
- Redshift
- Gamma 1 (weak lensing)
- Gamma 2 (weak lensing)
- Magnification parameter (weak lensing)
- RA offset (radians)
- Dec offset (radians)
- Source type (spatial model used by PhoSim: point, gauss, movingpoint, sersic, sersic2d, or more complicated model and associated parameters)
- Dust rest frame model name and associated parameters (can be set to none)
- Dust lab frame model name name and associated parameters (can be set to none)

```
object 1 100 10 20 sedfile.txt 0 0 0 0 0 0 point none none
```



Premade Catalogs and the SED Library

- Premade catalogs can be found online (CatSim)
- Most premade catalogs refer to specific SEDs for each object
- Most of these common SED files can be found in a downloadable “SED Library”
- https://bitbucket.org/phosim/phosim_release/wiki/Using%20PhoSim



Inline physics overrides

- Operating conditions can be set within the instance catalog
- Defaults result in the most realistic simulation
- Overrides be done in in command line
- Ex: `-c command_name`
- Ex: `-c examples/nobackground`



Running PhoSim

- Controlled from command line
- In PhoSim directory:
- `.\phosim instance_catalog -c commands`
- PhoSim will run and write out its actions
- Images (FITS files) will be automatically named and sent to the outputs folder within PhoSim's directory



Understanding a PhoSim Run

- Sorts the instance catalog by chip
- Sorts objects from brightest to dimmest
- Runs simulation for each chip separately, each with separate output
- Runs simulation for each exposure of each chip separately, each with separate output



PhoSim Outputs

- Found in outputs folder
- Title of each file:
 - Image type
 - Filter type
 - Chip identifier
 - Slice identifier



lsst_a_99999999_f2_R22_S11_C00_E000.fits.gz
lsst_a_99999999_f2_R22_S11_C01_E000.fits.gz
lsst_a_99999999_f2_R22_S11_C02_E000.fits.gz
lsst_a_99999999_f2_R22_S11_C03_E000.fits.gz
lsst_a_99999999_f2_R22_S11_C04_E000.fits.gz
lsst_a_99999999_f2_R22_S11_C05_E000.fits.gz
lsst_a_99999999_f2_R22_S11_C06_E000.fits.gz
lsst_a_99999999_f2_R22_S11_C07_E000.fits.gz
lsst_a_99999999_f2_R22_S11_C10_E000.fits.gz
lsst_a_99999999_f2_R22_S11_C11_E000.fits.gz
lsst_a_99999999_f2_R22_S11_C12_E000.fits.gz
lsst_a_99999999_f2_R22_S11_C13_E000.fits.gz
lsst_a_99999999_f2_R22_S11_C14_E000.fits.gz
lsst_a_99999999_f2_R22_S11_C15_E000.fits.gz
lsst_a_99999999_f2_R22_S11_C16_E000.fits.gz
lsst_a_99999999_f2_R22_S11_C17_E000.fits.gz
lsst_e_99999999_f2_R22_S11_E000.fits.gz

Example PhoSim Output



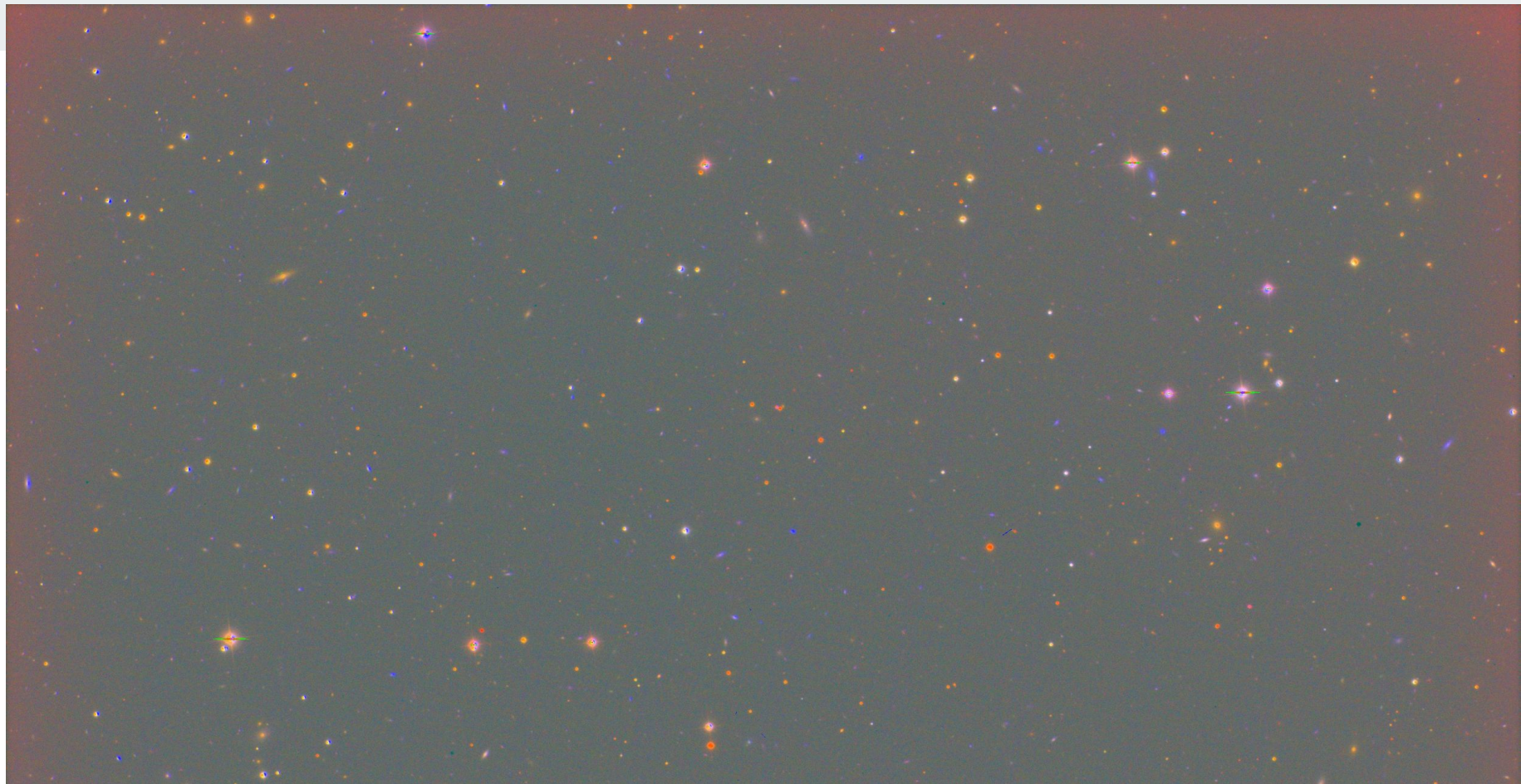


Image Credit: LSST Project/NSF/AURA

https://lsst.rcac.purdue.edu/doc/phosim_picture.pdf



Walkthrough

1. Installation and unpacking (10 minutes)
2. Testing (3 minutes)
3. Creating a simple instance catalog (10 minutes)
4. Command line running/physics command (5 minutes)
5. PhoSim running (5 minutes)
6. Finding and parsing outputs (3 minutes)



Installation

- PhoSim BitBucket website
- Download and unpack tarball
- Python 2.6 or later required
- https://bitbucket.org/phosim/phosim_release/wiki/Home



Links

Astronomical image explanation (slide 17):

https://lsst.rcac.purdue.edu/doc/phosim_picture.pdf

PhoSim Primer:

<https://docs.google.com/document/d/1tmWogRHLZjvGOsZNzJGgFZ9T6azyf9Dha6P4RZP0zo0/edit?usp=sharing>