Phaethon

Userguide

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1 Source code

You can download the code by typing in a terminal (git need to be available on your system):

```
git clone https://github.com/distamio/phaethon.git
cd phaethon
```

This command will create a directory `phaethon`, with the following files and subdirectories (among others)

phaethon	
Name	Description
`Makefile`	
`makefiletai.mk`	
`params.dat`	general parameters, including flow control, ambient and stellar radiation field, SEDs and intensity maps
`params.grid.dat`	parameters relating to the grid construction
`main`	directory containing the main code routines
`exec`	directory where executables and required files are put
`grid.spherical`	contains the routines for constructing the grid, and grid related routines, e.g. advance photon, find photon cell, find photon origin, grid density profile
`isrf`	contains the data for the ambient radiation field
`opacity.OH5_0.1_200`	contains the opacity tables for OH5 (Ossenkopf & Henning, column 5) opacity. The tables are constucted for temperatures up to 200K, with temperature resolution of 0.1 K. Other opacities are available. Please check as they may not be up-to-date.
`utils`	various routines for analysing results
`userguide`	contains the userguide

To update the code from GitHub, change into the `phaethon` directory and type:

```
git pull https://github.com/distamio/phaethon.git
```

2 Building and running the code

After you configure `Makefile` to your liking you build the code by typing `make`. This will copy everything the code needs to run in the directory `exec` (including the sample files `params.dat` & `params.grid.dat`. To run the code move into `exec` and type `phaethon`. During your run there is information printed on the screen and the following output files are produced:

Output files	
File name	Description
`incells.dat`	information about the initial state of your system (eg. cells, density, temperature)
`outcells.dat`	information about the initial state of your system (eg. cells, density, temperature, energy absorbed per cell)
`Av.r.dat`	shows the optical visual extinction vs radius (for spherically symmetric cores
`restart.dat`	information needed when restarting a run
`step.info`	information about how long it takes the code to run
`sed.id.lbin.mbin`	SEDs for a specific photon id for a specific direction (lbin,mbin)
`iso.fs.id.lbin.mbin`	intensity maps for a specific λ (fs) photon id for a specific direction (lbin,mbin) (NXPIXELS $\times$ NYPIXELS)
`isodata.fs.id`	radial intensity profilesfor a specific photon id (this is only for spherically symmetric cores
`intercount.s`	
`fnum.star.0.dat`	
`fnum.star.cgs.0.dat`	

Photon ids	
id	Description
0	all photons are counted
1	only direct photons from the radiation source are counted (i.e. if they do not have any interaction at all with the system)
2	only photons coming from a part system are counted (set by `R_ORIGIN` in `params.grid.dat`)
3	only scattered photons are counted (just scattered!)
4	only reprocessed photons are counted (absorbed and maybe scattered)

Makefile			
Variable name	Description	Recommended values	S
`CC`	sets the c compiler	gcc	√
`OPENMP`	compile the paraller version	0: NO 1: YES	×
`OPTIMISE`	optimisation level	3	?
`PROFILE`	sets the -p -pg flag for time profiling	0: NO 1: YES	?
`MAIN_DIR`	directory of the main code	$(PWD)/main	√
`GRIDDIR`	directory of the grid making code	$(PWD)/grid.spherical	√
`OPACITY_DIR`	directory of opacity	$(PWD)/opacity.0H5_0.1_200	√
`ISRFD_IR`	directory of the ambient radiation field		√
`EXEC_DIR`	directory to put executable and required files	$(PWD)/exec	√
Grid			
`SPHERICAL`	sets a spherically symmetric grid and adjusts code for better performance (note: other options maybe disabled when this flag is on)	0: NO 1: YES	√
`DIM`	refers to the 'dimensions' of the physical system 3: fully 3D system, 2: azimuthal and θ, -θ symmetry (e.g. flattened cloud, disc), 4: azimuthal symmetry	3, 2, 4	√
SEDs & Intensity maps			
`NFBINS`	number of frequency bins to put escaping photons	120	√
`FS`	number of wavelenghts to calculate intensity maps	1-10	√
`NLBINS`	number of polar angles (theta) to calculate intensity maps	1-10	√
`NMBINS`	number of azimuthal angles (phi) to calculate intensity maps	1-10	√
`DO_ISOMAP`	calculate SEDs and isophotal maps?	0: NO 1: YES	√
`NBBINS`	number of radial bins to calculate intensity (only for SPHERICAL case)	80	√
`NXPIXELS`	number of xpixels for intensity maps	128	√
`NYPIXELS`	number of ypixels for intensity maps	128	√
`ISODIM`	refers to the 'dimensions' of the appearence of the system (i.e. SEDs and intensity maps). The physical system maybe 3D but may look the same from different directions when viewed e.g. in long wavelengths. 3: fully 3D system, 2: azimuthal and θ, -θ symmetry (e.g. flattened cloud, disc), 4: azimuthal symmetry	3, 2, 4	√
`EXTRA_SYMMETRY`			×
`SPHERICAL_ISOMAP`	calculates intensity maps assuming that the system is spherically symmetric (it just makes radial bins and computes averages)	0, 1	?
`SPHERICAL_SED`	calculates SEDs assuming that the system looks the same from all viewing angles (counting all available photons)	0, 1	√
Other options			
`NO_INTERACTION`	photons escape without any interactions (for testing)	0: NO 1: YES	√
`MULTIPLE_PHOTONS`			×
`TREE_INFO_OUT`			×
`INFO_OUTPUT`	output info as photon propagates (for testing)		√
`NO_OPA_TABLE`	there is an opacity equation not a table		×
`DUST_MIX`	use 2 types of dust		×
`INC_SHADOW_PHOTONS`			×
`LENGTH_UNIT`	length unit for inputing in params.dat and params.grid.dat	PC or AU	√
`SPH_SIMULATION`	RT in SPH snapshots		×

params.dat (I)			
Variable name	Description	Value(s)	S
Control options			
OUTPUT_FACTOR	how often to output data (in units of total photon number)	0.1	√
RESTART	is the run a restart?	0: NO 1:YES	√
MORE	is the run adding another luminosity source to existing run?	0: NO 1:YES	√

params.dat (II)			
Variable name	Description	Value(s)	S
Ambient radiation field			
ISRF	is there an ambient radiation field	0: NO 1:YES	√
ISRF_NPACKETS	number of ambient radiation field photon packets to use	10^8	√
R_ISRF==R_MAX	are ambient photons injected from cloud radius	0: NO 1:YES	√
R_ISRF	radius from which ambient photons are injected from (if above is 0) (pc or AU)	0.3	√
ISRF_MULTIPLY	value you multiply ambient radiation field (to weaken or strengthen)	1	√
ISRF_IGNORE_SCATTER	ignore ISRF scattering photons when making SED	1	√
STAR_ISRF_TEMP	temperature of the star-like (blackbody) ambient field	20	?
DILUTION	STAR_ISRF :: value you multiply star-like ambient radiation field	1	?
Stellar radiation field			
MANUAL_STAR	include an extra star in the simulation?	0: NO, 1: YES	√
MANUAL_STAR_TYPE	type of star included (star.type)	0: star in the centre of coordinates 3: star outside cloud	√
STAR_NPACKETS	number of stellar photons to use	10^7	√
STAR_RADIUS	star radius (in solar radii)	1-3	√
STAR_X	star x-location (pc or AU)	0	√
STAR_Y	star y-location (pc or AU)	0	√
STAR_Z	star z-location (pc or AU)	20000 AU	√
STAR_MASS	star mass (in solar masses)	0	√
STAR_TEMP	star temperature (K)	6000	√

params.dat (III)			
Variable name	Description	Value(s)	S
SED & Intensity maps parameters			
`DISTANCE`	distance of the object (from Earth, in pc)	2000	$\surd$
`DTHETA`	tolerance angle from observer's line-of-sight to count photons $[0, 1]$ (in units of π)	0.05	$\surd$
`SL1`	lower λ (in μm) of placing escaping photons in λ-bins	0.005	$\surd$
`SL2`	upper λ	4000	$\surd$
`F0`	$1^{\text{st}}\lambda$ to calculate intensity map	10	$\surd$
`F1`	$2^{\text{nd}}\lambda$	850	$\surd$
`F2`	$3^{\text{rd}}\lambda$		$\surd$
`F3`	$4^{\text{th}}\lambda$		$\surd$
`F4`	$5^{\text{th}}\lambda$		$\surd$
`F5`	$6^{\text{th}}\lambda$		$\surd$
`F6`	$7^{\text{th}}\lambda$		$\surd$
`F7`	$8^{\text{th}}\lambda$		$\surd$
`F8`	$9^{\text{th}}\lambda$		$\surd$
`F9`	$10^{\text{th}}\lambda$		$\surd$
`XMIN`	minimum x coordinate of intensity map (in pc or AU)		$\surd$
`XMAX`	maximum x		$\surd$
`YMIN`	minimum y		$\surd$
`YMAX`	maximum y		$\surd$
`THETA0`	$1^{\text{st}}\theta$ of observer to calculate intensity map		$\surd$
`THETA1`	$2^{\text{nd}}\theta$		$\surd$
`THETA2`	$3^{\text{rd}}\theta$		$\surd$
`THETA3`	$4^{\text{th}}\theta$		$\surd$
`THETA4`	$5^{\text{th}}\theta$		$\surd$
`THETA5`	$6^{\text{th}}\theta$		$\surd$
`THETA6`	$7^{\text{th}}\theta$		$\surd$
`THETA7`	$8^{\text{th}}\theta$		$\surd$
`THETA8`	$8^{\text{th}}\theta$		$\surd$
`THETA9`	$10^{\text{th}}\theta$		$\surd$
`PHI0`	$1^{\text{st}}\phi$ of observer to calculate intensity map		$\surd$
`PHI1`	$2^{\text{nd}}\phi$		$\surd$
`PHI2`	$3^{\text{rd}}\phi$		$\surd$
`PHI3`	$4^{\text{th}}\phi$		$\surd$
`PHI4`	$5^{\text{th}}\phi$		$\surd$
`PHI5`	$6^{\text{th}}\phi$		$\surd$
`PHI6`	$7^{\text{th}}\phi$		$\surd$
`PHI7`	$8^{\text{th}}\phi$		$\surd$
`PHI8`	$9^{\text{th}}\phi$		$\surd$
`PHI9`	$10^{\text{th}}\phi$		$\surd$

params.dat (IV)			
Variable name	Description	Value(s)	S
Dust parameters			
DUST_TEMP	Dust destruction temperature (in K)	1200	
SCATTER_MULTIPLY	multiply scattering opacity ($k_s cat$) by this factor	1.0	
G_SCATTER		0.5	
Propagate photons			
STEP_MFP			
STEP_DENS			
STEP_R			
STEP_CELL			
INNER_STEP_SIZE			

`grid.1`

Prestellar/protostellar cores (3 types of geometries: spherical, flattened, comet-like, with/without disc around the protostar), with/withouth jets. Discs can work independently (by setting `ENVELOPE` to 0).

grid :: params.grid.dat			
Variable name	Description	Value(s)	S
	Cloud/Core parameters		
`CDENS0`	central density (in cm^{-3})	10^5	√
`R0`	flattening radius (in AU or PC, as set in `Makefile`)	0.3	√
`R_MAX_CORE`	size of core (in AU or PC)	0.5	√
`R_MAX`	size of core and ambient cloud (sets auto to 0 if MC-CELLS=0) (in AU or PC)	0.7	√
`R_ORIGIN`	radius within which photons are counted with id=2	0.5	√
`DENS_EXT_FACTOR`	ratio of cloud density to the core density at `R_MAX_CORE`	0.8	√
`R_DUST`	size of the innermost cell (in units of `R_MAX_CORE`)	0.01	√
`MU`	mean mocular weight	2.3	√
`BECELLS`	number of radial cells-1 to divide the core (≥ 2)	102	√
`MCCELLS`	number of radial cells to divide the ambient cloud (≥ 0)	10	√
`NLCELLS`	number of polar cells-1 to divide the cloud (≥ 2)	10	?
`NMCELLS`	number of azimuthal cells-1 to divide the cloud (≥ 2)	10	√
`LINEAR`	radial cells have 1: equal widths 0: equal log widths	0 or 1	√
`ISOANGLES`	polar cells have 1: equal angles 2: equal cosines	0 or 1	√
`FTAU_POINTS`	number of points to use to calculate τ_{visual} for the cloud & core	1000	√
`GEOMETRY`	1: spherical cloud, 2 : flattened cloud, 3: comet-like cloud	1, 2, 3	√
`SIN_POWER`	Sine exponent (p) in the density profile	1, 2, 4	√
`ASYMMETRY_FACTOR`	Relates to A and sets how pronounces the asymmetry is	>= 1 & < 3	√
	Disc around central star parameters		
`DISC`	is there a disc around the central source?	0: No, 1: Yes	√
`DISC_CDENS0`	Disc density at 1AU from the central source (cm^{-3})		√
`DISC_THETA_OPENING`	Up to what angle (in units of `DISC_ALPHA`, from the mid-plane) the disc extends	2 – 5	√
`DISC_R`	Size of disc (in AU)	5 – 100 AU	√
`DISC_ALPHA`	thickness-to-radius ratio (z/R) of the disc		√
`DISC_AMBIENT_DENS`	the density at angles (theta) outside `DISC_THETA_OPENING*DISC_ALPHA`		?
`DISC_INNER_GAP`	Size of the gap around the central source in AU (this is always >= the dust destruction radius)	0.1 – 2 AU	√
`DISC_INNER_GAP==R_DUST`	Set the inner disc gap the same as R_DUST?		√
	Jet from central star parameters		
`JET`	Is there a jet from the central star?	0: No, 1: Yes	√
`JET_DENS`	Density in the the jet cavity(cm^{-3})	10^3	√
`JET_BETA`		3	√
`JET_THETA`	(in unit of π)	0.027	√

SPHERICAL CLOUD

$$n = n_0 \, \frac{1}{1 + (r/R_0)^2} \tag{1}$$

n_0: CDENS0
R_0: R0

FLATTENED CLOUD

$$n(r,\theta) = n_0 \frac{1 + A\left(\frac{r}{R_0}\right)^2 [\sin(\theta)]^p}{\left[1 + \left(\frac{r}{R_0}\right)^2\right]^2} \; . \tag{2}$$

n_c is the the density at the centre of the core, and r_0 the scale length. A is a factor that determines the equatorial-to-polar optical depth ratio e (i.e. the optical depth from the centre to the surface of the core at $\theta = 90$ divided by the optical depth from the centre to the surface of the core at $\theta = 0$) , see page 84 of my thesis.

p: SIN_POWER
E: relates to A