Sunrise:

Panchromatic SED Models of Simulated Galaxies

Lecture 2:

Working with Sunrise

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Lecture outline

- Lecture 1: Why Sunrise? What does it do? Example science. How to use the outputs? Projects?
- Lecture 2: Sunrise work flow. Parameters, convergence, other subtleties.
- Lecture 3: Radiation transfer theory. Monte Carlo. Polychromatic MC.
- Lecture 4: Dust emission, dust self-absorption. Sunrise on GPUs.

Working with Sunrise

Episode 1: Building

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A long process...

- This is explained in detail on "Compiling" page on the Sunrise Wiki:
- Sunrise is written in C++, with several dependencies
  - Blitz++ (matrix library)
  - CCfits (C++ I/O library)
  - cfitsio (C I/O library)
  - Boost (generally useful C++ stuff)
  - HDF5 (optional)
  - CUDA (if you have a GPU)
- Works with gcc or Intel icpc

A long process...

- Won't go through the whole thing, but:
- Unless you are very experienced in compiling C++ programs, expect to have to fiddle a bit. Every system's a bit different.
- If you really can't figure it out, post to the Sunrise discussion group.

Working with Sunrise

Episode 2: Workflow

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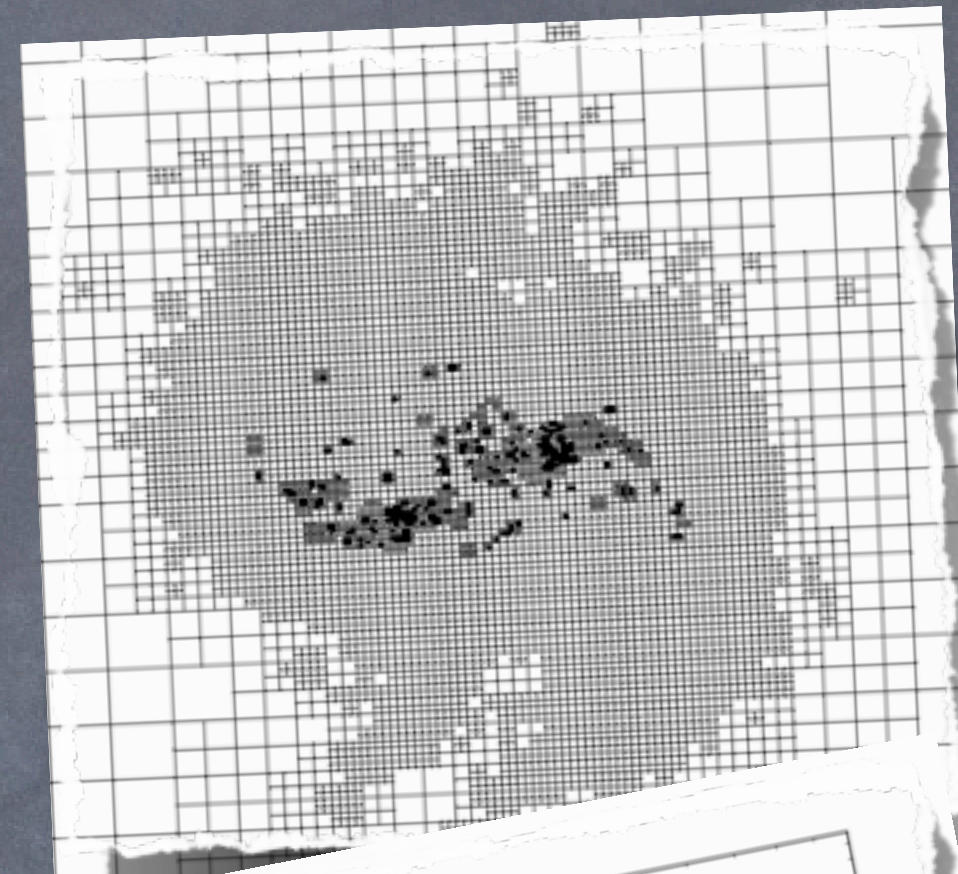
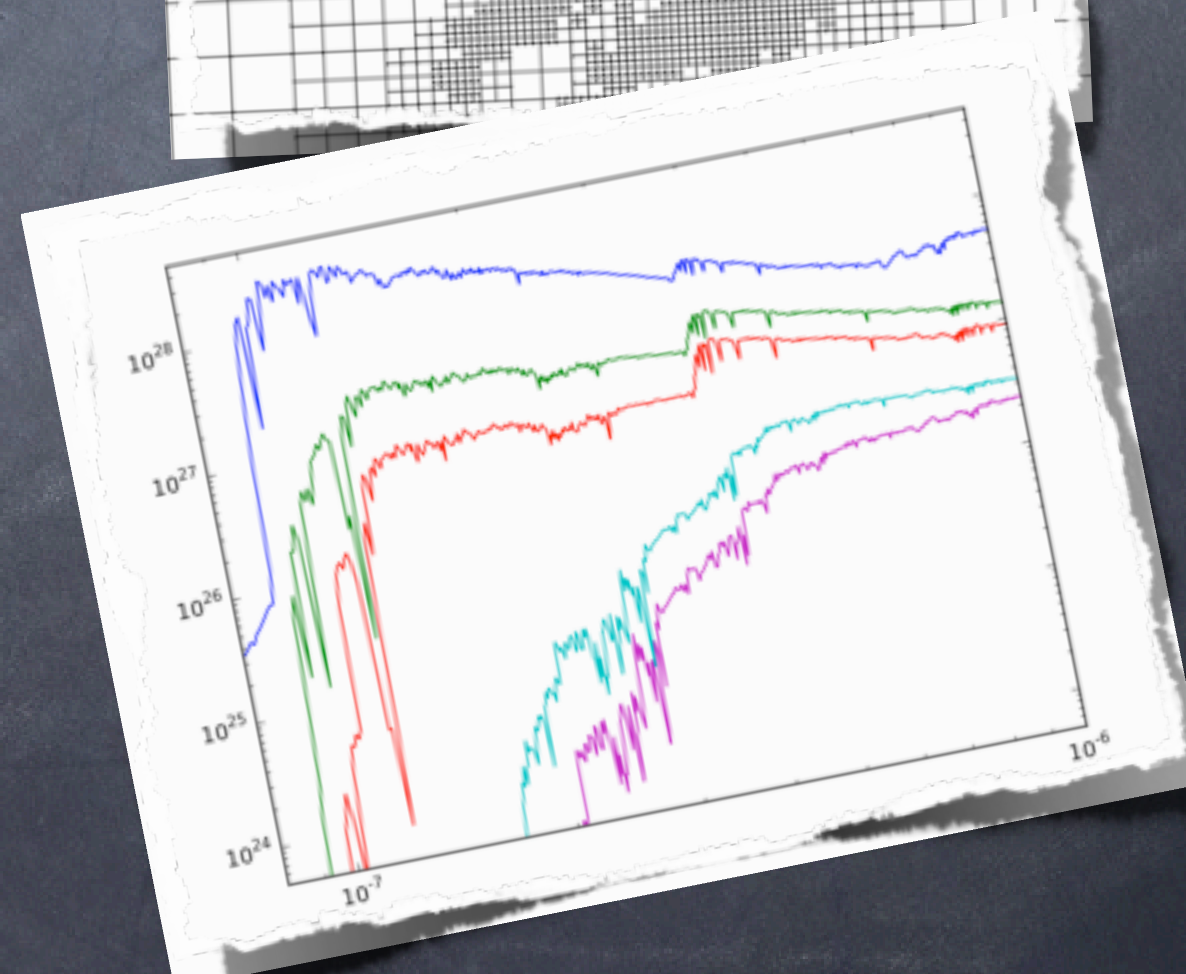
Workflow

- This is explained in detail on "Sunrise Overview" page on the Sunrise Wiki
- Processing a hydro snapshot with Sunrise involves running 3 executables
  - **sfrhist** - calculation of source SEDs and adaptive-mesh grid
  - **mcrx** - the actual radiation transfer calculation
  - **broadband** - integration of outputs over filter bands to get magnitudes and images

First: sfrhist

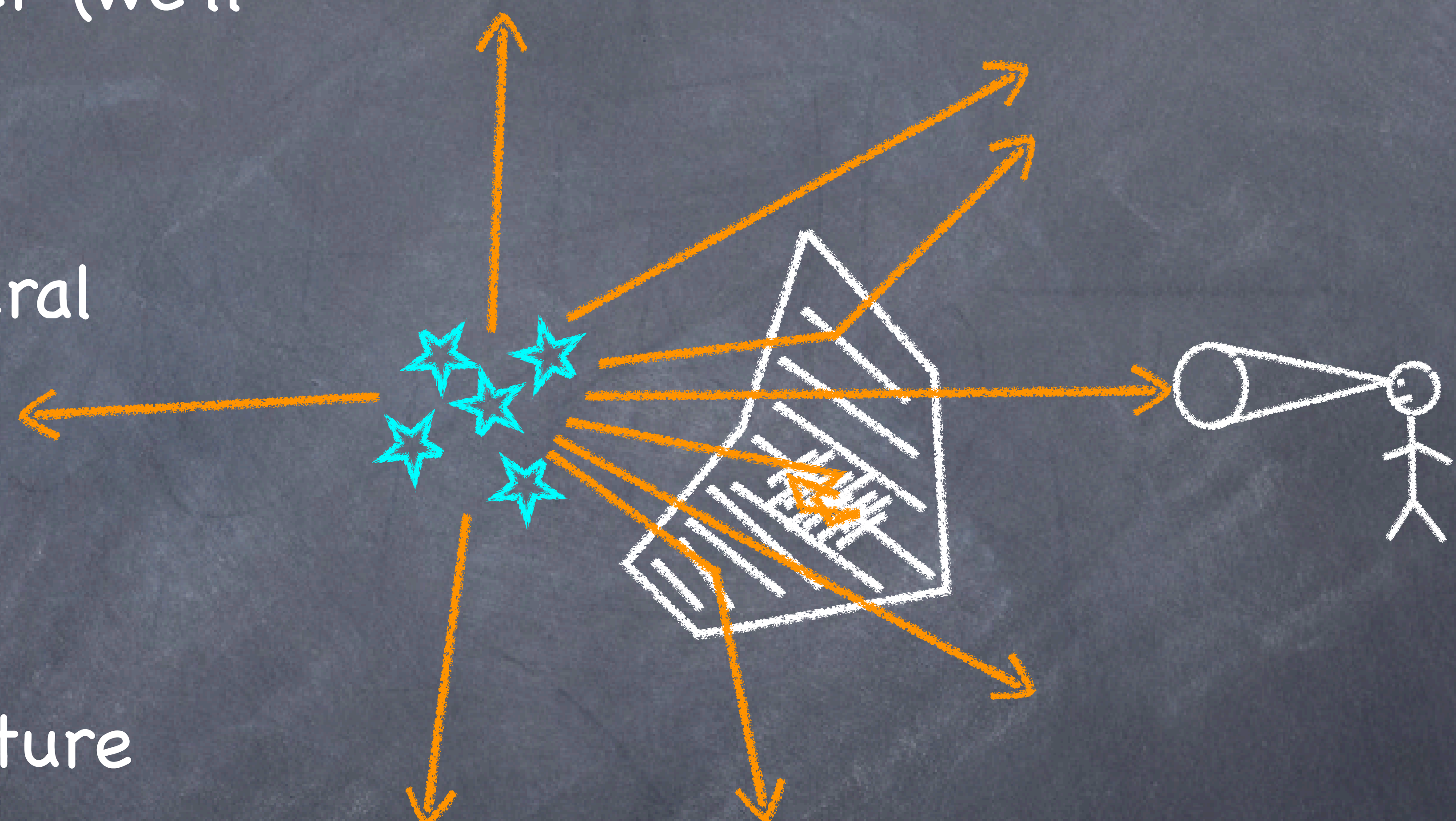


- Loads the snapshot data
- Constructs the adaptive mesh grid for the dust distribution
- Calculates the SEDs of the stellar particles, based on age and metallicity
- Calculates AGN SED (if applicable)



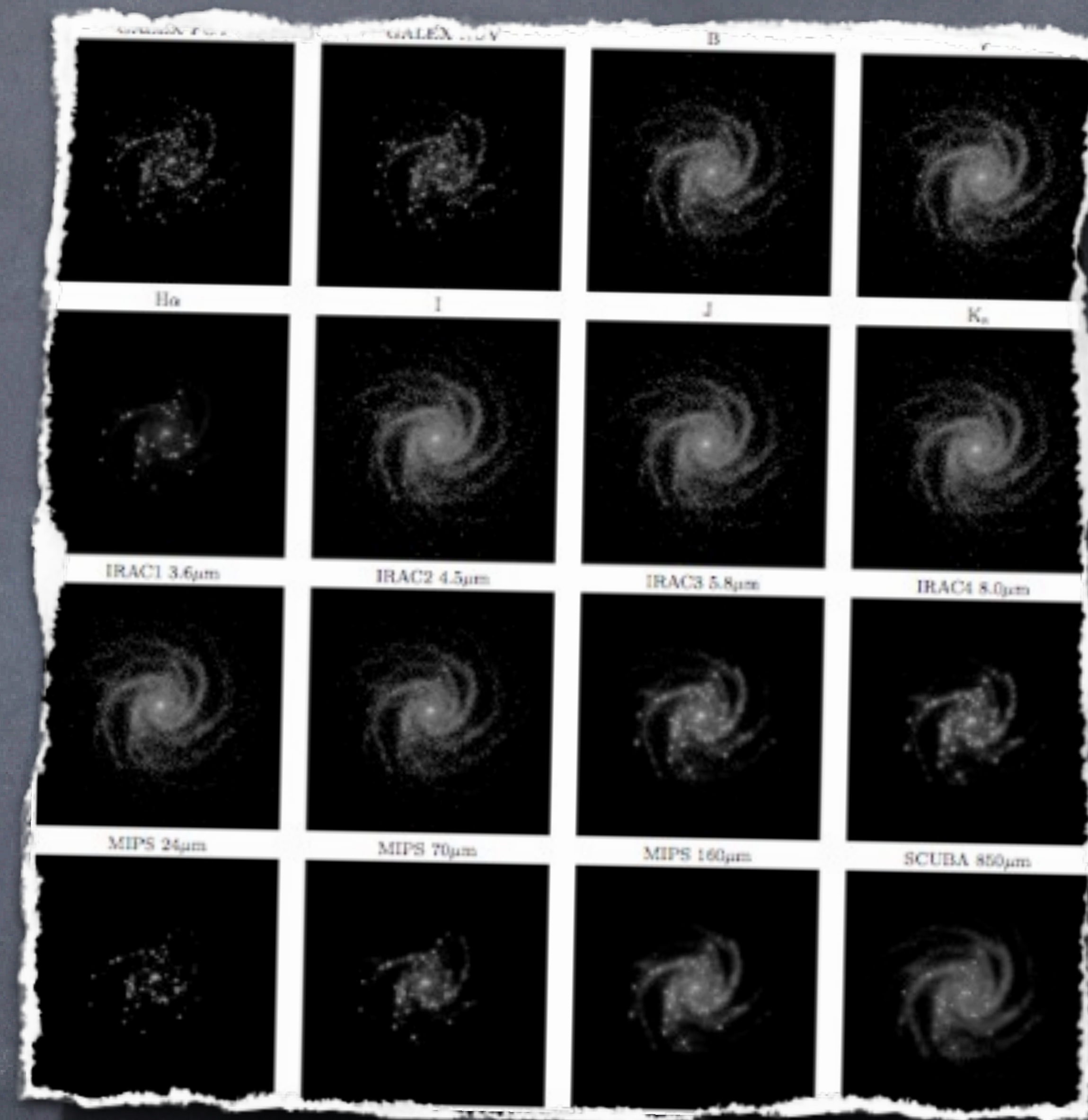
Second: mcrx

- Does the Monte Carlo radiation transfer (we'll talk about this tomorrow)
- Proceeds in several stages:
  - without dust
  - with dust
  - dust temperature
  - dust emission
- We looked at the output files yesterday



Third: broadband

- Creates images and magnitudes in specific filter bands
- Can do redshift effects:
  - k-correction
  - surface-brightness dimming



Working with Sunrise

Episode 3: Configuration

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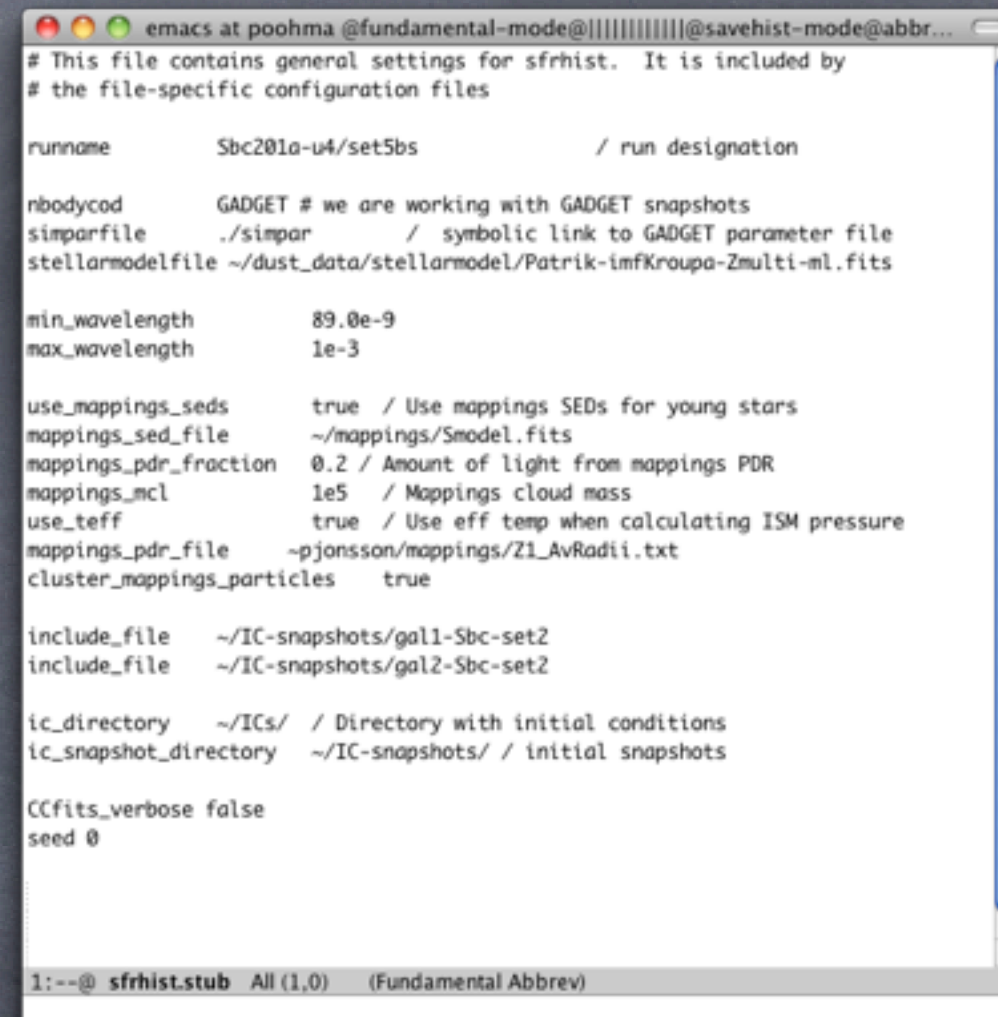
Configuration files



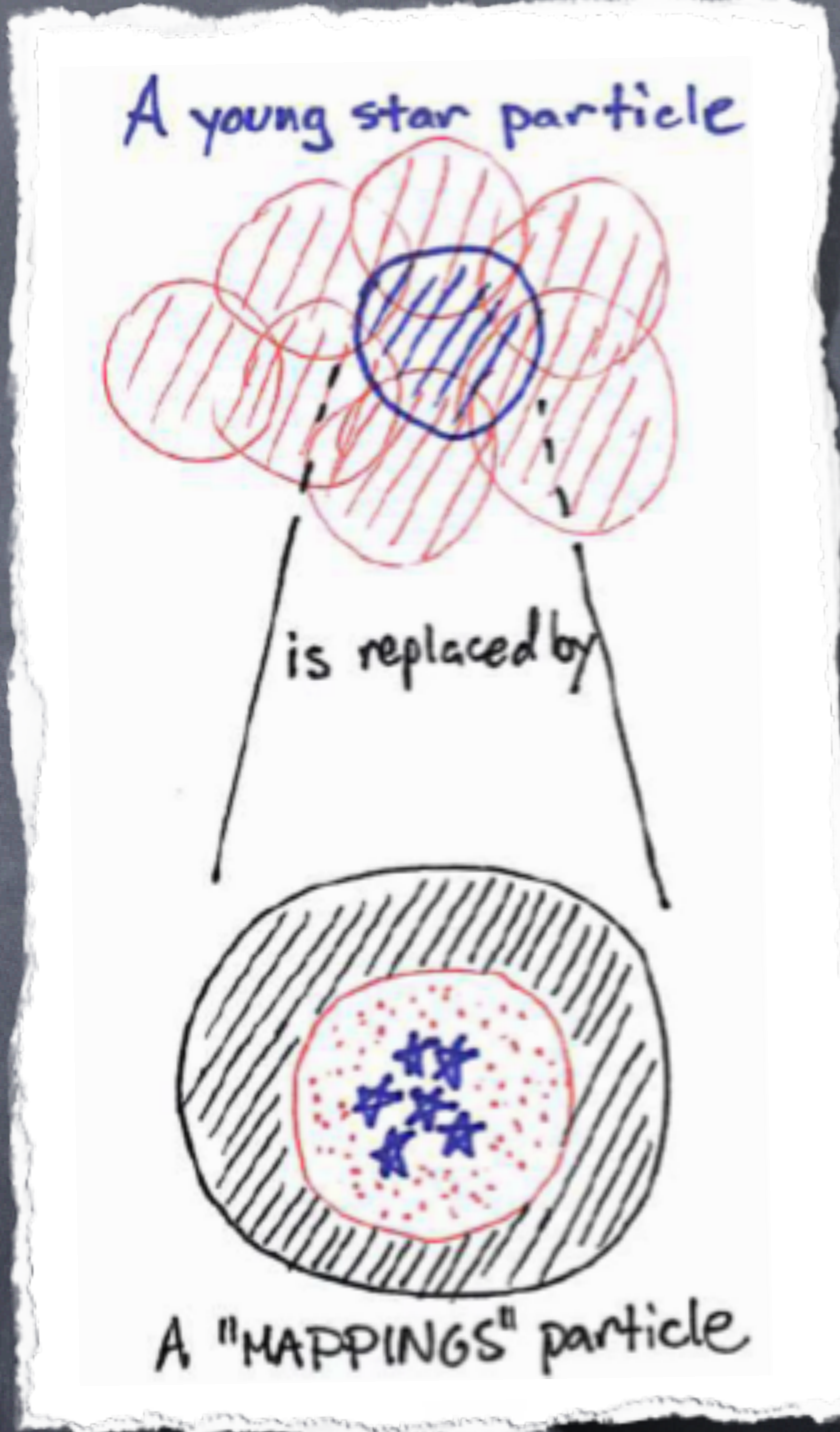
- Each of the executables take a **configuration file** as the argument
- keyword-value pairs

sfrhist configuration

- The sfrhist options are explained in detail in "Sfrhist Config and Output Format" on the Wiki.
- sfrhist configuration comprises 4 main sets:
  - stellar population model (e.g. Starburst99)
  - MAPPINGS parameters
  - grid creation parameters
  - galaxy initial conditions (if simulation starts with galaxies)

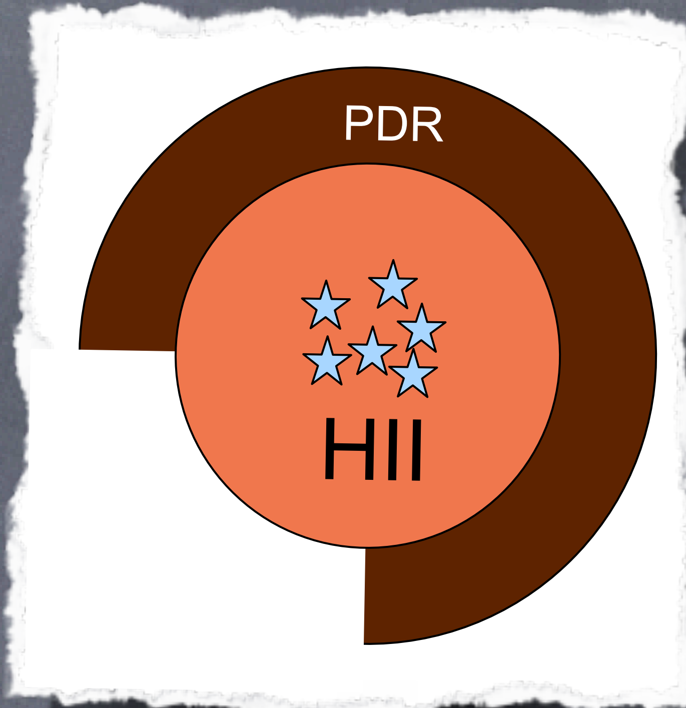
MAPPINGS models

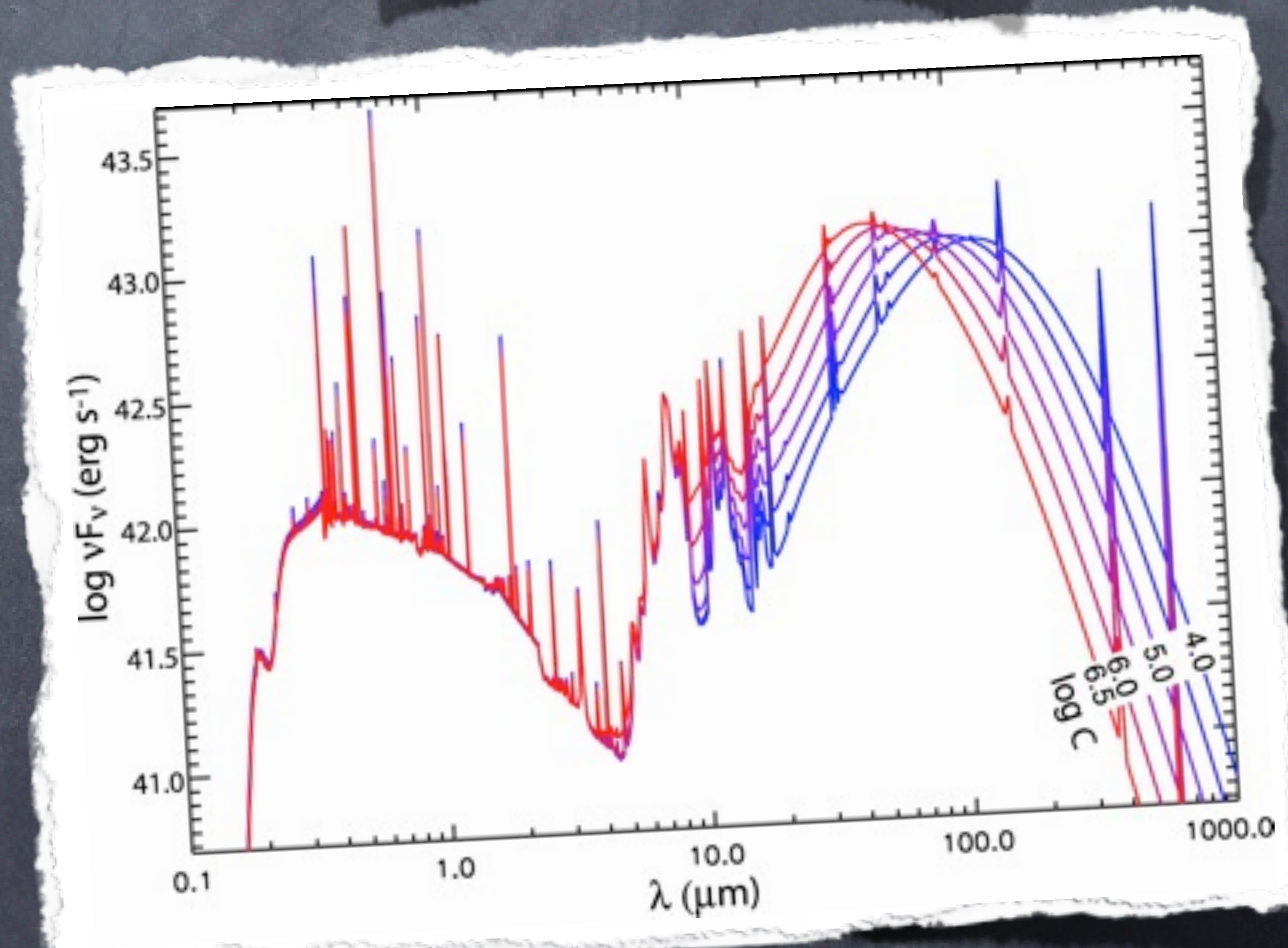
- Star-forming regions are a problem:
  - Young stars are enshrouded in dust
  - HII regions and molecular clouds are (normally) not resolved
  - Want to predict line strengths
- Solution: Use a separate "sub-particle" model of HII regions/MCs



MAPPINGS models

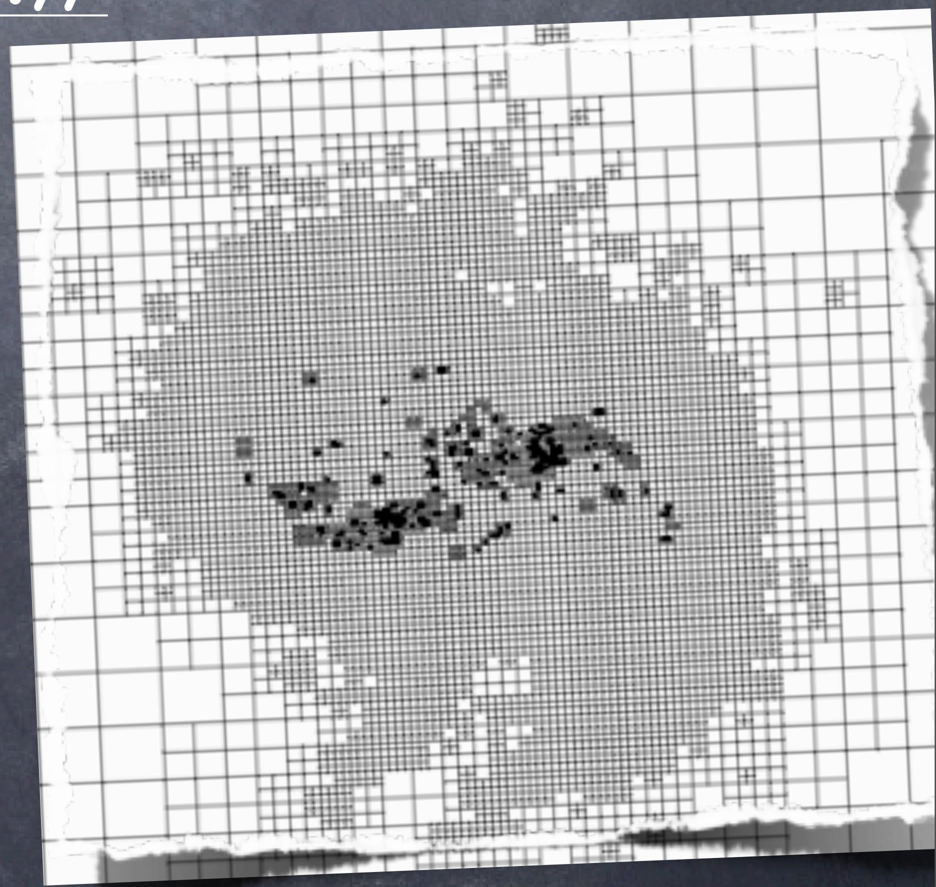
- MAPPINGS models are parametrized by:
  - Z (from hydro)
  - ISM pressure (from sim)
  - PDR covering frac
  - Cluster mass
- 2 config parameters
- Each particle <10Myr old gets its own model
- Groves et al. (2008)





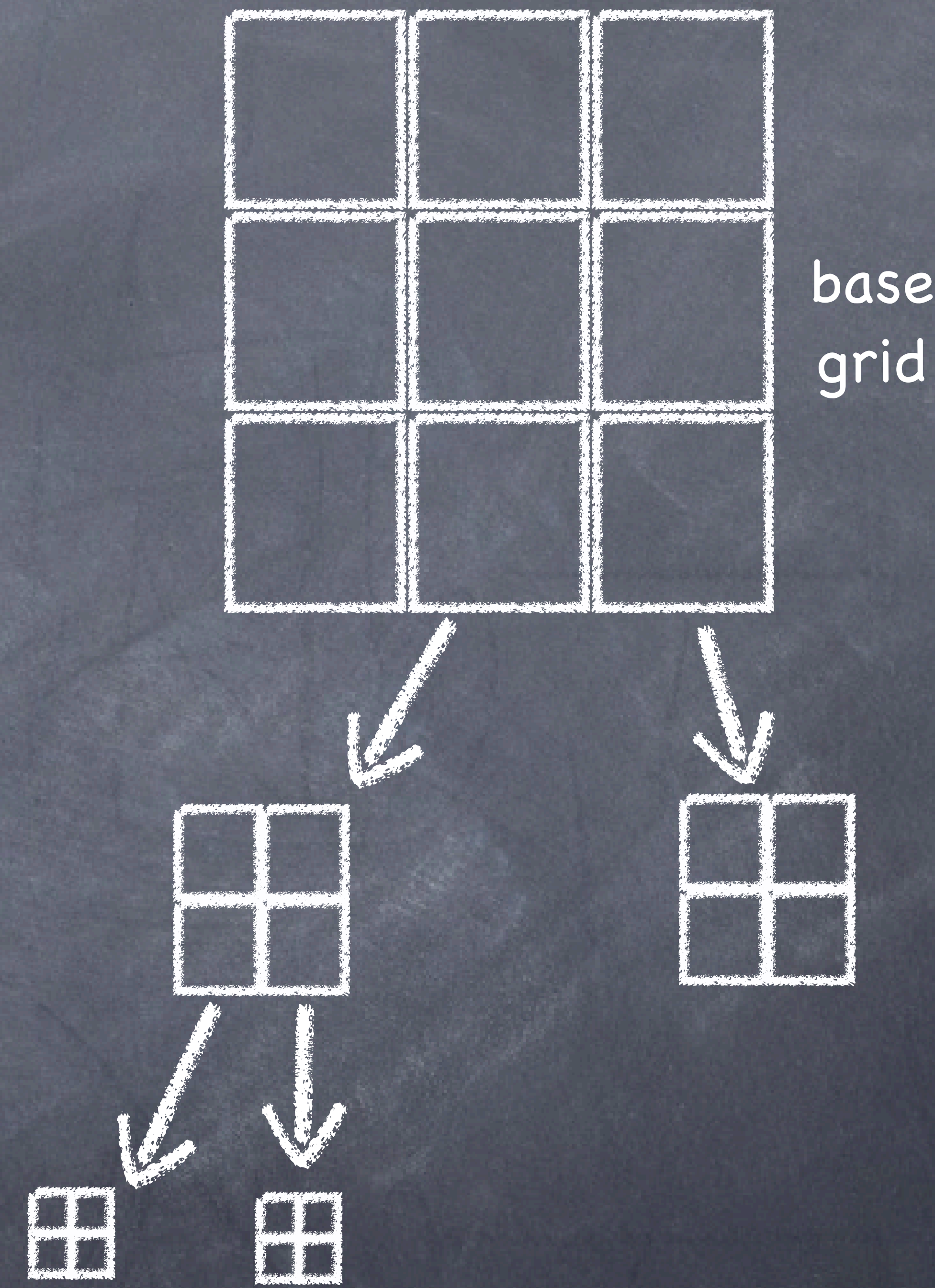
Grid creation parameters

- Sunrise uses a recursively refined grid structure ("octree")
- Algorithm described in Sunrise papers
- There is NO local way to determine refinement - depends on unknown radiation field
- Parameters explained on Wiki: http://code.google.com/p/sunrise/wiki/SfrhistConfigAndOutputFileFormat
- Sufficient grid resolution is very important for converged results!
- Read the "ConvergenceTests" page on the Wiki!



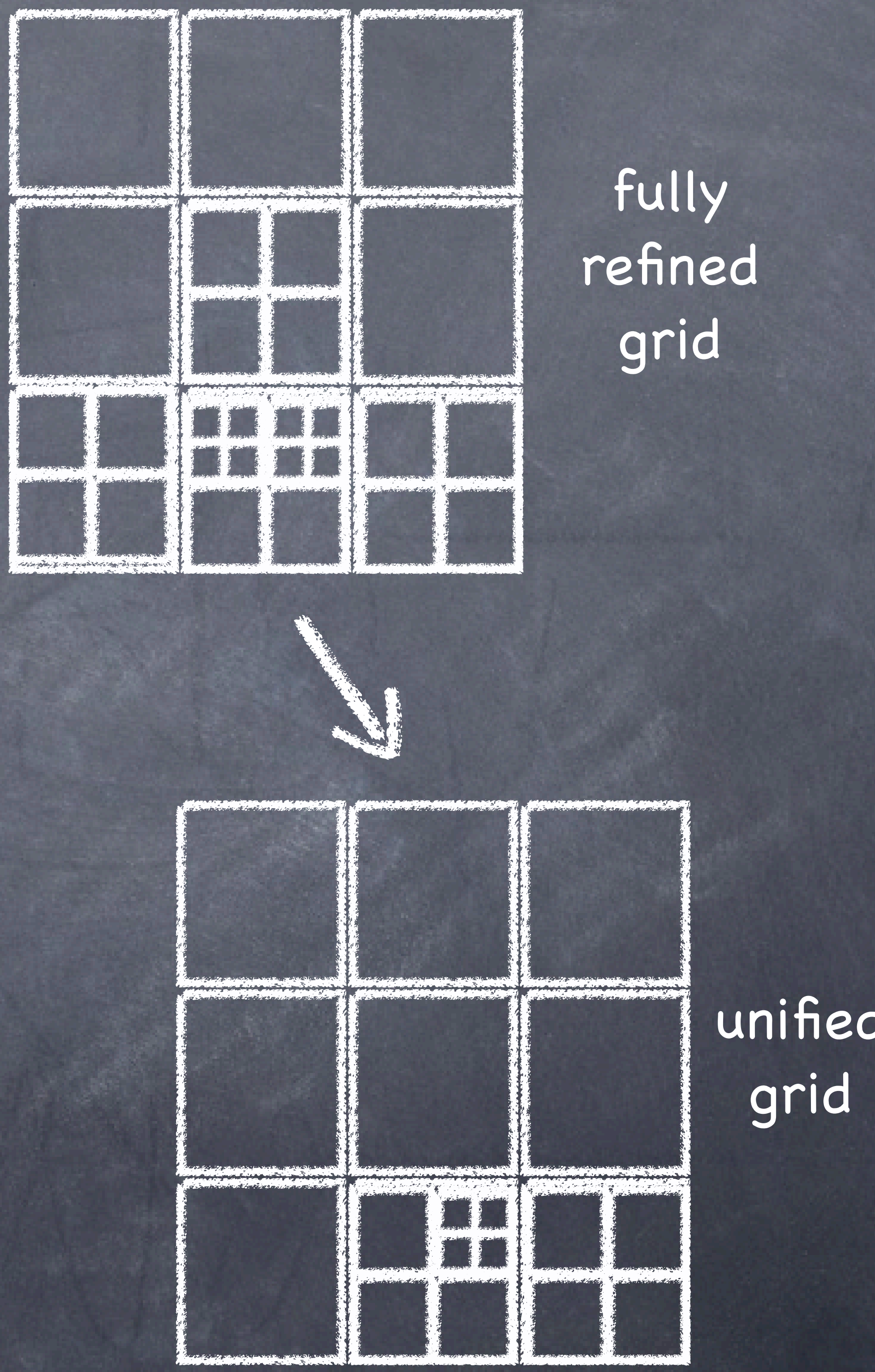
Grid creation step 1

- First, subdivide cells until:
  - cells are no larger than the particles
  - optical depth through cells are below specified value: **tau_tolerance**, or
  - **max_level** is reached
- This ensures all structure has been captured



Grid creation step 2

- Second, re-unify cells if:
  - they are sufficiently uniform (**metal_tolerance**), or
  - they are sufficiently low density they won't affect the result (**n_rays_estimated**), and
  - optical depth through unified cell still would be below **tau_tolerance**
- This minimizes the number of cells necessary



Initial conditions parameters

- Only applies if your simulation starts with pre-existing galaxies (and not for Gasoline)
- Need to specify SF history and metallicity distribution for these galaxies
  - **ic_file<i>** - a snapshot of the isolated progenitor galaxy
  - **(disk|bulge)popmode<i>** - the SF history (constant, exponential, or instantaneous)
  - **central_metallicity<i>**
  - **metallicity_gradient<i>**
- see special requirements for the snapshots

mcrx configuration

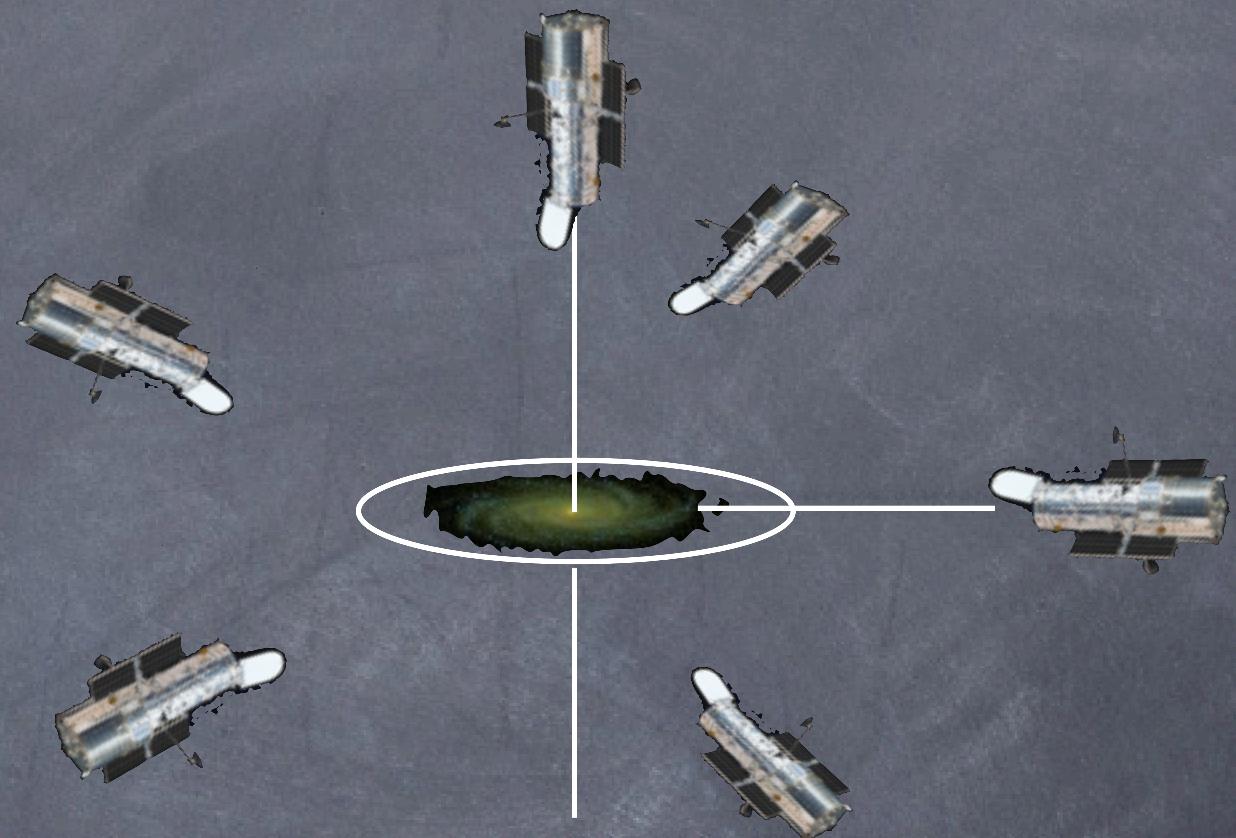
- Described in detail on the Wiki at "mcrx config and output file format"
- Many settings, quite complicated
  - camera setup parameters
  - dust model/dust emission parameters
  - monte carlo/radiation transfer parameters
  - runtime stuff

mcrx stages

- The calculation proceeds in several stages
  - Make images of stellar emission w/o dust
  - Make images of stellar emission w dust
  - Estimate stellar radiation intensity in cells
  - Calculate dust temperature and dust self-heating (iterative)
  - Make images of dust emission
- Can be restarted at any stage

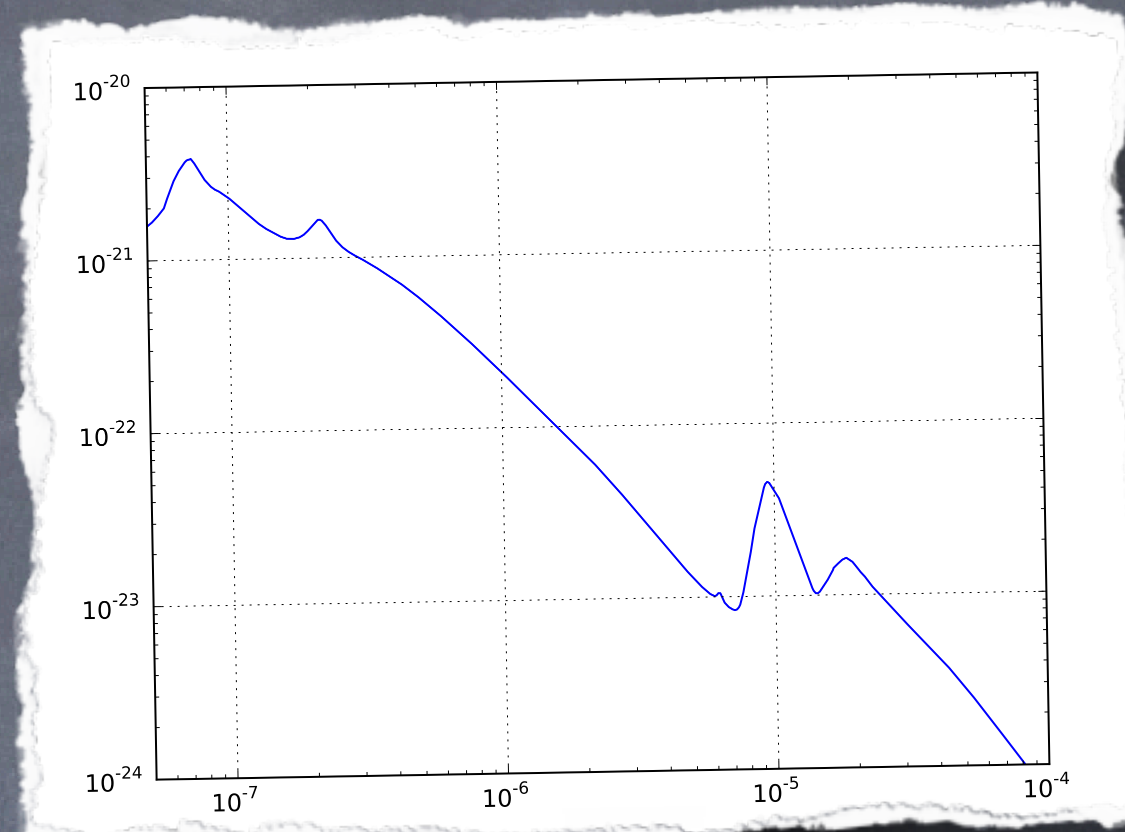
Camera settings

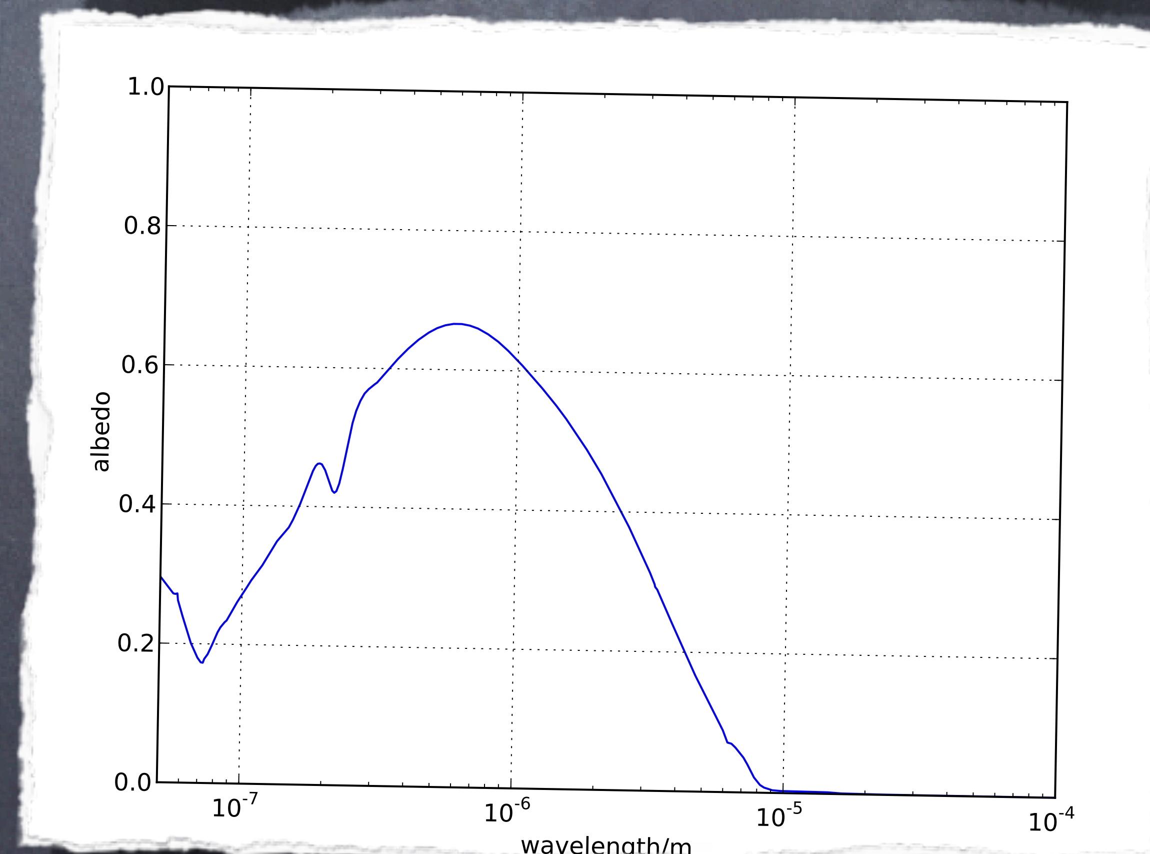
- Cameras register the radiation reaching them from the simulated object
- Can be arranged isotropically or in individually specified positions
- Also defines their distance and resolution



Dust model parameters

- A dust model specifies the dust opacities
- Two options:
  - If you don't care about dust emission, just specify opacity, albedo, scattering asymmetry
  - Otherwise, you need a full model of grain composition and size distribution.

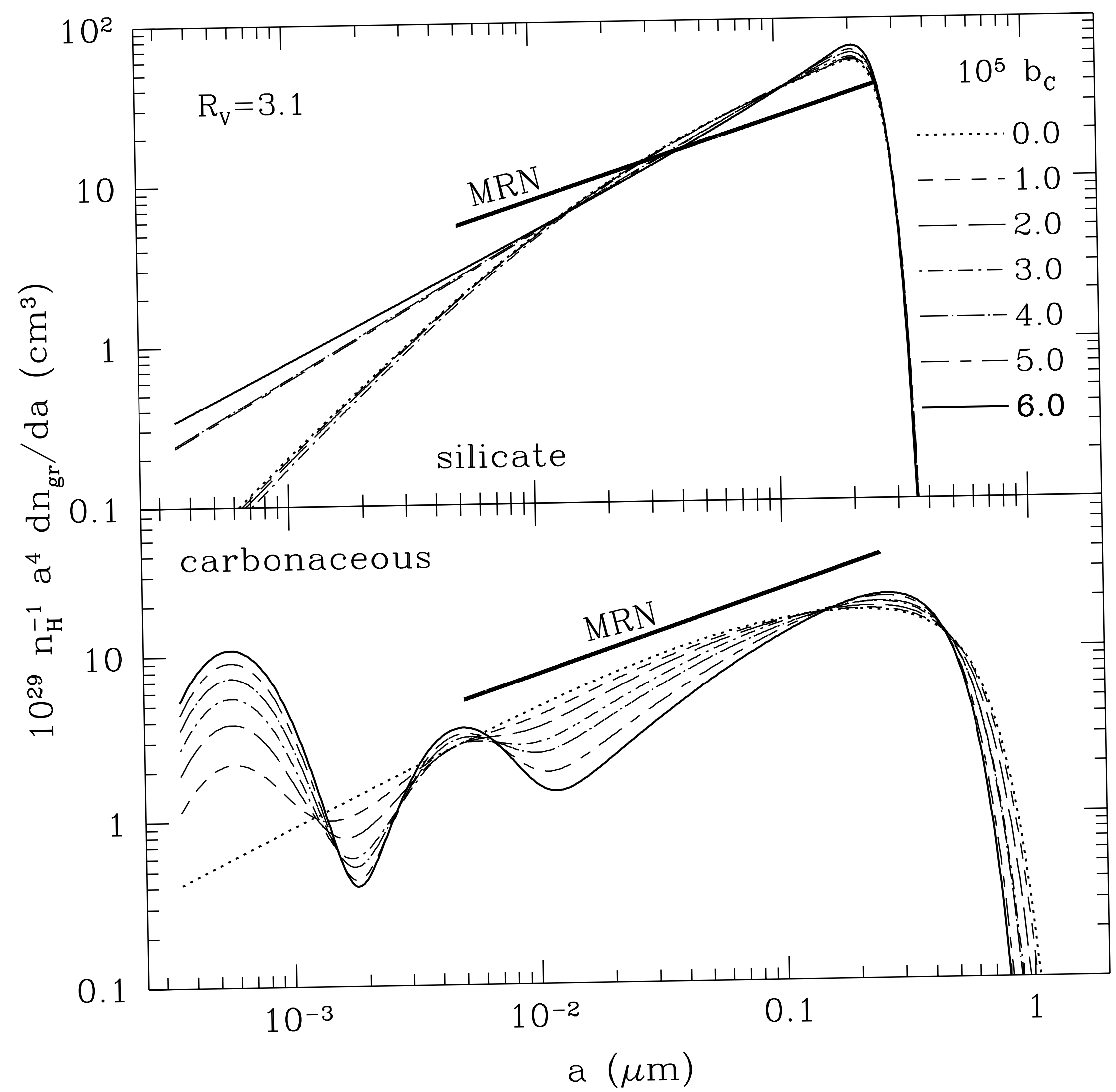




Dust model parameters

- For a physical model, use

  grain_model "wd01_Brent_PAH"
- Picks a model from Weingartner & Draine (2001)
  - specify with **wd01_parameter_set**
  - e.g. "MW3.1_60_DL07"
  - Milky Way, LMC and SMC models exist



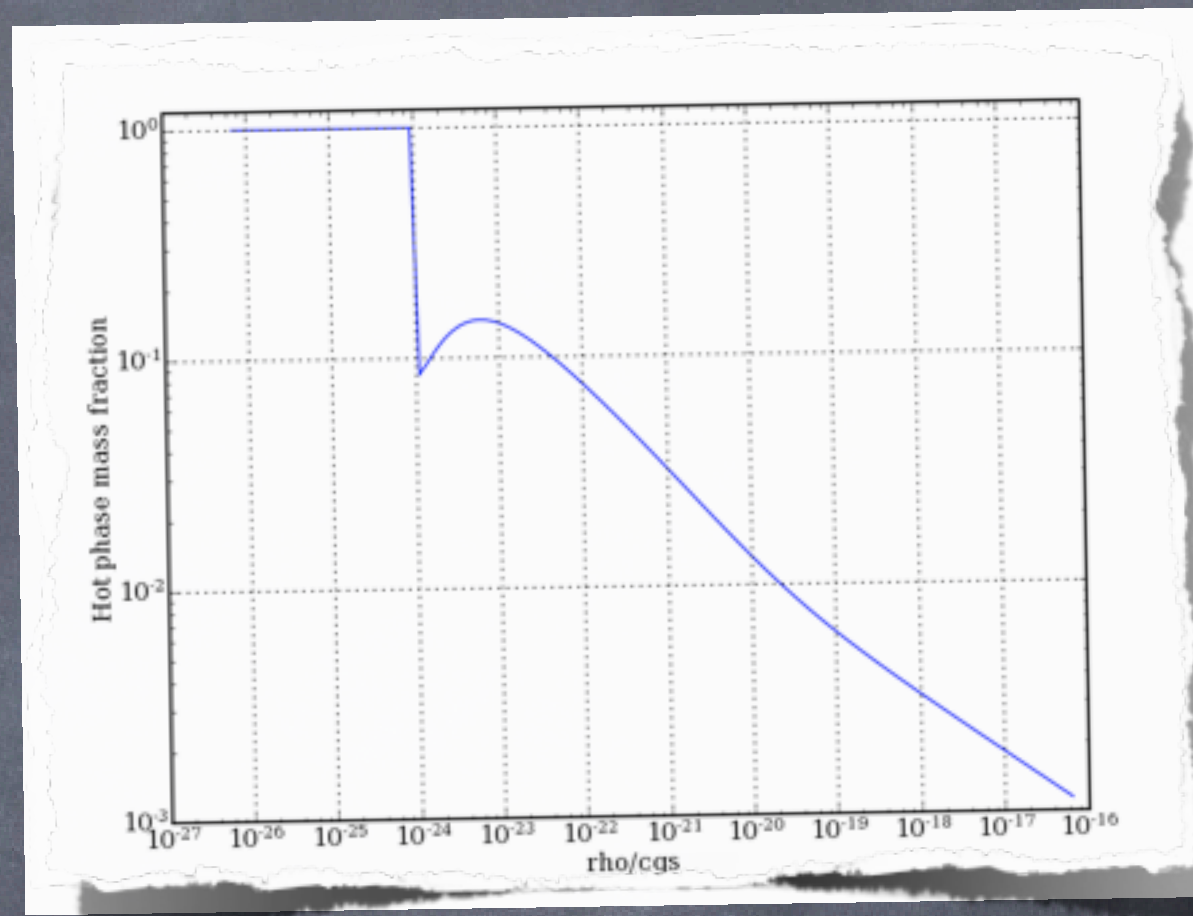
From Weingartner & Draine (2001)

Dust density parameters

- Affects the conversion from density of gas and metals in the Gadget snapshot to density of dust
- **dust_to_metal_ratio** - normally 0.4
- **dust_to_gas_ratio** - normally 0
- Multiphase parameters

Multiphase model

- There's also clumps **without** embedded stars
- These still matter for the dust attenuation
- Can use Springel & Hernquist (03) multi-phase model to estimate mass in diffuse vs. clumps.
- Clumps are assumed to be dense enough to have negligible cross section



This option makes a HUGE difference in gas-rich mergers!

MC/Radiation transfer parameters

- Determines how the actual calculation is performed
  - The number of MC rays used (more rays, less noise, more time)
  - The ray intensity below which it may be dropped or above which it will be split
  - Reference wavelengths for the polychromatic algorithm
  - Number of wavelengths for the dust temperature determination
  - Accuracy with which radiative equilibrium is reached - important

MC/Radiation transfer parameters

- Determines how the actual calculation is performed
- The number of MC rays used (more rays, less noise, more time).
  - Typical values 10^6–10^7.
  - Set separately for dust free, dusty
    - The ray intensity below which it may be dropped or above which it will be split
    - Reference wavelengths for the polychromatic algorithm
    - Number of wavelengths for the dust

Other stuff

- input file (!)
- output file
- the number of threads to use
- random seed
- whether to use a GPU
- self-documenting keywords (just get copied into the output file for your own reference)

broadband parameters

- Simple stuff
- Name of file specifying which filters you want
- Where to find the filter files
- Redshift
- Include Lyman alpha forest absorption?

A note about images

- The image outputs have units of surface brightness
  - W/m/m^2/sr
- Because surface brightness is independent of distance, it's only affected by redshift dimming and k-correction
- If you want the **flux**, you need to know the solid angle subtended by the pixels, and for that you need the angular diameter distance
- Sunrise does not do cosmology – this you need to do yourself

Working with Sunrise

Episode 4: Performance

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Performance

- Unlike (most of) the hydro codes you've heard about, Sunrise doesn't use MPI but pthreads
- One process per job means 1 node <=> 1 job
- Job sizes mostly limited by available memory
  - Want a lot of memory on the node (32GB enough for moderately large runs)
  - Many cores on the node
- Less memory required with fewer wavelengths and by skipping IR emission

Performance

- Runtime is 10 - 100 CPU hours per snapshot
- Depends on spatial & spectral resolution and optical thickness of model
- Can accelerate dust emission calculation with a GPU (see Lecture 4)