Predicting interstellar radiation fields from chemical evolution models

Mario Romero, Pablo Corcho-Caballero, Iker Millán-Irigoyen, Mercedes Mollá, and Yago Ascasibar

Universidad Autónoma de Madrid

XIII Estallidos Workshop

Elements and entities within a galaxy

1. Dark matter
2. Stars
   - Young population
   - Old population
3. Interstellar medium
   - Gas
     - Cold
     - Warm
     - Hot
   - Dust
     - Grains
     - PAH
   - Cosmic rays, magnetic fields, etc

Is something missing?

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A chemical evolution model can track the evolution of stars and the ISM over time to recreate the current distributions of stars, gas and dust.

Is something missing?

Elements and entities within a galaxy

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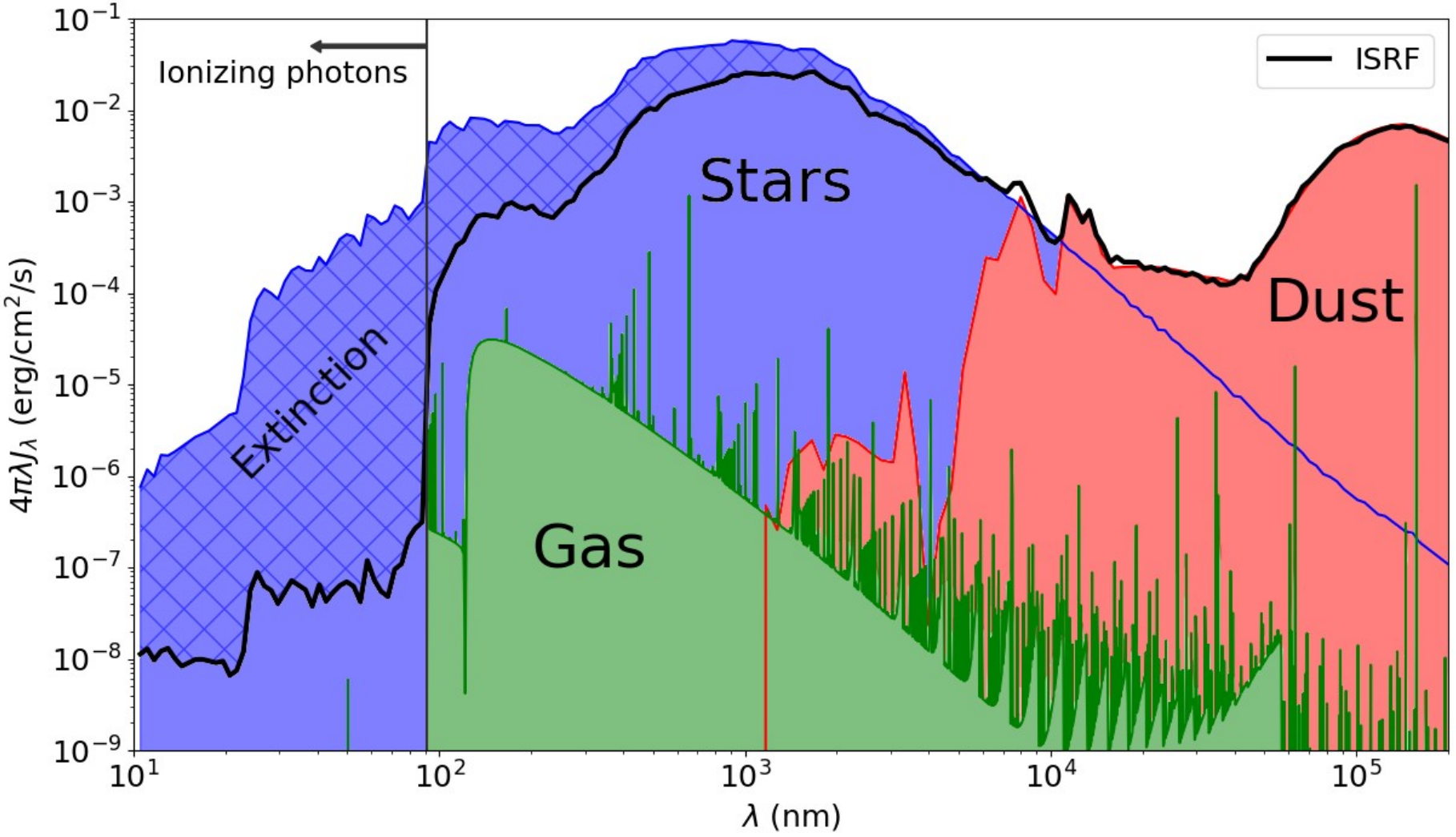
A chemical evolution model

of stars, gas and dust.

What about the interstellar photons generated by stars and dust, and absorbed by the ISM?

Is something missing?

The interstellar radiation field



How do we create an interstellar radiation field from a chemical evolution model?

Mixclask: Mixing **Cl**oudy **a**nd **Sk**irt

Cloudy

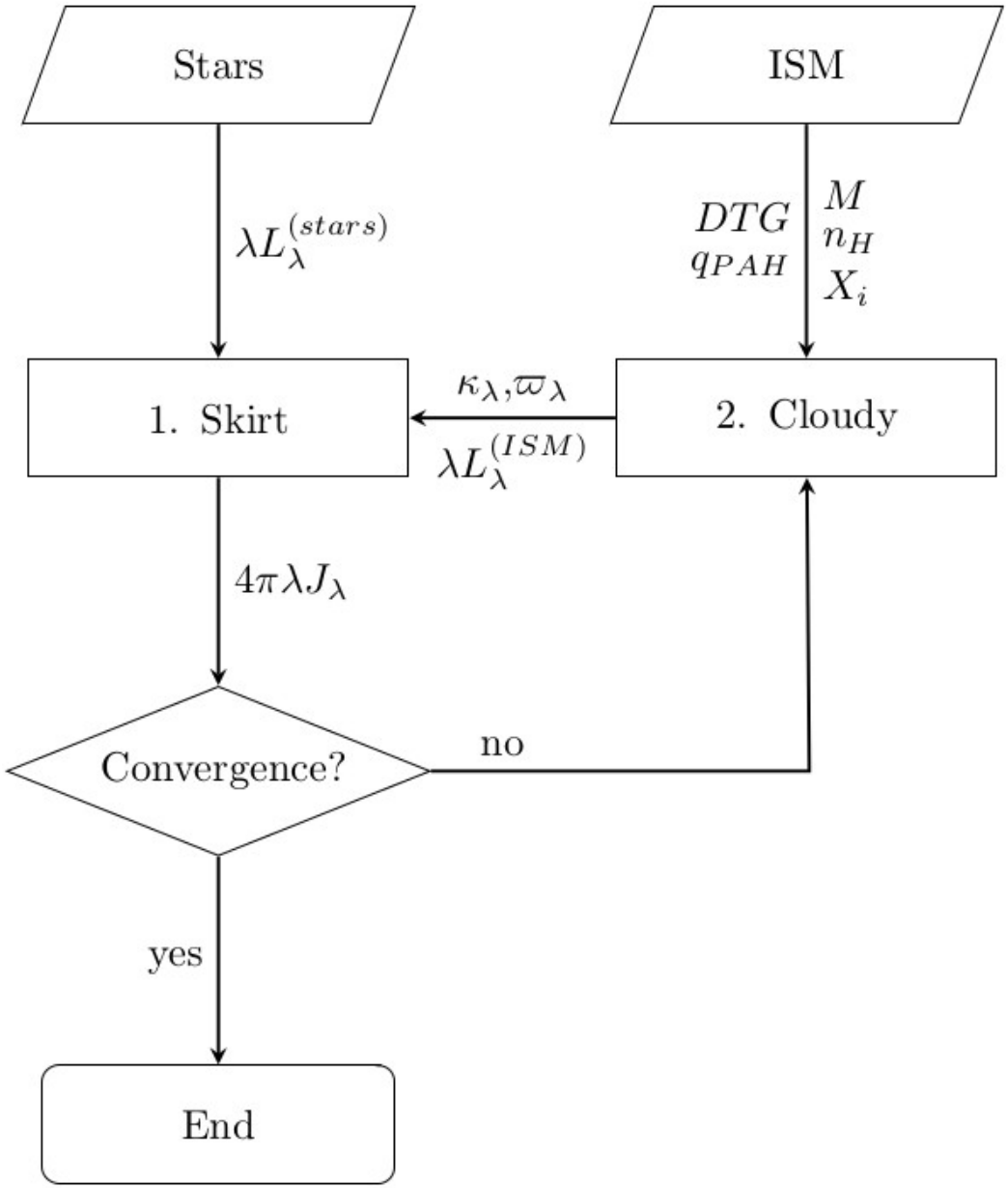
- Focused on the microphysics of the ISM (e.g.: ionization state of chemical elements, line emission, etc).
- Here it is used to compute the emissivity and opacity of the ISM.
- Solves radiative transfer in 1D.

Skirt

- Focused on generating observables from simulations (e.g.: mock galaxies), up to 3D.
- Here it is used to perform radiative transfer in 2D.
- At this moment, gas has not been implemented.

There is a good synergy between both codes

Mixclask: Mixing Cloudy and Skirt



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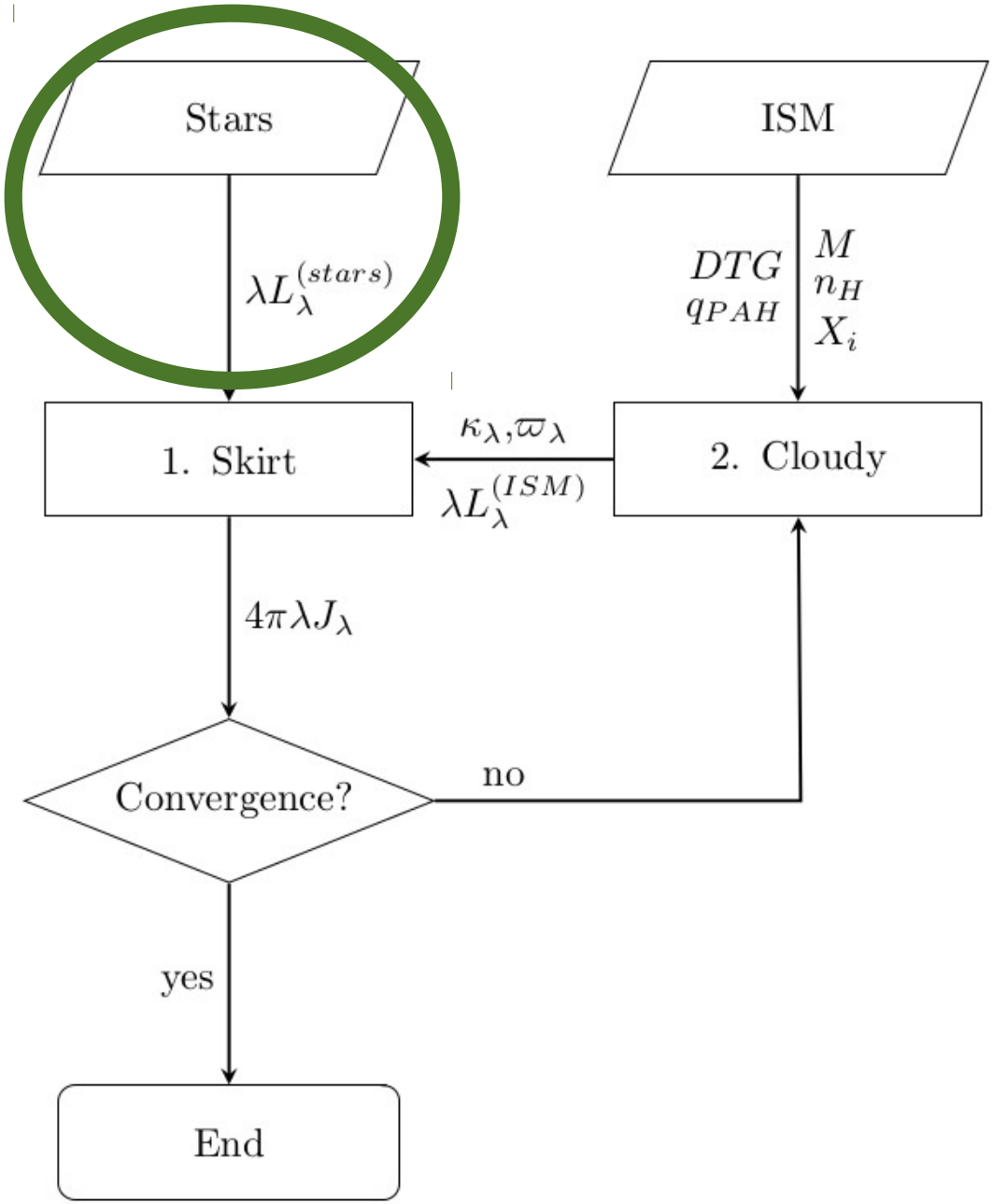
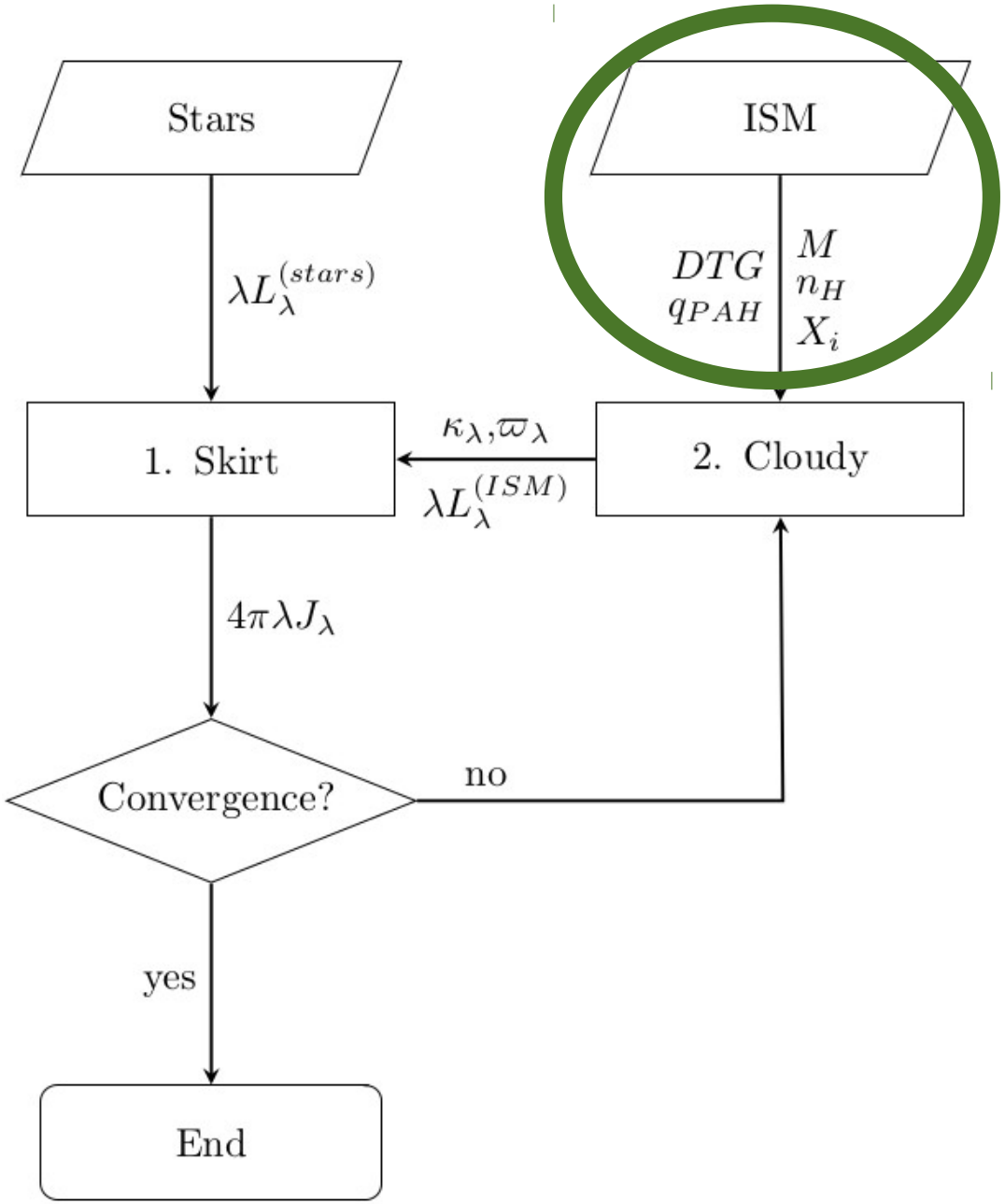


Stellar input

- Emitted luminosity (erg/s) from only stars.

Mixclask: Mixing Cloudy and Skirt



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ISM input

- Total mass of the ISM
- Mass fractions of chemical abundances
- Dust-to-gas
- PAH-to-dust

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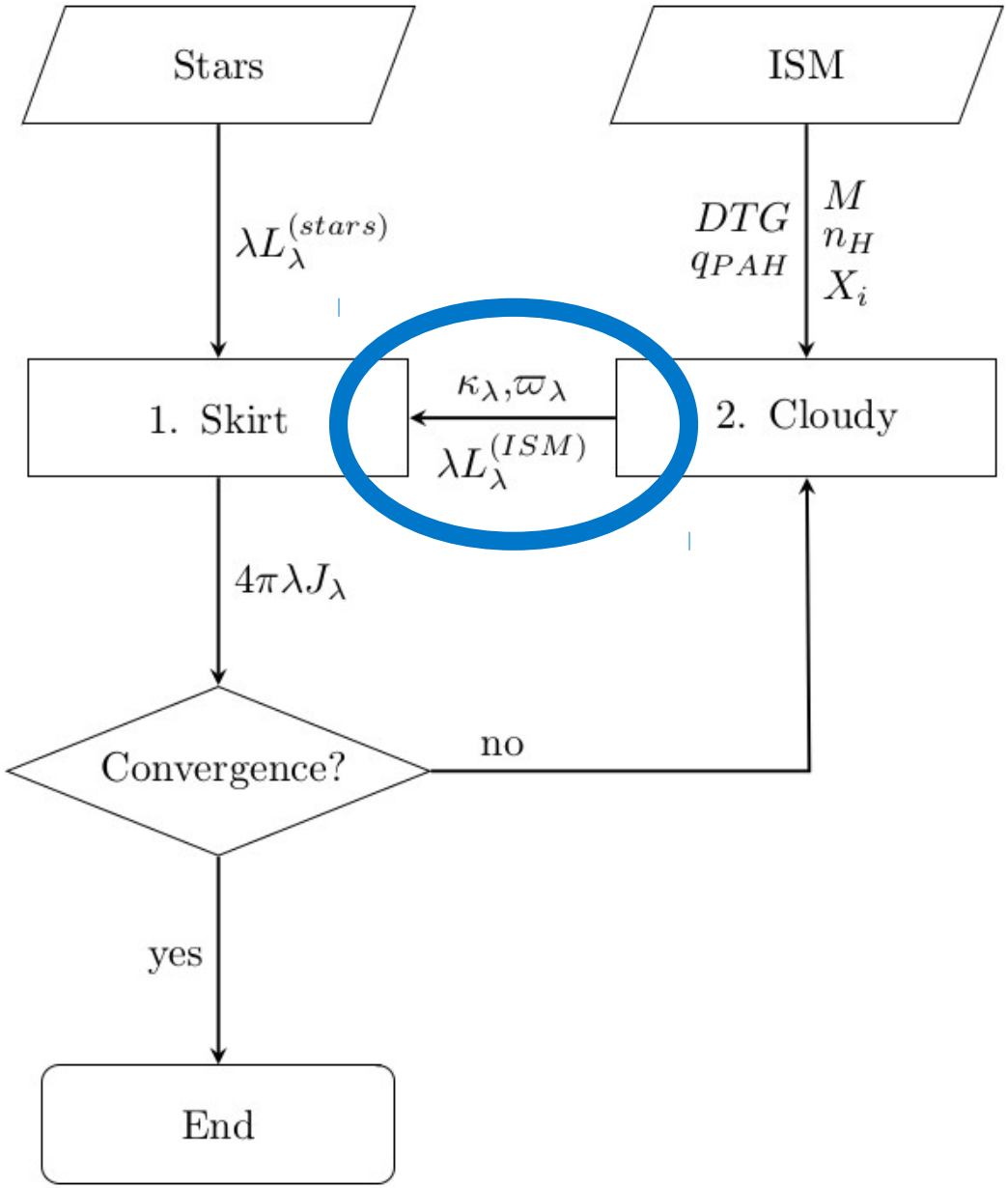

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Cloudy output

- Emitted luminosity from gas and dust.
- Extinction coefficient
- Albedo

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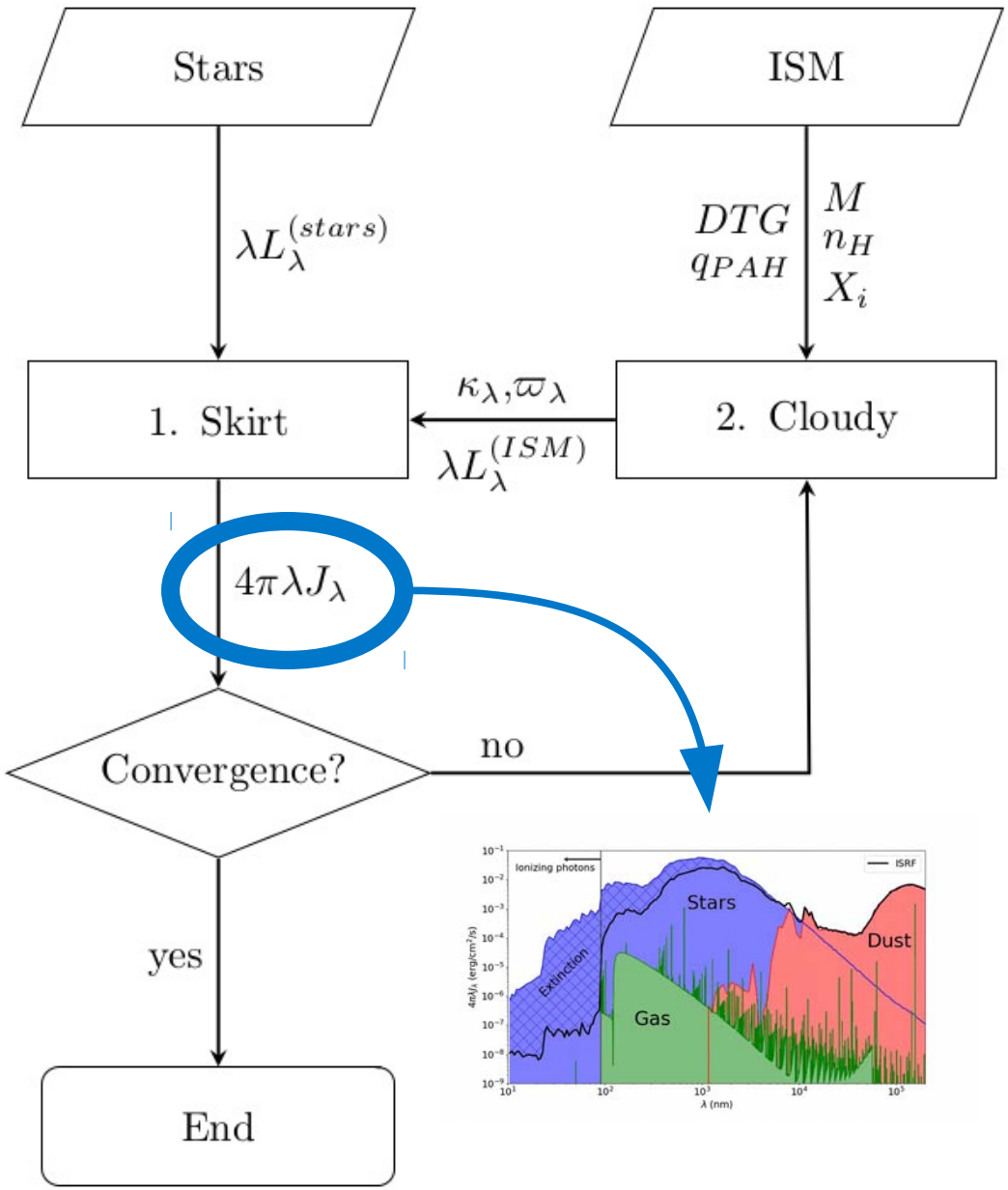

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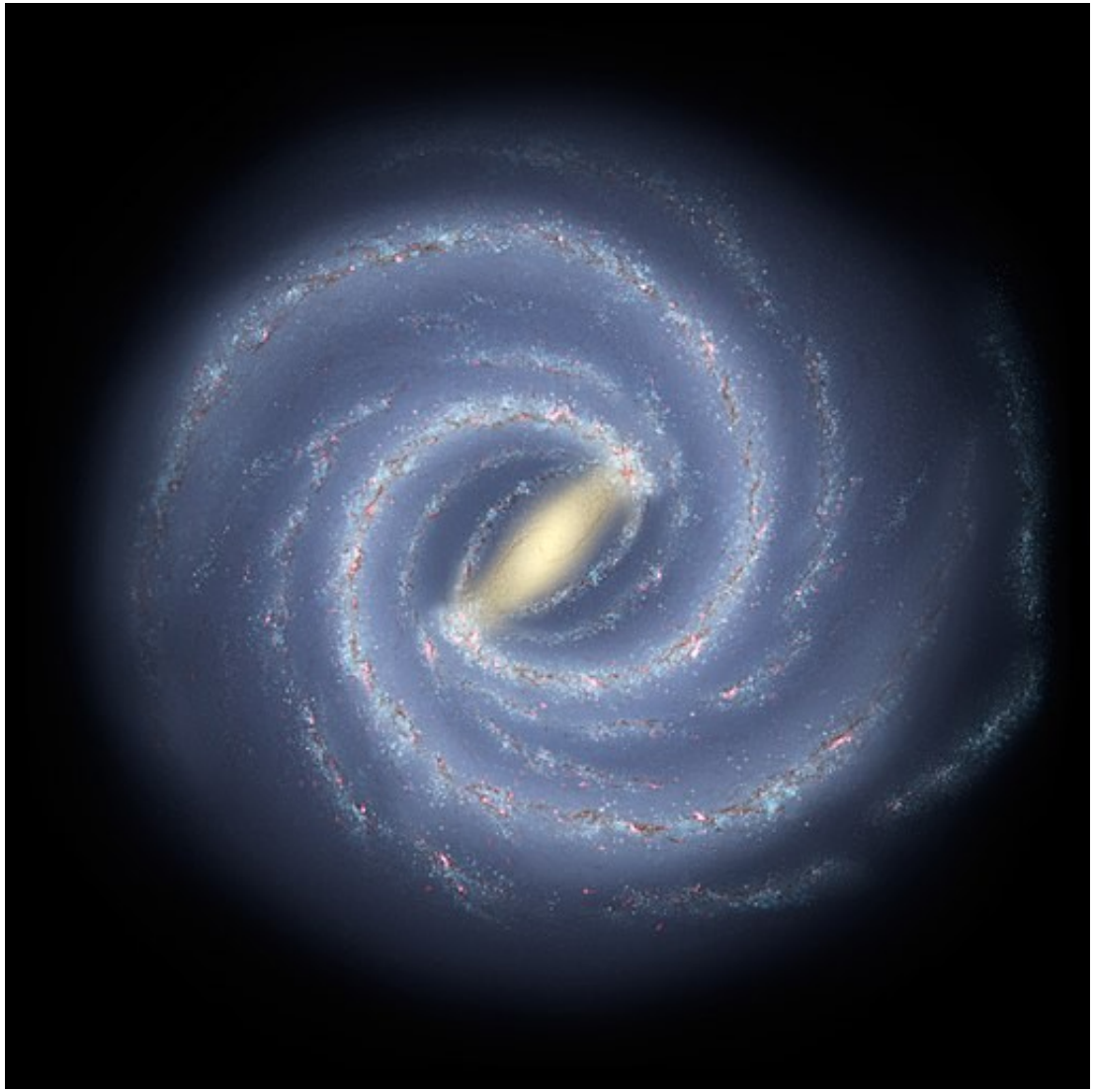
Main output

- Mean intensity field (erg/s/cm²)

Mixclask: An example



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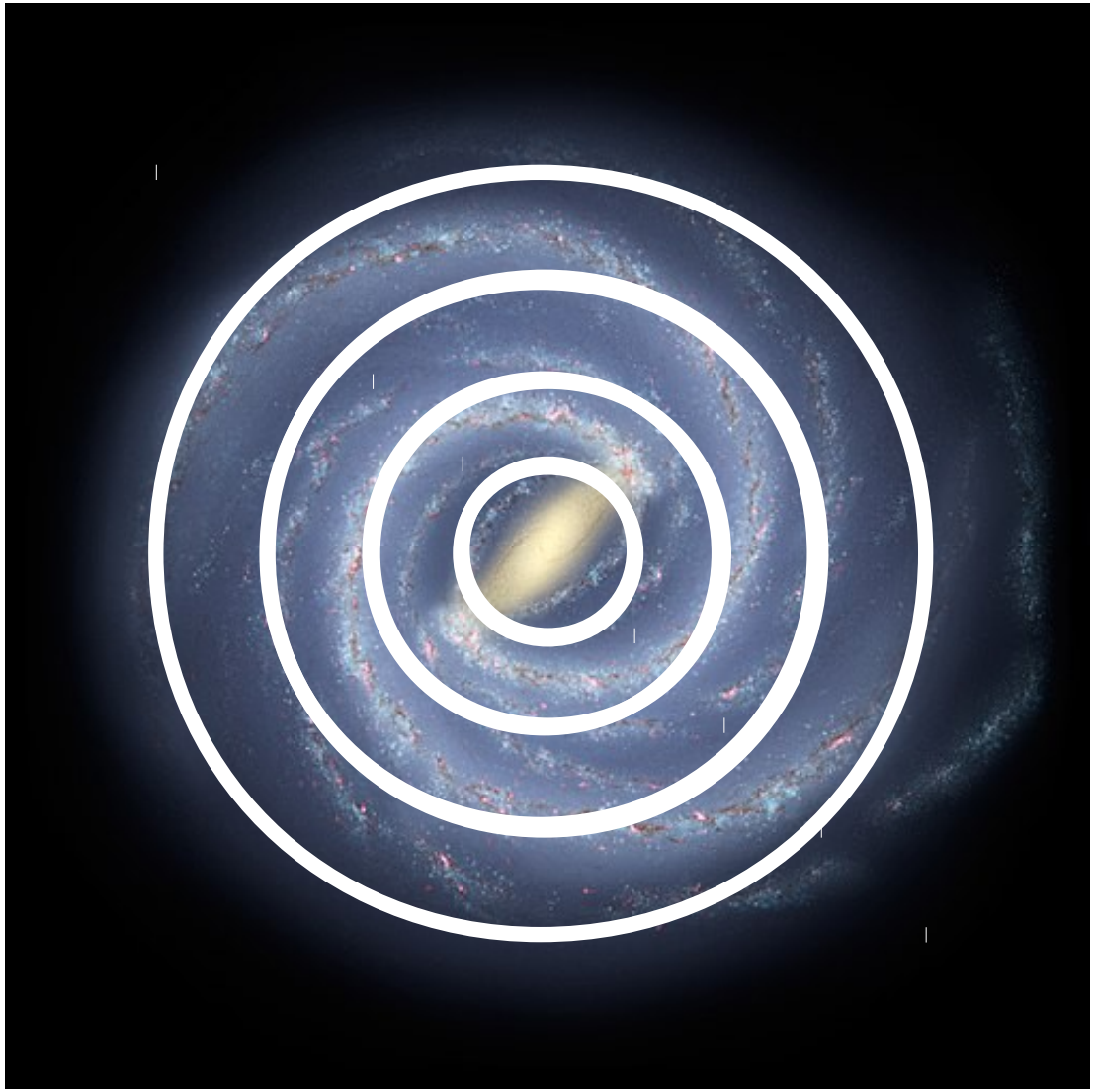
1. Take a galaxy

Mixclask: An example



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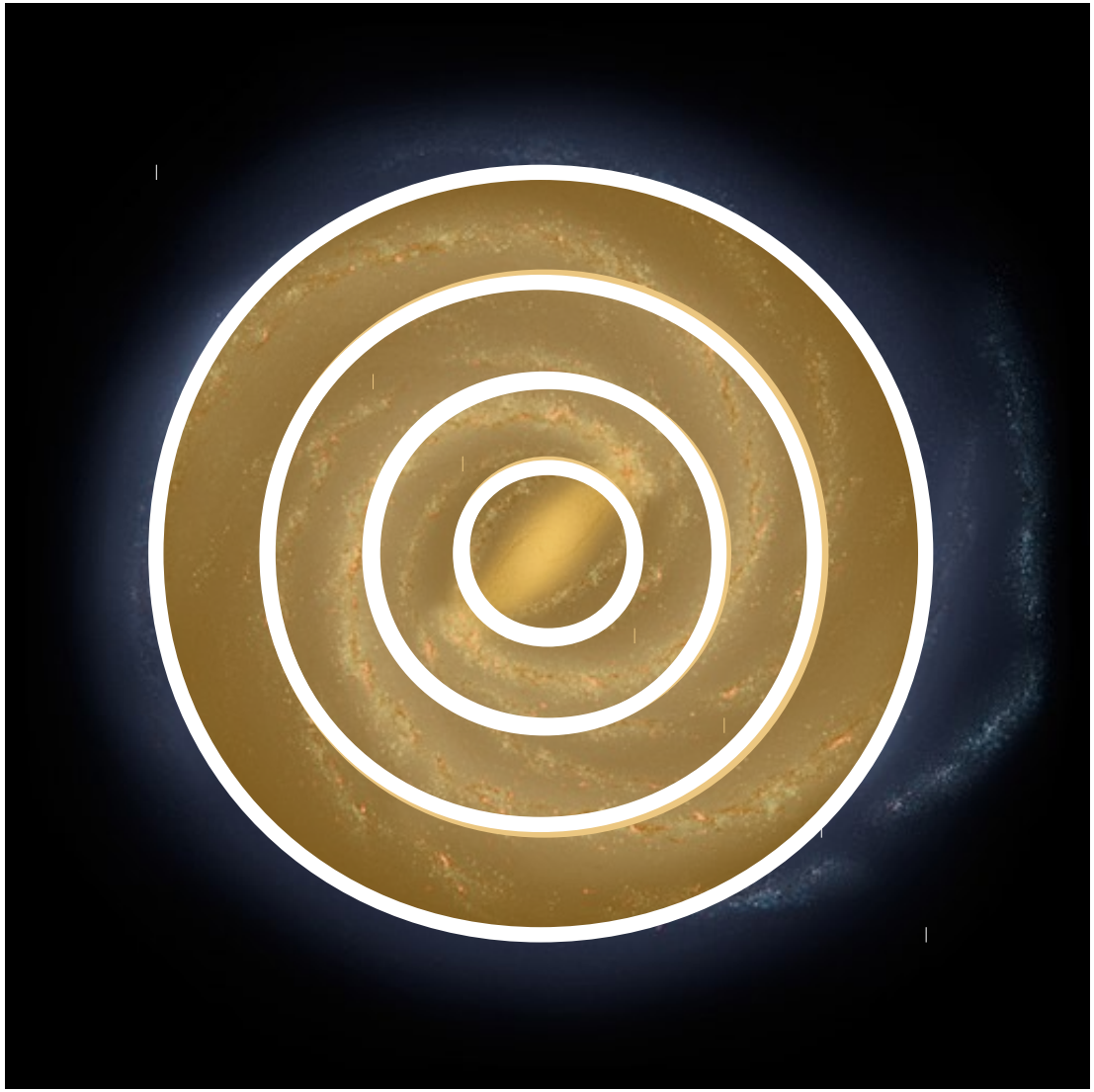
1. Take a galaxy
2. Divide into concentric cylinders
3. Run Mixclask

What does Mixclask do?

Mixclask: An example



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<u>What does Mixclask do?</u>

i. Skirt performs radiative transfer to the whole galaxy with <u>only stars</u>

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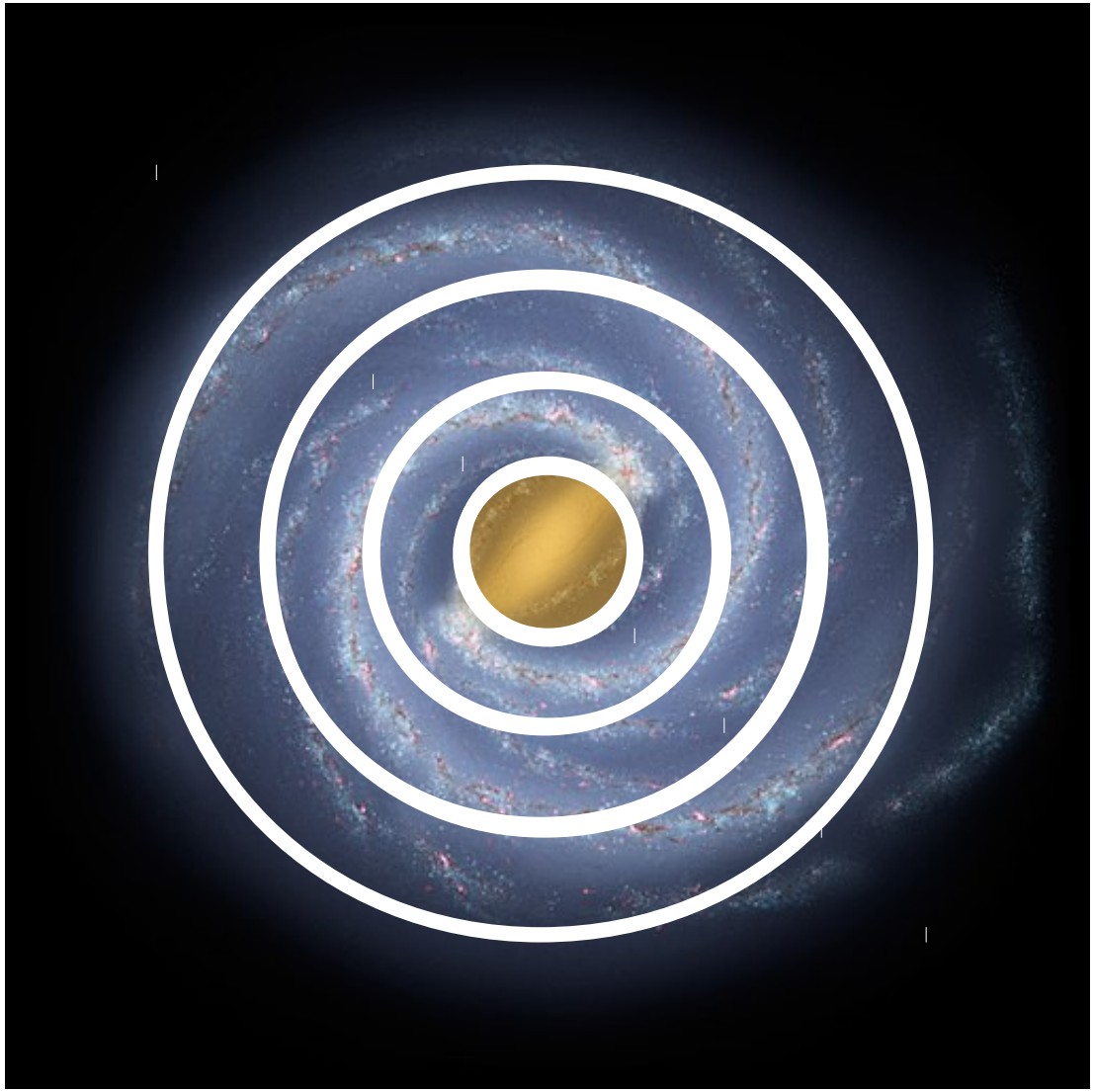

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ii. Cloudy computes the ISM properties of each cylinder

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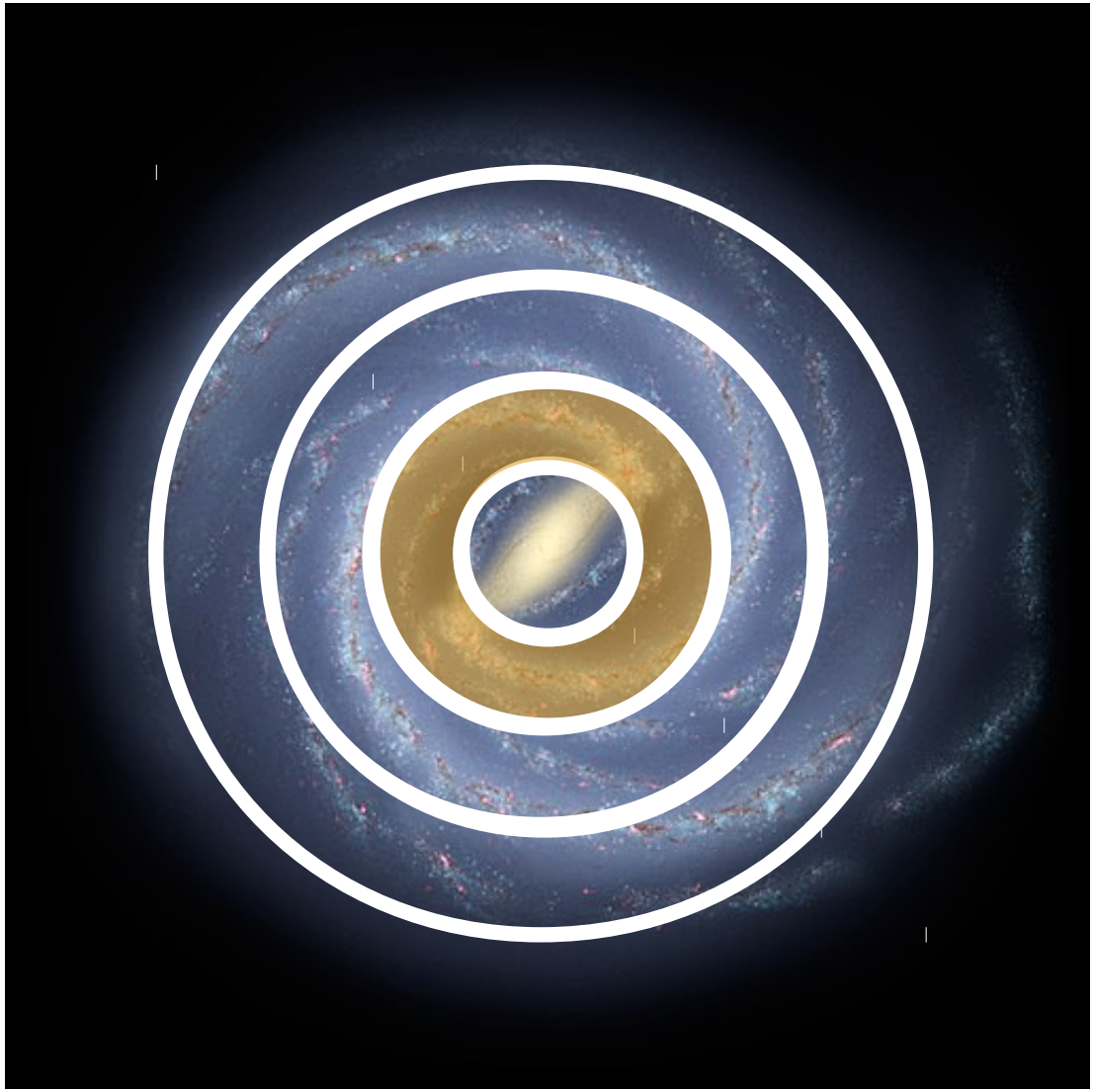

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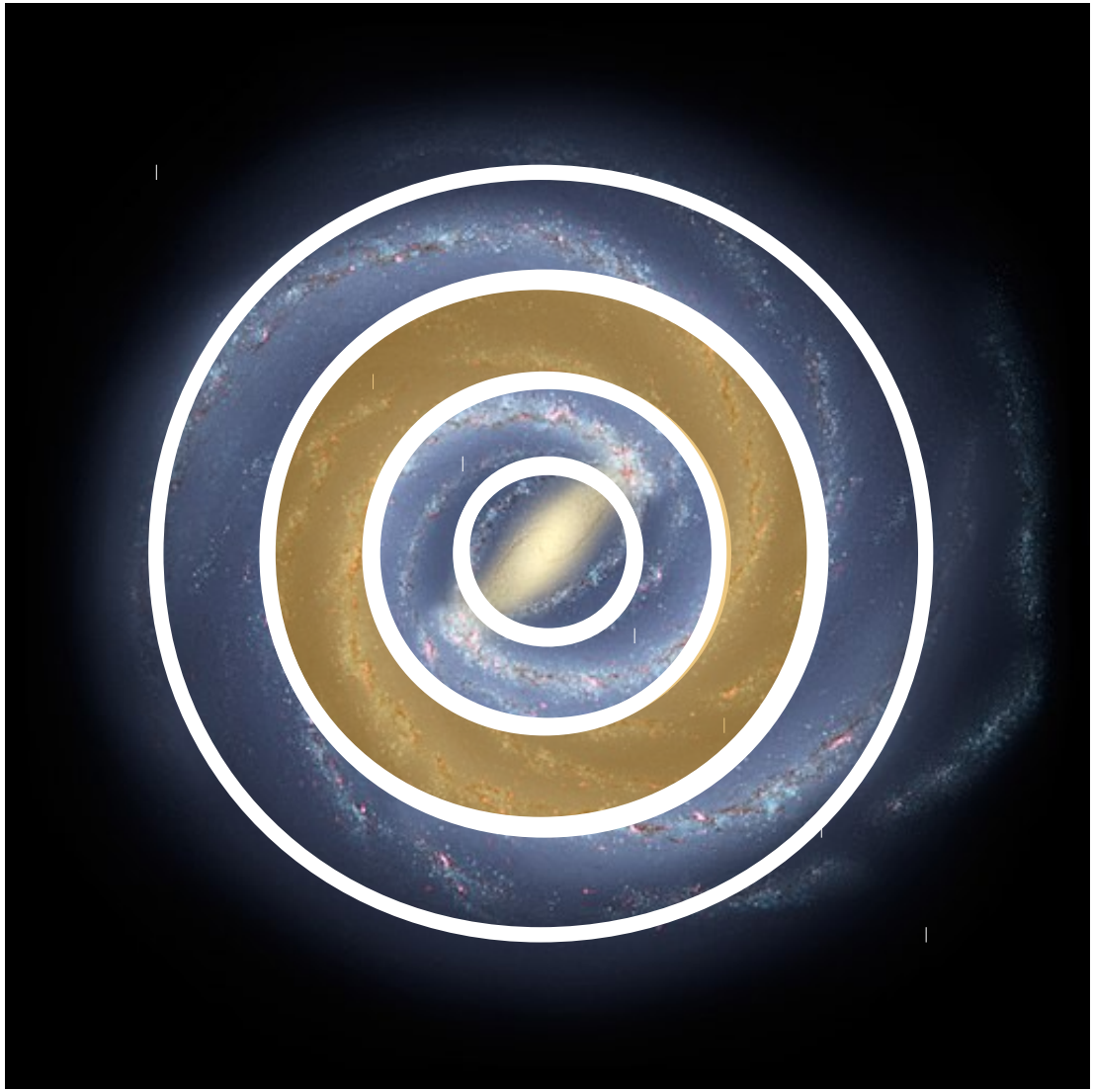

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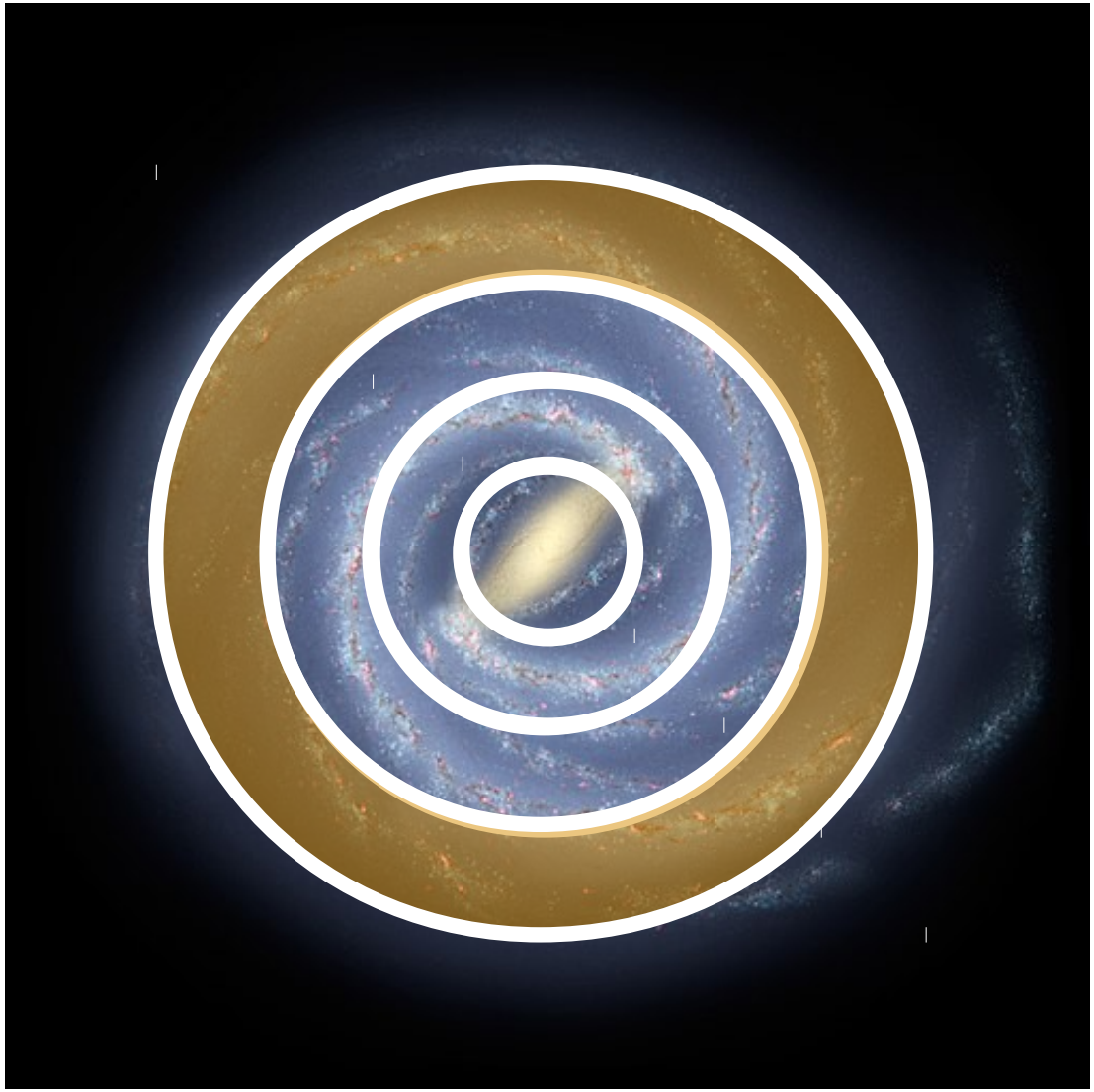

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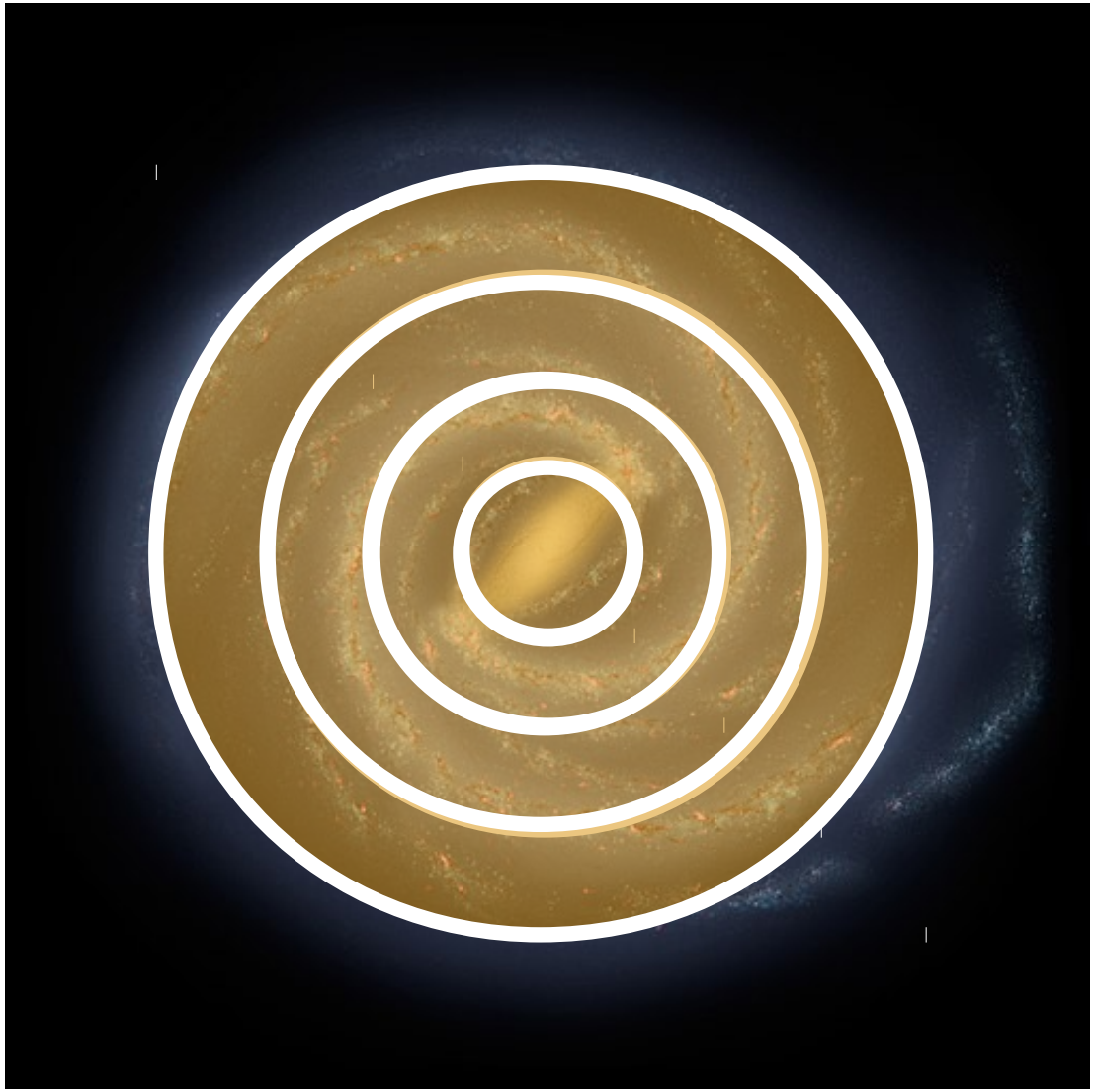

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1. Take a galaxy
2. Divide into concentric cylinders
3. Run Mixclask

What does Mixclask do?

i. Skirt performs radiative transfer to the whole galaxy with only stars
ii. Cloudy computes the ISM properties of each cylinder
iii. Run Skirt again to the whole galaxy with stars and ISM
iv. Repeat until convergence

Further considerations

- Geometry of the problem.
- Choice of chemical evolution models.
- Create Mixclask input from CEM.

Further considerations : Chemical evolution model

Mulchem

Mollá et al. (2017,2022)

Returns the time evolution of:

- ISM mass (diffuse, molecular)
- Stellar mass
- Star formation rate
- Elemental abundances of 15 elements

MMA

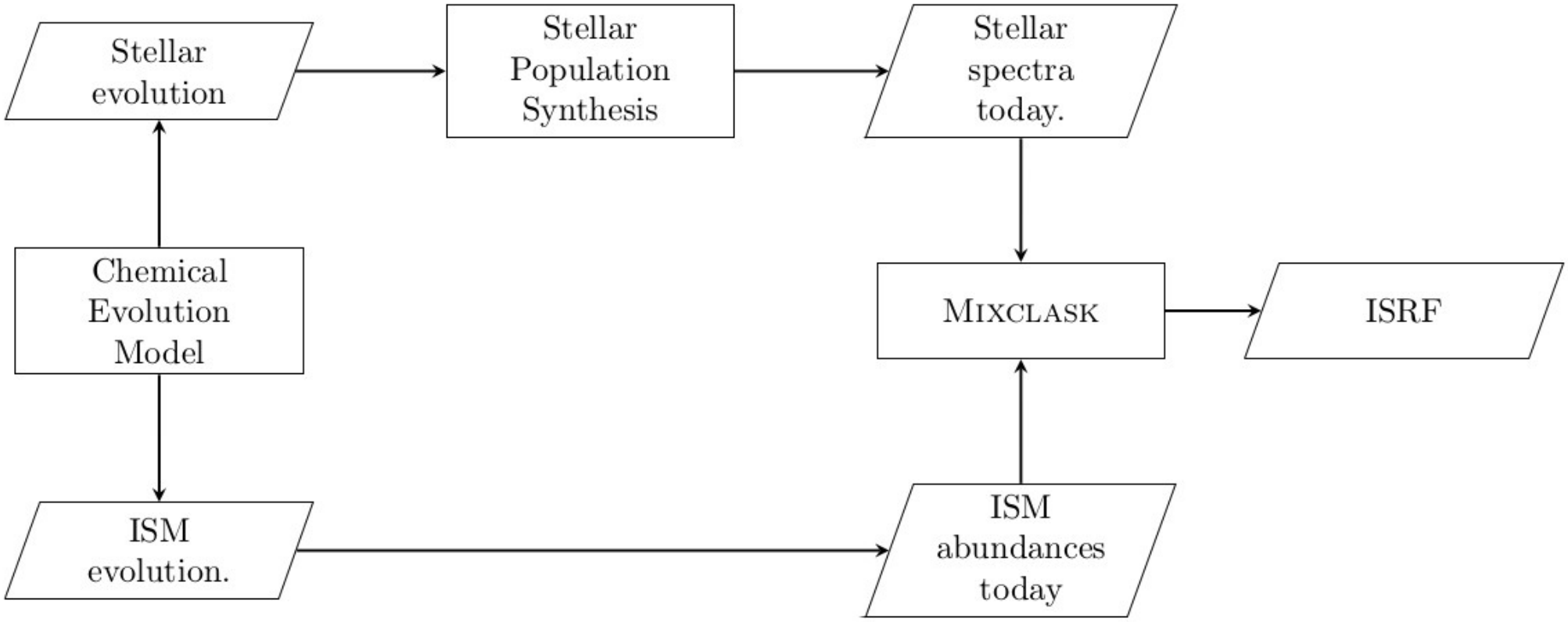
Millán-Irigoyen et al. (2021)

Returns the time evolution of:

- Gas mass (hot, warm, cold)
- Stellar mass
- Star formation rate
- Dust grain mass

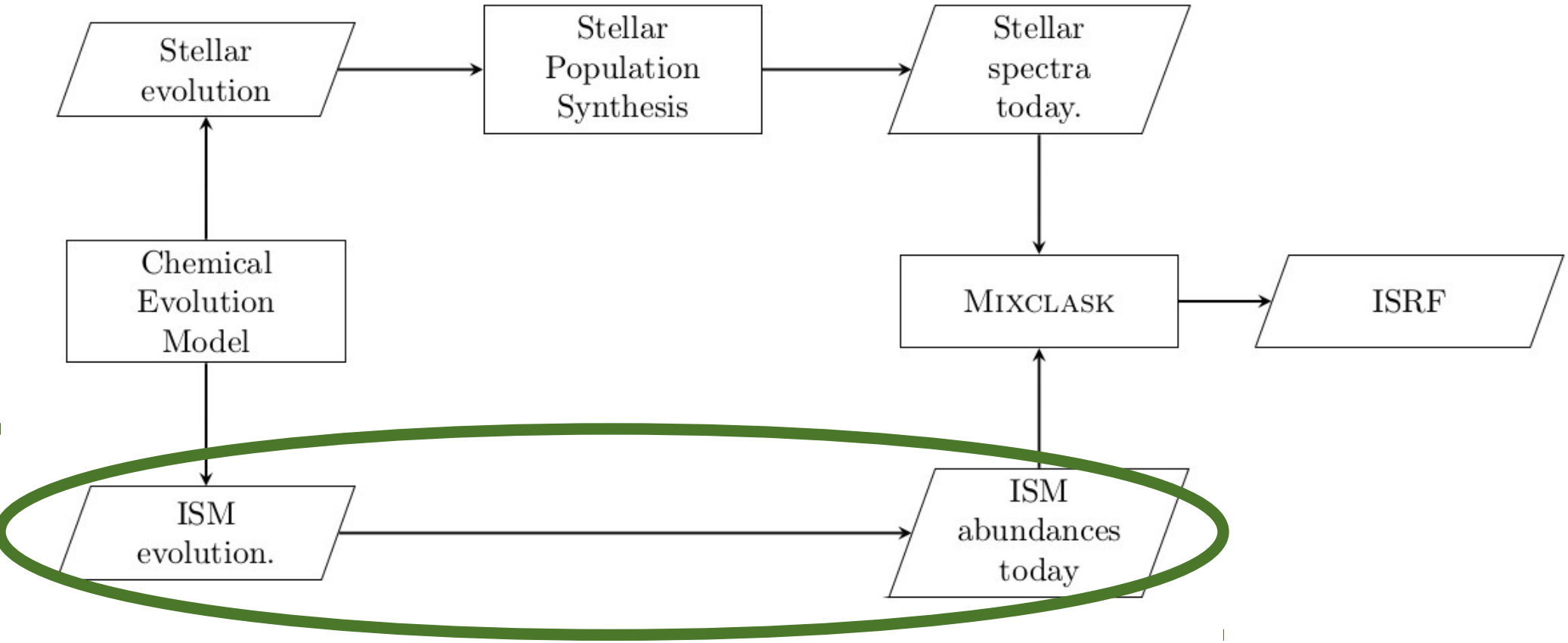
Both are calibrated with Mollá et al. (2015) for the Milky Way Galaxy

Further considerations : Mixclask input



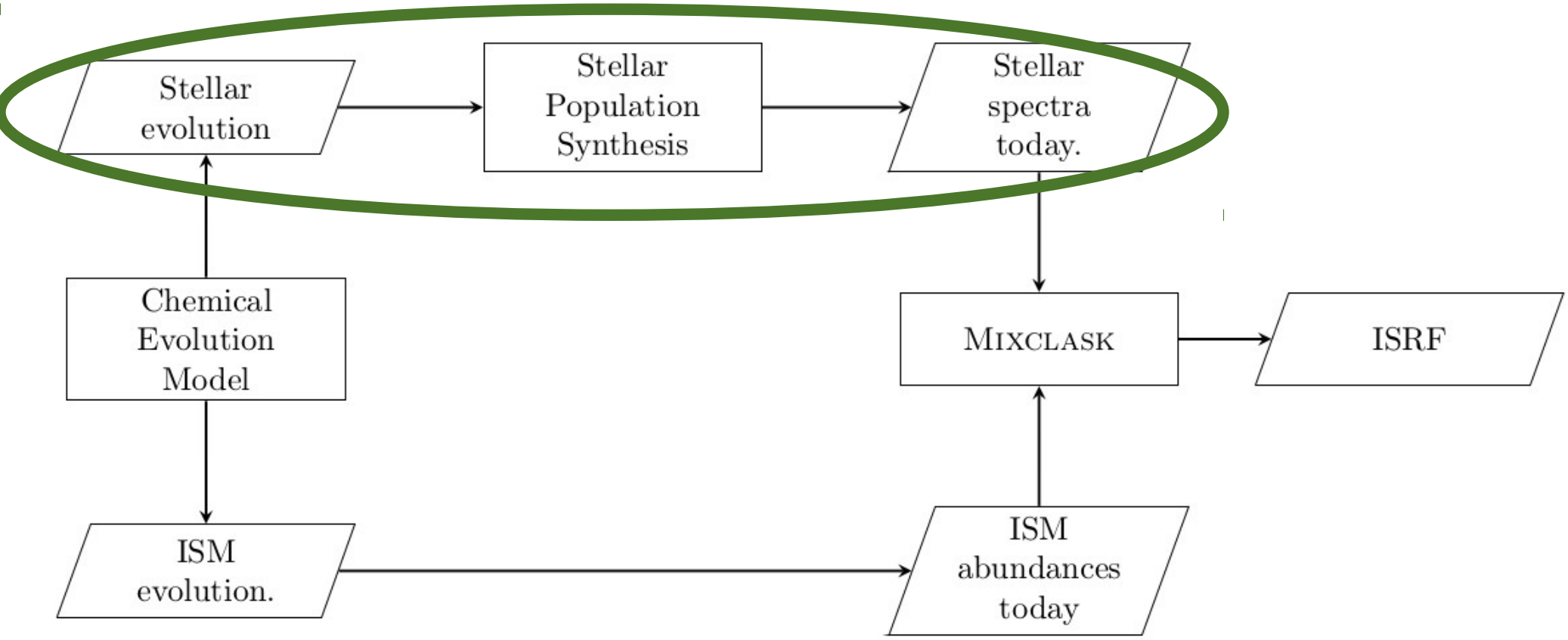
Further considerations : Mixclask input

ISM data (gas and dust) are straightforward for MMA model.
You have to deplete elements for Mulchem.



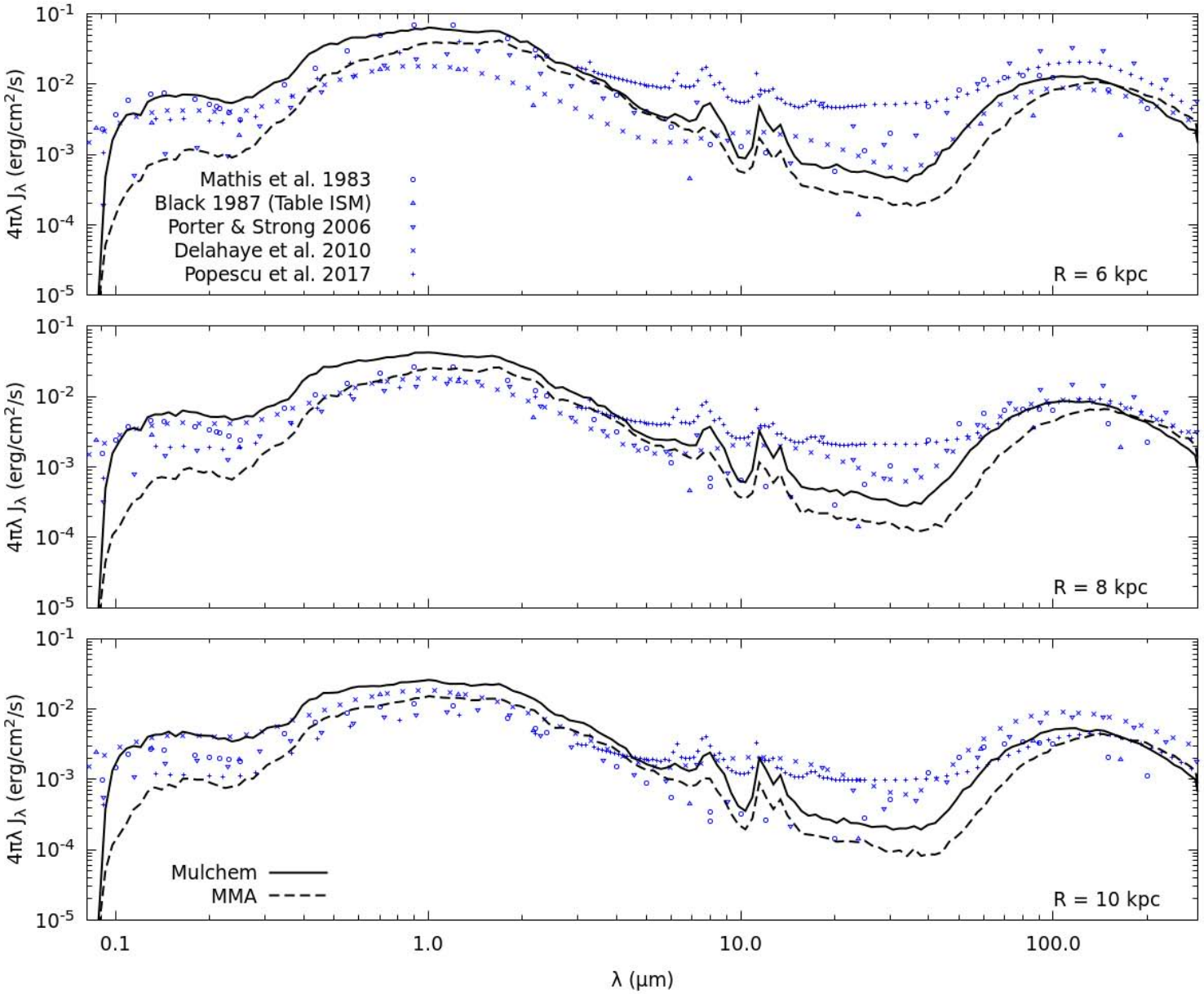
Further considerations : Mixclask input

$$L_\lambda = \int_0^t \psi(t-t')L_{\mathrm{SSP},\lambda}(Z(t-t'),t')dt'$$

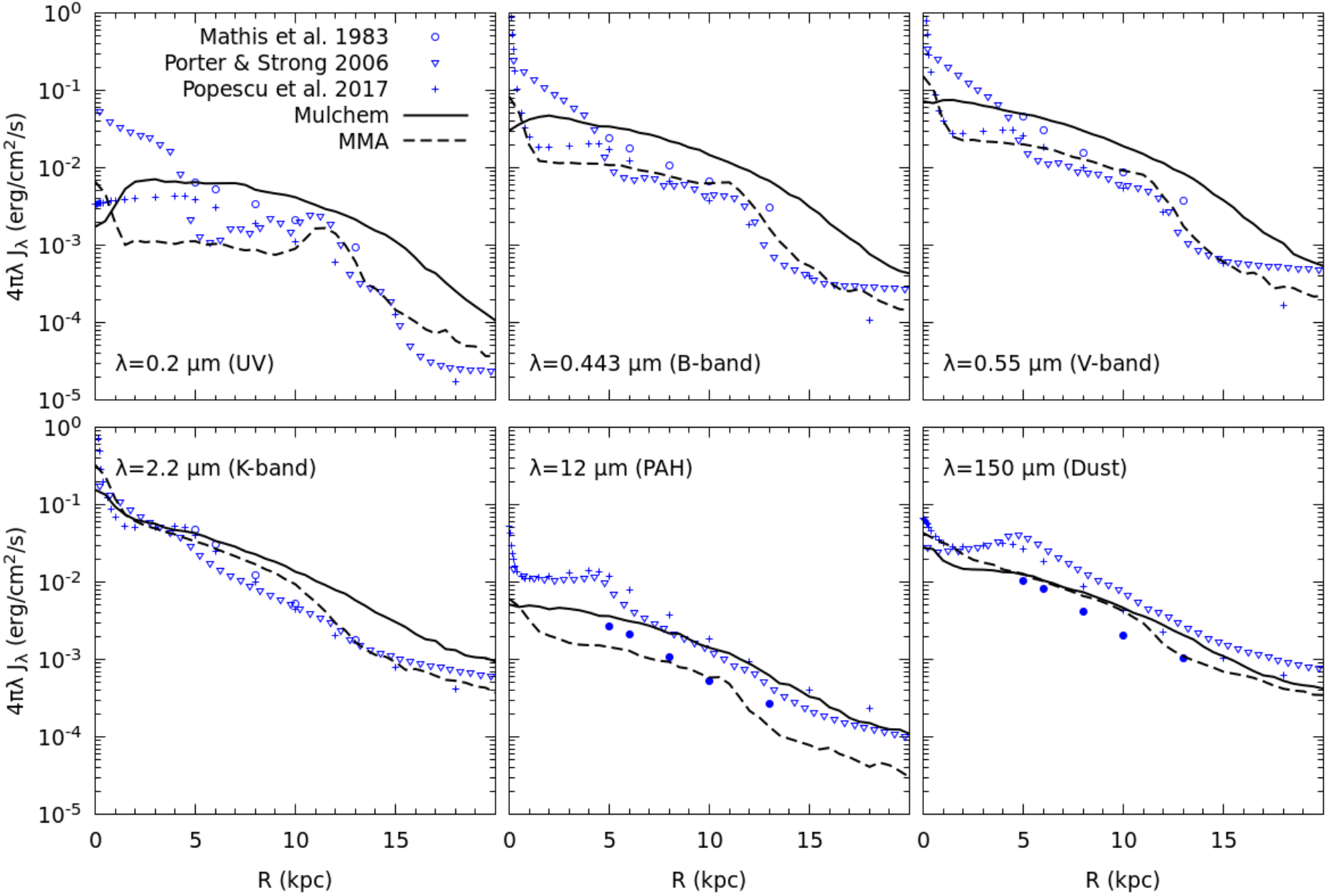


The ISRF of the Milky Way Galaxy

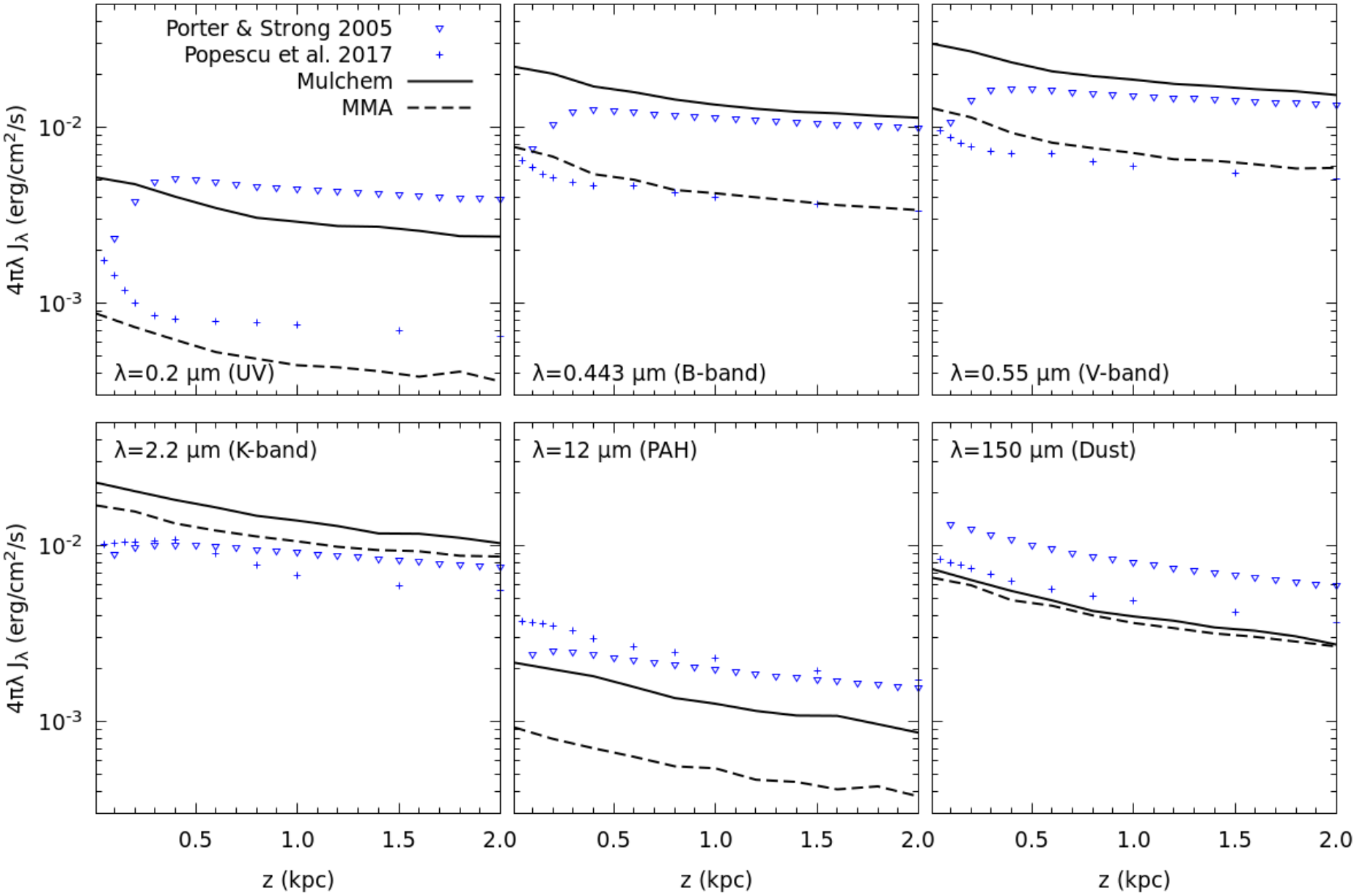
Milky Way ISRF : Spectral energy distribution



Milky Way ISRF : Radial distribution



Milky Way ISRF : Radial distribution



Final remarks

- These ISRF models have been made from theoretical models, not from observations like previous works in the literature.

- Both CEM can reproduce the ISRF, and they also display differences between them. → New method to constrain CEM.

- What would the ISRF be from other galaxies predicted from theoretical models?

Thank you for your attention

Find more details in:

- Romero et al. (2022,submitted). ArXiv: 2203.04782
- Mixclask Github: https://github.com/MarioRomeroC/Mixclask