Danmarks Grundforskningsfond
Danish National Research Foundation

DAWN
Cosmic Dawn Center

UNIVERSITY OF COPENHAGEN

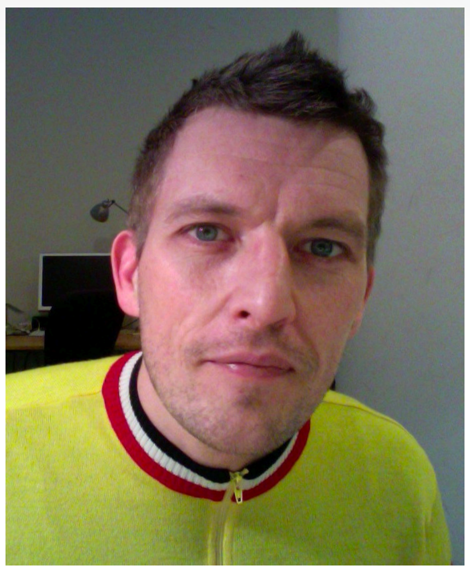
Probing the first galaxies

Vision

Develop a numerical tool and an immense grid of model galaxies to fit and interpret observations of the first galaxies.

Additional goal

Publish the source code "MoCaLaTA" and model grid, so that the whole astrophysical community can benefit from, and contribute in expanding, the grid.



Peter Laursen

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1. Background

Galaxies are the building blocks of our Universe. Most information about the Universe comes to us in the form of light. In the very distant Universe, which is where we must look in order to catch the galaxies in their formation phases, we are often forced to observe at a few, selected wavelengths, in particular the so-called Lyman alpha (Lyα) spectral line, originating from neutral hydrogen.

Lyα is a resonant line, implying that it is all the time absorbed by hydrogen and re-remitted in random directions, changing its spectral distribution, its position on the sky, and its amplitude. This makes Lyα notoriously hard to interpret, but at the same time a rich source of information about the galaxy emitting it.

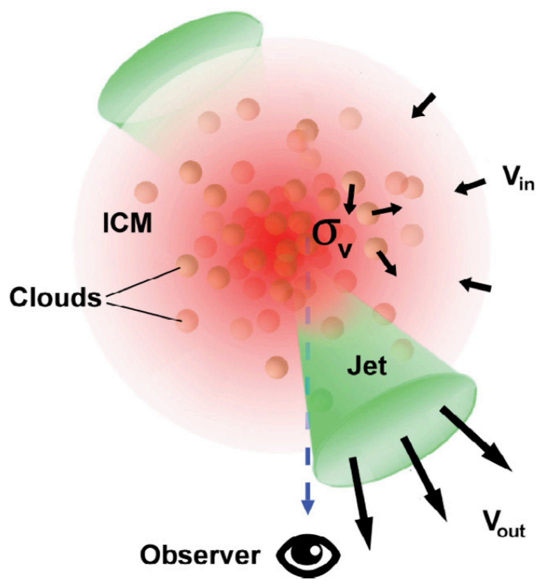
2. Method

Comparing computer simulations of galaxies to real observations gives insight into the properties of the real galaxies. The idea is to:

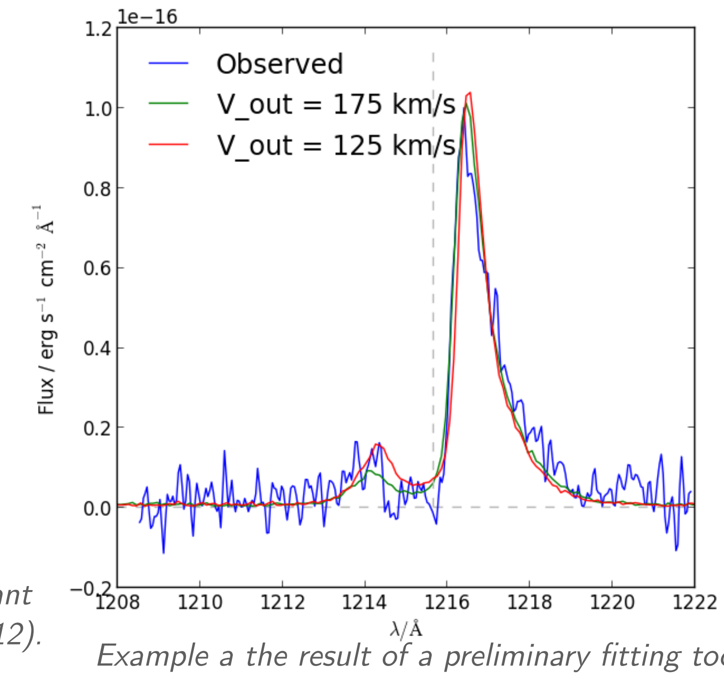
1. Define an idealized galaxy by a number of parameters,
2. Vary those parameters, running radiative transfer simulations for a "grid" of models,
3. Search the grid, looking for the best-fitting model to a given observation.

3. Model galaxy

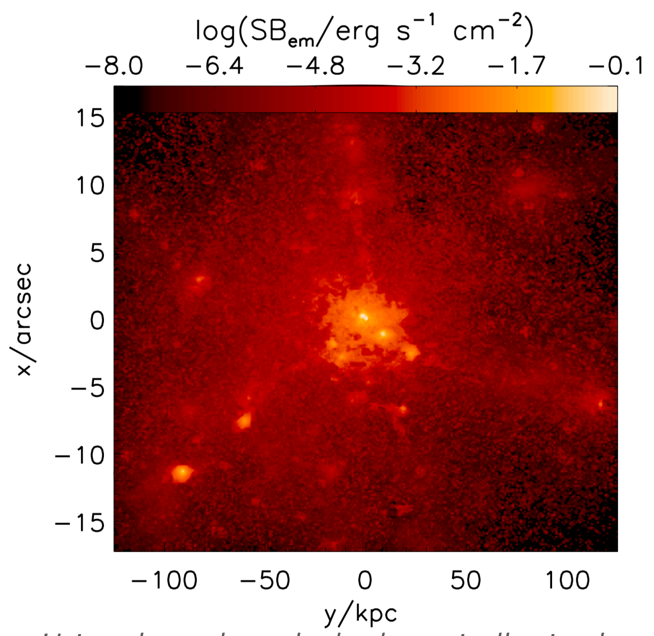
Galaxies are modeled as a multiphase, clumpy interstellar medium of several physical parameters, in which individual photons are traced as they scatter stochastically out through the gas, toward an observer.



Example of a model galaxy where a few of the important parameters are indicated. From Noterdaeme et al. (2012).



Example a the result of a preliminary fitting tool, used to fit the gas outflow velocity. From Krogager et al. (in prep.)



Using the code on hydrodynamically simulated galaxies yields more realistic, but less tunable models.

4. Parameters probed

Parameters such as gas/dust densities, clumpiness, velocity fields, temperatures, etc., of the different interstellar phases affect the outcome to a greater or lesser extent, and are thus the parameters that can be constrained by fitting the observations.

5. Possible issues

- A galaxy is described by 10–20 parameters, so a sufficiently well-sampled grid will be unfeasibly large.
- Each simulation takes ~an hour to ~a day.
- Some parameters are (almost) degenerate.
- Developing the grid search engine will take a long time by itself.
- Developing at some point the RT code further should not mean that previous models should be recalculated.

6. Possible solutions

- Adaptively sampled grid: A coarse grid is constructed, then the best-fitting region can be found for a given galaxy, and more RT simulations can be run in this region.
- The code will be published, so others can help in slowly expanding the grid.
- Various tools already exist for efficiently searching multidimensional spaces; this part could advantageously be outsourced to people at KU's Dept. of Computer Science, who allegedly are eagerly waiting to apply their skills to real-world problems.
- Certain parameters may be excluded due to unrealistic physics, or constrained tightly due to well-known physics.
- Interpolating between grid points may provide better fits without having to run more simulations.