Simulating Molecular Cloud Regulated Star Formation in Galaxies

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Abstract

This thesis is primarily concerned with understanding the process of galaxy formation via the simulation of the interstellar medium, star formation and supernova feedback. In order to probe galaxy formation it is necessary that we first obtain a basic knowledge of the cosmological framework in which we are working. Therefore in chapter 1 we provide a brief overview of the salient features of the current cosmological paradigm in addition to discussing in some detail the physics of the interstellar medium

In chapter 2 we focus on the numerical methods necessary to perform accurate cosmological simulations. We begin by providing an overview of the different simulation techniques currently in use in the field before performing comparisons of two simulation codes that work via two completely different methods. We then introduce a code for generating high-resolution initial conditions for the simulation of individual objects and investigate the numerical effects of mass resolution in cosmological simulation.

In chapter 3 we describe a statistical model of the interstellar medium, in which the conversion of cooling gas to stars in the multiphase interstellar medium is governed by the rate at which molecular clouds are formed and destroyed. In the model, clouds form from thermally unstable ambient gas and get destroyed by star formation, feedback and thermal conduction.

In chapter 4 this statistical model is applied to the simulation of isolated disk galaxies. We show that it naturally produces a multiphase medium with cold clouds, a warm disk and hot supernova bubbles. We illustrate this by evolving an isolated Milky Way-like galaxy. Many observed properties of disk galaxies are reproduced well, including the molecular cloud mass spectrum, the molecular fraction as a function of radius, the Schmidt law, the stellar density profile and the appearance of a galactic fountain.

Finally in chapter 5 we perform an investigation into more dynamic situations, namely the evolution of gravitationally interacting disk galaxies and the formation of a galaxy in a fully cosmological simulation. It is found that the sticky particle model does a good job of reproducing many of the observed properties of interacting galaxies, including the properties of the ISM in the resulting elliptical galaxy.

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A thesis submitted to the University of Durham
in accordance with the regulations for
admittance to the Degree of Doctor of Philosophy.

Department of Physics
University of Durham
January 2007

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Declaration

The work described in this thesis was undertaken between 2003 and 2006 while the author was a research student under the supervision of Dr. Tom Theuns in the Department of Physics at the University of Durham. This work has not been submitted for any other degree at the University of Durham or any other University.

Chapter 3 and 4 of this thesis have been published in the form of a paper

- Booth C. M., Theuns T., Okamoto T., "Simulating Molecular Cloud Regulated Star Formation in Galaxies", MNRAS, 376, 1588

The simulations from chapter 2 have been used in the following paper

- Brooks A.M. , Governato F., Booth C. M., Willman B., Gardner J.P., Wadsley J., Stinson G., Quinn T., "The Origin and Evolution of the Mass-Metallicity Relationship for Galaxies: Results from Cosmological N-Body Simulations", ApJL, 655, L17

Acknowledgements

My time in Durham surely ranks amongst the happiest periods of my life and for this I am indebted to a great many people.

This thesis is dedicated firstly to Tom Theuns, who has had a profound effect on my development over the past three and a half years. I could not imagine working alongside a better advisor and teacher. Secondly to my officemates – and hopefully still friends after the stresses of the thesis writing process! – Greg Davies, John Helly, Mark Swinbank and Kristen Coppin who have always been ready with helpful words and stimulating discussion. Between them they have made life in the office an absolute pleasure.

Many thanks must also go to my friends, who never fail to brighten a dull day, and whose company has made even the most testing times at work enjoyable. In alphabetical order particular credit must go to: Rob Crain, Claudio Dalla Vecchia, Jim Geach, Geraint Harker, Noam Libeskind, Jim Mullaney, Mark Norris, Chris Power, David Radburn-Smith, Nic Ross, John Stott and Dave Wake.

It is, perhaps, inevitable that I have neglected somebody in this list so if you stumble over this thesis and feel deeply upset that you are absent try not to hold it against me. It wasn't personal, I promise.

Nothing I have done over the past few years would have been possible without my family, who have patiently supported me at all stages of this long journey and from the youngest age have nurtured in me an attitude of playful scientific discovery and love of learning. Finally – and most of all – this thesis is for Gemma Harrison, who makes the universe worth studying.

Thank you!