

## Case Studies in Star Formation

*Case Studies in Star Formation* offers an overview of our current observational and theoretical understanding in the molecular astronomy of star formation. The book is divided into six sections: the first introduces an overview of star formation and the essential language, concepts, and tools specific to molecular astronomy studies. Each subsequent section focuses on individual sources, beginning with a description of large-scale surveys. The volume covers low- and high-mass star formation, ionisation and photodissociation regions, and concludes with the extragalactic perspective. Conventional textbooks begin with principles, ending with a few convenient examples. Through copious examples, *Case Studies* reflects the reality of research, which requires the creative matching of ongoing observations to theory and vice versa, often raising as many questions as answers. This supplementary study guide enables graduate students and early career researchers to bridge the gap between textbooks and the wealth of research literature.

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Case Studies in Star Formation  
A Molecular Astronomy Perspective

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*Geoffrey Hill Macdonald*  
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## Preface

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*Science is not reliable because it provides certainty. It is reliable because it provides us with the best answers we have at present.*

– Carlo Rovelli†

To place *Case Studies* in its pedagogical context the reader could do worse than look to a statement by João Alves, on his appointment in October 2020 as the new editor of *Star Formation News* (SFN), a broadsheet that has served the astronomy community for over 30 years ([www.starformation.news](http://www.starformation.news)). Alves wrote:

*An essential goal of the SFN is to welcome young researchers into the field, help them navigate the community, and inspire them to make their mark. A paradox in today's incredibly easy access to large amounts of information is PhD students' hyper-specialization. In part, this is a structural problem arising from what is expected from young researchers to succeed. The SFN web will minimize this drawback and avoid dividing the SFN into sub-fields to expose the reader to a broader view, following Bo [Reipurth]'s original design. Given the current information growth, this will be a difficult path to tread, but the spirit will be kept. (SFN #334, 2020)*

In the same spirit, for graduate students and early researchers, *Case Studies* introduces an overview of our current understanding of star formation from a molecular astronomy perspective, making no initial assumptions beyond that which we might expect of an undergraduate knowledge base in the more familiar facets of astronomy, physics, and chemistry. The Introduction identifies the key stages in the formation process of both low- and high-mass stars, linearly tracked from their diffuse interstellar raw material origins through to protostellar nuclear ignition and the early impact of that on the progenitor molecular envelope. This chapter also introduces some of the essential language and ideas specific to molecular astrophysics and astrochemistry, plus several observational and theoretical tools to be applied in subsequent

chapters. The Introduction concludes by referencing some standard textbooks that offer greater detail on the subjects raised.

For the bulk of the book, each of its five parts begins with examples of recent large-scale surveys, before focusing on individual representative sources. Of the five, the first focuses on low-mass star formation, the second on high-mass star formation, the third on ionised regions and their interactions with hot molecular cores, the fourth on photodissociation regions, and the fifth takes us to star formation in galaxies beyond our own. Each chapter concludes with a brief summary of contents and links to the ongoing pedagogical purpose. Since *Case Studies* is targeted principally at postgraduate students and early researchers, unlike a standard textbook our motivation is to reflect some of the research realities in which a creative pursuit of understanding seeks to match unfolding observations to the theory that underpins them. This contrasts with the conventional teaching route more familiar at the undergraduate level in which we would begin with first principles and end with convenient examples.

Real life is not necessarily convenient, and typically questions more often than answers arise at the postgraduate level. In offering more detailed exemplars than are customarily found in textbooks, *Case Studies* presents a sufficient descriptive introduction to each individual source to give the uninitiated reader some sense of the wider Galactic and extragalactic environment. In addition, copious references are offered to the research literature readily available through the online Astrophysical Data System (ADS) operated by the Smithsonian Astrophysical Observatory (SAO) under a grant from NASA, known as ‘adsabs’ (<https://ui.adsabs.harvard.edu>). At various points throughout the text, the principal observational techniques of radio, millimetre, and submillimetre astronomy are placed in their practical research context, as are references to the major single-dish and interferometric instruments – past, present, and those approaching commission.

We hope the text may also be as useful to the teacher as to the student of a taught course in bringing together much disparate information, as well as to the self-studies of early researchers. Molecular astronomy specifically informs our understanding of the stages of star formation through the chemical tracers of physical conditions and dynamics. Both large-scale surveys and individual source studies reinforce or undermine what it is we think we know about the particular molecular species that we are using as an astronomical probe. This close interchange between observation, theoretical modelling, and laboratory experiment is the route through which molecular astronomers are continually contributing to the development of knowledge of star formation both within our own Galaxy and increasingly to that occurring far beyond.

<sup>†</sup> Carlo Rovelli, *Reality Is Not What It Seems: The Journey to Quantum Gravity*, trans. Simon Carnell and Erica Segre. London: Penguin Books (2017).

## Acronyms

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ALMA	Atacama Large Millimetre Array
APEX	Atacama Pathfinder Experiment
ATLASGAL	APEX Telescope Large Area Survey of the Galaxy
BIMA	Berkeley Illinois Maryland Association
CSO	Caltech Submillimetre Observatory
ESA	European Space Agency
ESO	European Space Observatory
FUSE	Far Ultraviolet Spectroscopic Explorer
GLIMPSE	Galactic Legacy Infrared Mid-Plane Survey
IRAC	Infrared Array Camera
IRAM	Institut de Radioastronomie Millimetrique
IRAS	Infrared Astronomical Satellite
JCMT	James Clerk Maxwell Telescope
JVLA	Jansky Very Large Array
JWST	James Webb Space Telescope
e-MERLIN	enhanced Multi-Element Remote-Linked Interferometer Network
MIPS	Multiband Imaging Photometer
NASA	National Aeronautics and Space Administration
NOEMA	Northern Extended Millimetre Array
NRAO	National Radio Astronomy Observatory
PdBI	Plateau de Bure Interferometer
PILS	Protostellar Interferometric Line Survey
SCUBA	Submillimetre Common User Bolometer Array
SMA	Submillimetre Array
VLA	Very Large Array
WISE	Wide Field Infrared Explorer

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