50 Years of Brown Dwarfs

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50 Years of Brown Dwarfs
From Prediction to Discovery to Forefront of Research
Foreword

This book tells the story that contains all the excitement involved in the process of scientific discovery. Amazingly, from that perspective, brown dwarfs are not unlike pulsars, despite their being so extremely different in nearly every way. In 1934, Walter Baade and Fritz Zwicky predicted the existence of neutron stars. Five years later, in 1939, Robert Oppenheimer and George Volkoff calculated their properties, based on the still very young science of quantum mechanics, and even more recent neutron detection. Just about 30 years after Baade and Zwicky, in 1962–1963, Shiv Kumar published a series of calculations, in which he predicted the existence of substellar objects that would not be massive enough to function like stars, slowly cooling down and contracting to a steady-state supported by the quantum mechanical electron degeneracy.

In the times of Oppenheimer and Volkoff, nobody knew how would the objects so extreme as neutron stars reveal themselves to astronomers. Luckily, almost 30 years later, in 1967, Anthony Hewish and Jocelyn Bell made a serendipitous discovery of radio pulsars, which turned out to be one of the several observational manifestations of neutron stars. In the case of brown dwarfs, it was quite clear from the very start what to look for. However, the practical searches proved to be difficult and frustrating, and lasted over 30 years to finally culminate in almost simultaneous identifications of the first three brown dwarfs by Tadashi Nakajima, Ben Oppenheimer, Rafael Rebolo, Gibor Basri, and their teams, in 1995.

These developments have revealed to us the two radically different endpoints of the evolution of baryonic matter, both supported by quantum mechanical equilibria, discovered in the amazingly similar, roughly 30-year cycles, with the two Oppenheimers involved in the process. Even more incredibly, some brown dwarfs do, in fact, behave like pulsars, emitting radio pulses of coherent radiation once every rotation period!

However, these astrophysical and historical coincidences pale in the face of the most dramatic one, which is that the discovery of the first planet orbiting a normal, Sun-like star was announced by Michel Mayor and Didier Queloz at the same 1995 Cool Stars meeting in Florence, Italy, at which the first brown dwarf was uncovered by Ben Oppenheimer. It is hard not to think about the simultaneity of these two
events as of a symbolic, almost prophetic emphasis on the special role that brown dwarfs play in astrophysics by sharing properties of stars and planets.

This collection of articles is about the past, the present, and the future of the brown dwarf research seen through the eyes of experts. It looks back at the brown dwarf history with reverence, but, perhaps even more importantly, it is full of enthusiastic anticipation and excitement about future discoveries. Reading this book, especially for a newcomer to the field like myself, feels very much like watching science fiction become reality. Enjoy!

Pennsylvania, USA

Alex Wolszczan
June 2013
“Brown dwarfs don’t exist” expressed the culmination of frustration in 1994 after decades of unsuccessful searches for these cool and dim objects. Starting in the early 1960s, theorists like Hayashi, Kumar, and Nakano followed by many others had worked out the properties of brown dwarfs in great detail. Whether our universe is home to such objects, however, remained a completely open question for more than 30 years. Then in 1994/1995 everything seemed to be happening at the same time. Within only two months in the fall of 1994, Tadashi Nakajima and Ben Oppenheimer detected in a coronographic observation “something quite red” next to the red dwarf star Gliese 229, Rafael Rebolo and his team confirmed the object Teide 1 by high-resolution spectroscopy to be a late M-type brown dwarf in the Pleiades, and Gibor Basri and co-workers used the brand-new 10 m Keck telescope and detected the “brown dwarf test element” lithium in PPl 15. These news reached the public in 1995 after the data were carefully analyzed, the journal referees satisfied, and the Gliese 229B team pinned down their detection by finding “There’s methane in that thing!”

Brown dwarfs play a key role to understand both planets and stars as they are the link between these two populations. This position became even more pronounced with the recent discoveries of free-floating ultra-cool brown dwarfs with temperatures and masses in the canonical planetary regime. The cover of this book shows an artist’s view of some of the first discovered brown dwarfs (Teide 1, Gliese 229B) and of the coolest brown dwarf known to date (WISE 1828 + 2650; cf. also Fig. 1). They are compared in this illustration to our Sun, a very low-mass red dwarf star – the host star of Gliese 229B happens to be such an M dwarf – and Jupiter. Two of the characteristics of brown dwarfs can be seen in this graphic. Firstly, brown dwarfs have no substantial inner energy source, and therefore, after birth “they cool off inexorably like dying embers plucked from a fire” as phrased dramatically by Adam Burrows in 2001. Teide 1 and Gliese 229B have a similar mass, but Teide 1 is still in its adolescence and therefore slightly bigger and significantly hotter than Gliese 229B. The chart shows another peculiarity of brown dwarfs: after an early contraction phase, all brown dwarfs have roughly the same size of about one Jupiter radius regardless of their mass. This phenomenon has its reason in quantum
mechanical effects. As can be seen, Gliese 229B, WISE 1828 + 2650, and Jupiter have about the same size but span a mass range of several tenth of Jupiter masses.

The idea for a book featuring the discoverers of brown dwarfs was born during the Ringberg conference on “50 Years of Brown Dwarfs: from Theoretical Prediction to Astrophysical Studies” which took place in October 2012 (http://www.mpia.de/homes/joergens/ringberg2012.html). It was a great pleasure and honor to welcome there Shiv Kumar, Gibor Basri, Ben Oppenheimer, Rafael Rebolo, and many of the leading experts in the field of brown dwarfs. The conference took place 50 years after the submission of Kumar’s two relevant papers to a scientific journal in 1962, and the book is published 50 years after the pioneering theoretical work by Kumar, and Hayashi and Nakano went into print in 1963.

The authors of this book tell in the articles their story of the theoretical and observational discovery and characterization of brown dwarfs. This story starts with the visionary theoretical prediction of the existence of brown dwarfs, as described in a summary of the work of S. Kumar and in an article from Takenori Nakano. Before brown dwarfs were actually discovered, they were given their today’s name. Jill Tarter describes in this book how and why she introduced the term “brown
dwarf” in 1975. Then follow the thrilling stories of the first brown dwarf discoverers Rebolo, Basri, and Oppenheimer, who share their personal memories of the wild discovery days. These first detections opened the door to almost two decades of detailed characterization of brown dwarfs. Michael Cushing, who found the coolest known brown dwarf, the planetary-like Y-dwarf WISE 1828 + 2650, reviews the development of the surveys to probe for cooler and cooler brown dwarfs and of the substellar spectral sequence. Our understanding of the physics of brown dwarfs is inextricably linked with the name of Isabelle Baraffe, who reviews in her article the current state and open questions in this field.

The creation of this book involved the commitment of many people. Foremost, I would like to thank the authors. It is through their work, expertise, and openness to share their memories and thoughts that we have been able to prepare a book on brown dwarfs in which exciting science is embedded into historical and personal background stories in a wonderful and unique way. Furthermore, I am very grateful to Thomas Henning for his support during the preparation of this book. I would also like to thank Nicola Reusch, Alex Golovin, Christian Fendt, Ramon Khanna, and Markus Pössel for their support.

Heidelberg, Germany

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Viki Joergens
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