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Valerio Bozza  
Luigi Mancini  
Alessandro Sozzetti  
*Editors*

# Methods of Detecting Exoplanets

1st Advanced School on  
Exoplanetary Science

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 Springer

# Methods of Detecting Exoplanets

# Astrophysics and Space Science Library

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# Methods of Detecting Exoplanets

1st Advanced School on Exoplanetary  
Science

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*To our princesses*



# Preface

Life as we know it on Earth intrinsically needs to explore and colonize new lands with suitable conditions in order to persist and propagate. In this sense, the “search for other world” has started long before the appearance of human beings. However, while the discovery and colonization of new lands was a relatively slow process for inferior organisms, the abilities of pre-historic men were enough to create villages on the whole habitable lands on our planet in the relatively short span of one million years. With so little left to explore on Earth, philosophers and astronomers in the last five thousand years started to wonder whether stars in the sky actually hosted other planets similar to ours. In more modern times, science fiction has been able to imagine many different worlds inhabited by more or less frightening or friendly creatures. At the end of the twentieth century, with such a strong cultural background, corroborated by the first successful explorations of our nearby celestial body (the Moon), the scientific proof of the existence of planets around other stars was highly expected and sought for. In more recent years, after several economic and political crisis, with the ghosts of global warming, pollution, and overpopulation, the existence of distant habitable worlds is no longer regarded as a simple satisfaction of human curiosity. The conscience of the fragility of our Earth forces us to study other planets to better understand their evolution and what the fate of our old Earth may finally be. Furthermore, it is foreseeable that in a (still) far future, with technologies that we cannot barely imagine yet, we shall move away from Earth looking for new home-worlds. With this very distant but inevitable perspective in mind, we can regard the present time as the beginning of a new era in which humanity first sights distant lands trying to scrutinize their habitability conditions in view of possible future colonization.

Indeed, with its philosophical and political implications, there is probably no other field in modern astrophysics for which the outreach to the general audience can be so easy as in the search for exoplanets. This fact has boosted this newly born field to top ranking in the attention by the media and by the funding agencies. In spite of this fact, the techniques used to detect and characterize extrasolar planets are far from being immediately understandable to a nonspecialist. Even within the same astrophysics community, there are not many people aware of



what the words “Strehl ratio,” “caustic,” “periodogram,” and “Rossiter- McLaughlin effect” exactly mean. In order to fill this gap between an esoteric planet-finder community and the average physics and astrophysics student, we have gathered four top scientists, representative of the four most successful detection methods known today, in the enchanting cornice of Vietri sul Mare, in the Amalfi Coast. The lectures given by these renown scientists cover the direct imaging method, transits, radial velocities, and microlensing. Each of these methods has its own merits and lacks in investigating planetary systems.

Transits and radial velocities have produced the greater return in terms of number of exoplanets, also thanks to the first space mission (*Kepler*) fully devoted to exoplanets discovery. When combined together, these two techniques can yield the best characterization of the planets, including mass, radius, density, and orbital parameters. In some cases, it has been even possible to infer the chemical components of the atmospheres of transiting planets through fine spectroscopic techniques. However, these methods are best suited for planets very close to the parent star and only recently have started to graze the so-called habitable zone.

Microlensing can probe the frequency of planets orbiting at intermediate distances from the parent star, just beyond the so-called snow line, where giant planets are believed to form. It is also the only method to find planets that are very far from our Earth or even in other galaxies. It is finally the only way to find isolated planets, ejected from the system where they were born. Unfortunately, microlensing events are non-repeatable and do not allow further measurements to refine the planetary parameters.

Direct imaging is probably the most rewarding technique since it makes the planets shine out of the glare of their parent star. Very refined adaptive optics and coronagraphic techniques are needed to achieve such spectacular results. In some cases it is possible to follow the orbits of the planets and study their spectra. Of course, only planets very far from the star and still hot enough can be directly detected in this way.

These very short statements of the four methods are sufficient to understand how they complement each other as in a big puzzle where every piece is necessary for a full understanding of the global architecture of planetary systems. By probing the planetary frequency at different distances and in different conditions, these techniques are helping astrophysicists to reconstruct the scenarios of planetary formation and to give a robust scientific answer to the questions regarding the frequency of potentially habitable worlds. More difficult is to answer the question about the existence of forms of extraterrestrial life, because the conditions for habitability are always temporary and may not last long enough to allow the development of advanced creatures.

Nevertheless, a great effort is being lavished on the construction of new facilities, both on ground and in space, with the main aim of investigating these problems. It is no surprise that the search and characterization of exoplanets appears in the main goals of ALMA, E-ELT, JWST, and most of the spacecraft missions that are being designed by the main space agencies. With the increasing attention toward the search for exoplanets, it is then imperative to prepare the future generation of scientists to

take over from the present researchers, with the hope that they will be able to further expand our knowledge with innovative and enlightening ideas, stemming from the roots of our secular and instinctive spirit of exploration. In this respect, we hope that this book, by unveiling the tricks of the trade of planet detection to a wider community, will make a good service to science and humanity in general.

May 25, 2015

Valerio Bozza  
Luigi Mancini  
Alessandro Sozzetti



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Participants to the 1st Advanced School on Exoplanetary Science, Vietri sul Mare, May 25, 2015



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