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Detection of Point Sources in Maps of the Cosmic Microwave Background Radiation by means of Optimal Filters

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by

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Prologue

When we observe the sky with the most advanced instruments operating at microwave frequencies, the photons that we see were originated in very different regions in the universe. Most of them come from our own Galaxy (diffuse synchrotron, free-free and dust emission), that can be very bright at some frequencies. Then, some of the photons come from very distant galaxies and clusters of galaxies, and, finally, a fraction will have their origin in the relic radiation of the Big Bang, known as the Cosmic Microwave Background Radiation. This radiation was discovered in the second half of the XXth century and, since then, it has become the most important tool to probe the early universe and a definite evidence of the Big Bang. Therefore, it is of great importance to study it in detail, because it is giving us information of the universe when it was only 375.000 years old, that is, approximately 14.000 million years ago. But, this radiation is contaminated by other components previously enumerated, and the separation of the different emissions in a satisfactory way is still an open problem. It is also important to note that not all the contamination comes from outside the Earth. If our experiment is located in the surface of the planet, or even in a high-altitude balloon, our own atmosphere will introduce additional contamination. Regardless of its location on the earth or in the space, the instrument used for the observation will also contribute to the observed signal with a noise.

The purpose of this thesis is to explore different techniques based on linear filters to detect and separate one of the contaminants, the contribution to the observed signal of distant radio and infrared galaxies. These galaxies are known as "extragalactic point sources" because, for the angular resolution of the typical experiments in microwave frequencies, they appear as point-like unresolved objects. In Chaper 2 we will study the performance of a family of matched filters when detecting point sources, where we allow the scale of the filter to be modified and where we introduce a Neyman-Pearson test to define the region of acceptance. In Chapter 3, we will consider a new one-dimensional linear filter, the *Biparametric Scale-Adaptive Filter (BSAF)*, that has two parameters that can be optimised to maximise the number of real detections for a fixed number of spurious detections, used in conjuction with a Neyman-Pearson test. In Chapter 4, we will extend the BSAF to two dimensions, and compare it with the Mexican Hat Wavelet. In Chaper 5, we will explore a new technique that combines lineal and quadratic fusion of images with linear filters, testing it with realistic simulations of one of the Planck satellite channels. In Chapter 6, we will study in detail the performance of three filters, the Matched filter and two members of the Mexican Hat wavelet in realistic simulations of the nine channels of Planck. To conclude, in Chapter 7, we will use the second member of the Mexican Hat Family to do a non-blind study in the five frequencies of WMAP of a complete sample of 2491 sources observed at 5 GHz, producing a catalogue of 932 objetcs detected above 3σ and a catalogue of 380 objects observed above 5σ.

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