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A New Coronal Loop Identification Method Based on Phase Congruency[†] [⋆]

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Abstract We have tried to apply the enhanced image by a phase congruency method to the identification of coronal loop structures, and proposed a new coronal loop identification method (simply called the PCB method) based on the enhanced image by the phase congruency method. On account of the smooth morphological variation in the direction along a coronal loop, the propelling direction of coronal loop identification is restricted in a small range for improving the identified result. Beyond that, inspired by the structural characteristics of coronal loops, we firstly suggest that both the variation of propelling direction in the identification process and the magnitude of phase congruency at the identified point are simultaneously taken as the criterion to terminate the identification. Finally, several coronal images are used for testing our coronal loop identification method, and the result indicates that the enhanced image by the phase congruency method is really suitable for the coronal loop identification, and the coronal loop structures identified by the PCB method have simultaneously a good completeness and a high accuracy, hence, the PCB method is a set of practical and feasible method of automated coronal loop identification.

Key words Sun: corona—Techniques: image processing—Methods: observational

1. INTRODUCTION

As the main radiation sources of X-rays in the solar corona, coronal loops are considered as the bright loop-like structures formed by the thermal plasmas confined by magnetic fields[1].

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Hence, the coronal loop structures well reflect the structures of magnetic field in the solar corona, in the mean while they are also the energy channels between the solar photosphere and the solar corona. Coronal loops generally exist in the coronal layer, and can be detected by a great amount of satellites in space, the study on coronal loops is useful for us to well understand the properties of coronal plasmas [2,3]. Actually, the basic properties and evolution rules of coronal loops have not yet been understood very well sofar[4]. Firstly, the classification criterions of various coronal loops have not been established yet. In the earlier period, Vaiana et al.[5] took the morphological characteristics of coronal loops as the criterions, to classify coronal loops into the bright-point loops, active-region loops, and large-scale loops. With the enrichment of observational data in multiple wavebands, a more detailed study on the coronal temperature and density becomes possible. Due to the obviously different properties of temperature and density in the coronal loops with different temperatures, for example, the temperatures at the different positions of a warm coronal loop are basically identical, but they are different in a hot coronal loop, hence, another classification method based on the temperature was proposed, to classify coronal loops into the cold coronal loop[6], warm coronal loop, and hot coronal loop[7] three kinds according to the difference of temperature. The different temperature and density properties of the coronal loops with different temperatures imply that these coronal loops may be produced by different physical mechanisms[8]. However, the basic problems about the practical physical mechanisms to produce the various kinds of coronal loops and whether they can transform each other have not been solved very well[9]. In addition, because it is very difficult to directly measure the coronal magnetic field, the study on the geometric shapes of coronal loops has an important reference meaning for exploring the coronal magnetic structure and the magnetic reconnection in the corona. Generally, the coronal loops appear as a symmetrical loop-like structure[10], especially, the cross section of a coronal loop has only a very small variation along the direction of this coronal loop[11], this is different from the predicted result by the force-free field assumption that is commonly used by us, the predicted cross section of magnetic structures as extrapolated from the force-free field assumption will have an expansion of several times. Based on this problem, some different models of coronal loops were proposed, but there is no any model which can explain all the problems. It is noteworthy that the result observed by us is actually a projective result, it has a definite difficulty to study the real shape of a coronal loop, while the launch of the Solar Terrestrial Relations Observatory (STEREO)[12] has provided the solar observational data in multiple viewing angles, which make us possible to reconstruct better a 3D coronal loop structure[13]. Besides, all the problems of plasma motion inside coronal loops[14−16] and the propagation of MHD waves in coronal loops[17−19] etc. have not been understood very well. A more detailed study and in-depth learning absolutely need a great number of samples, this requires us to make a vast of accurate identification and extraction on the coronal loops.

Since the coronal loop structures were discovered, many research groups have made