INFERENCE OF SOLAR SUBSURFACE FLOWS BY TIME-DISTANCE HELIOSEISMOLOGY

A DISSERTATION
SUBMITTED TO THE DEPARTMENT OF PHYSICS
AND THE COMMITTEE ON GRADUATE STUDIES
OF STANFORD UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

Junwei Zhao

March 2004

I certify that I have read this dissertation and that, in my opinion, it is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy.

Philip H. Scherrer
(Principal Advisor)

I certify that I have read this dissertation and that, in my opinion, it is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy.

Vahé Petrosian

I certify that I have read this dissertation and that, in my opinion, it is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy.

Alexander G. Kosovichev

Approved for the University Committee on Graduate Studies.

Abstract

The inference of plasma flow fields inside the convection zone of the Sun is of great importance. On the small scales, this helps us to understand the structure and dynamics of sunspots and supergranulation, and the connections between subsurface flows of active regions and coronal activity. On the large scales, it helps us to understand solar magnetic cycles and the generation and decay of solar magnetic fields. In this thesis, the flow fields in the upper convection zone are inferred on both large and small scales by employing time-distance helioseismology.

A detailed description of time-distance measurements is presented, together with the derivation of the ray-approximation kernels that are used in data inversion. Two different inversion techniques,the LSQR algorithm and Multi-Channel Deconvolution, are developed and tested to infer the subsurface sound-speed variations and three-dimensional flow fields. The subsurface flow field of a sunspot is investigated in detail, converging flows and downdrafts are found below the sunspot's surface. These flows are believed to play an important role in keeping the sunspot stable. Subsurface vortical flows found under a fast-rotating sunspot may imply that part of the magnetic helicity and energy to power solar flares and CMEs is built up under the solar surface. A statistical study of numerous solar active regions reveals that the sign of subsurface kinetic helicity of active regions has a slight hemispheric preference.

On the large scales, latitudinal zonal flows, meridional flows and vorticity distribution are derived for seven solar rotations selected from years 1996 to 2002 from SOHO/MDI Dynamics data, covering the period from solar minimum to maximum. The zonal flows display mixed faster and slower rotational bands, known as torsional oscillation. The residual meridional flows, after the meridional flow of the minimum

year is subtracted from the flows of each following year, display a converging flow pattern toward the active zones in both hemispheres. The global vorticity distribution is largely linear with latitude, mainly resulting from the solar differential rotation. In addition, a linear relation between the rotation rate of the magnetized plasma and its magnetic field strength is found: the stronger the magnetic field, the faster the plasma rotates.

Acknowledgment

I feel grateful for the generosity, kindness and patience of many people towards me during these years of my study at Stanford University. First of all, I thank my adviser Phil Scherrer, who continues to offer me various advice, understanding and support. I thank Sasha Kosovichev and Tom Duvall, whose help made the studies inside this dissertation possible, whose knowledge, suggestions and insights were incorporated into this dissertation. I also thank Aaron Birch, Rick Bogart, Doug Braun, Sebastien Couvidat, Laurent Gizon, Rasmus Larsen, Charlie Lindsey, Yang Liu, Jesper Schou and those I may forget to mention, whose frequent or occasional discussions with me helped me progress in my study, more or less. I thank Keh-Cheng Chu and Brian Roberts, who are always ready and skillful to help me solve all kinds of computer problems. Additionally, I thank Jeneen Sommers, whose kind help facilitated my life at Wilcox Solar Observatory.

On the other hand, I thank my family, without whose support I could hardly have made through my study. I thank my parents, who always support and understand me, and forgive me being so far away from their sides for so many years. At last but not least, I thank my wife Ting, whose love and patience that I can never ask for more, for supporting me through all these years. The life at Stanford, including both happiness and sadness, both comfort and hardship, both laughter and depression, will be cherished as beautiful lifelong memories for both of us.

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