Measuring Surface Effects by Time-Distance Helioseismology

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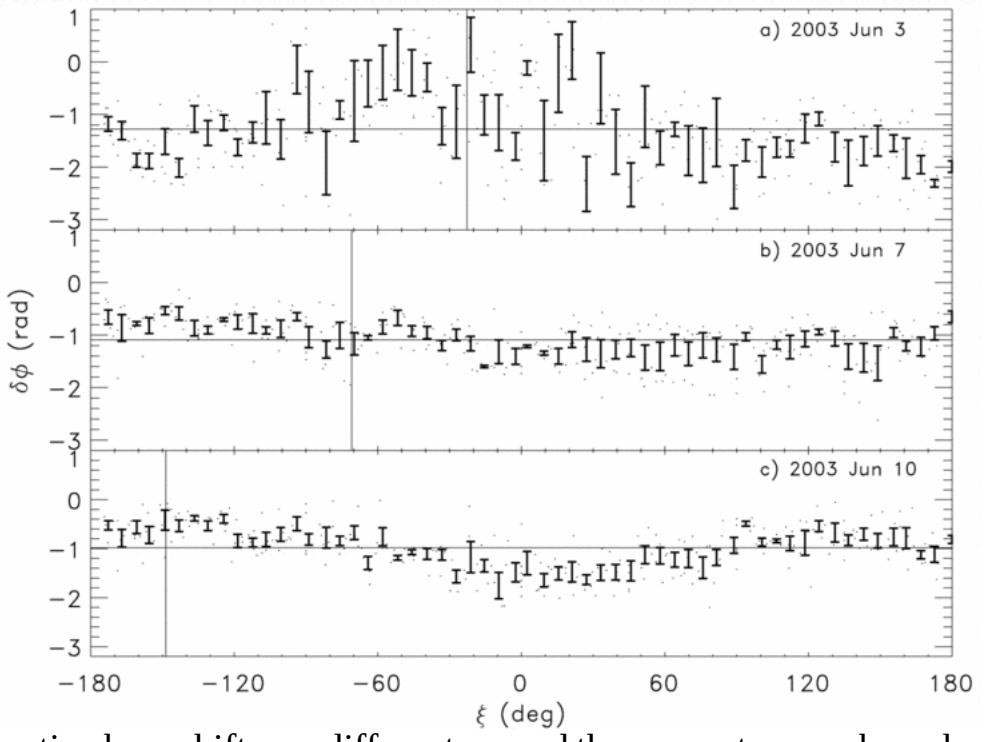
A Few Observational Surface Effects

- “Inclined Magnetic Field Effect” (Schunker et al., 2005), observed when the magnetic field line has an angle with the line-of-sight direction;
- “Showerglass Effect” (Lindsey & Braun, 2005): the presence of magnetic field would shift the phase of acoustic waves;
- For time-distance measurement, outgoing travel time plus ingoing travel time may not be equal to the double-skip travel time through the sunspot area (Braun, 1997).

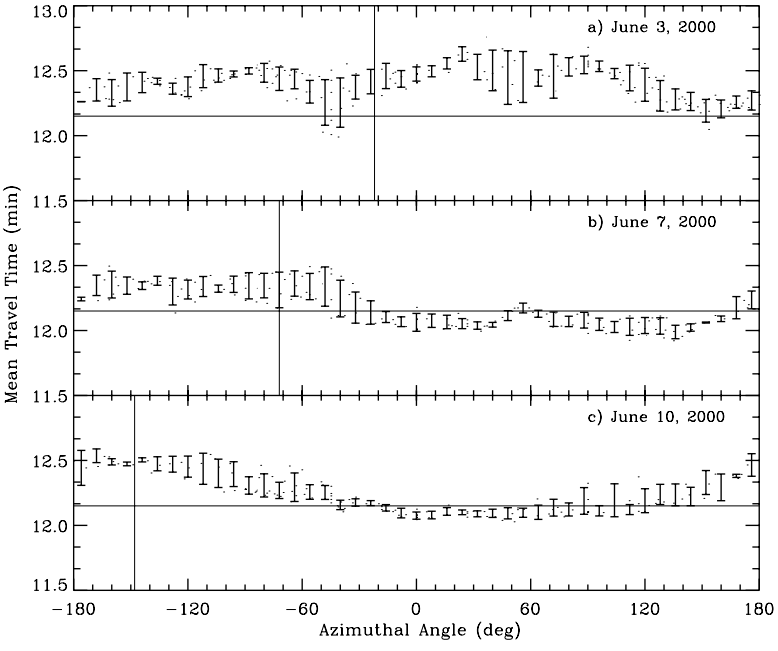
Inclined Magnetic Field Effect from Helioseismic Holography

(Schunker et al., 2005, ApJ Letters)



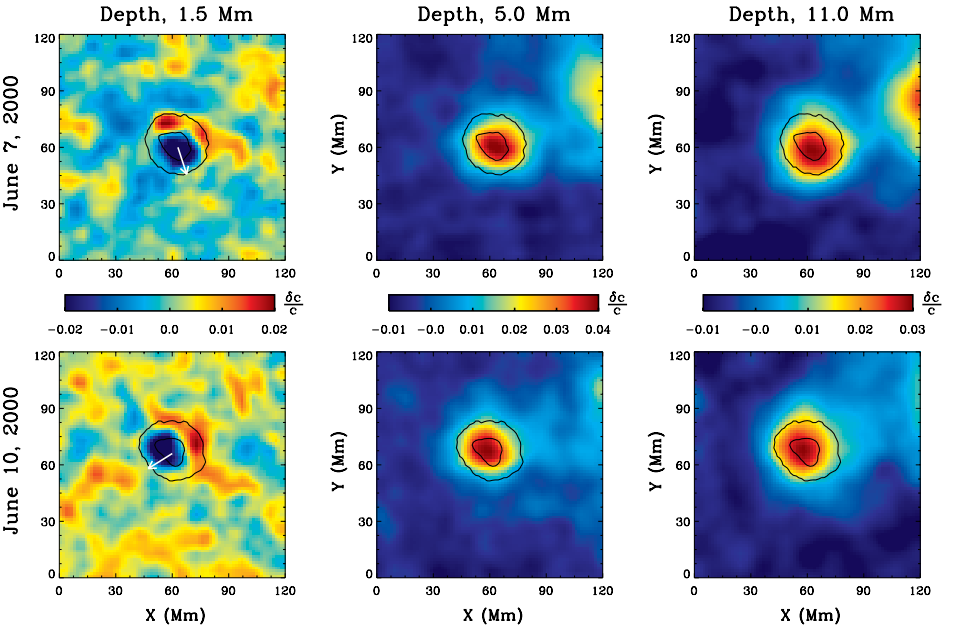
The acoustic phase shifts are different around the sunspot penumbra when viewing from different angles.

Inclined Magnetic Field Effect from Time-Distance



Time-distance measurement confirms the existence of this observational effect, but with a significant smaller magnitude.

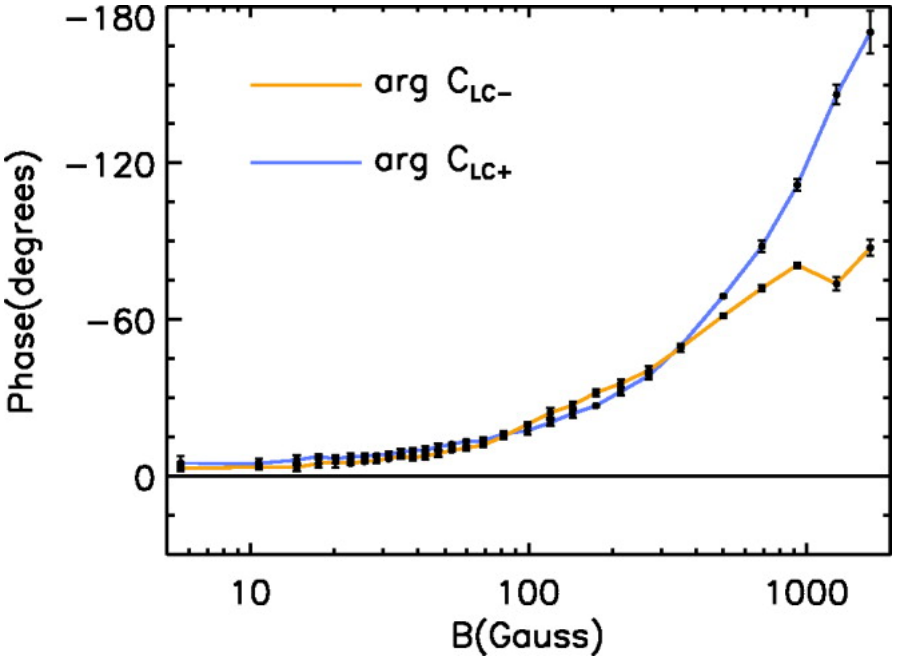
Time-Distance Inversions with Inclined Magnetic Field



Inversions of time-distance measurements show that this observational effect is only limited to the surface layers, and for the deeper interior, structures are left unchanged by this effect. But it is worthwhile further studies.

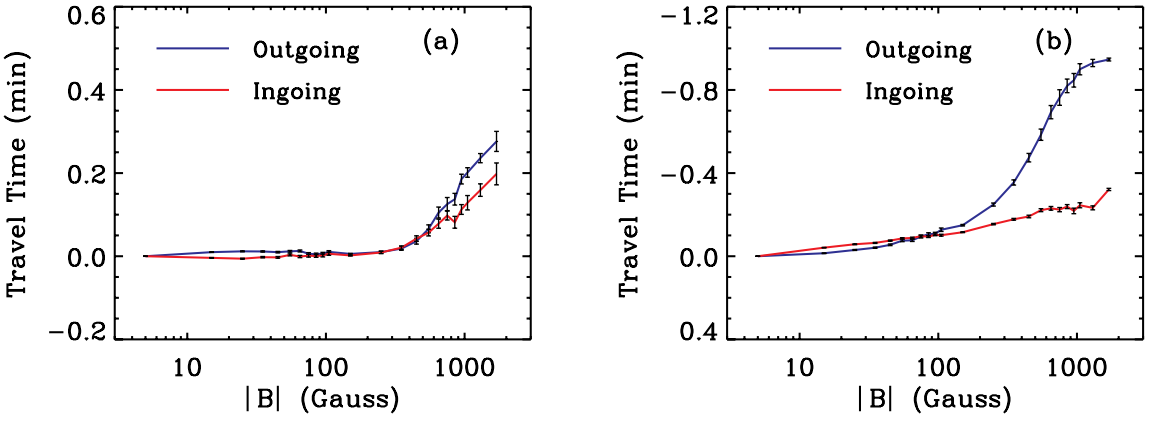
Showerglass Effect from Helioseismic Holography

(Lindsey & Braun, 2005, ApJ)



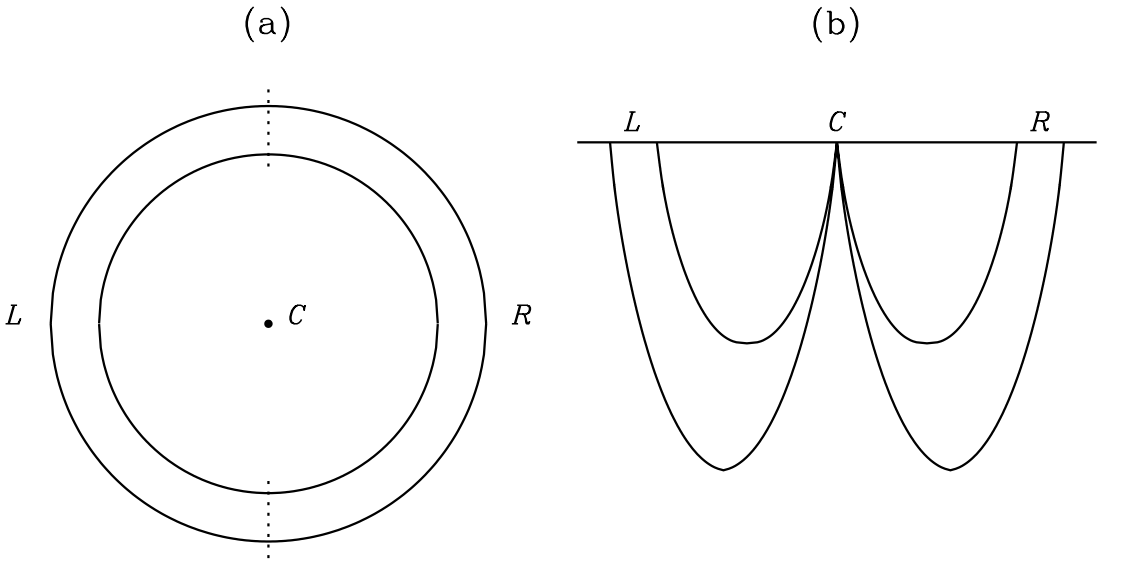
The local control correlation egression phase shift exhibits asymmtry comparing with the ingression phase shift when magnetic field strength is high.

‘Showerglass Effect’ from Time-Distance Measurement



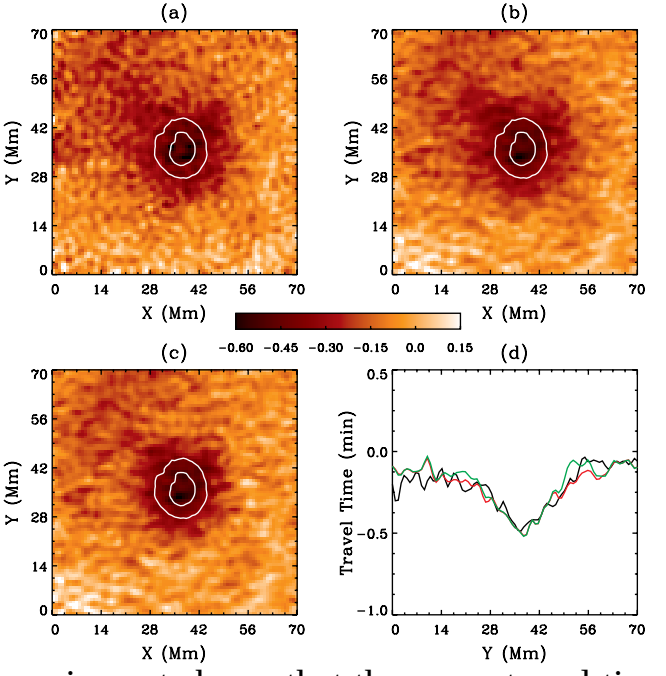
Using different annulus radii, time-distance measurements give out very different asymmetry between ingoing and outgoing travel times. These asymmetries are significantly smaller than those observed by helioseismic holography, and interpreted as caused by flow fields.

Double-Skip Experiment: Measurement Scheme



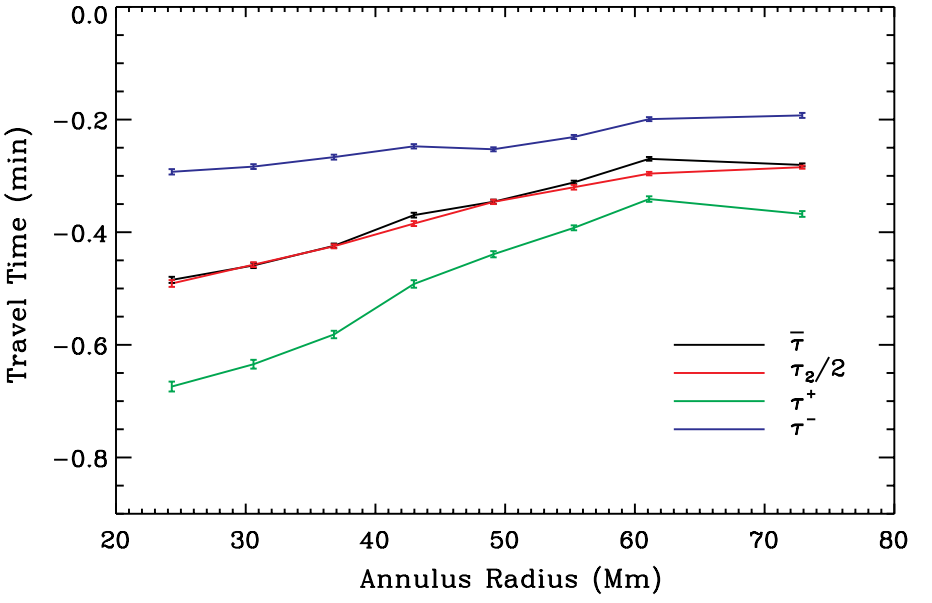
The traditional time-distance is to measure acoustic travel times by cross-correlating signals from the central point with signals averaged from its surrounding annulus. The double-skip experiment is to measure travel times by cross-correlating signals from the left semi-annulus and signals from the right semi-annulus.

Double-Skip Experiment: Results (I)



Our double-skip experiement shows that the mean travel times measured from the traditional time-distance measurement agree very well with the double-skip measurements that do not use the signals from the central point, which is located inside the sunspot.

Double-Skip Experiment: Results (ii)



For different annulus radii, the double-skip experiment agree very well with the traditional measurements. This indicates the oscillation signals inside the sunspots are useful in computing local helioseismological analysis. This does not agree with what Doug Braun showed in his Tuesday talk.

What Do All These Imply to HMI

- It is true that the "inclined magnetic field effect" exist. No matter how significant it is to helioseismic holography/time-distance, we have to find a way to correct for this effect, analytically or empirically.
- Though our recent analysis showed that the showerglass is not a significant effect to time-distance, the debate will continue on how to understand the asymmetry between the ingoing and outgoing travel times, or egression and ingression phase shifts.
- Clearly, numerical simulations may help us understand what are really going on inside the sunspot, and how to interpret our observations, by both helioseismic holography and time-distance.
- The double-skip experiment is very encouraging to show us that the oscillation signals inside the sunspots are useful for local helioseismological analysis. Some collaborative comparison will be carried out soon with Doug Braun to understand what caused the differences.