***S**olar **A**ctivity **FAR**side **I**nvestigation (SAFARI) Science*

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Abstract

This presentation describes what kind of heliospheric problems can be solved with simultaneous observations of spatially separated sound signals on the Sun. It is based on previously published work.

Science Goals

SAFARI substantially increases the understanding of basic processes that cause solar variability

- *The prime science goal is to quantify where solar variability originates, how it emerges to the solar surface and evolves there*

The goal will be achieved by

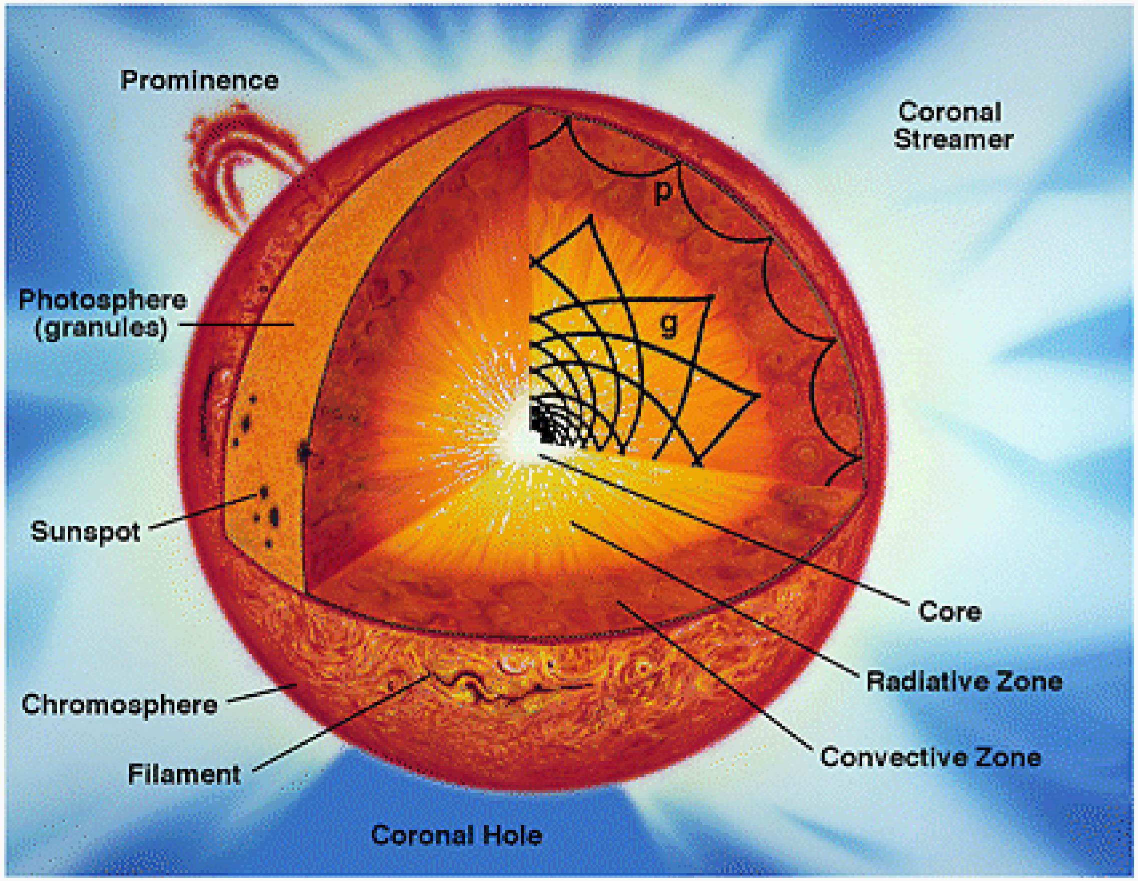
- *obtaining time-distant characteristics of naturally excited sound waves propagating through the interior of the Sun - a 3-D viewing*

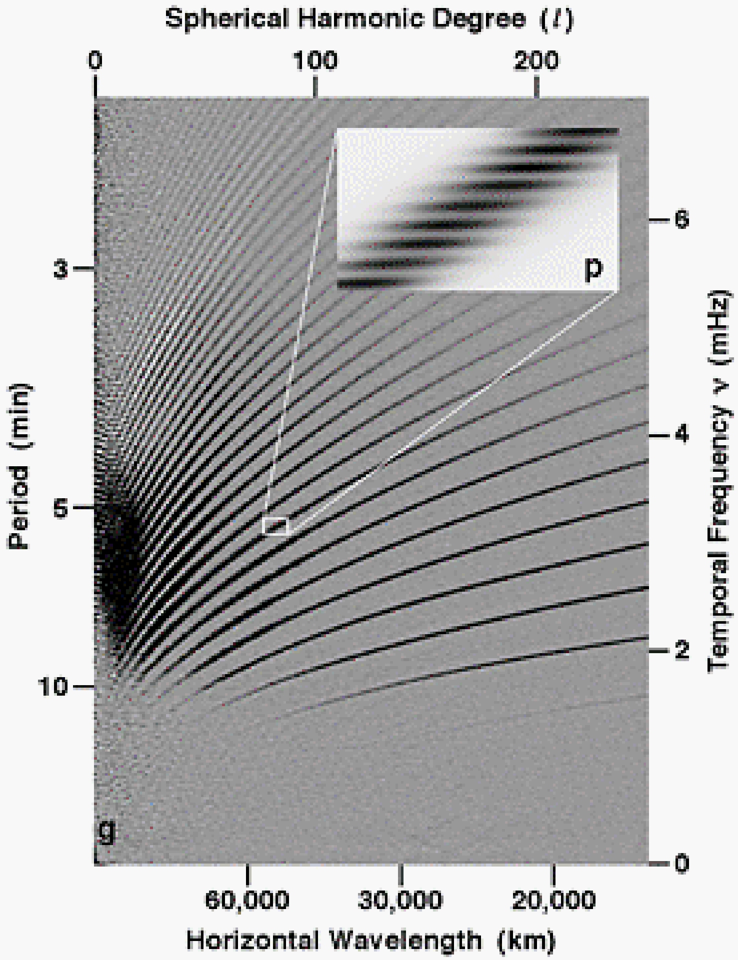
- *by measuring magnetic fields on the solar surface.*

The data received will uncover thermal, fluid and magnetic conditions at the base of the convection zone where the dynamo operates.

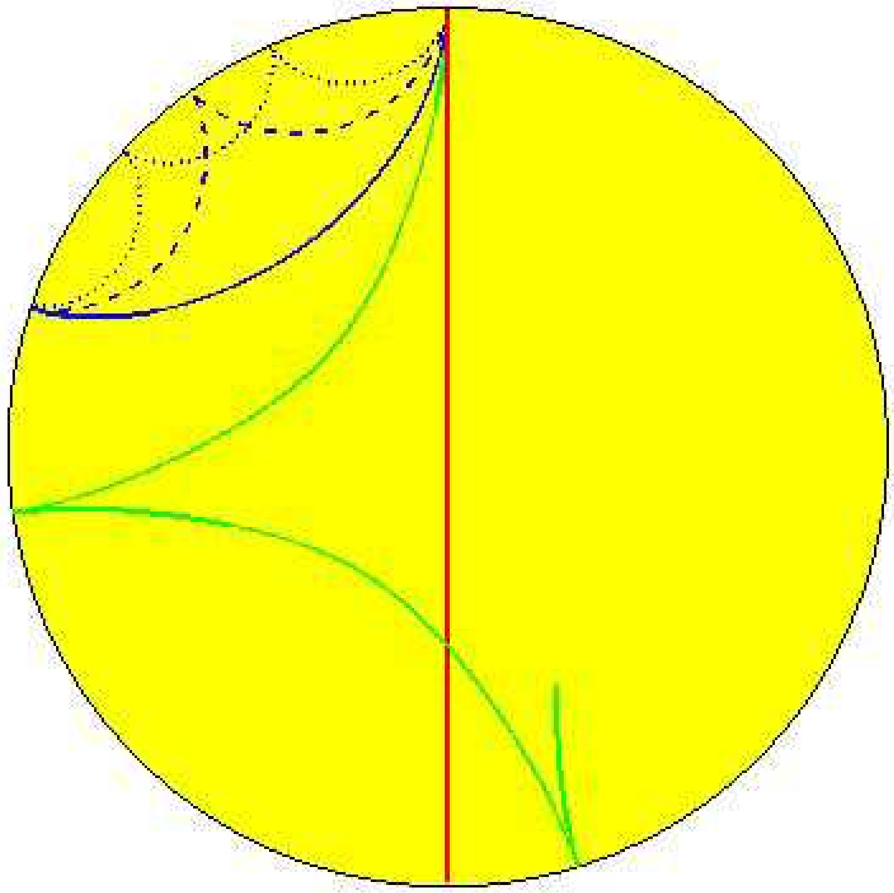
SAFARI will contribute greatly to providing a scientific basis for predicting space weather.

The Sun and its Sounds



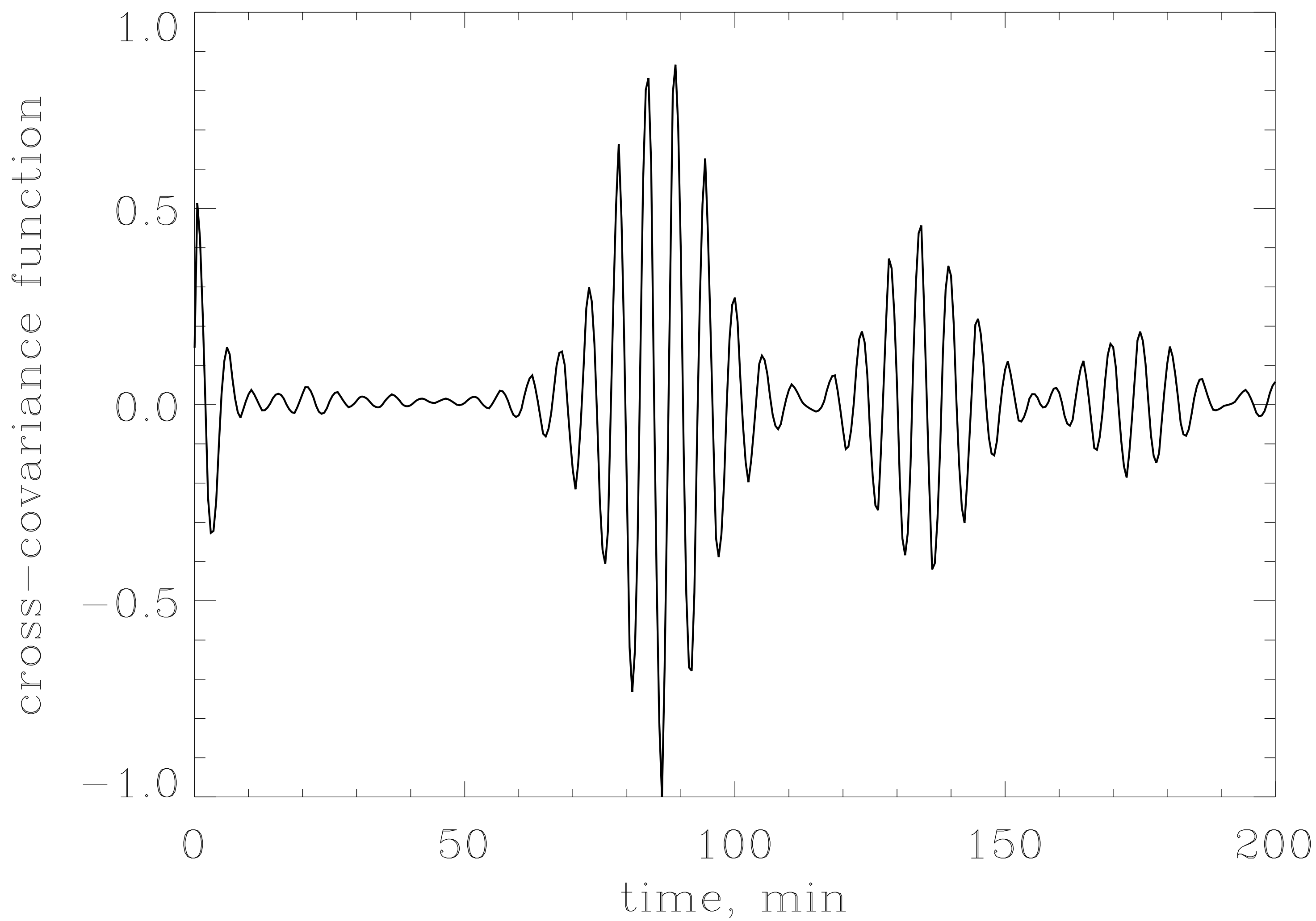


Helio Tomography (stereoscopic helioseismology)



Three-dimensional helioseismic views of the convection zone where solar activity originates are reconstructed by correlating SAFARI and Earth-side Doppler signals from acoustic wave packets traversing deep solar layers.

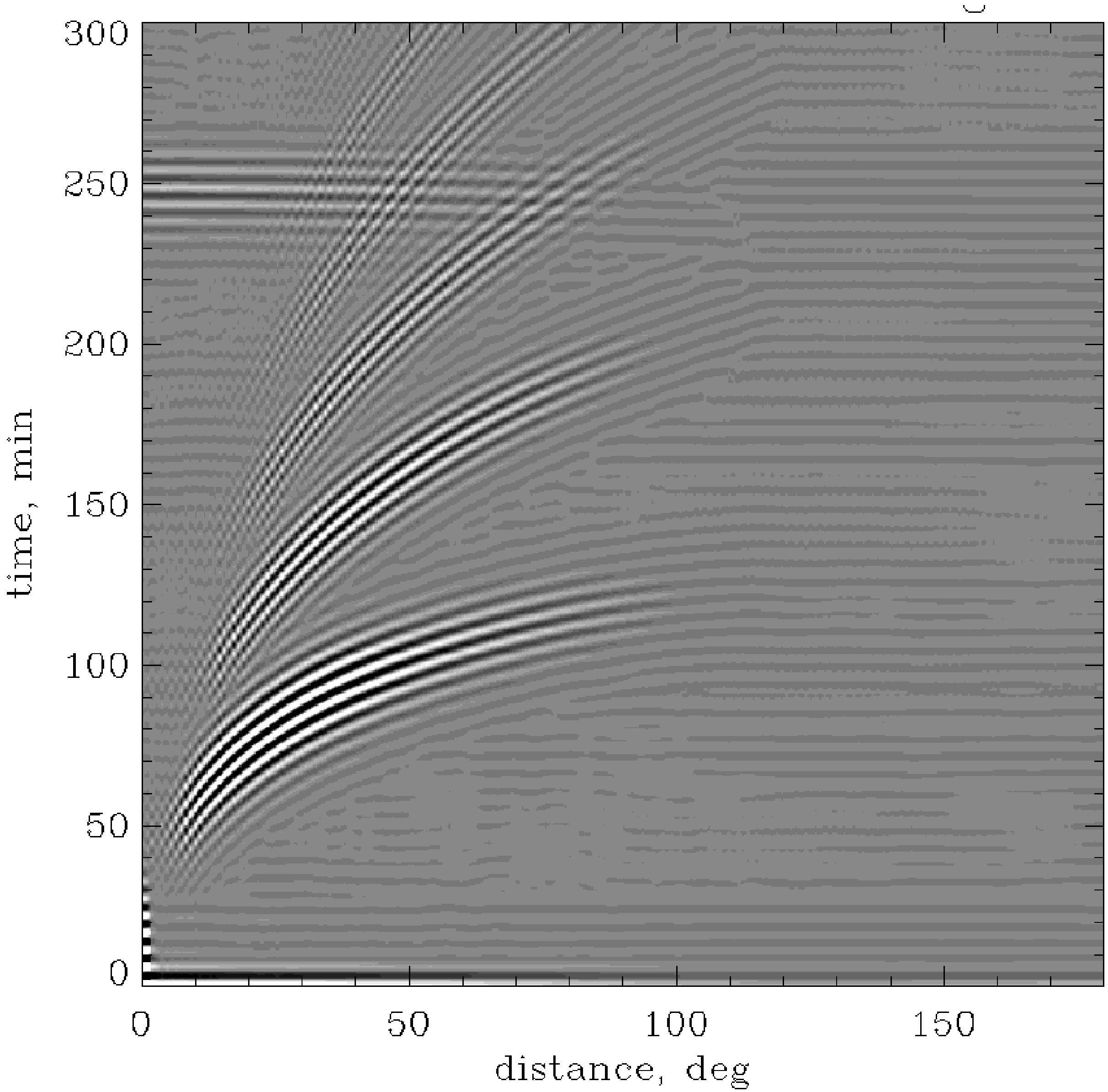
Cross-Correlation



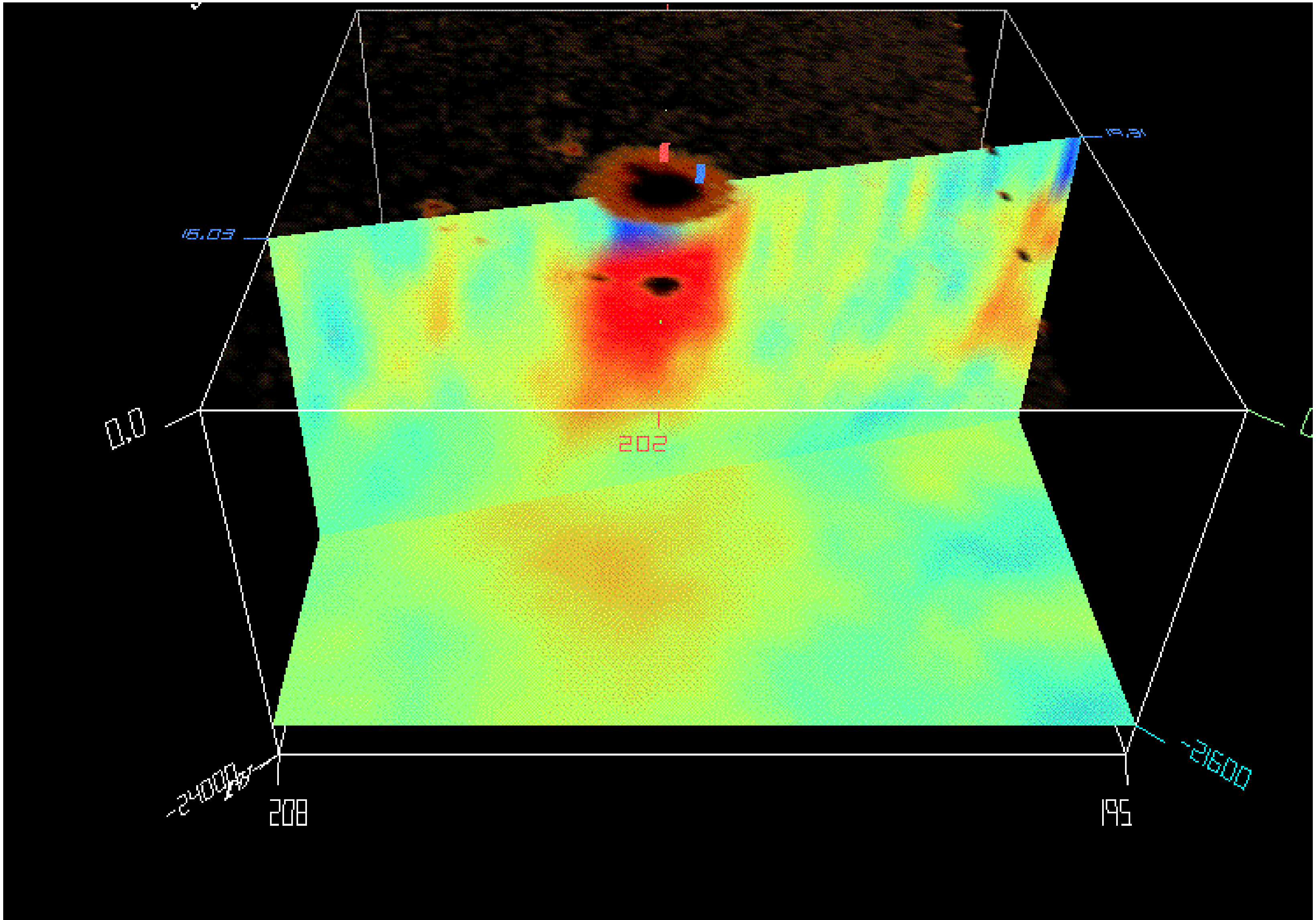
$$<v(t,\mathbf{r})v(t+\tau,r+\Delta)> \approx <v_0^2> \cos(\omega_0(\tau-\Delta/v))e^{-[\delta\omega(\tau-\Delta/u]2}$$

Kosovichev and Duvall (1997)

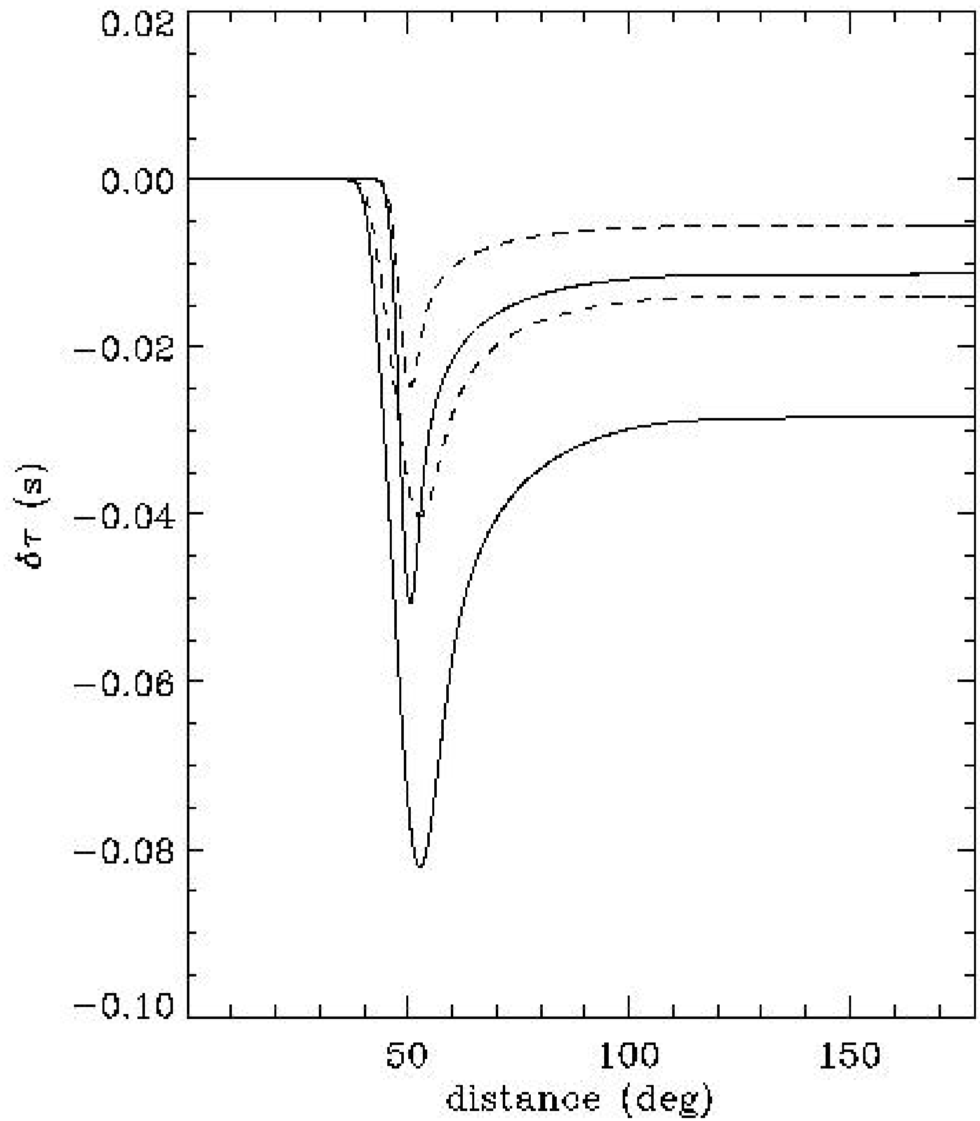
Cross-Correlation (SOHO)



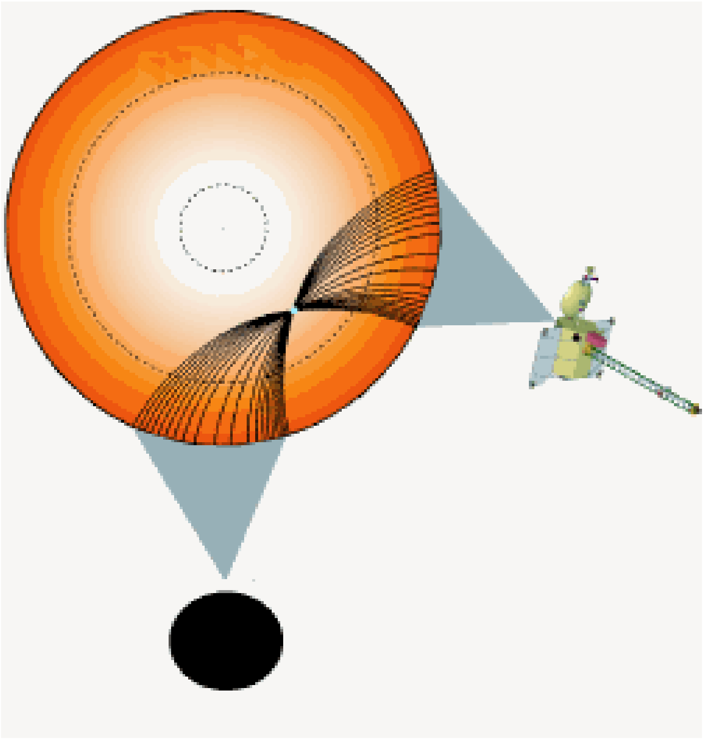
What is Under a Sunspot? (MDI)

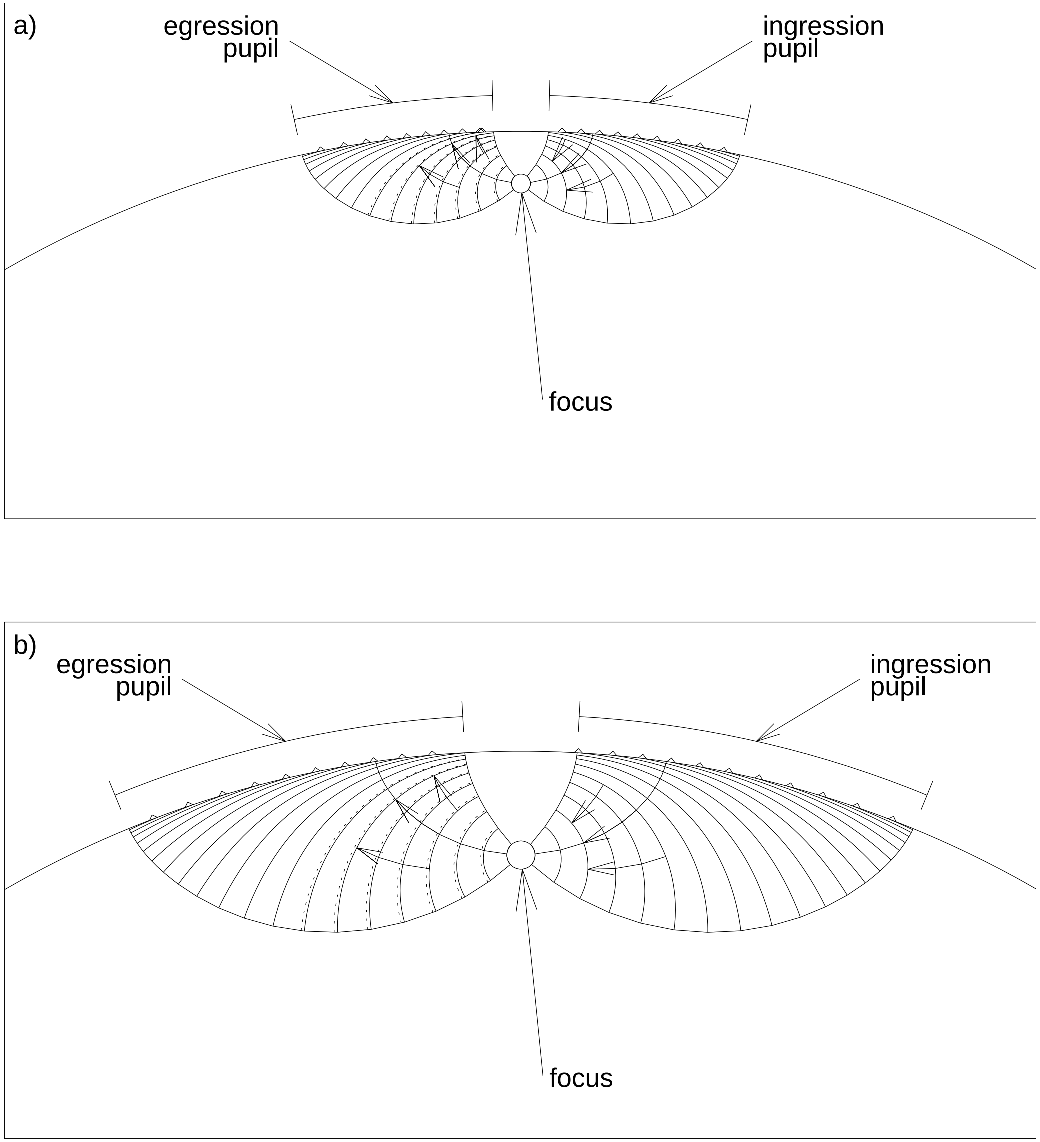


Travel Time at Tachocline



Helio Holography





$$\tau = (2\pi\nu_0)^{-1} \arg \int_{\Delta\nu} \langle V_-(\nu, \mathbf{r}) V_+^*(\nu, \mathbf{r}) \rangle d\nu$$

Lindsey and Braun (2000)

Measurement Requirements

$$\delta\tau = \delta\phi/2\pi\nu \approx 1/\,2\pi\nu(N_s N_\nu)$$ - error in time delay

$$N_\nu = \delta\nu T, \quad N_s = S/\lambda^2,$$

$\delta\nu$ is bandwidth, T is integration time, S is area of resolution pupil,
$\lambda = c/\nu$ determines diffraction–limited resolution size.

For $1/\nu = 150$s, i.e. $\lambda = 75$ Mm at tachocline ($c = 0.5$ Mm/s). $S = 60^o \times 60^o$,
bandwidth 2mHz, and T = 1day, $\delta\tau = 0.2$ s.

Repeat for 100 days: $(100)^{1/2} = 10$.
Multiple bounces: $n = 3$ (Chou and Serebryanskiy, 2002)

$$\delta\tau = 0.01 \text{ s}$$

Detection of Flows and Fields

$$\delta\tau_v = -2\int \mathbf{v} d\mathbf{s}/c^2$$

$$\delta\tau_v/\tau \approx O(v/c)$$

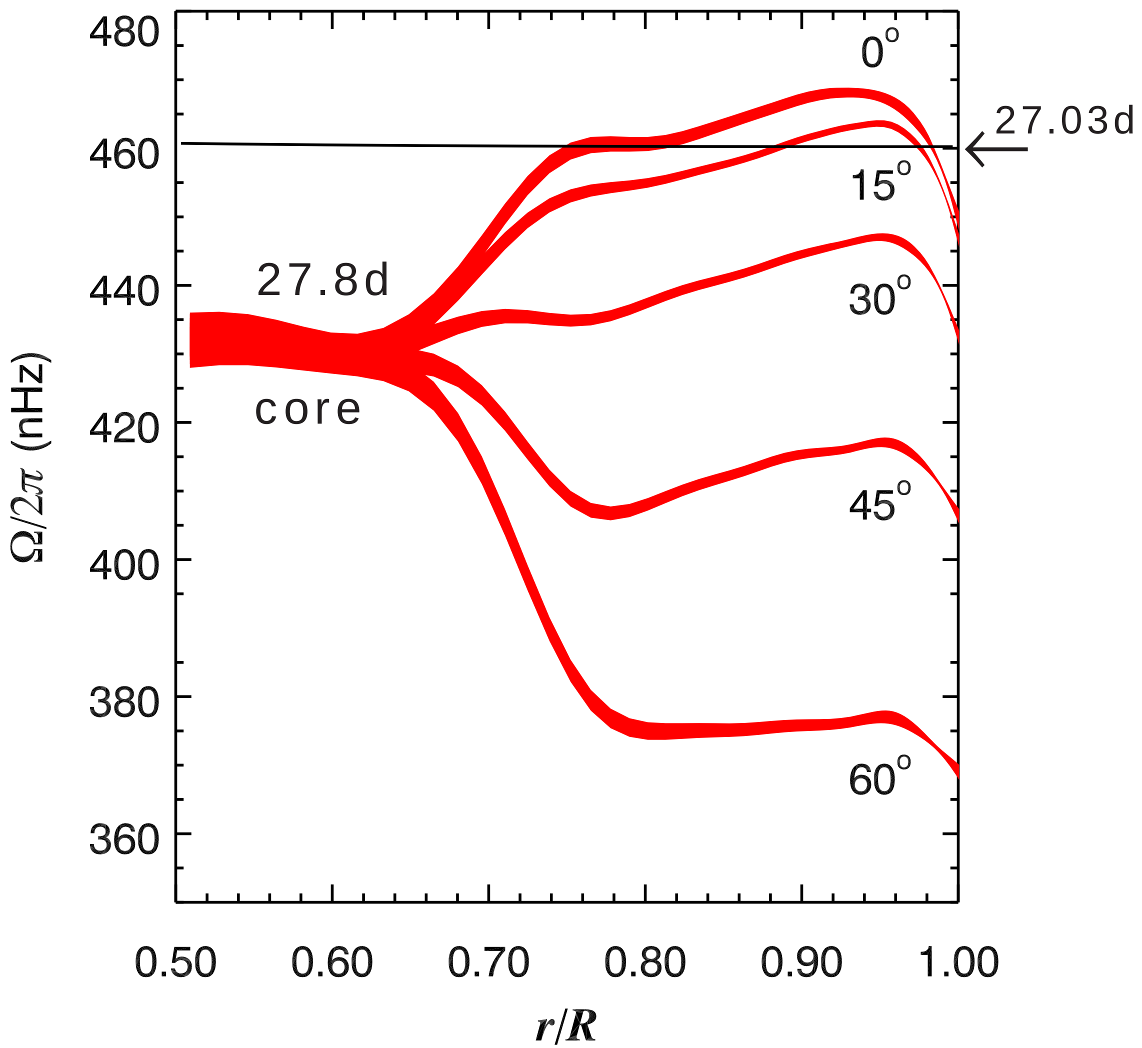
With accuracy 0.01 s, we can detect

$v \approx 0.1 m/s\ (R/ds) \approx 1 m/s$ near tachocline

$$\delta\tau_B \approx (1/\nu)(B^2/8\pi\rho c^2)(\delta s/R) \approx 2.5\times10^{-3}(B/10^6 G)$$

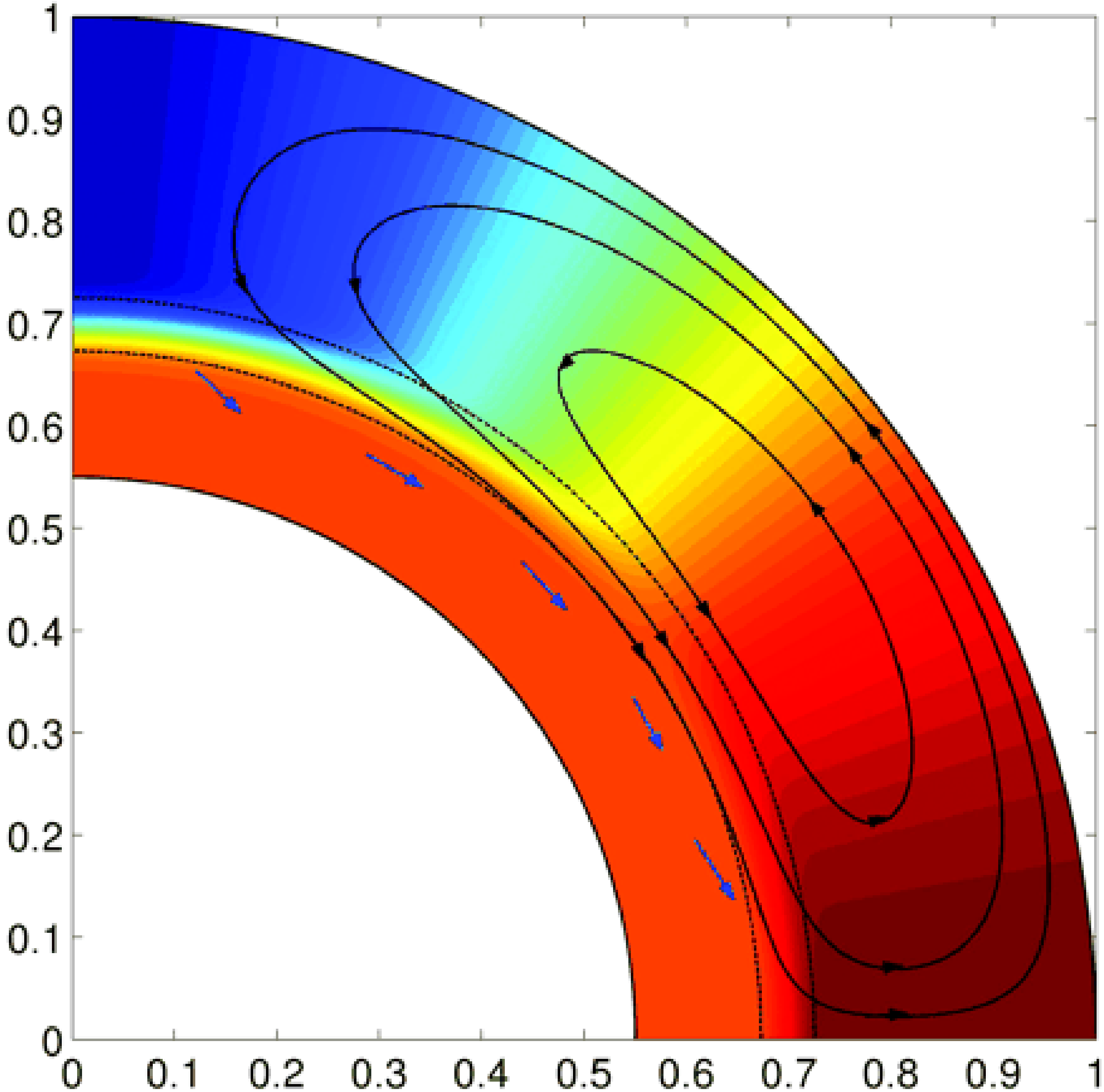
With $\delta\tau_B = 0.01s$ only $2\times10^6 G$ is directly measurable

Differential Rotation



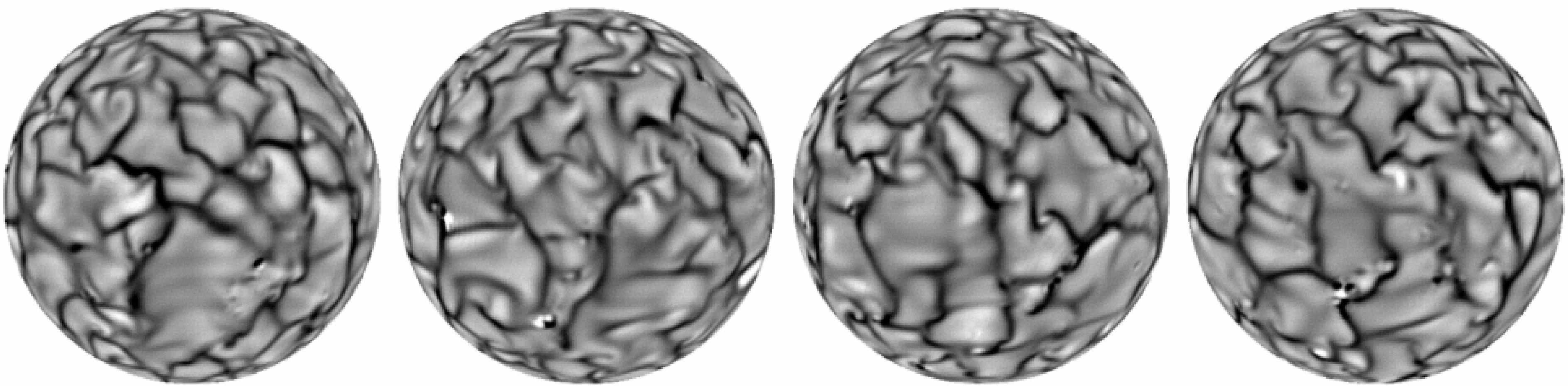
Howe et al.(2000)

Meridional Circulation



Nandy&Choudhuri(02)

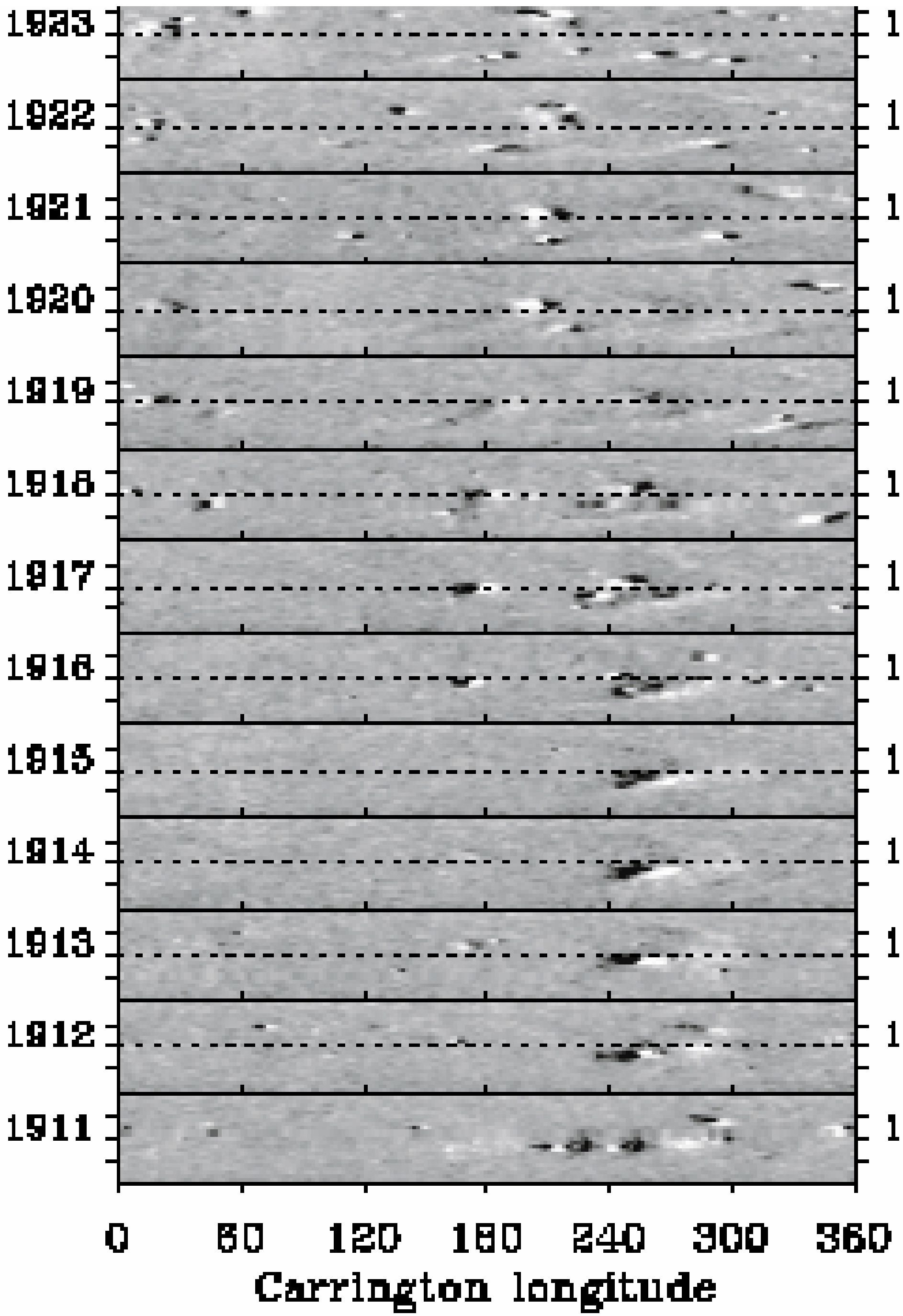
Giant Convection Cells



$\Delta t = 0$ $\Delta t = 0.33$ P $\Delta t = 0.67$ P $\Delta t = 1.0$ P

Miesch, Toomre et al.(2000)

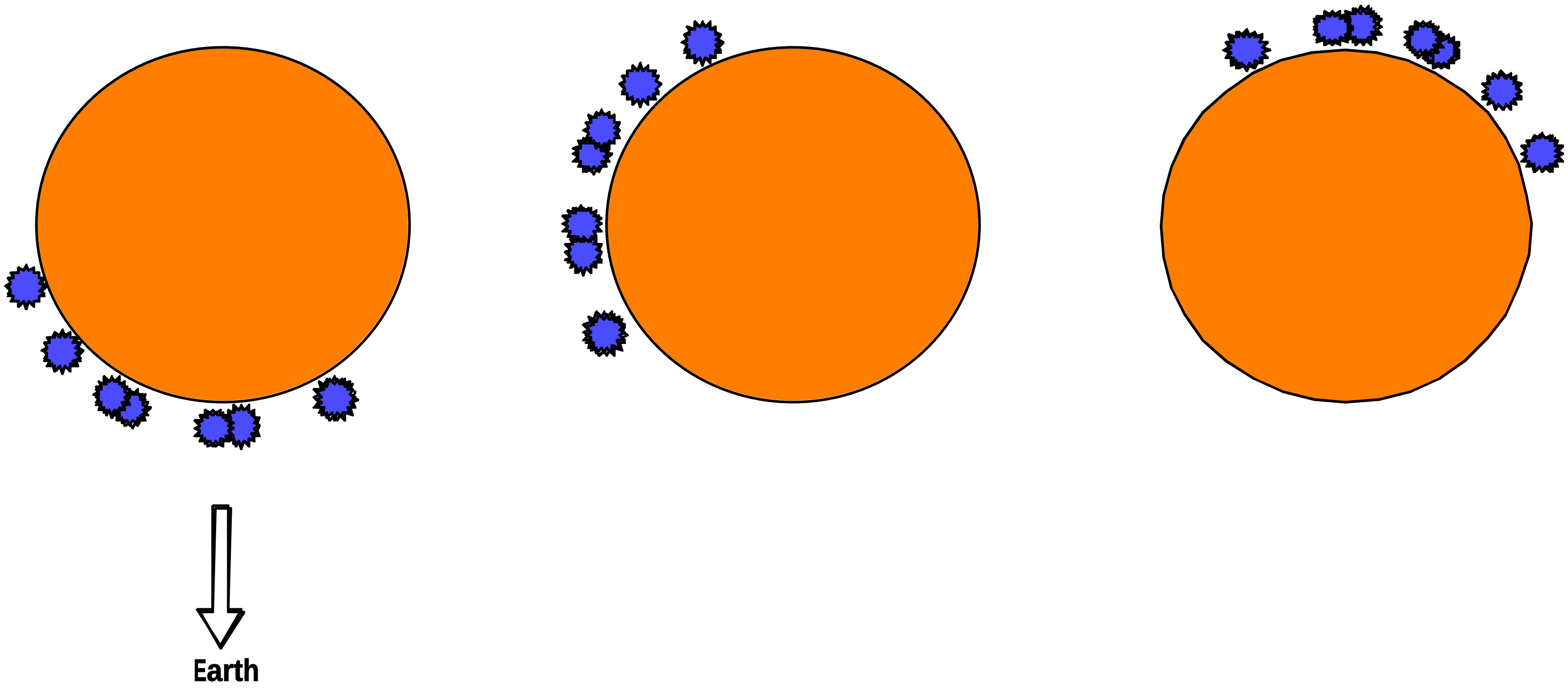
Preferred Longitudes



Preferred Longitudes at the transition from cycle 22 to 23

-Benevolenskaya, Hoeksema, Kosovichev, Scherrer (1999)

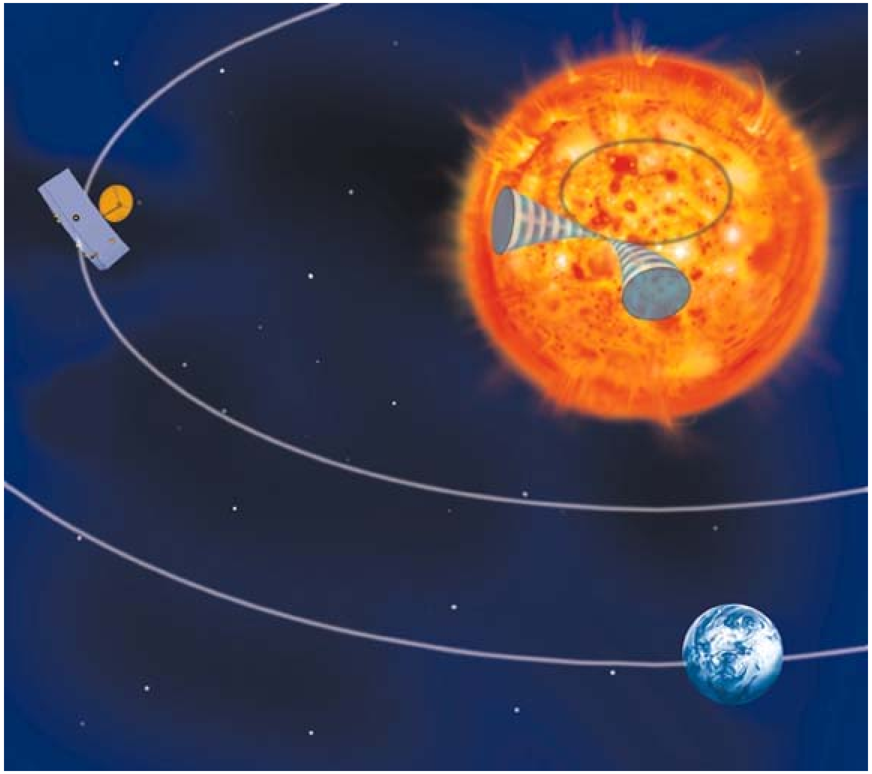
Predicting SEPs on Day/Week Scale



observed, onset 1 week before 2 weeks before

Major Observed Solar Energetic Particles, 10 to 60 MeV

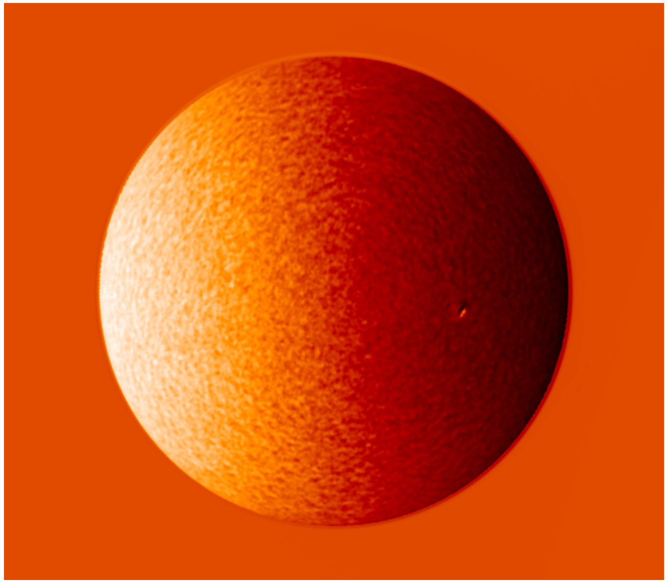
Science Implementation
Mission Design



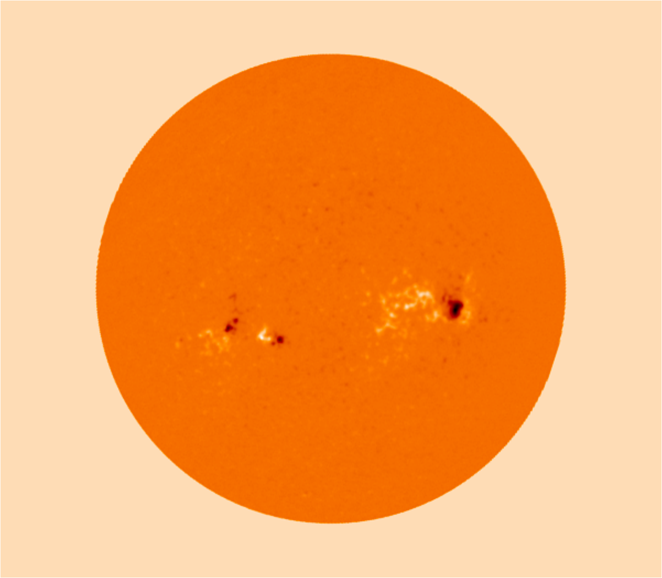
SAFARI orbits the Sun in a circular orbit ahead of the Earth (at 0.72 AU, or 1 AU) carrying a Doppler-magnetic imager.

For 1.6 years, it images the Sun over a wide range of Earth-Sun-SAFARI angles.

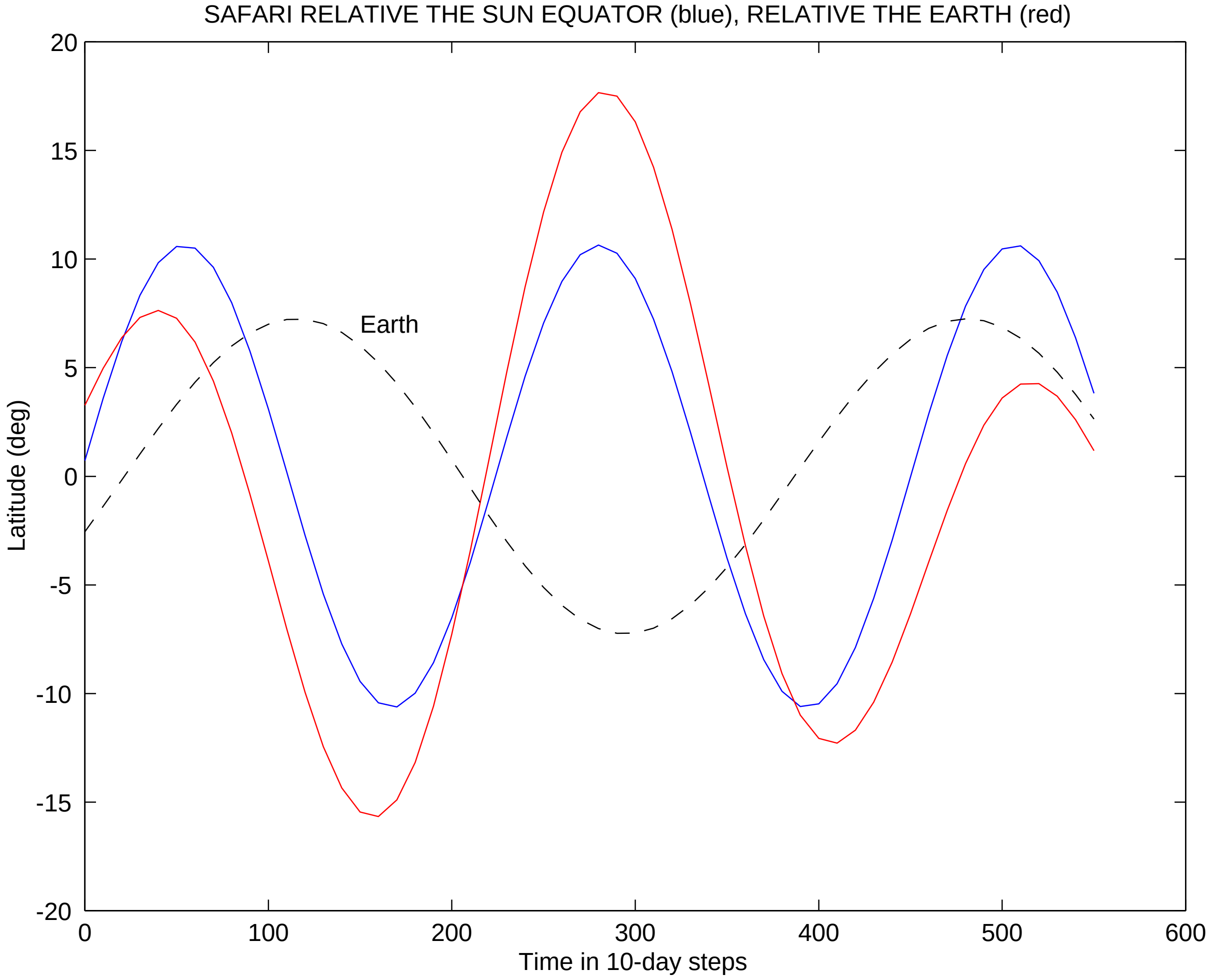
Science Implementation
Doppler/magnetograph



A magneto-optical filter (MOF) based Doppler/magnetograph provides simultaneous Doppler and magnetic images



SAFARI Over the Solar Equator



This allows observations of near polar solar regions.