

The Science for Plan -A  
Why dynamo in Solar-C plan-A ?

T. Yokoyama  
(Univ. Tokyo)

## What is our standpoint now ?

We have learned (been learning) much about the **plasma dynamic phenomena strongly coupled with the magnetic evolutions on the surface** of the Sun by Yohkoh, Hinode, other spacecrafts', and ground-based observations.

The **origin and the maintenance of the magnetic fields** might be one of the most interesting issues which we should address **next**.

What is the background for the appearance of the dynamo as an important subject of Solar-C/a ?

Theoretical pictures of the dynamo have been established based on the helioseismic observations in this a few decades. The roles of the tachocline and the meridional flow is becoming more and more important. (e.g. Charbonneau 2005)

The simulation studies have made clearer the mechanisms for sustaining the differential rotation and meridional flows. (e.g. Rempel 2005, Miesch et al. 2005)

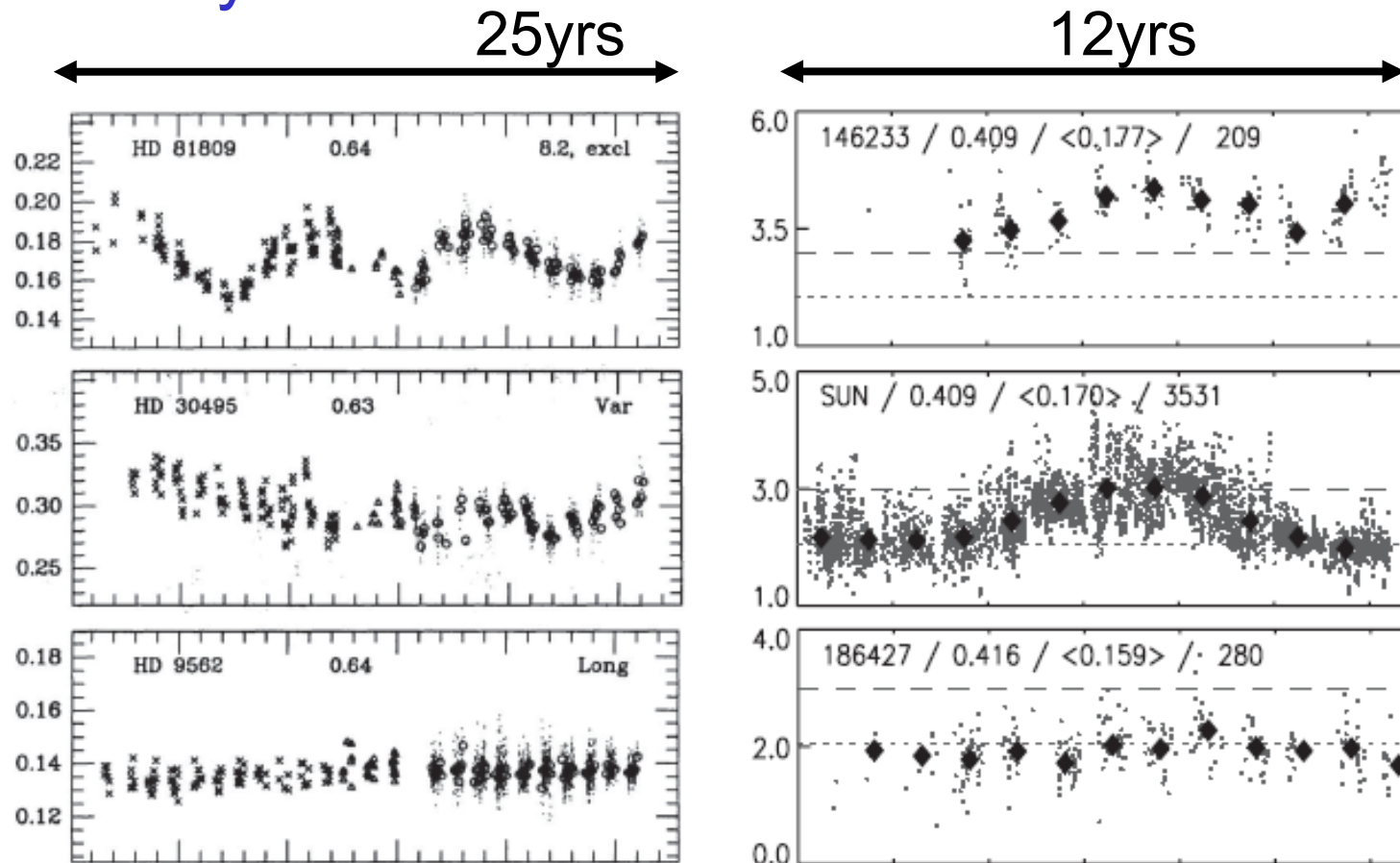
The local helioseismological technique gave more new information on the local structures of the interior. (e.g. Zhao et al. 2001)

## from Astrophysical point of view

### Dynamos in astrophysical objects

- **Stellar dynamos** :
- **Accretion disk dynamo**: The magnetic field plays a role to sustain a turbulent angular momentum transport (through the MRI) leading to the accretion of the matter into the central object, such as a black hole.
- **Magnetar**: It is believed that the several orders of magnitude stronger magnetic field of magnetars beyond the ordinary pulsars are generated by the dynamo effect during its generation at the supernova period.
- Gamma ray bursts, galactic dynamo etc.

# Stellar cycle



**Figure 9:** Left: Representative time series from the MWO HK Project, illustrating periodically variable (top), irregular (center), and flat (bottom) chromospheric activity, expressed in terms of the dimensionless  $S$  index, running from 1966–1991 (from Baliunas *et al.*, 1995). Right: Analogous series from the Lowell Observatory SSS project, showing the flux-calibrated time series for the Sun (top), the cycling solar twin 18 Scorpii = HD 146233 (center), and the relatively inactive solar analog 16 Cygni B = HD 186427. Quantities in brackets at the top of each panel are the  $S$  values derived from the spectra. The time span of the SSS series is 1994–2006 (from Hall *et al.*, 2007b).

# The important issues in solar physics

- Flares, CMEs
  - The "standard picture" is established based on many S/Cs' observations including Yohkoh. (Particle acceleration issue is still a remained homework...)
- Coronal heating
  - This should be solved by Hinode.
- Dynamo
  - Much progress has been achieved by SOHO etc. but still open.

Issues related with the dynamo to be addressed  
in Solar-C/a

## Note

Solar dynamo theory is still "fragile" (by A. Title?).

– (following is my personal interpretation ...)

There does not exist a theoretical perfect model which describes all of the observational aspects. So we should not expect that "some key observations" may solve the dynamo issues.

However, **any information on polar observations by plan-A may greatly advance the dynamo science.**



## Issues to be addressed in Solar-C/a (1/2)

### Meridional flow

- What is the flow pattern/speed near the poles ? Especially the latitude of the flow sink is of much interest.
- Solar cycle variability.
- Flows in the interior. What is the depth of the return flow ? Is it a single-cell flow ?

### Differential rotation

- Omega distribution in the poles
- $\Delta T$  as a function of latitude: Source of the non-Taylor-Proudman rotation

## Issues to be addressed in Solar-C/a (2/2)

### Polar surface magnetism

- Cycle polar-field reversal
- magnetic flux budget
- magnetic submergence ?

### Flux tube in the overshoot layer

- Does it anyway exist ? ( $10^{-5}$  anomaly)
- Where in latitude ? Do they show variability ?
- What is the structure, tubes, sheets or else ?

### Rotating flow in a troidal tube

- 200m/s flow is expected to keep the dynamical equilibrium
- in the emerging phase on the way up to the surface

## Conclusion

Solar dynamo is our frontier !  
This is the reason why we should go.