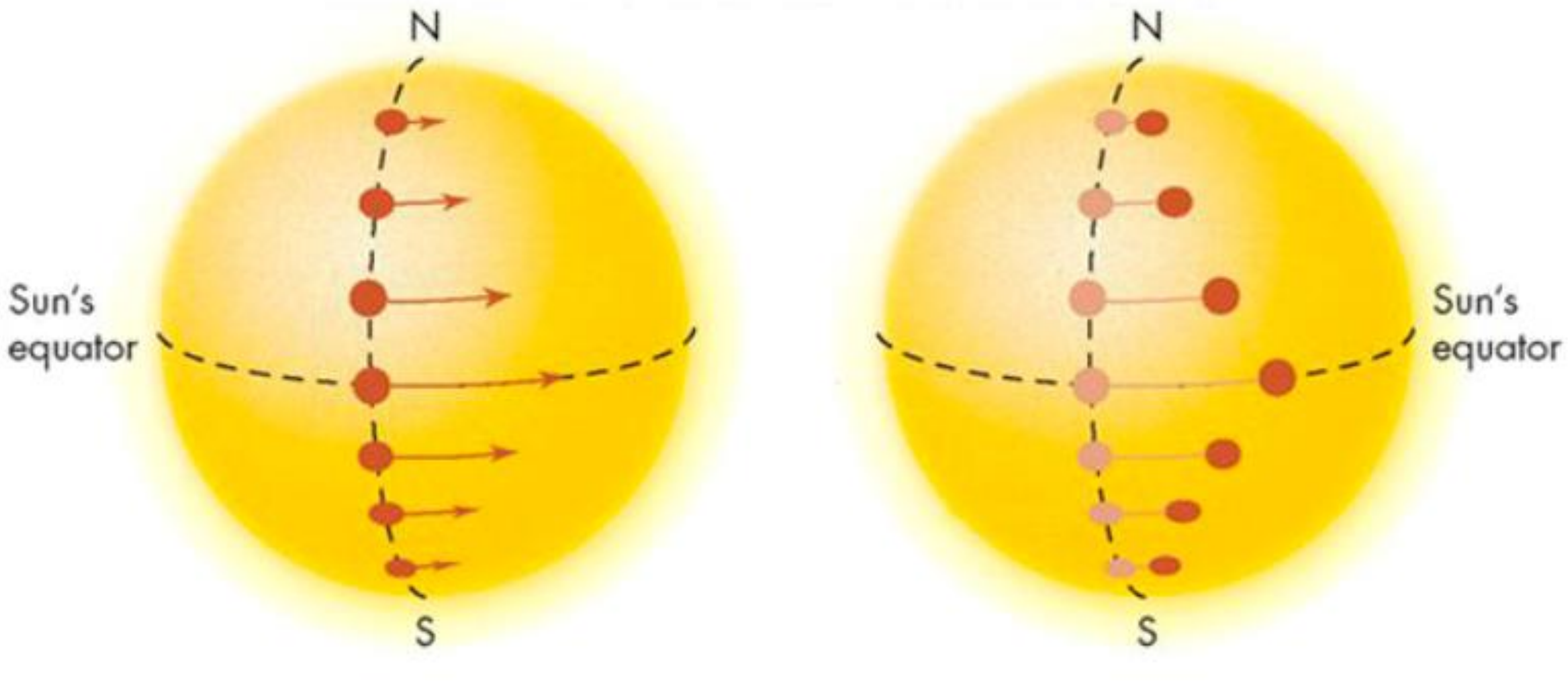
Вращение активных областей на уровне фотосферы Солнца

А.С. КУЦЕНКО, В.И. АБРАМЕНКО, Д.В. ЛИТВИШКО

КРЫМСКАЯ АСТРОФИЗИЧЕСКАЯ ОБСЕРВАТОРИЯ РАН

П. НАУЧНЫЙ



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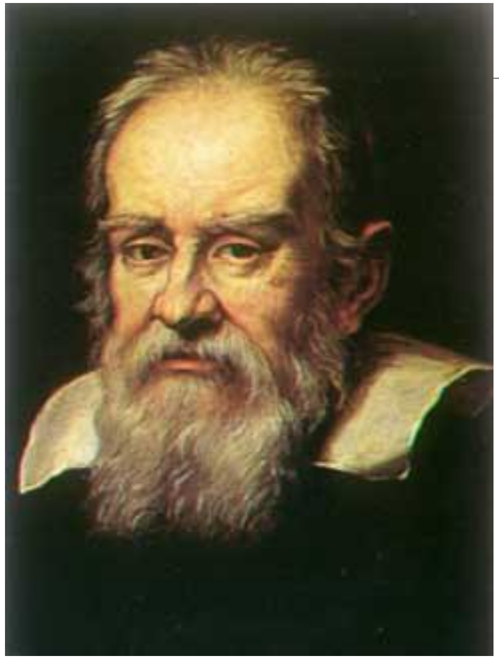

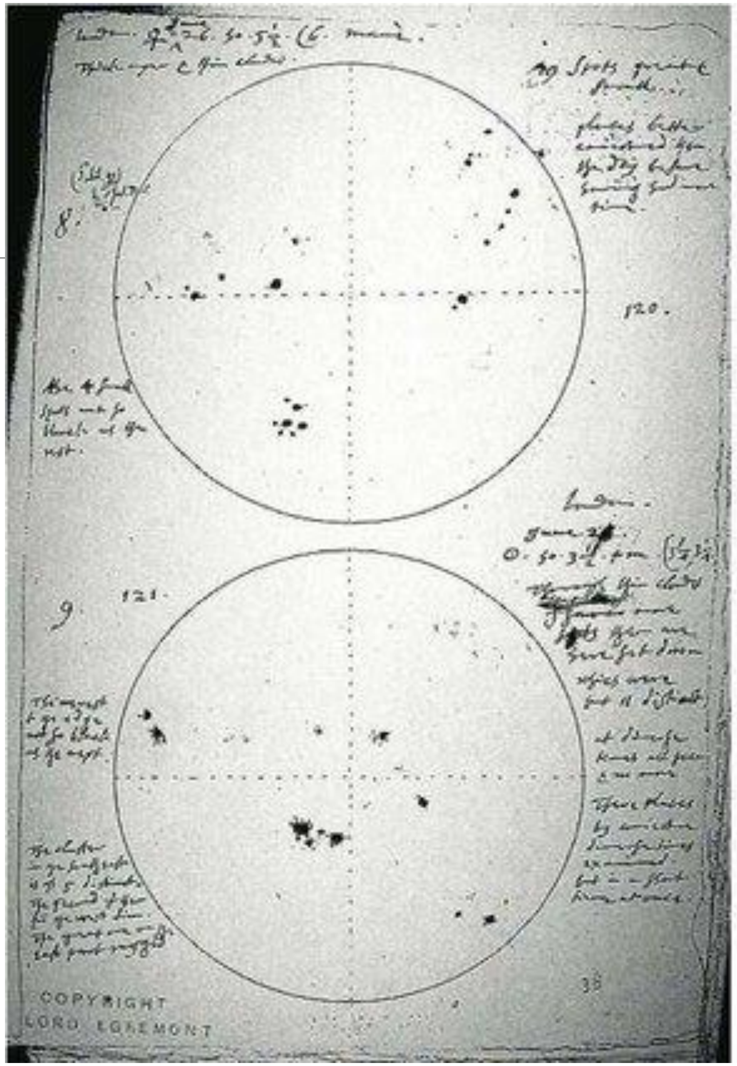
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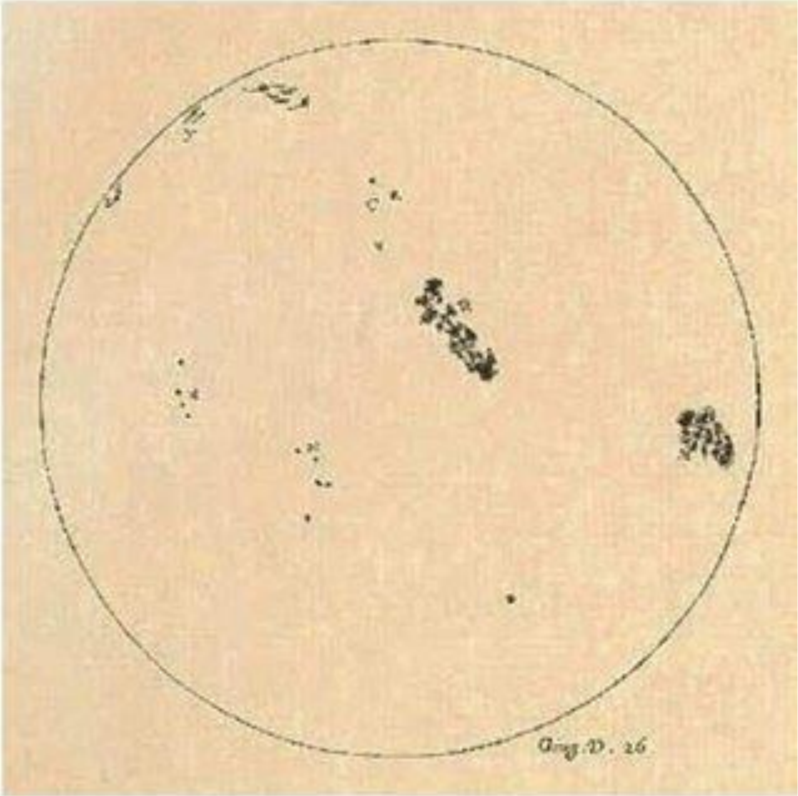

Более 150 лет надёжных наблюдений солнечных пятен

- ✓Группы пятен на поверхности вращаются быстрее плазмы
- ✓Скорость вращения зависит от фазы цикла
- ✓Крупные группы пятен показывают тенденцию вращаться медленнее
- ✓Скорость вращения групп пятен изменяется со временем – вращение замедляется

или ускоряется?

Velocity structures from sunspot statistics in cycles 10 to 22

I. Rotational velocity

Pentti Pulkkinen[1,2] and Ilkka Tuominen[2]

[1] Department of Physics, P.O. Box 9, SF-00014, University of Helsinki, Finland
[2] Astronomy Division, University of Oulu, P.O. Box 333, SF-90571 Oulu, Finland

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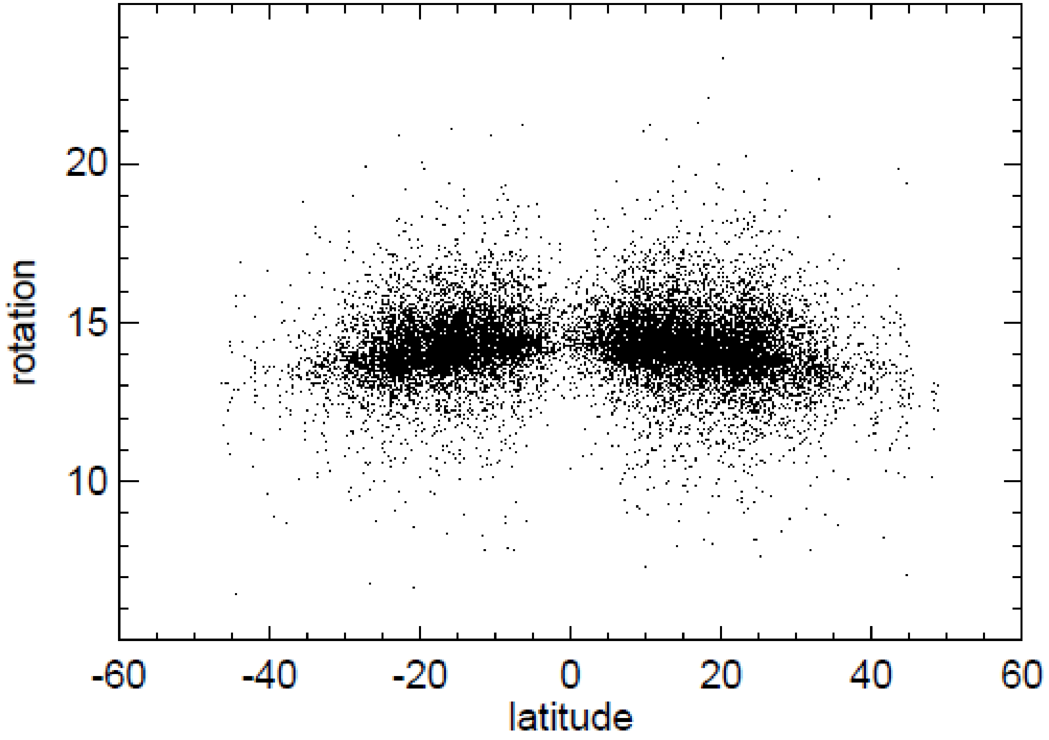
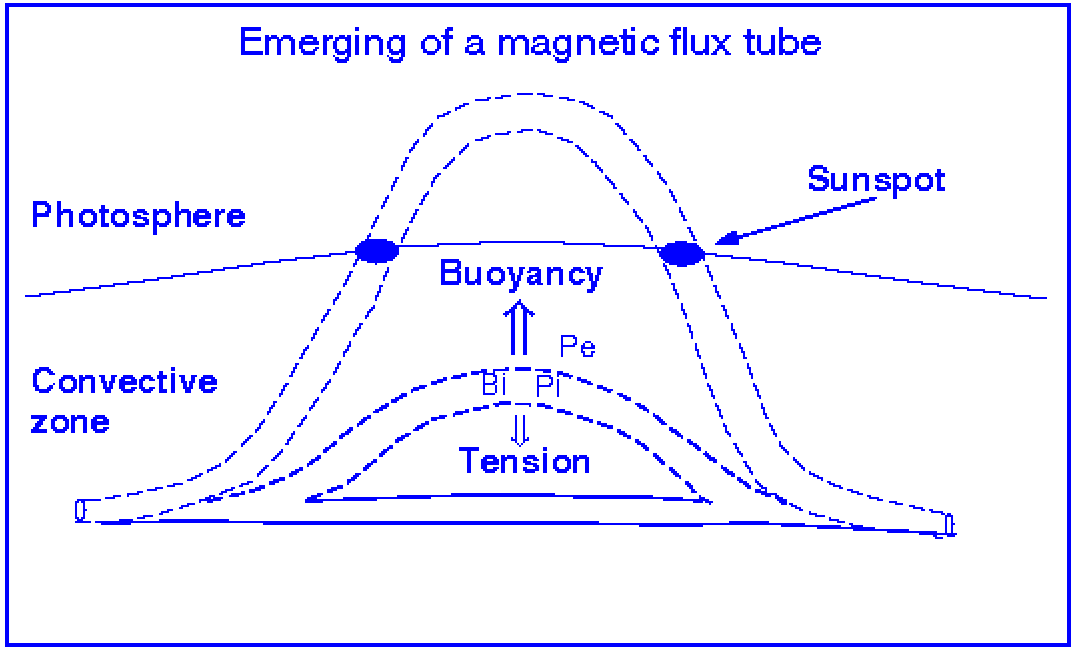
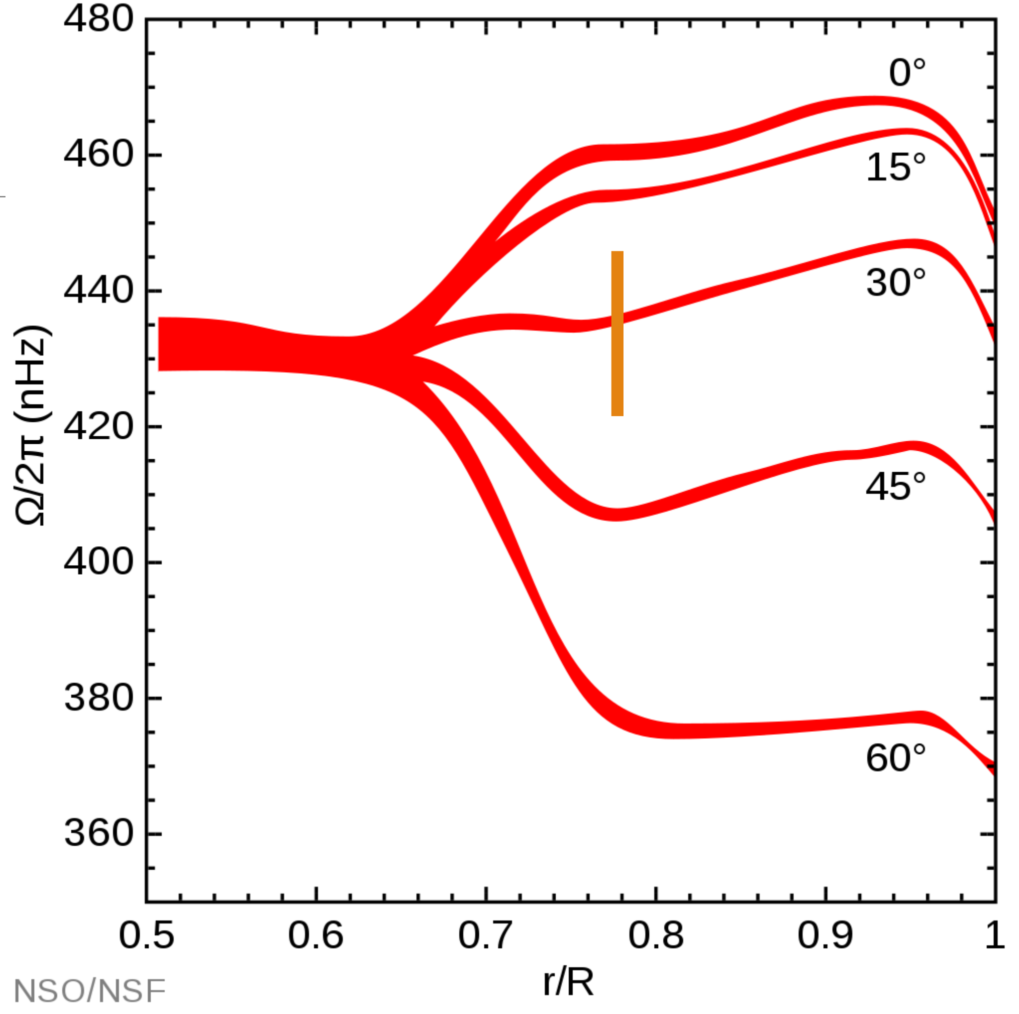


Fig. 1. Values of rotational velocity (in deg/day) for the GPR during cycle 19 with cut-off longitude of 60 degrees

Magnetic anchoring hypothesis





The Magnetic and Velocity Fields of Solar Active Regions
ASP Conference Series, Vol. 46, 1993
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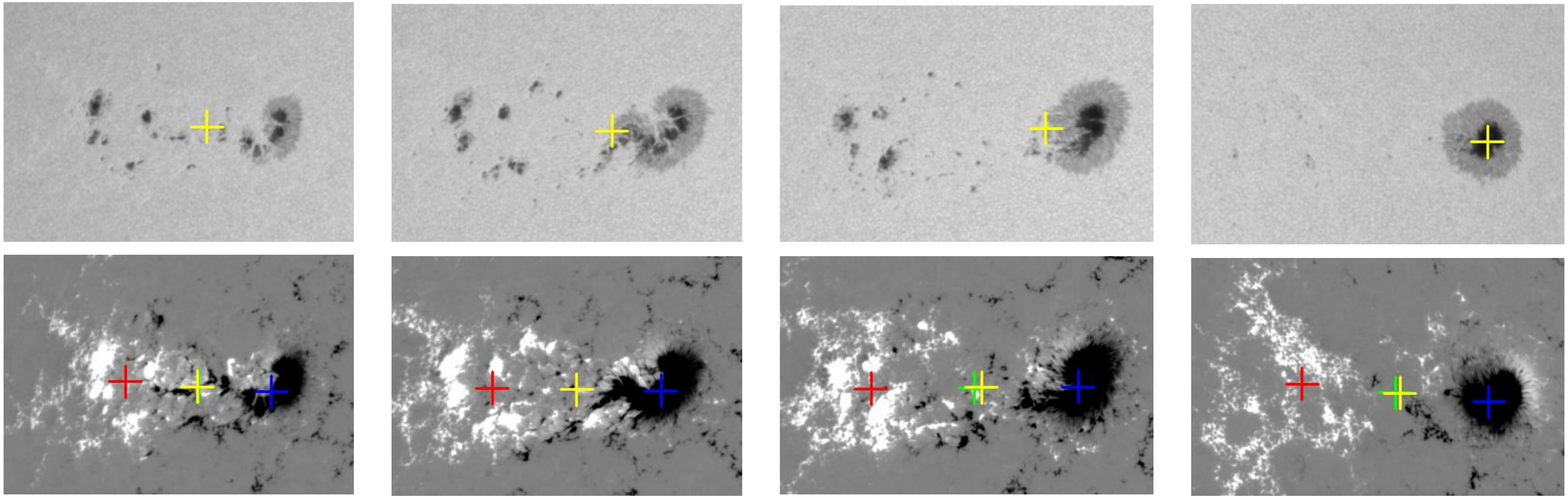
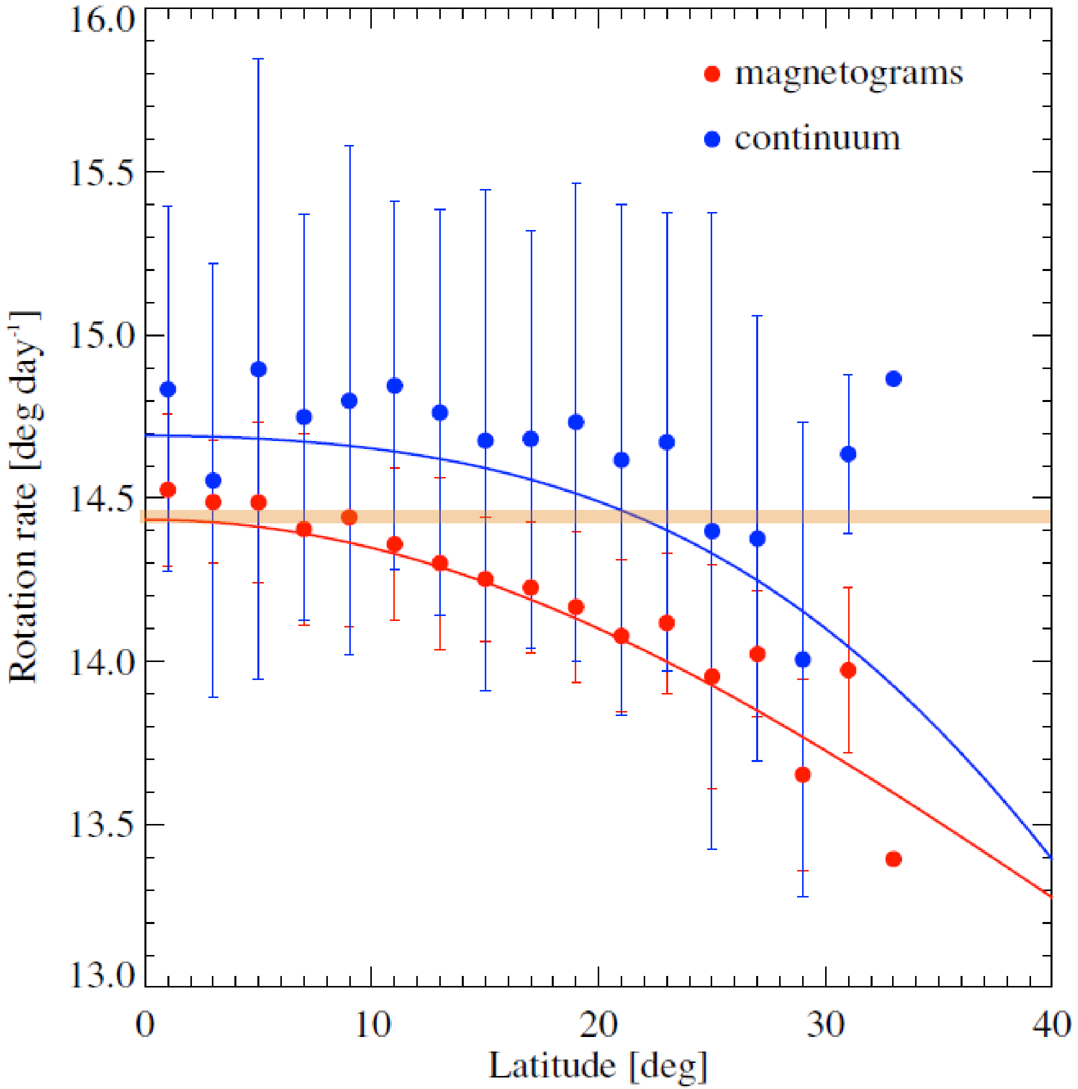
AREA-WEIGHTING OF SUNSPOT GROUP POSITIONS AND PROPER MOTION ARTIFACTS

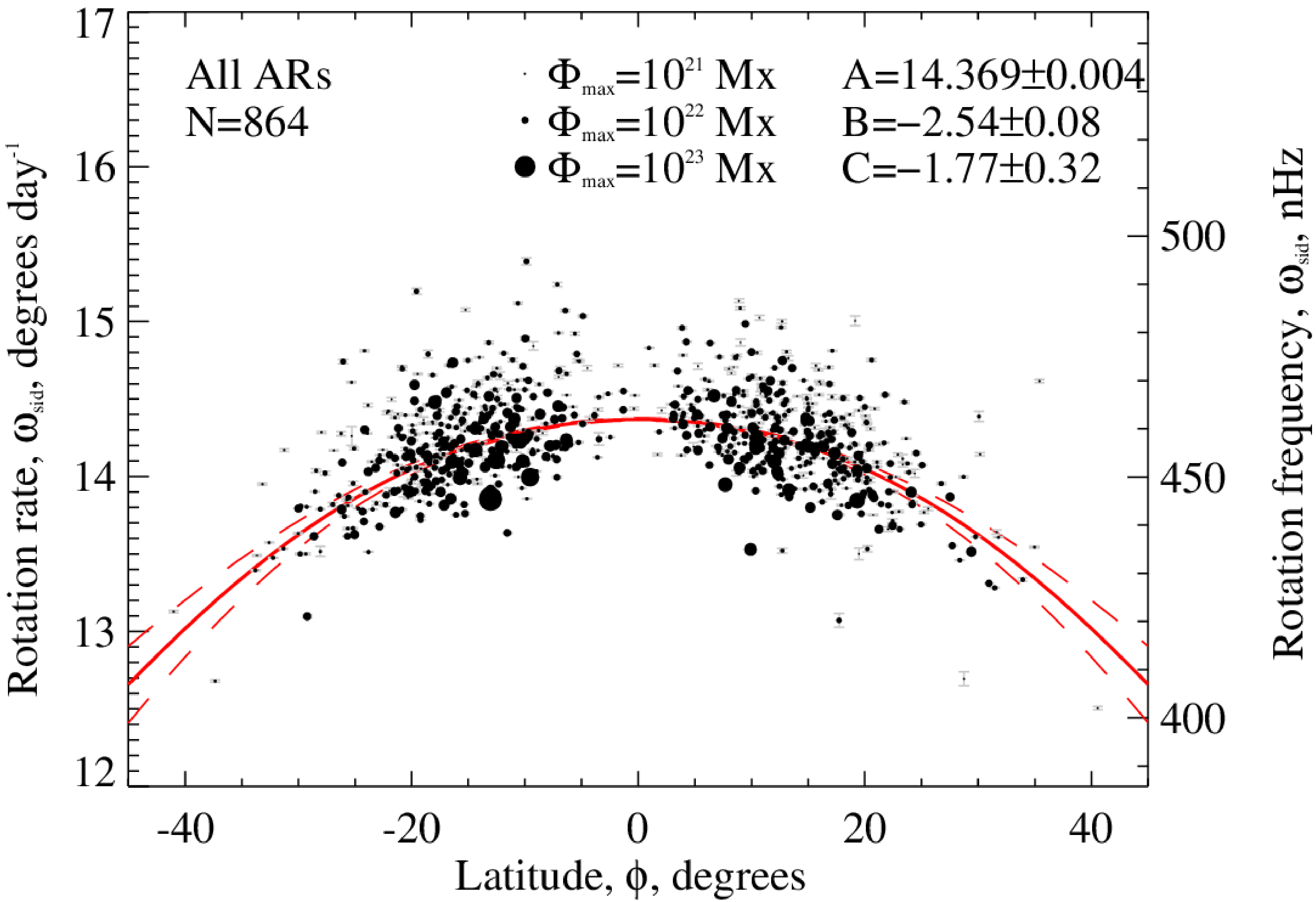
K. PETROVAY
Eötvös University, Department of Astronomy, Budapest, Ludovika tér 2, H-1083 Hungary

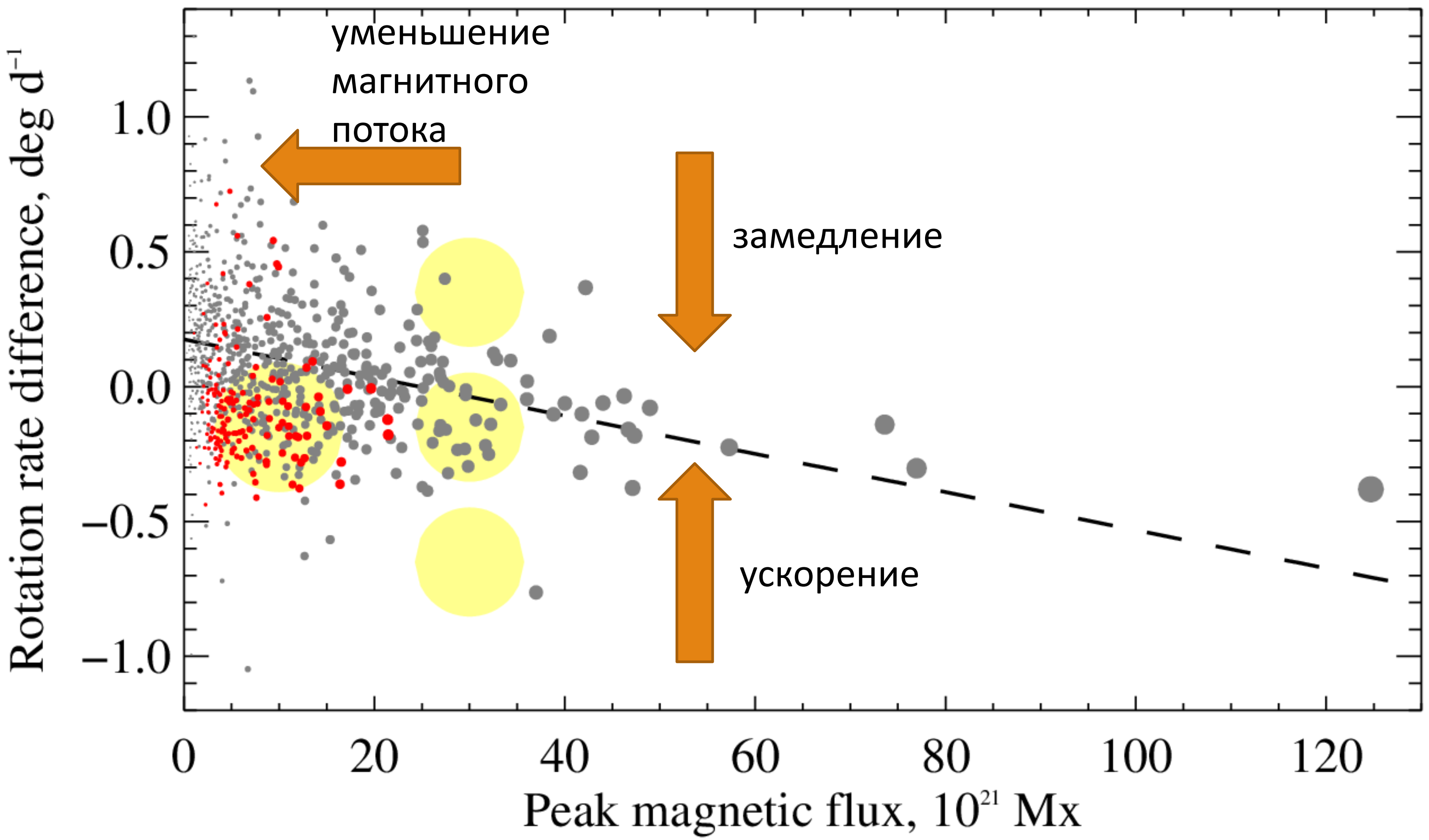




- Разность в измерении скорости по магнитограммам и изображениям в континууме сравнима с вариацией дифференциального вращения на экваторе и на широте 30 градусов

$$\omega_{sid} = A + B \sin^2 \phi + C \sin^4 \phi$$





- Крупные активные области вращаются, в среднем, медленнее
- Скорость вращения остается постоянной

Astron. Astrophys. 332, 748–754 (1998)

ASTRONOMY AND ASTROPHYSICS

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Скорость вращения на экваторе не максимальна

Вращение полушарий не симметрично

Чем активнее цикл, тем медленнее вращение

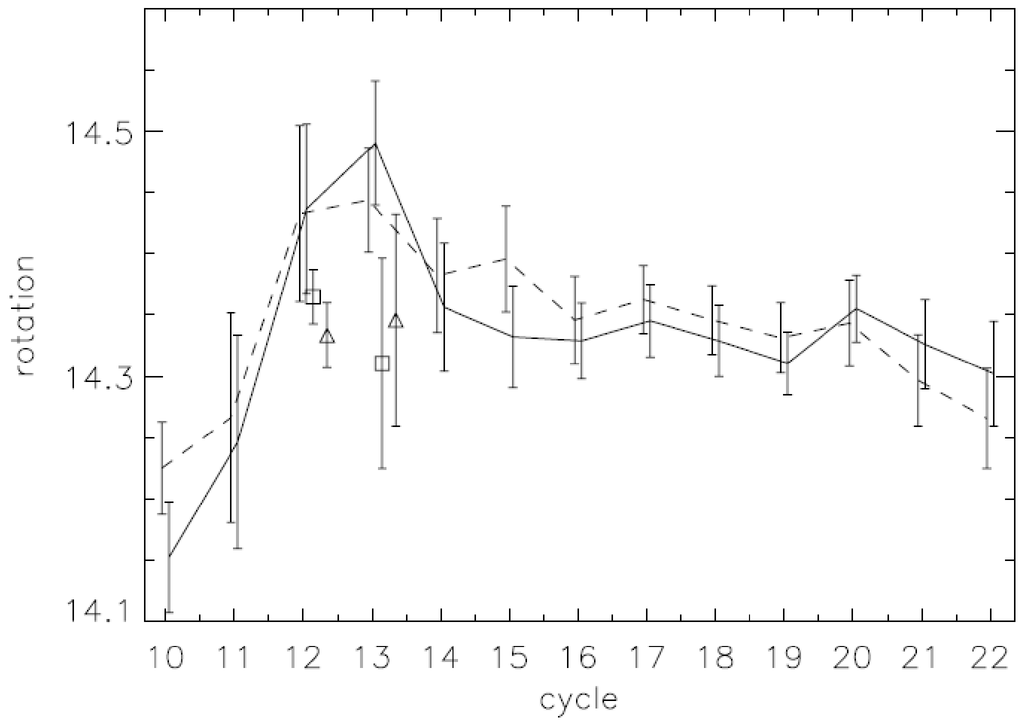

Fig. 4. The asymmetry of rotation between northern and southern hemispheres at different cycles. The solid (dashed) line shows the rotation rate at 15 degrees north (south) of the equator. Cycles 12 and 13 are also calculated based on the Spörer data the triangles representing northern and squares southern hemisphere

Astrophys Space Sci (2010) 328: 269–277
DOI 10.1007/s10509-009-0218-0

ORIGINAL ARTICLE

The solar differential rotation: a historical view

Lucio Paternò

OBSERVATIONS

OF THE

SPOTS ON THE SUN

FROM NOVEMBER 9, 1853, TO MARCH 24, 1861,

MADE AT REDHILL,

BY

RICHARD CHRISTOPHER CARRINGTON, F.R.S.

SECTION II.

DEDUCED POSITIONS OF THE NUCLEI OBSERVED.

The dates are in all cases inserted on which the Sun was found to be free of Spots. In the years 1855 and 1856 the blanks in the record from this cause are very numerous. The contents of the different columns are explained in the Introduction.

1 Introduction

The discovery of solar differential rotation happened in 1630 when Christoph Scheiner, after Galileo's sunspot observations, first noticed that the equatorial sunspots showed a shorter rotation period than those present at higher latitudes. Since then, other scientists, like Carrington (1863), Spörer (1874), and Maunder and Maunder (1905), studied the phenomenon and determined some rotation laws. But it was not until the second half of the XXth century that the systematic studies of Newton and Nunn (1951) and Ward (1966) on sunspot motions led to a precise formulation of the law of solar differential rotation. On starting from the early years of the past century the observations of sunspot motions were integrated with the spectroscopic ones by Adams (1909), Plaskett and De Lury (1913), Plaskett (1915), and in more recent times by Cimino and Rainone (1951), Livingston (1969), and Howard and Harvey (1970).

План доклада

Методы измерения дифференциального вращения

Вращение трассеров

Вариации вращения активных областей

Группы пятен vs. карты магнитных полей

Открытые вопросы

Группы пятен при движении по поверхности показывают дифференциальное вращение

- НО

- Скорость вращения пятен не совпадает со скоростью вращения плазмы – группы пятен вращаются быстрее

- Скорость вращения зависит от характеристик группы пятен – размера (магнитного потока), возраста, морфологии…

Astron. Astrophys. 332, 748–754 (1998)

ASTRONOMY
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[2] Astronomy Division, University of Oulu, P.O. Box 333, SF-90571 Oulu, Finland

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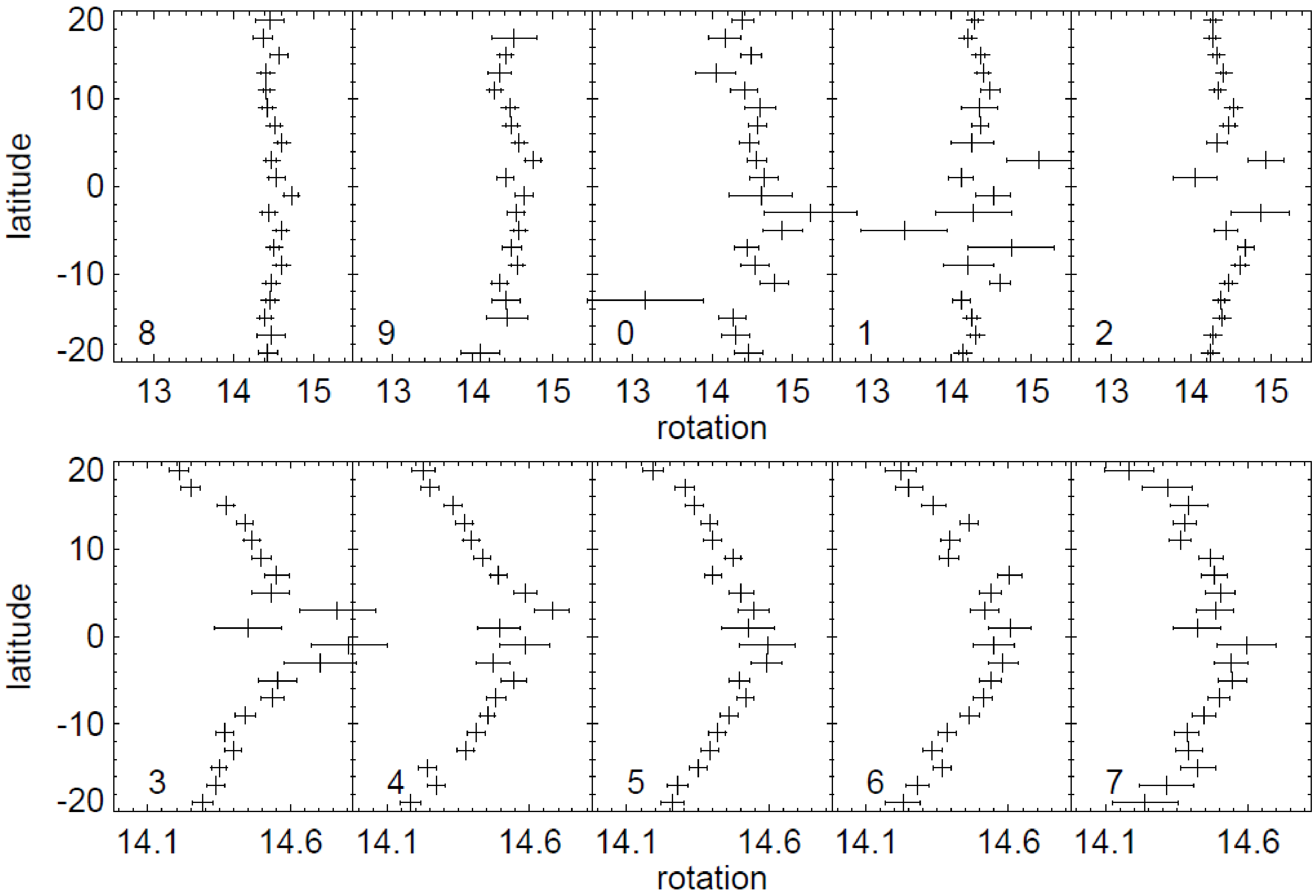


SPECTROSCOPIC DETERMINATIONS OF SOLAR ROTATION

ROBERT HOWARD and J. HARVEY*
Hale Observatories, Carnegie Institution of Washington, California Institute of Technology, Pasadena, Calif., U.S.A.

(Received 28 October, 1969)

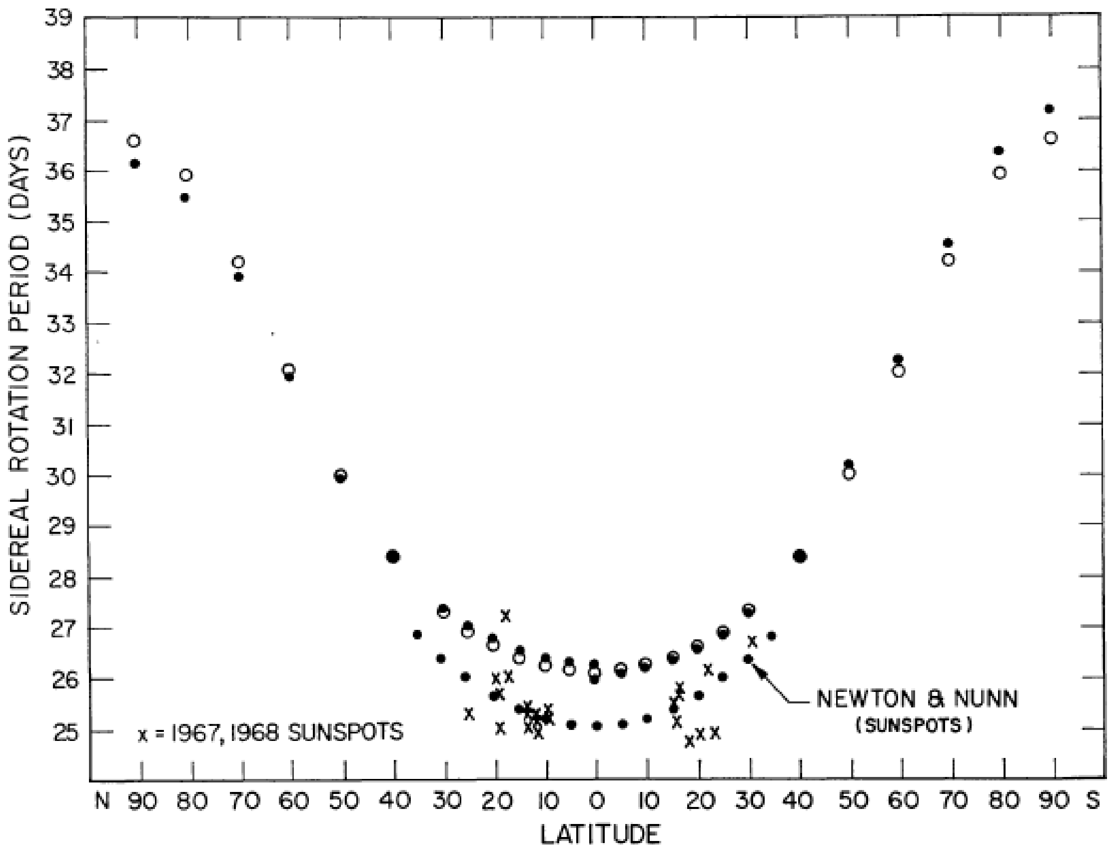
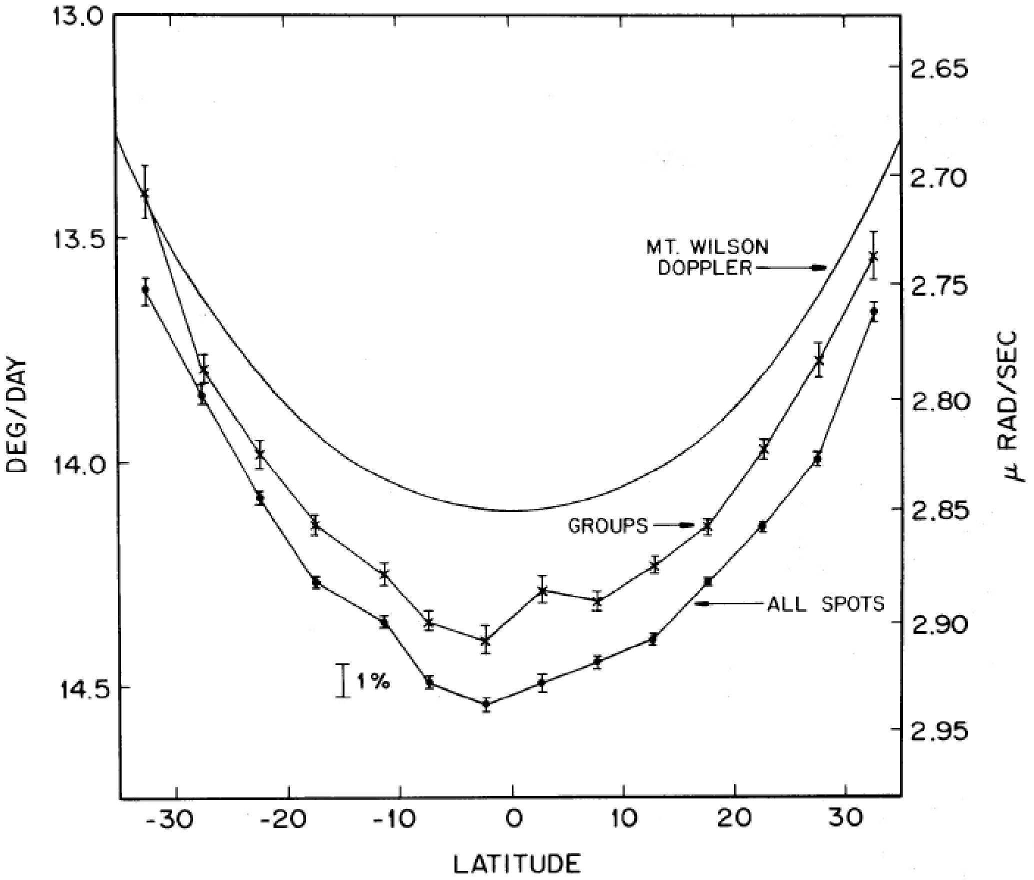


Fig. 6. A plot of sidereal rotation period vs. solar latitude. The upper curve represents the results of this investigation; the open circles are the average of both the northern and southern hemisphere data, and the black dots near them represent the northern and southern hemispheres separately. The lower black dots represent the sunspot rotation results of Newton and Nunn (1951). The crosses represent recent sunspot results from Mount Wilson data.

ROTATION OF THE SUN MEASURED FROM MOUNT WILSON WHITE-LIGHT IMAGES

Robert Howard
Mount Wilson and Las Campanas Observatories, Carnegie Institution of Washington
Peter A. Gilman
High Altitude Observatory, National Center for Atmospheric Research[1]
AND
Pamela I. Gilman
Mount Wilson and Las Campanas Observatories, Carnegie Institution of Washington
Received 1983 November 28; accepted 1984 February 17



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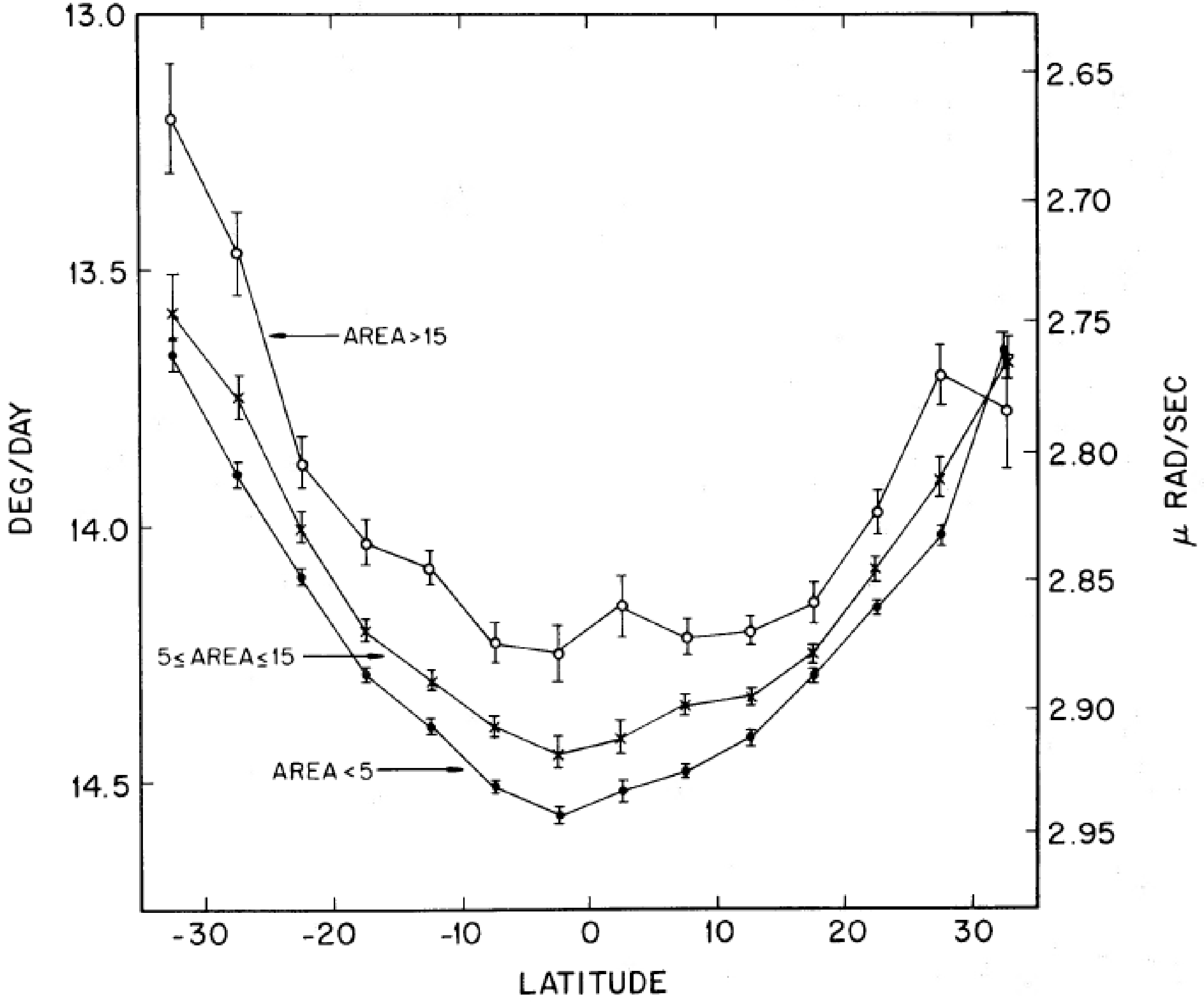

FIG. 4.—The rotation rate of spots of various sizes as a function of latitude. The zones are 5° in width.

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Original Russian Text © Yu.A. Nagovitsyn, A.A. Pevtsov, A.A. Osipova, 2018, published in Pis'ma v Astronomicheskii Zhurnal, 2018, Vol. 44, No. 3, pp. 229–238.

Two Populations of Sunspots: Differential Rotation

Yu. A. Nagovitsyn[1,2*], A. A. Pevtsov[3], and A. A. Osipova[1,2]

[1]*Pulkovo Astronomical Observatory, Russian Academy of Sciences, Pulkovskoe sh. 65, St. Petersburg, 196140 Russia*

[2]*St. Petersburg State University of Aerospace Instrumentation, Bol'shaya Morskaya ul. 67, St. Petersburg, 190000 Russia*

[3]*National Solar Observatory, Sunspot, NM 88349, USA*

Received July 27, 2017

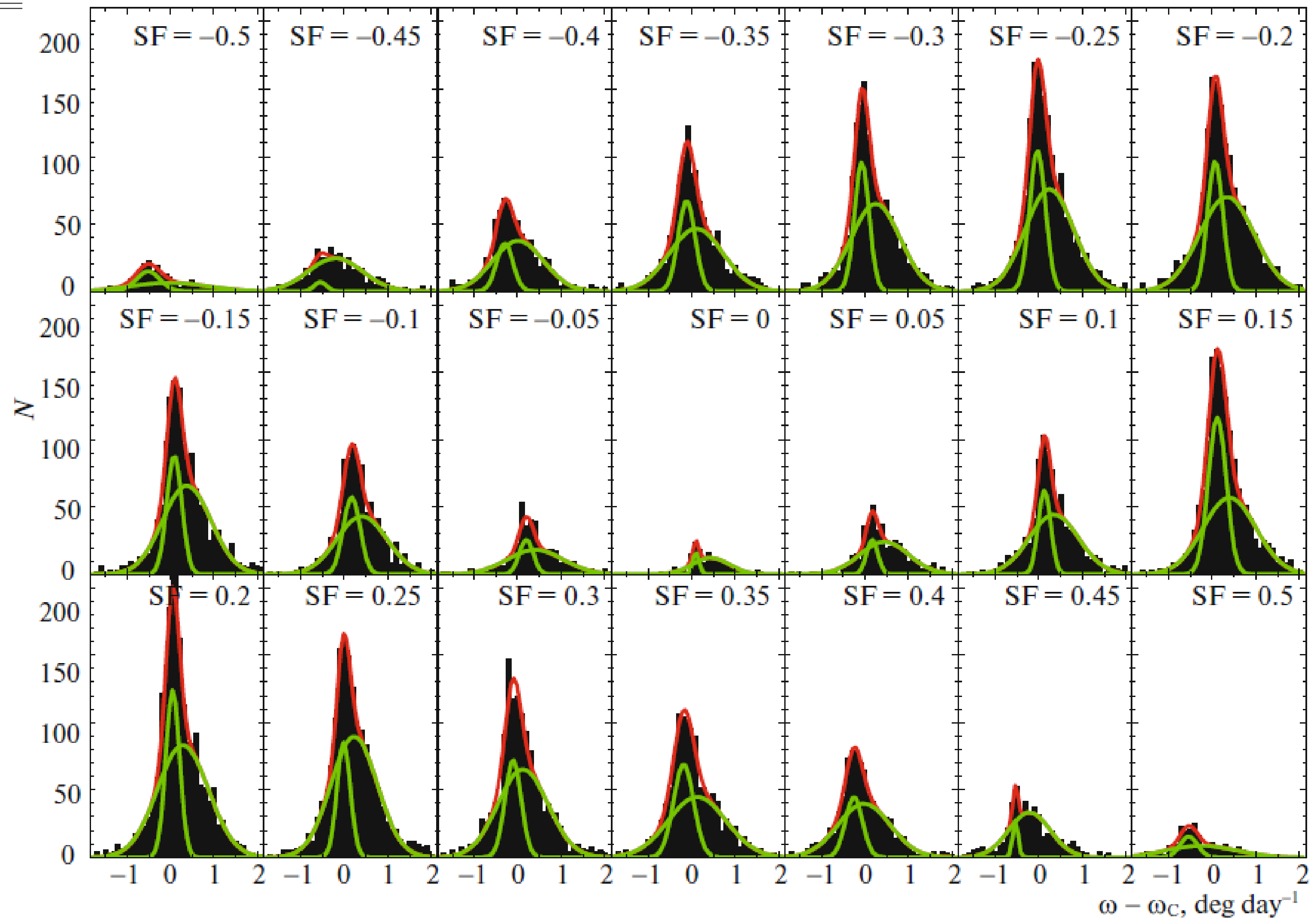

Fig. 3. (Color online) Occurrence histograms of rotation rates for all sunspot groups relative to the Carrington grid for various sines of the heliographic latitude SF and their bimodal Gaussian fit.

Astron. Astrophys. 332, 748–754 (1998)

ASTRONOMY
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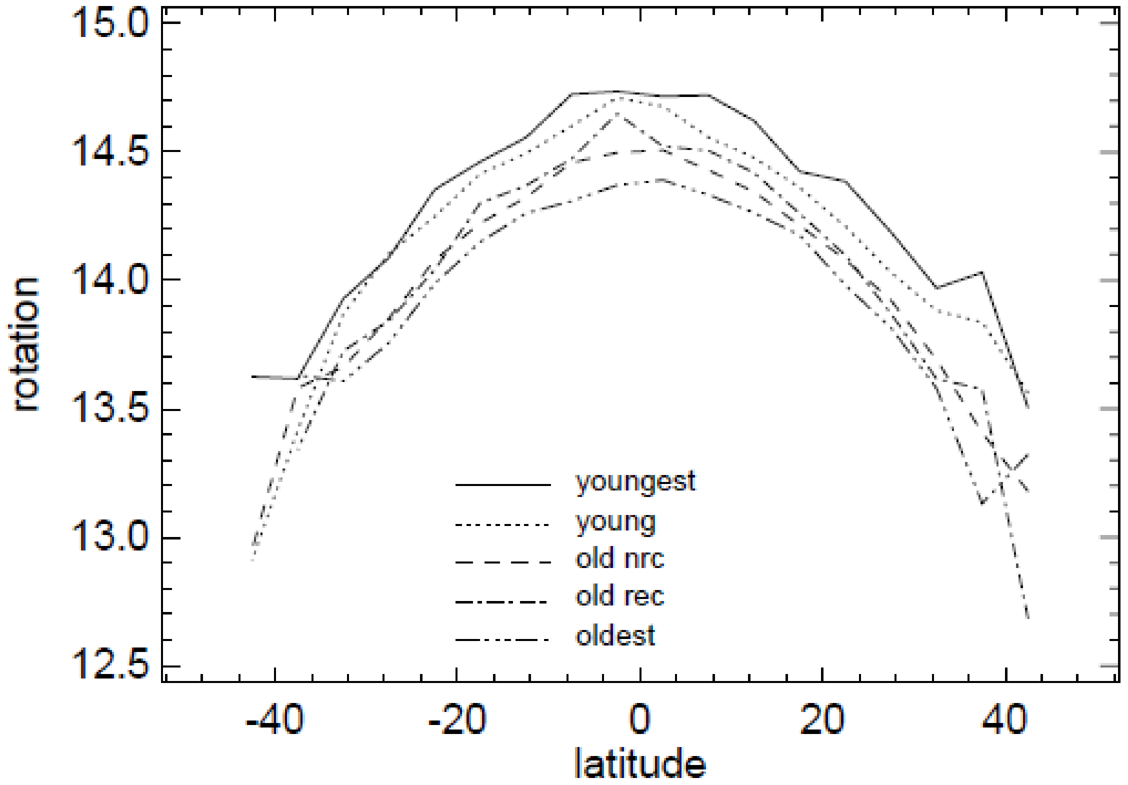

Fig. 8. Differential rotation for different-aged groups. The solid, dotted, dashed, dash-dotted, and dash-dot-dot-dotted lines correspond to the "youngest" (age less than 1.5 days), "young" (age 1.5 to 7.5 days), "old non-recurrent" (age over 7.5 days), "old recurrent" (age over 7.5 days), and "oldest" (recurrent, in 2nd or later rotation), respectively

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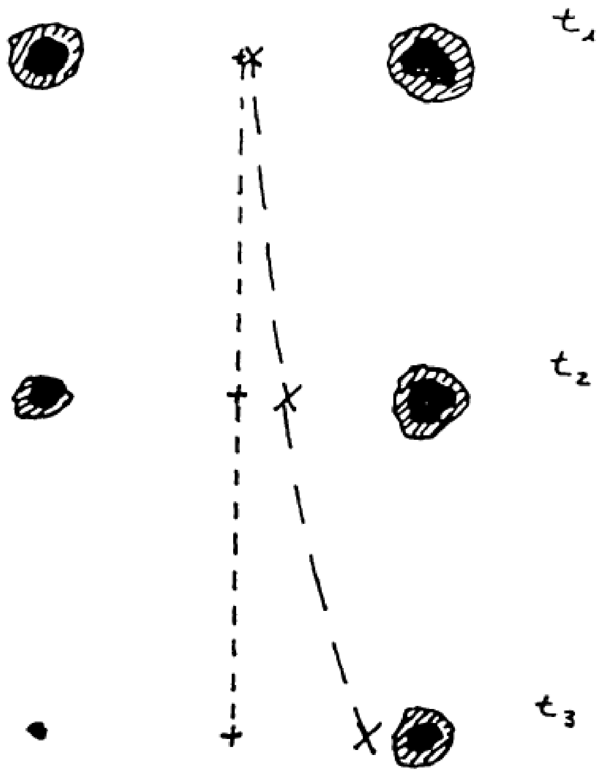
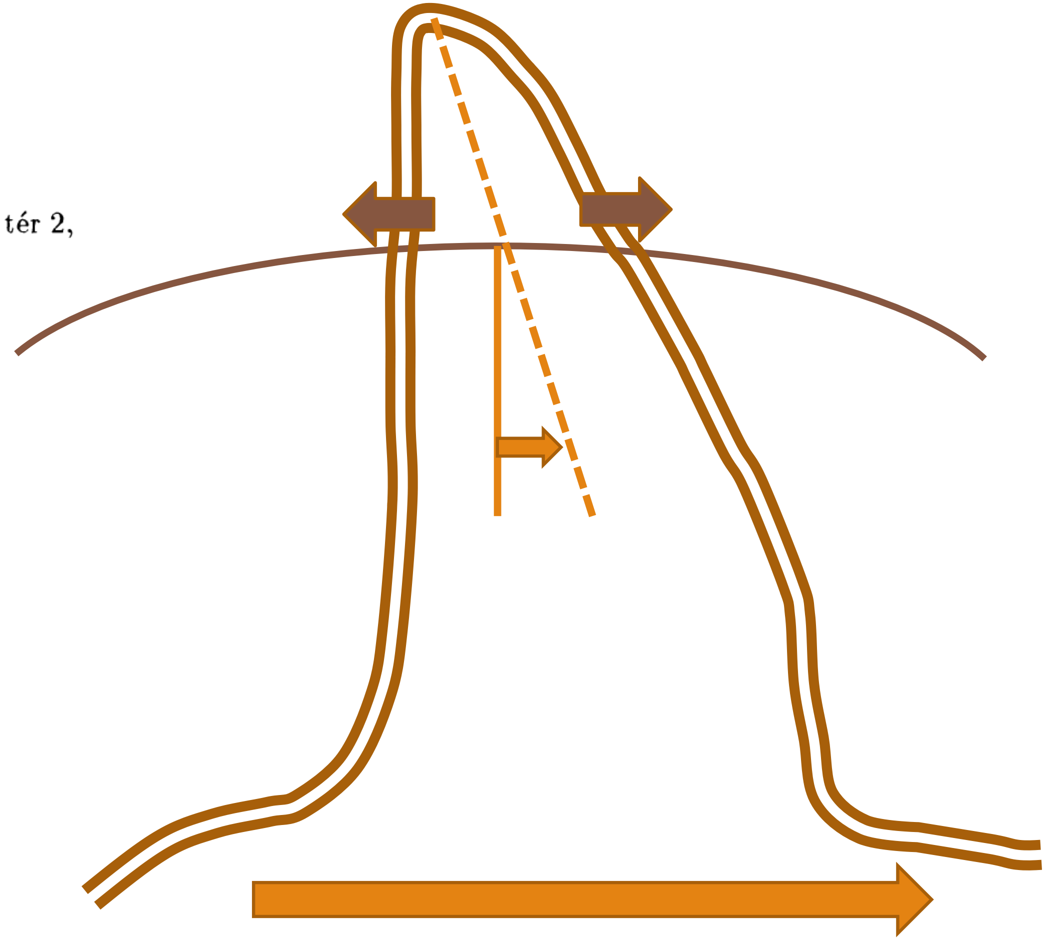
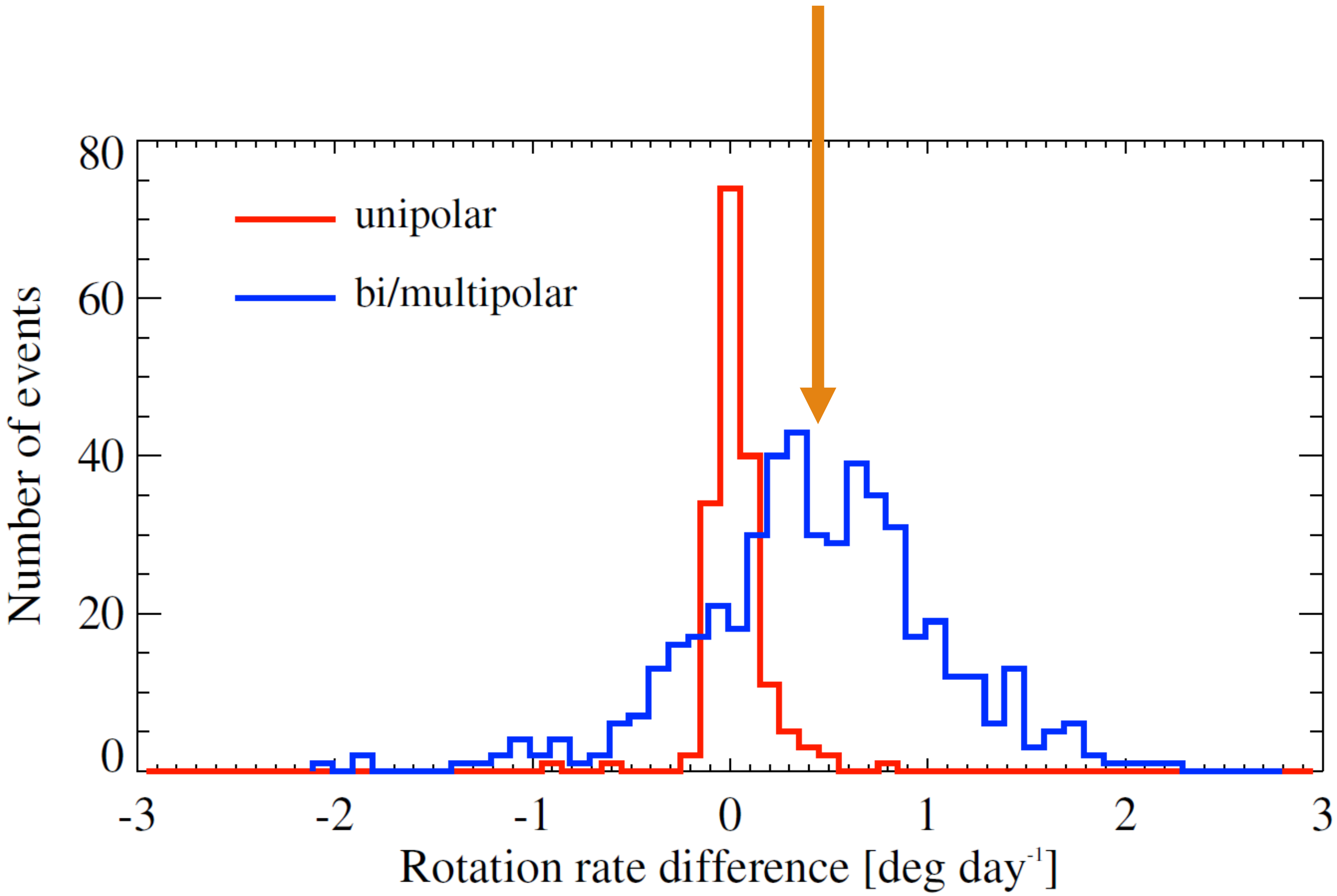
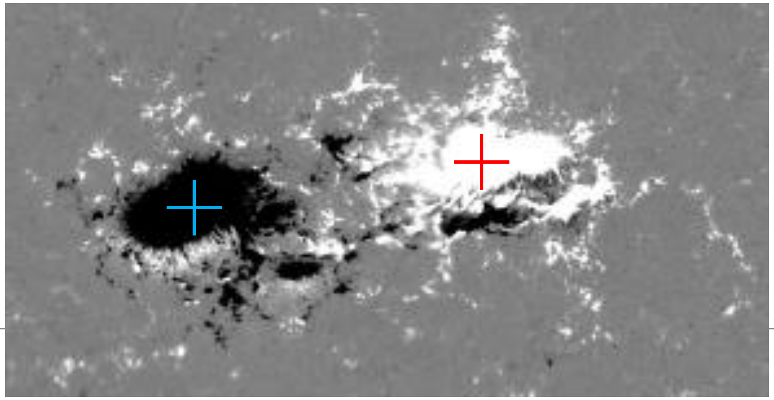
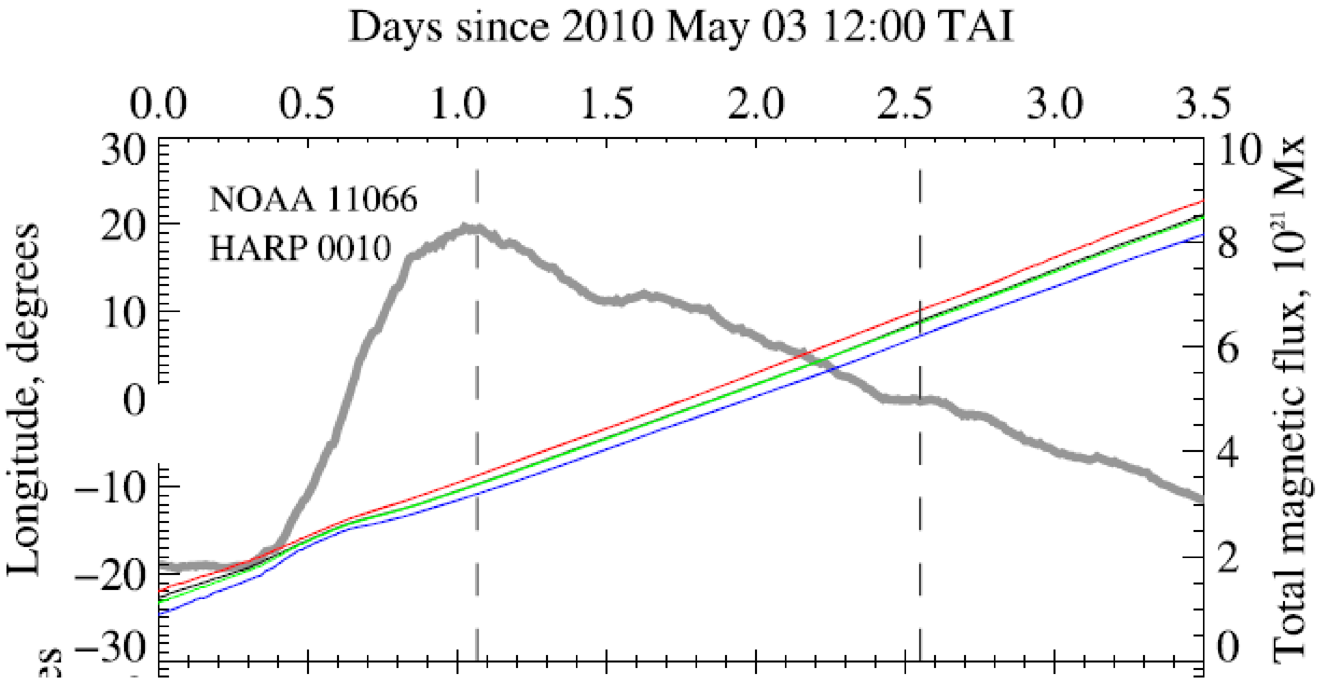


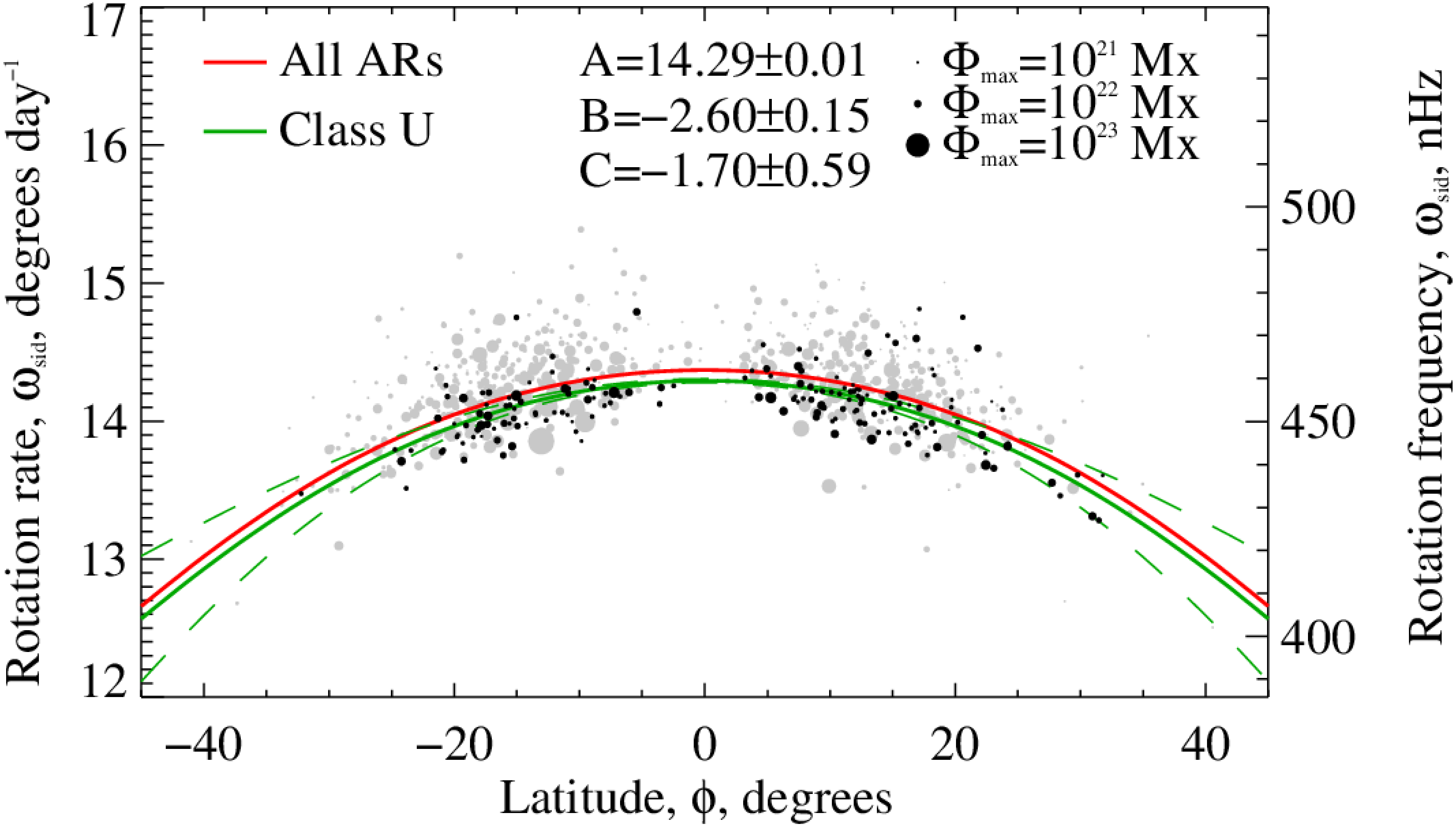




- Скорость вращения по изображениям в континууме оказывается, в среднем, больше для не униполярных активных областей на 0.45 градуса в день




Days since 2010 May 03 12:00 TAI
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
30
20
10
0
−10
−20
−30
NOAA 11066
HARP 0010
Longitude, degrees
10
8
6
4
2
0
Total magnetic flux, 10^{21} Mx


All ARs
Class U
A=14.29±0.01
B=−2.60±0.15
C=−1.70±0.59
Φmax=10^21 Mx
Φmax=10^22 Mx
Φmax=10^23 Mx
17
16
15
14
13
12
500
450
400
−40
−20
0
20
40
Rotation rate, ωsid, degrees day^−1
Rotation frequency, ωsid, nHz
Latitude, ϕ, degrees

Astron. Astrophys. 327, 795–799 (1997)

ASTRONOMY AND ASTROPHYSICS

Estimation of the depths of initial anchoring and the rising-rates of sunspot magnetic structures from rotation frequencies of sunspot groups

J. Javaraiah and M.H. Gokhale

Indian Institute of Astrophysics, Bangalore - 560 034, India

Received 11 April 1997 / Accepted 1 July 1997

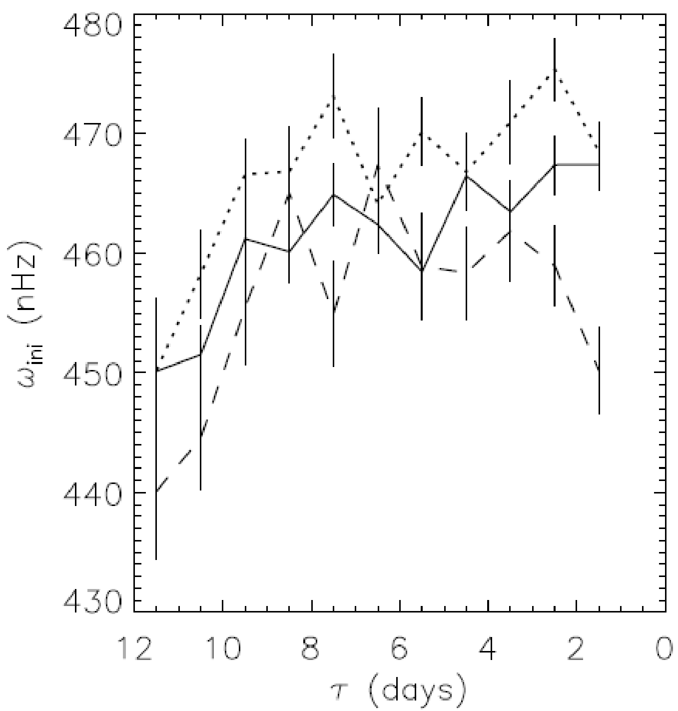


Fig. 1. The initial rotation frequency ω_{ini} as a function of the lifespan τ, for spot groups occurring in latitude intervals $0^o - 10^o$ (dotted curve), $10^o - 20^o$ (continuous curve) and $20^o - 30^o$ (dashed curve).

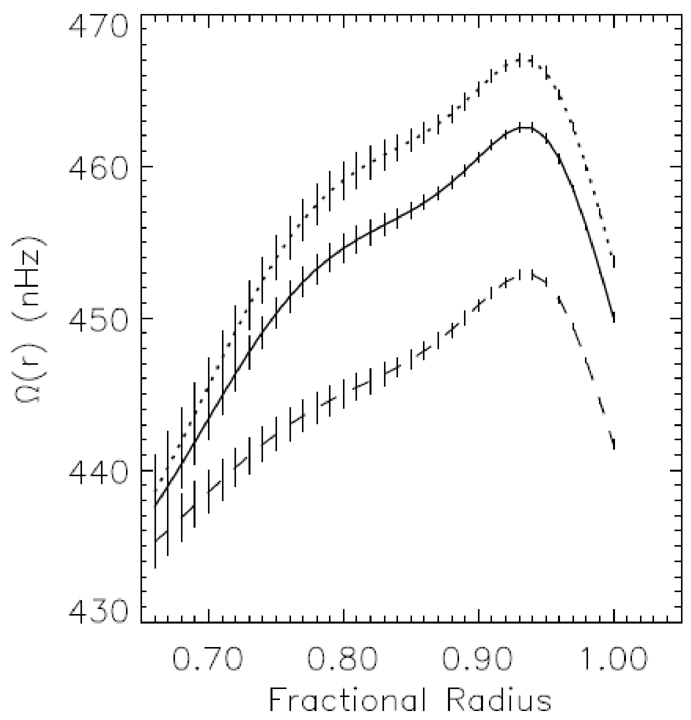


Fig. 2. Plasma rotation frequency $\Omega(r)$ as a function of r at latitudes 5^o (dotted curve), 15^o (continuous curve) and 25^o (dashed curve) provided to us by Dr. H. M. Antia, as determined from the BBSO helioseismoic data (Woodard & Libbercht 1993) using the inversion method of Antia and Chitre (1996).