# N-S asymmetry of the photospheric magnetic field: relation with the positive and negative flux imbalance

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# Abstract


- **Photospheric magnetic fields are studied using Kitt Peak synoptic maps for 1976 - 2003. Only strong magnetic fields (B>100 G) of the equatorial region were taken into account. N-S asymmetry of the magnetic fluxes is considered as well as the imbalance between the positive and the negative fluxes.**
- **It is shown that the sign of the imbalance does not change during 11 years from one inversion to the other and always coincides with the sign of the Sun's global magnetic field in the N-hemisphere.**

# Data

- **Synoptic Maps of the photospheric magnetic field (1976 - 2003): NSO Kitt Peak, http://nsokp.nso.edu/kpvt/**
- **Spatial resolution: 1° in longitude (360 steps); 180 equal steps in the sine of the latitude. Thus every map consists of 360x180 pixels of magnetic field strength in gauss.**
- **Pixels with magnetic strength B>100 G occupy 1.3% of the solar surface only. Even so, the total number of the latter pixels is large enough: it amounts to $3 \times 10^5$ for the period of 1976 – 2003.**

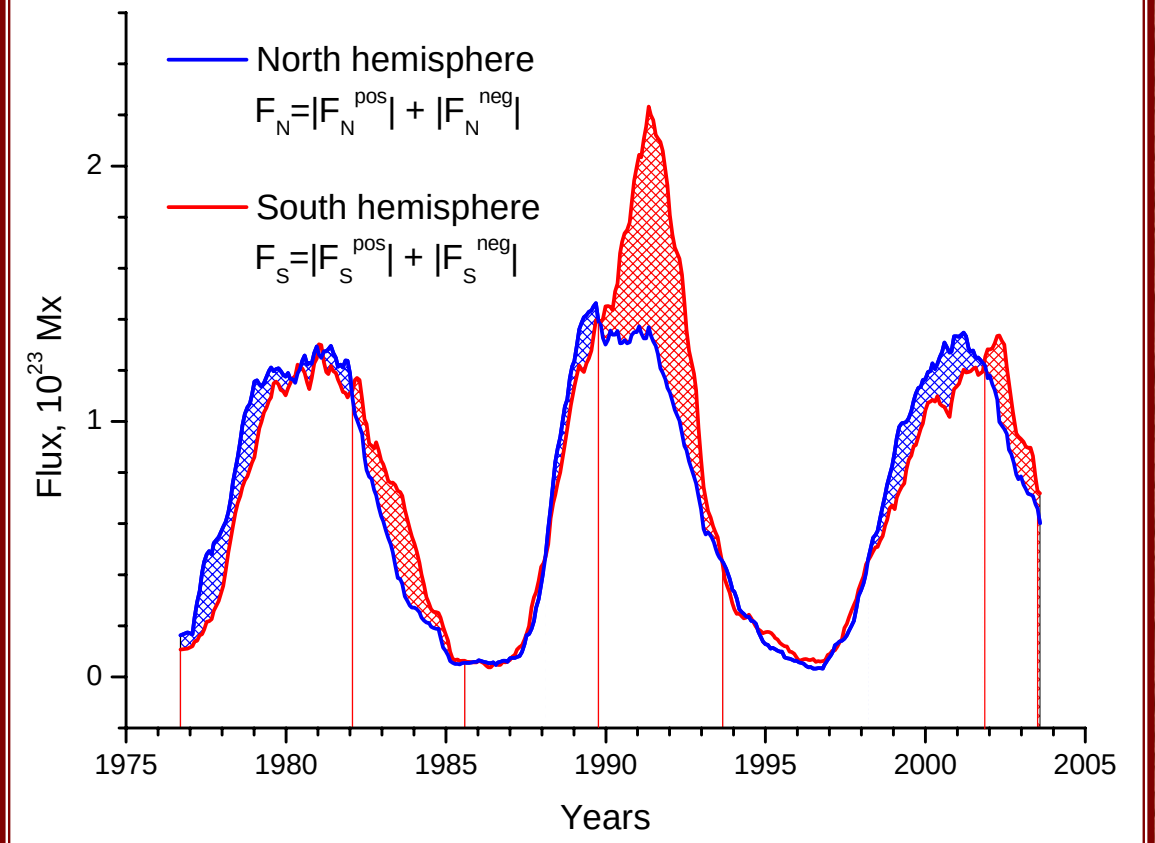
# Method

**Only strong magnetic fields (B>100 G) of the equatorial region (latitudes from -40° to +40°) were taken into account. Positive and negative magnetic fluxes were calculated for each of hemispheres. Thus, for each synoptic map four different characteristics of magnetic flux have been obtained:**

$$F_N^{pos}, F_N^{neg}, F_S^{pos}, F_S^{neg}$$

**Time changes of these fluxes, as well as time changes of the difference between positive and negative fluxes are considered.**

# Fig. 1. Photospheric magnetic fluxes of North and South hemispheres



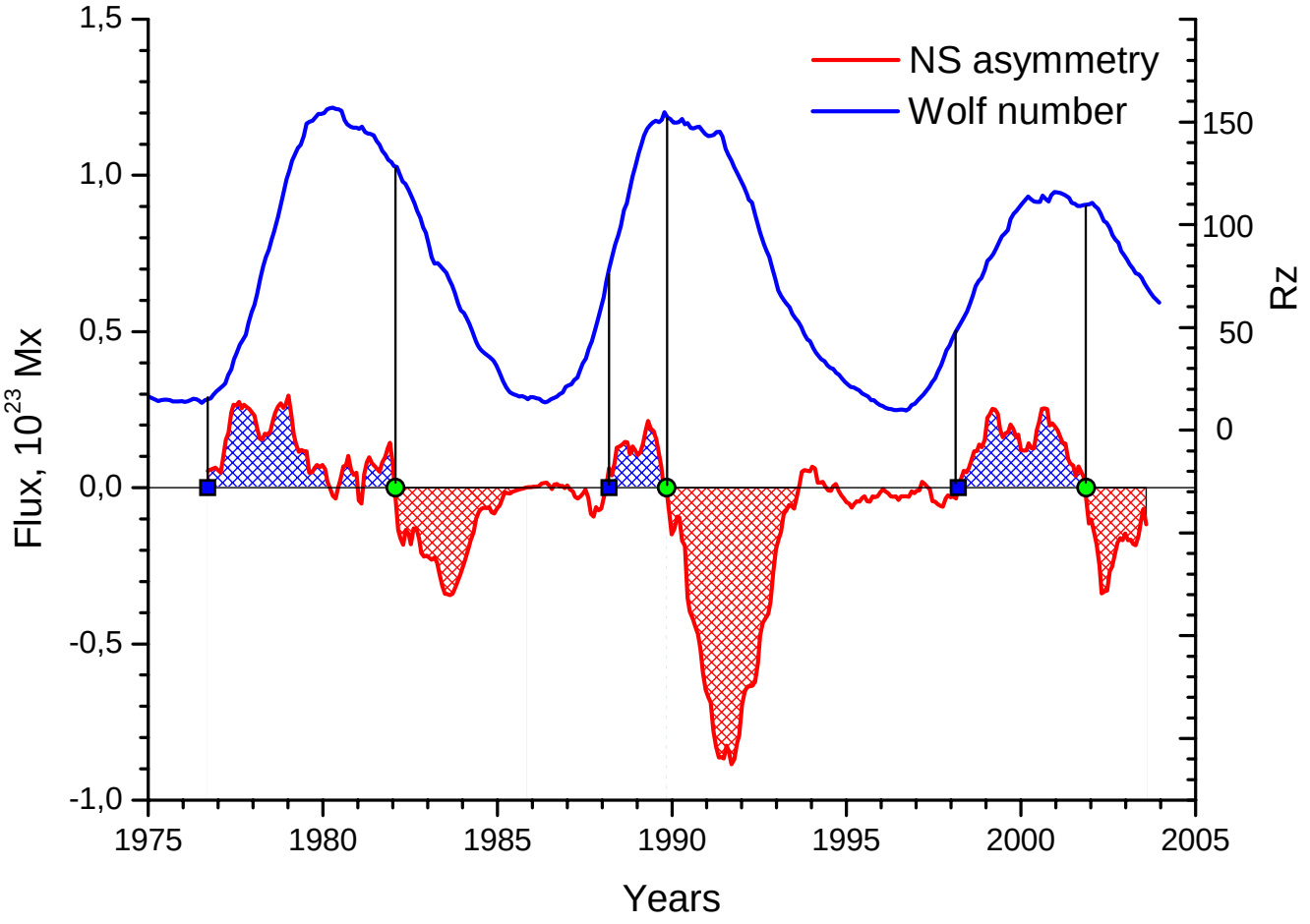

**Magnetic fluxes $F_N$ and $F_S$ follow the 11-year cycle of solar activity.**

**Note:**

**on the ascending phase – N-hemisphere dominates;**

**on the descending phase – S-hemisphere dominates**

# Fig. 2. N-S asymmetry of magnetic flux ($\Delta_{NS}=F_N-F_S$): solar cycles 21 – 23



♦ In each of the solar cycles N-S asymmetry of magnetic flux $\Delta_{NS}=F_N-F_S$ (Fig. 2) changes its sign twice: during the global magnetic field inversion and during the solar minimum.

♦ Thus the 22-year cycle can be divided in 4 quarters according to the relation between polarities of local and global magnetic fields:

a) on the ascending phase the North hemisphere always dominates. The leading sunspots of the North hemisphere have the same polarity as the global magnetic field in the North hemisphere.

b) on the descending phase the South hemisphere always dominates. The leading sunspots of the South hemisphere have the same polarity as the global field in the North hemisphere.

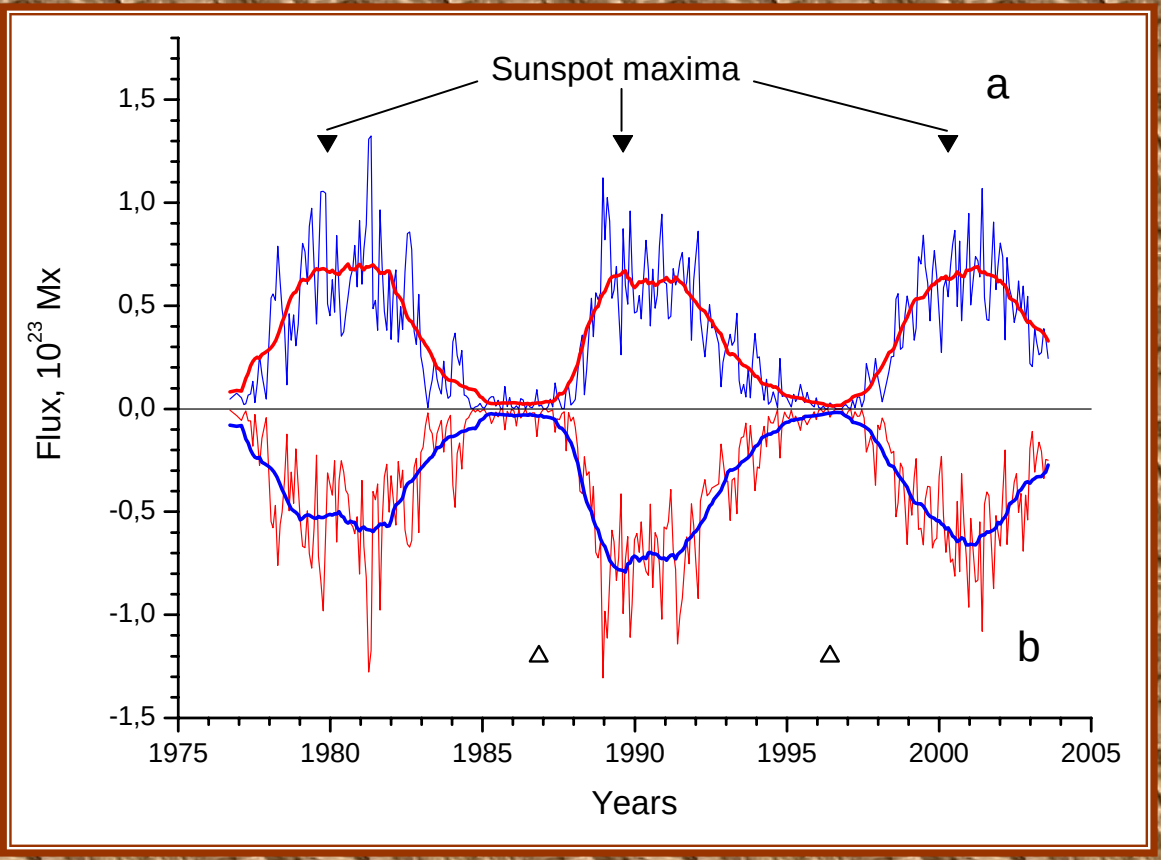
♦ Conclusion: the leading sunspots of the dominating hemisphere always have the same polarity as the global magnetic field in the N-hemisphere (Table 1).

# Table 1. Polarity of solar magnetic fields and North-South asymmetry

| Solar cycle | 21 from minimum to inversion | 21 from inversion to minimum | 22 from minimum to inversion | 22 from inversion to minimum |
|---|---|---|---|---|
| Quarter of the 22-year period | I | II | III | IV |
| Global magnetic field sign: N hemisphere | + | − | − | + |
| Dominating hemisphere | N | S | N | S |
| Leading sunspot: dominating hemisphere | + | − | − | + |
| Sign of the flux imbalance | + | − | − | + |

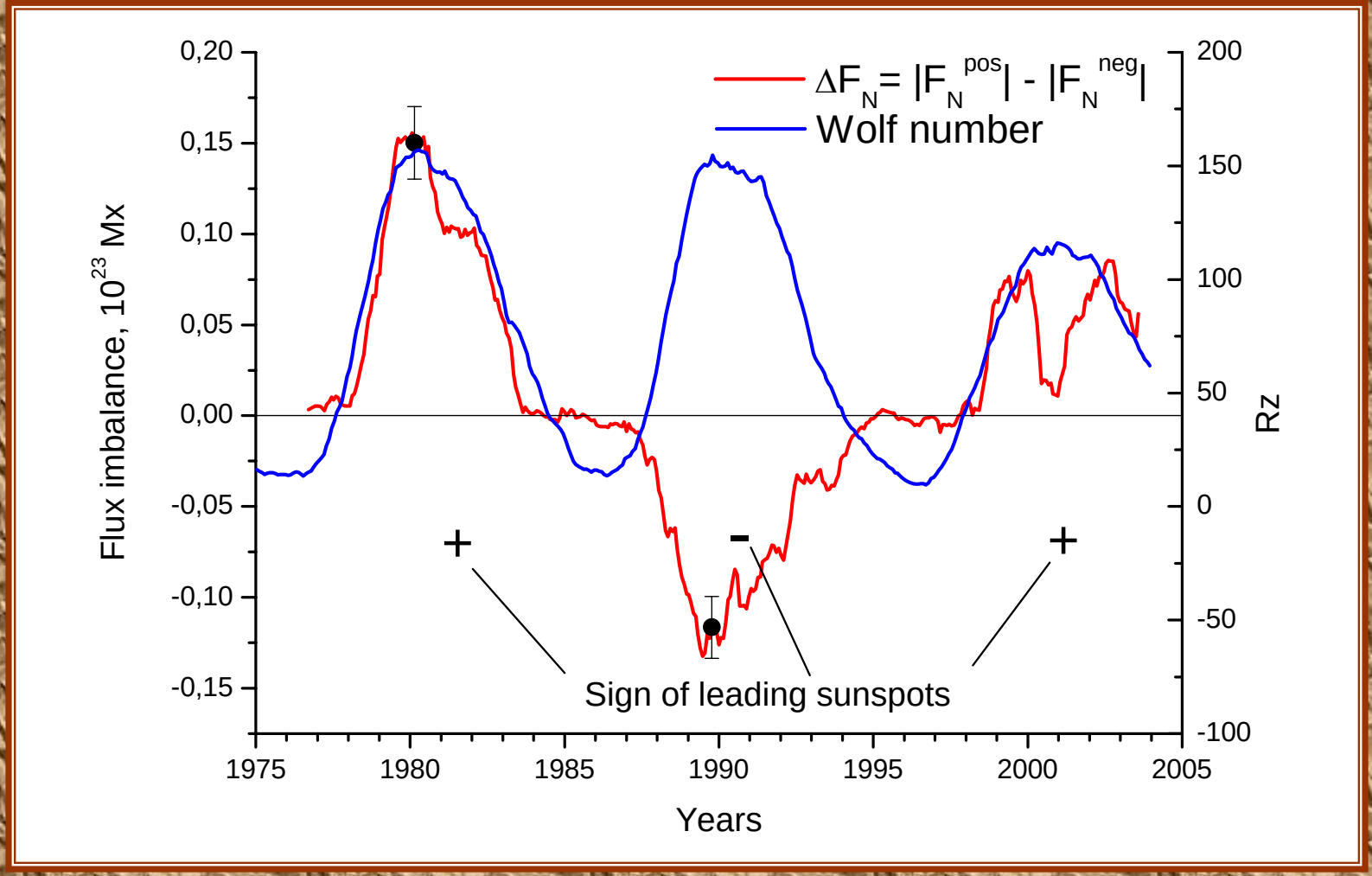
**Sign of the N-S asymmetry differs for two parts of the 11-year cycle - before the global magnetic field inversion and after it: sign $\Delta_{NS} = (-1)^{k+1}$ , where k=1,2 (k=1 corresponds to the interval from the minimum of the 11-year cycle to the inversion; k=2 corresponds to the interval from the inversion to the minimum).**

# Fig. 3. North hemisphere: positive (a) and negative (b) magnetic fluxes




**Both positive and negative fluxes of the strong magnetic fields (B>100G) show distinct 11-year periodicity**

# Fig. 4. North hemisphere: positive and negative flux imbalance



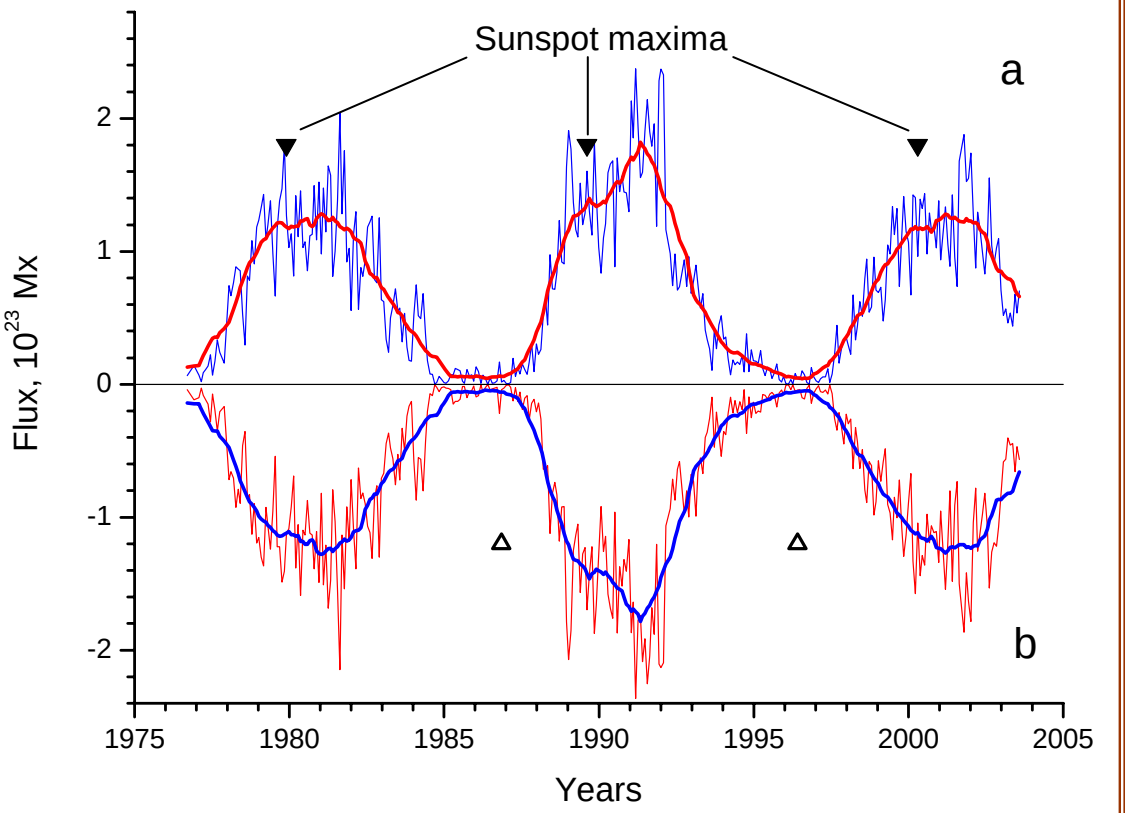
♦Sign of the imbalance does not change from one solar minimum to the next one and coincides with the sign of the leading sunspots in the North hemisphere (Fig. 4).

♦ This implies the domination of the leading sunspot flux over the flux of the following sunspots.

♦The 22-year periodicity of the imbalance is related directly to Hale's law.

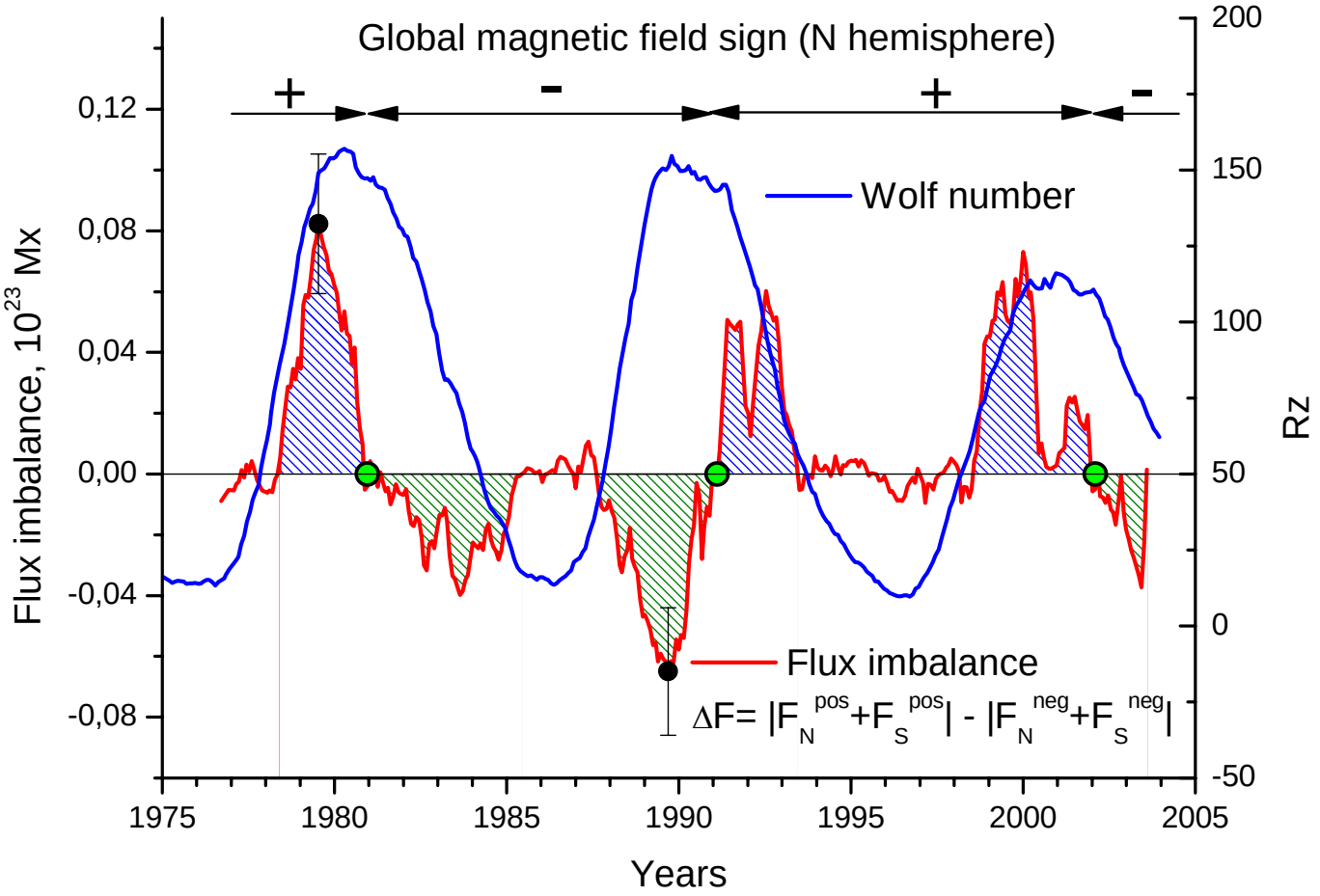
♦ The same effects are observed for the South hemisphere.

# Fig.5. Latitude interval -40° to +40°: positive (a) and negative (b) fluxes

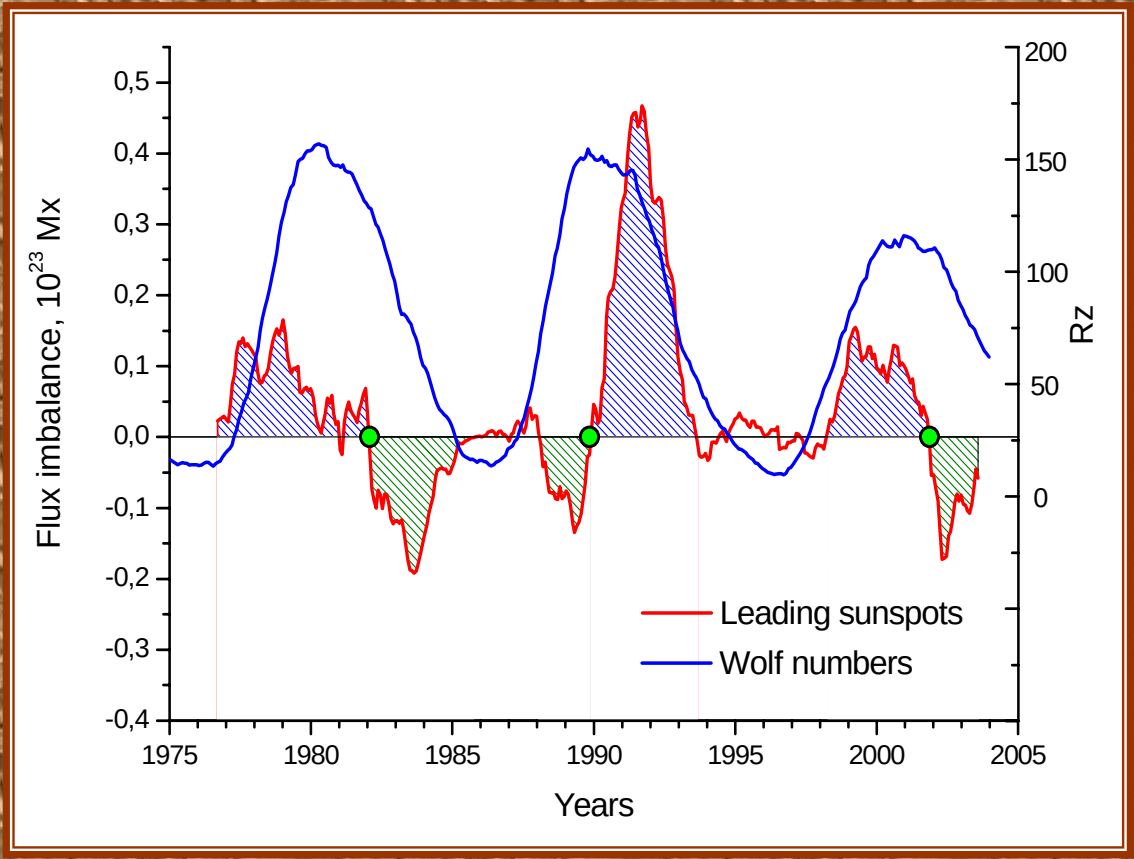



**Positive and negative fluxes for the latitude interval from -40° to +40° are well correlated and show distinct 11-year periodicity**

# Fig. 6. Flux imbalance for both solar hemispheres (from -40° to +40°)



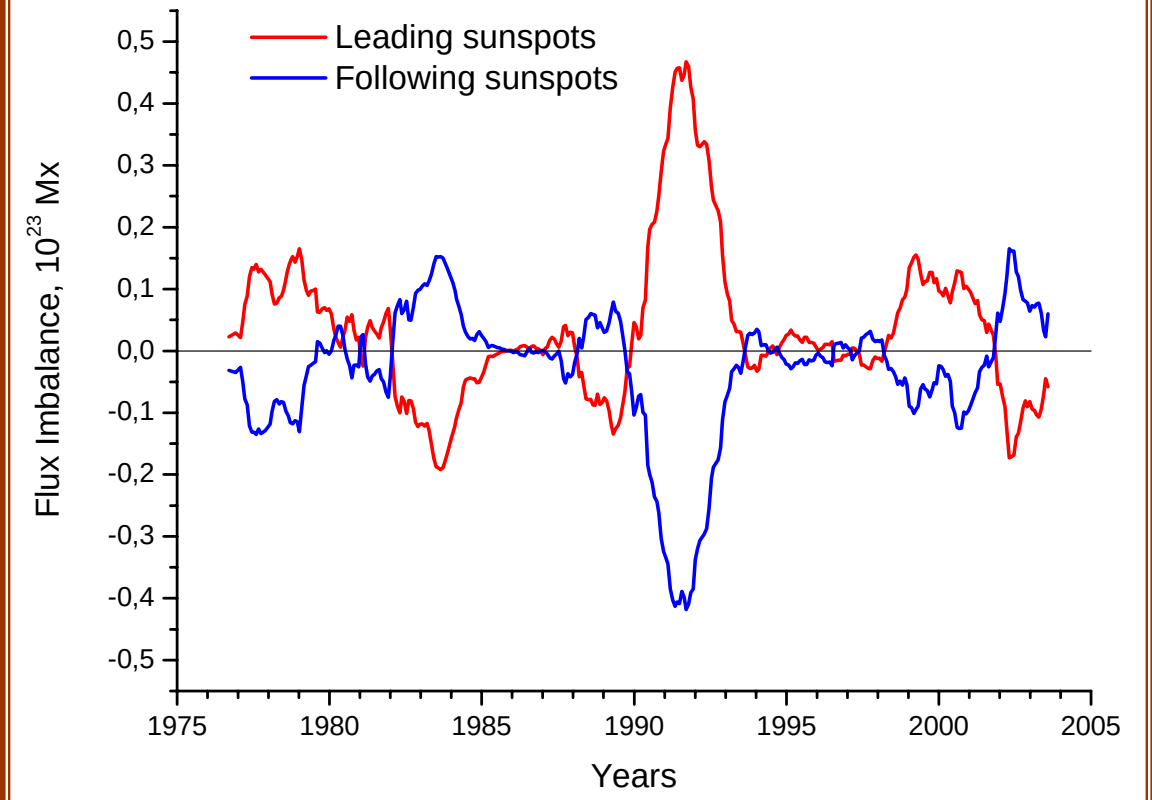
# Fig. 7. Leading sunspots: positive and negative flux imbalance




**Magnetic flux of the strong fields includes contribution both of leading and following sunspots.**

**All basic features of the imbalance (Fig. 6) can be observed when we consider imbalance of the leading sunspot fluxes only.**

# Fig. 8. Flux imbalance of leading and following sunspots: both hemispheres

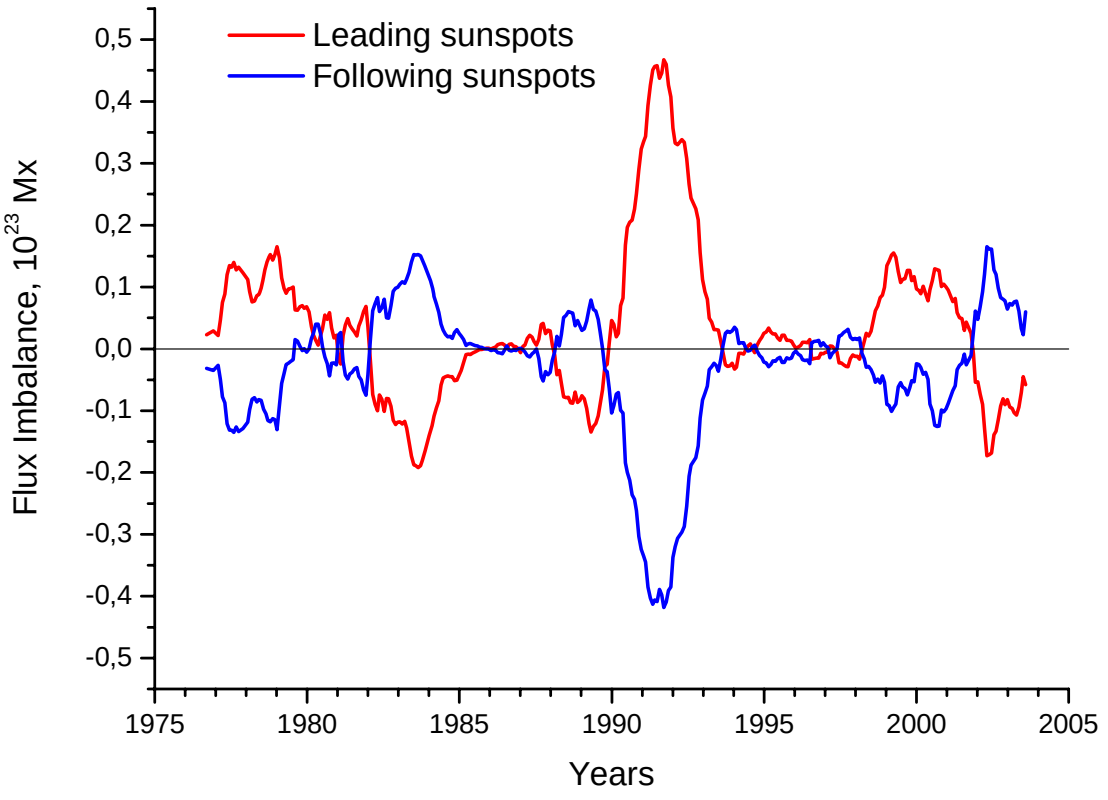



**The imbalance of the following sunspot fluxes is in an antiphase with the imbalance of the leading sunspot fluxes.**

**Therefore the leading sunspot imbalance is 3 times higher than the total flux imbalance.**

**Regular change of the magnetic flux N-S asymmetry during 11-year solar cycle can be deduced from the imbalance of fluxes.**

# Fig. 8. Flux imbalance of leading and following sunspots: both hemispheres




**The imbalance of the following sunspot fluxes is in an antiphase with the imbalance of the leading sunspot fluxes.**

**N-S asymmetry can be deduced from the flux imbalance. E.g., for the 1st quarter (Table 1) dF>0 due to the major contribution of leading sunspots of the North hemisphere. Both positive and negative fluxes of the North hemisphere exceed the fluxes of the South hemisphere. As a result North hemisphere will dominate. The same considerations are true for the quarters 2-4**

♦ In Fig. 6 positive and negative flux imbalance is shown: $\Delta F=|F_N^{pos} + F_S^{pos}| - |F_N^{neg} + F_S^{neg}|$ Green circles mark the change of the imbalance sign. Sign of $\Delta F$ is given in Table 1 (last line).

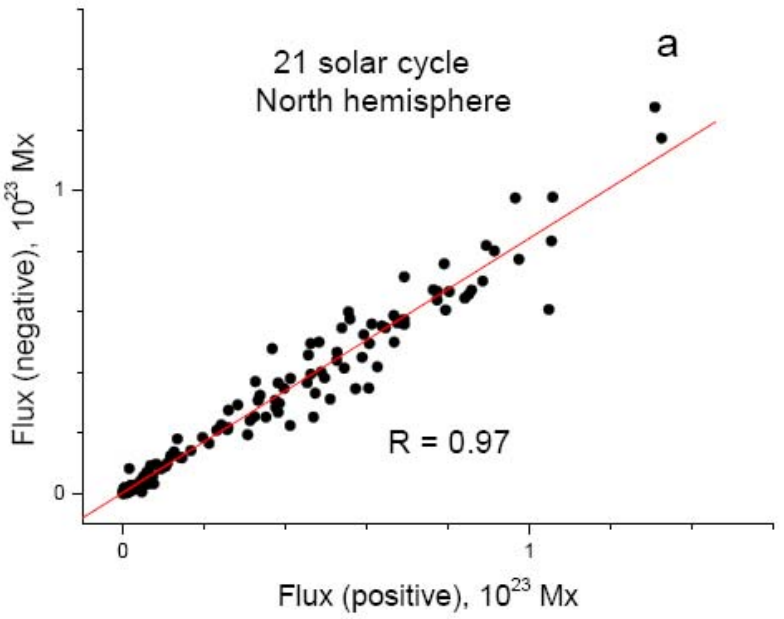
♦Flux imbalance for both hemispheres displays the 22-year periodicity. In contrast to any separately considered hemisphere (Fig. 4), the sign of the imbalance changes around the global magnetic field inversion.

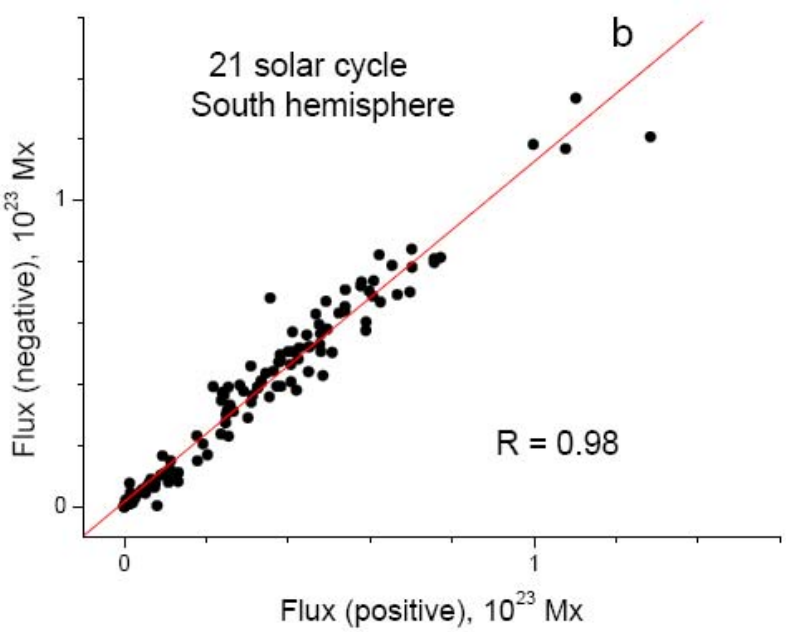
♦ Sign of the imbalance does not change during 11 years from one inversion to the other and always coincides with the sign of the Sun's global magnetic field in the North hemisphere.

♦ **There arises a question: whether it is possible to specify one of the four magnetic fluxes ($F_N^{pos}$, $F_N^{neg}$, $F_S^{pos}$, $F_S^{neg}$) which plays the dominating role and determines the imbalance sign?**

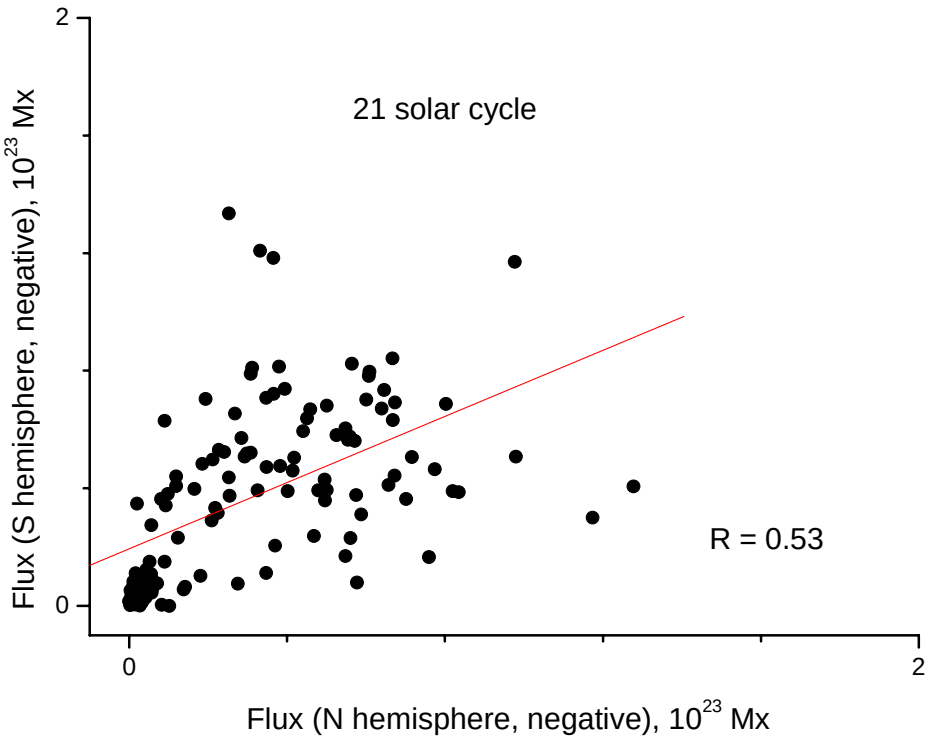
♦ **Answer: Imbalance is defined by the fluxes of leading sunspots which have the polarity coinciding with the global magnetic field sign in the North hemisphere. It follows from Figs. 7, 8.**

# Fig. 9. Correlation of positive and negative magnetic fluxes: North (a) and South (b) hemispheres



# Fig. 10. Magnetic flux correlation: North and South hemispheres




Correlation coefficients R

| Magnetic fluxes | $F_N^{neg}$ | $F_S^{neg}$ | $F_S^{pos}$ |
|---|---|---|---|
| $F_N^{pos}$ | 0.97 | 0.58 | 0.56 |
| $F_N^{neg}$ | | 0.53 | 0.52 |
| $F_S^{neg}$ | | | 0.98 |

**Strong correlation (Fig. 9) : leading and following sunspot fluxes of the same hemisphere: R=0.97 (North) and R=0.98 (South).**

**Weak correlation (Fig. 10): sunspot fluxes of the different hemispheres (R varies from 0.52 to 0.58).**

Change of the sign of the positive and negative magnetic flux imbalance ($\Delta F$) can be expressed by the following formula: $\text{sign } \Delta F = (-1)^{n+k}$ where n=1,2 (n=1 corresponds to the odd solar cycle, n=2 to the even one);

k=1,2 (k=1 corresponds to the interval of the 11-year cycle from the minimum up to the inversion;

k=2 to the interval from the inversion up to the minimum).

In this way, the imbalance sign will be determined by two factors: by the parity of the solar cycle on one hand, and by the phase of the 11-year cycle, on the other hand.

# Conclusions

- **For each of the Sun's hemispheres the imbalance of positive and negative fluxes shows systematic changes closely related to the 22-year magnetic cycle. The sign of the imbalance coincides with the sign of the leading sunspots which suggests the domination of the leading sunspot flux over the flux of the following ones. Imbalance changes its sign during solar minimum.**

- **For both hemispheres considered together (latitudes from -40° to +40°) the imbalance also changes with the 22-year period, yet the sign of imbalance changes during the magnetic field inversion. Sign of the imbalance always coincides with the sign of the Sun's global magnetic field in the N-hemisphere.**

# Conclusions

- **We have shown that both the sign of the N-S asymmetry of the magnetic fluxes and the sign of the imbalance of the positive and the negative fluxes are related to one of the quarters of the 22-year magnetic cycle where the magnetic configuration of the Sun remains constant.**
- **The sign of N-S asymmetry depends on the phase of the 11-year cycle only (before or after the inversion).**
- **On the other hand the imbalance sign depends both on the phase of the 11-year cycle and on the parity of the solar cycle.**
- **The obtained results demonstrate the connection of the magnetic fields in active regions with the Sun's global magnetic field in the North hemisphere.**

- **Photospheric magnetic field: relationship between N-S asymmetry and flux imbalance**
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