Spin-period model in eclipse using FGM data

Authors:

E. Georgescu[(1)], U. Auster[(2)], F. Plaschke[(2)], K-H. Fornacon[(2)] and H. Frey[(3)]

Affiliations:

[(1)] MPS, Katlenburg-Lindau

[(2)] IGEP, TU Braunschweig

[(3)] SSL, Berkeley

Abstract

Scientific interpretation of experimental data in magnetospheric missions where the attitude information comes only from a sun sensor is not possible during eclipses. Additionally, the temperature change of the spacecraft in eclipse causes a change of its moment of inertia and, hence, of its spin period.

We developed an “eclipse-spin” model for the spacecraft spin period behaviour using magnetic field vector measurements. This compensates for the lack of experimental spin phase information from the sun sensor. Using our model satellite experiments depending on correct spin phase information can deliver science data even during eclipses.

First results of the method are presented for CLUSTER and THEMIS spacecraft.

Outline

1. Experimental sun sensor and magnetometer data in eclipse examples for Cluster and Themis

2. Eclipse-spin model assumptions and their validity

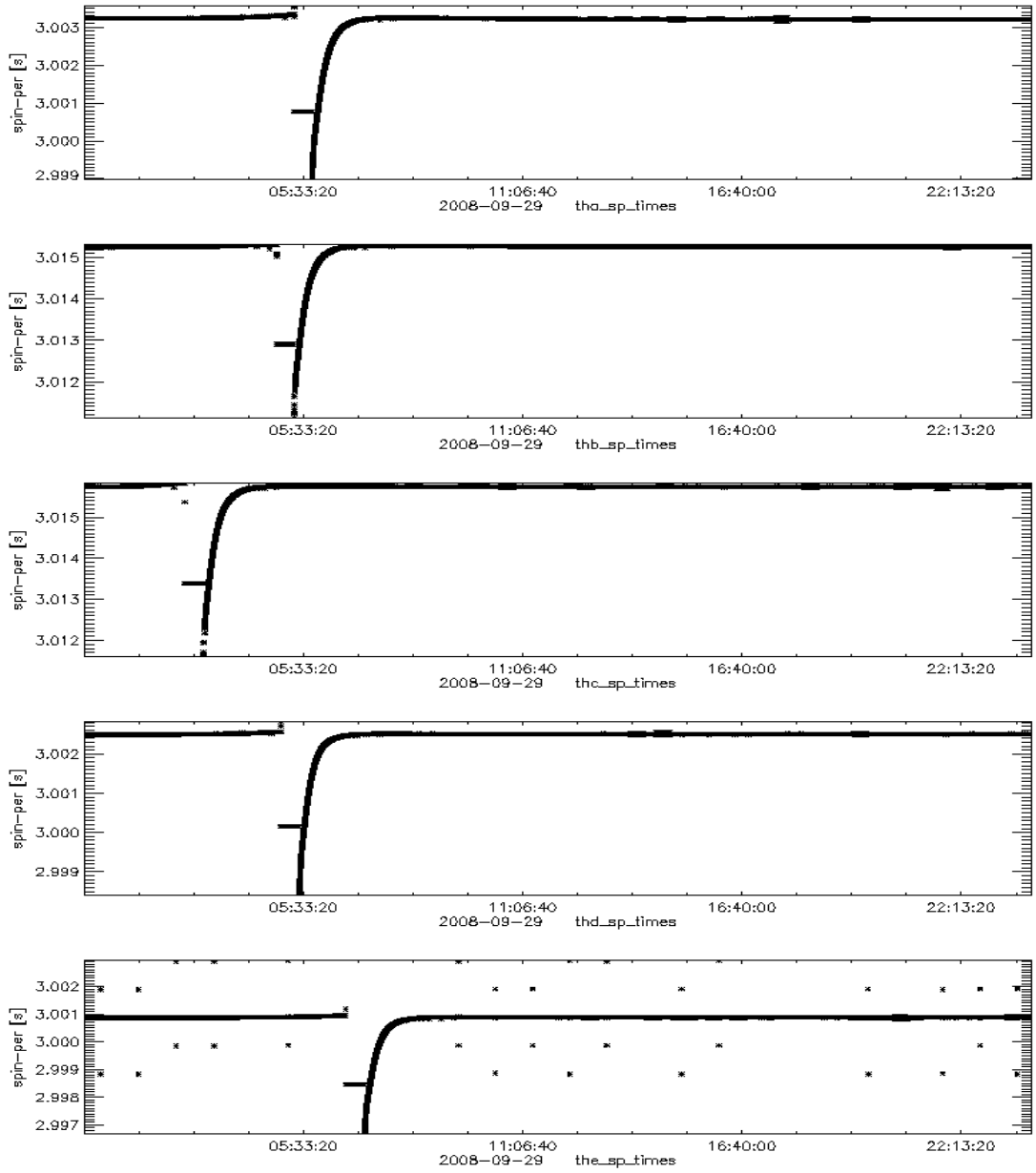
3. Description of the procedure to define the eclipse-spin model

4. Extend the model with long eclipse data in constant ambient magnetic field

5. Apply eclipse-spin model and check errors

6. Conclusion

1.1 Spin period of the 5 Themis spacecraft from Sun Sensor



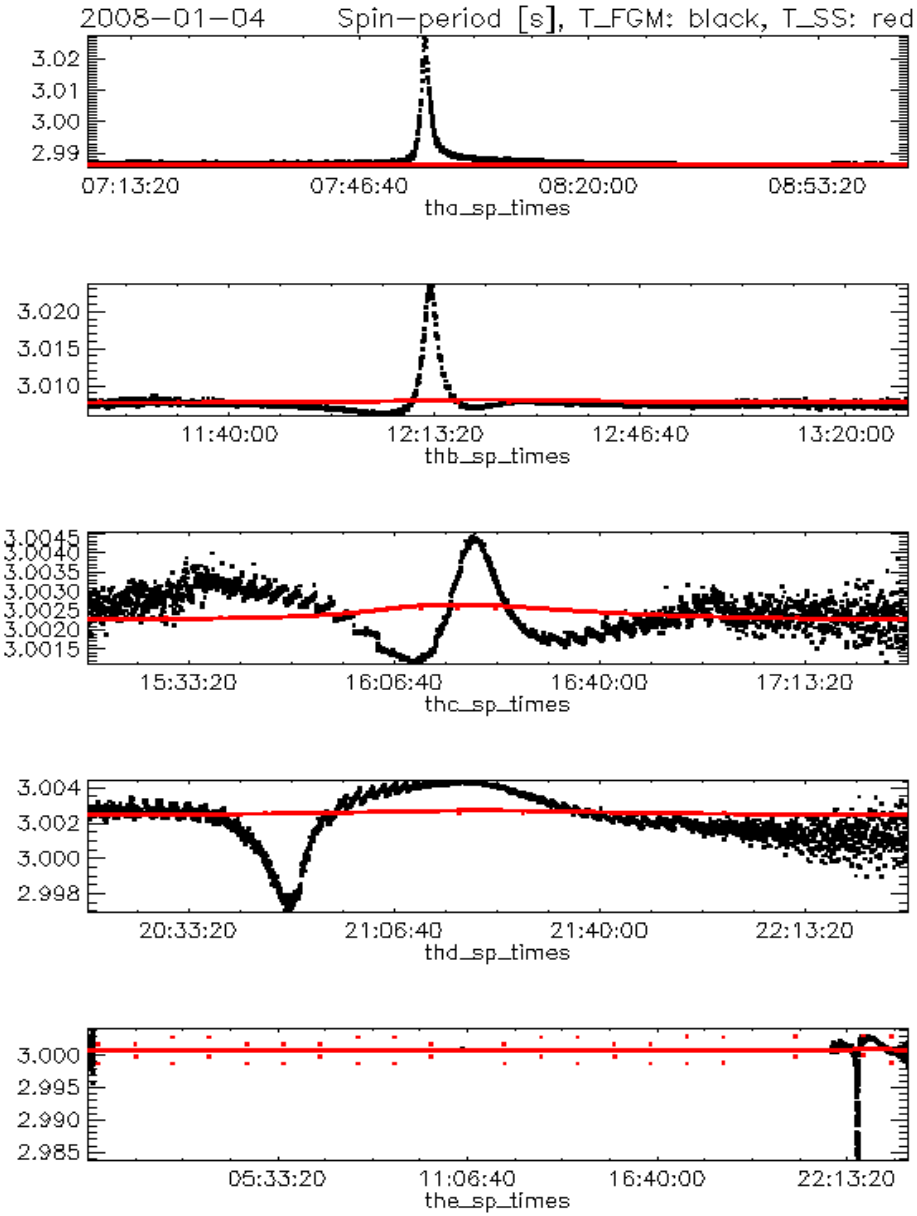
T_SS

2008-09-29

- **Eclipse:** NO experimental data. The T_SS values in the eclipse are „fake“.

- The differences of spin period after the eclipse to the value at eclipse start are of the order of 4 ms after 25 min of eclipse, > **0.1%.**

1.2 Spin period from Sun Sensor (red) and FGM (black)



Themis
2008-01-04

T_SS and T_FGM

- **NO eclipse**
- **Up to 1% discrepancies between T_SS and T_FGM**

⇒ ***Correction needed for*** **T_FGM**

The rotation of the magnetic field in the spin plane has to be subtracted

2. Eclipse-Spin model assumptions and their validity

Working hypotheses:

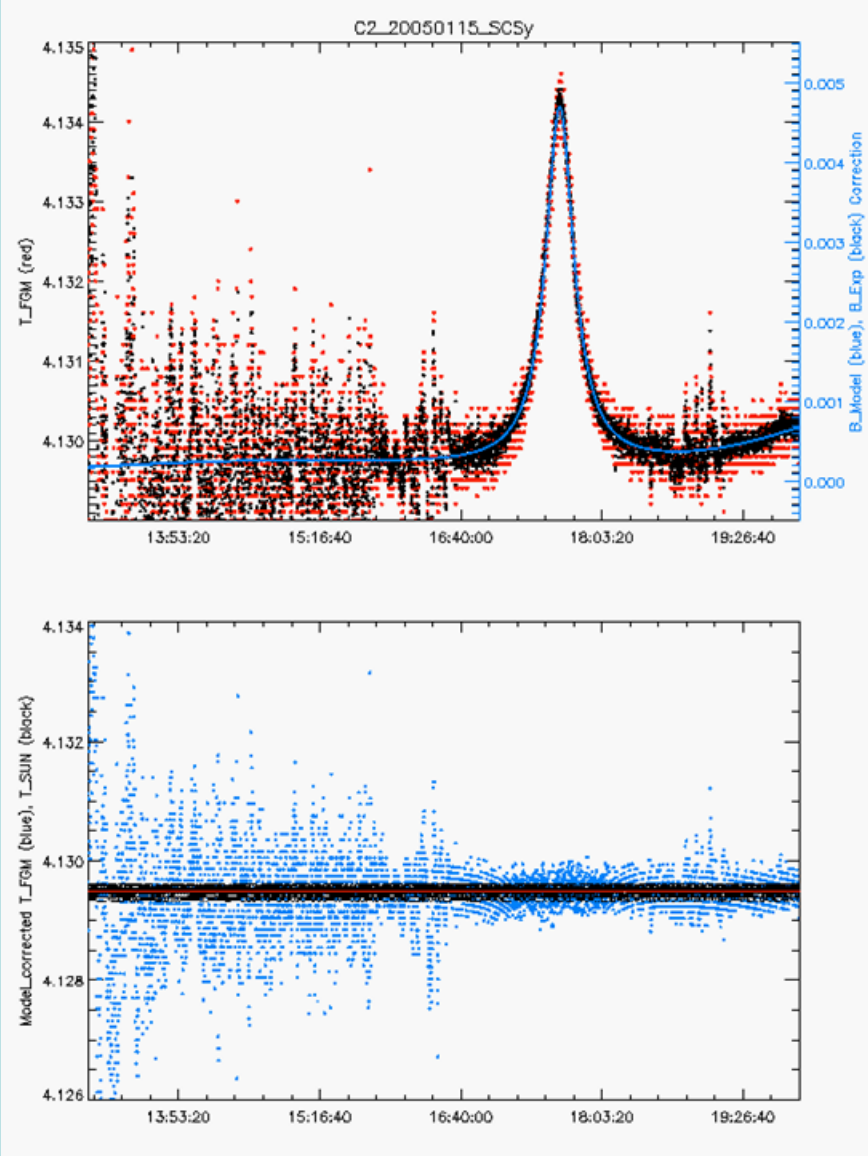
1) each spacecraft has a specific signature in the temperature dependence of its moment of inertia
The model intends to describe analytically this signature

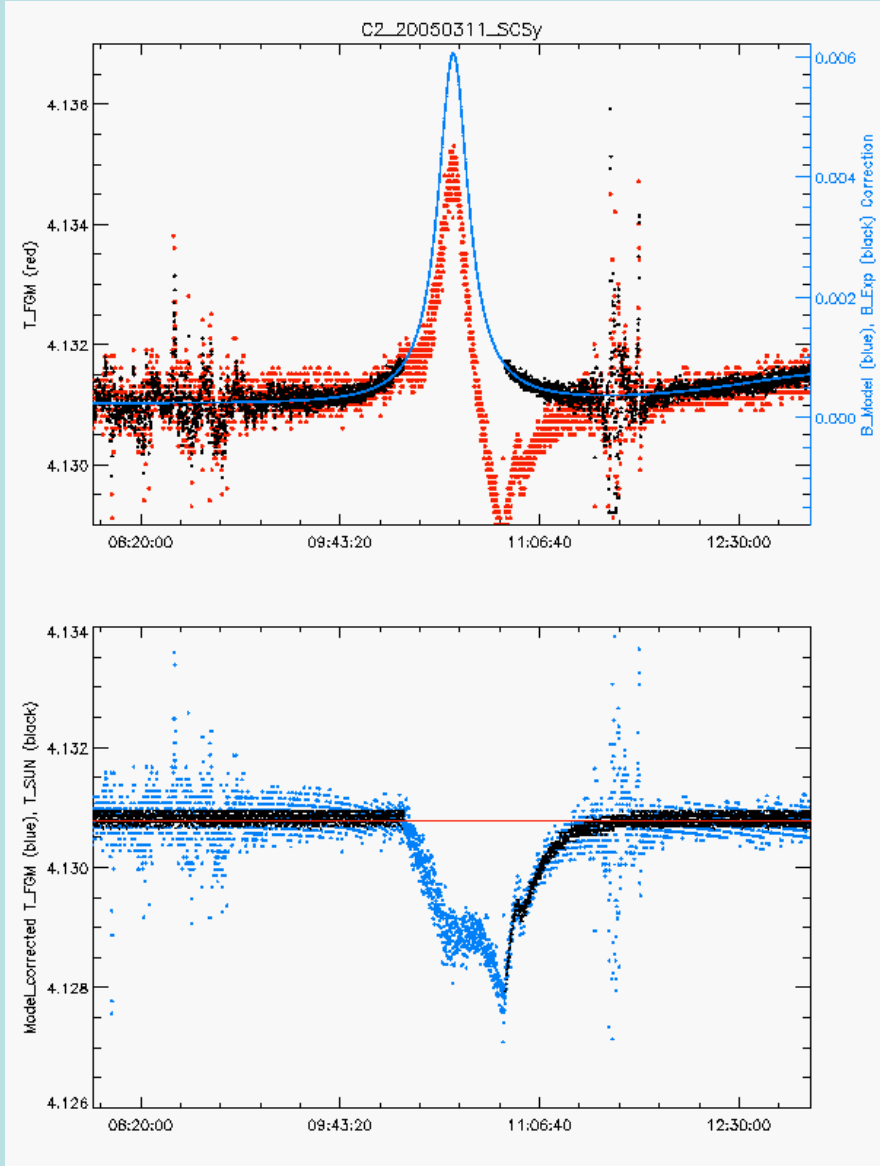
2) the spin period can be determined from the magnetic field in a rotating spacecraft system

Check working hypotheses:
1) with superposed epoch analysis (2.3, 3.4)
and
2) by comparing the sun sensor period with the magnetometer period when both data are available (2.1, 2.2)

2.1 T_SS & corrected T_FGM using field model

CLUSTER



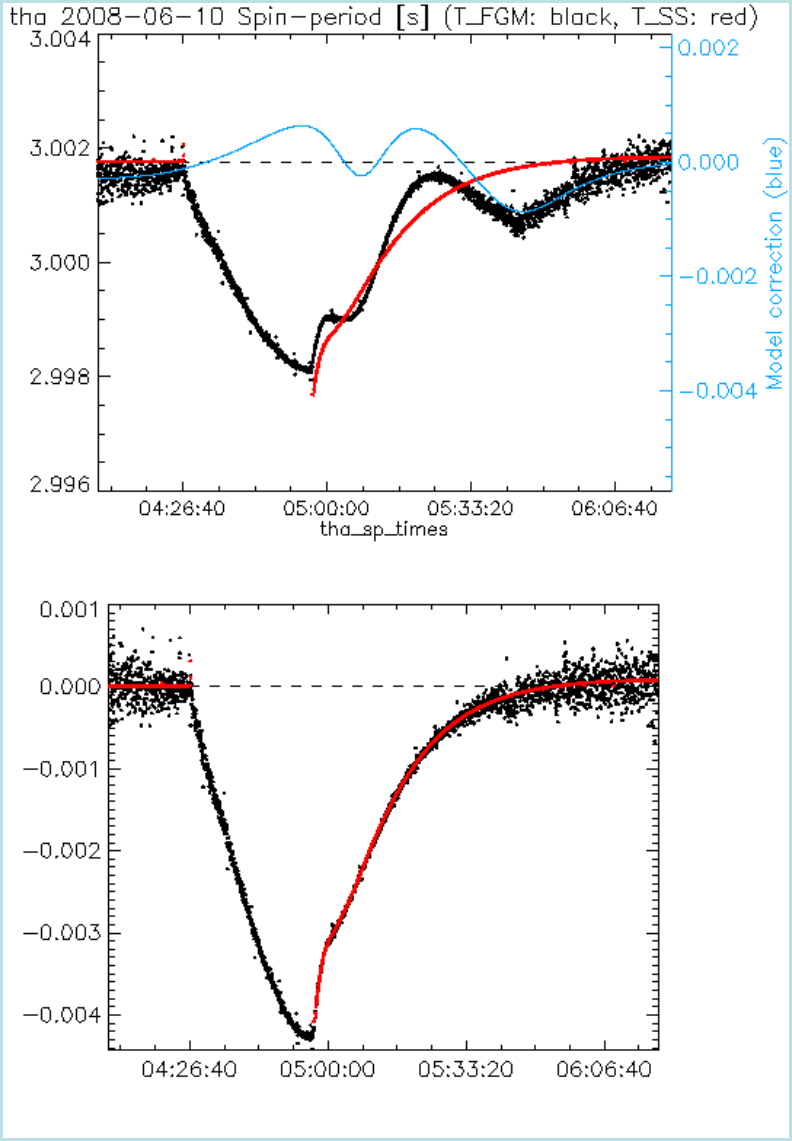


no eclipse

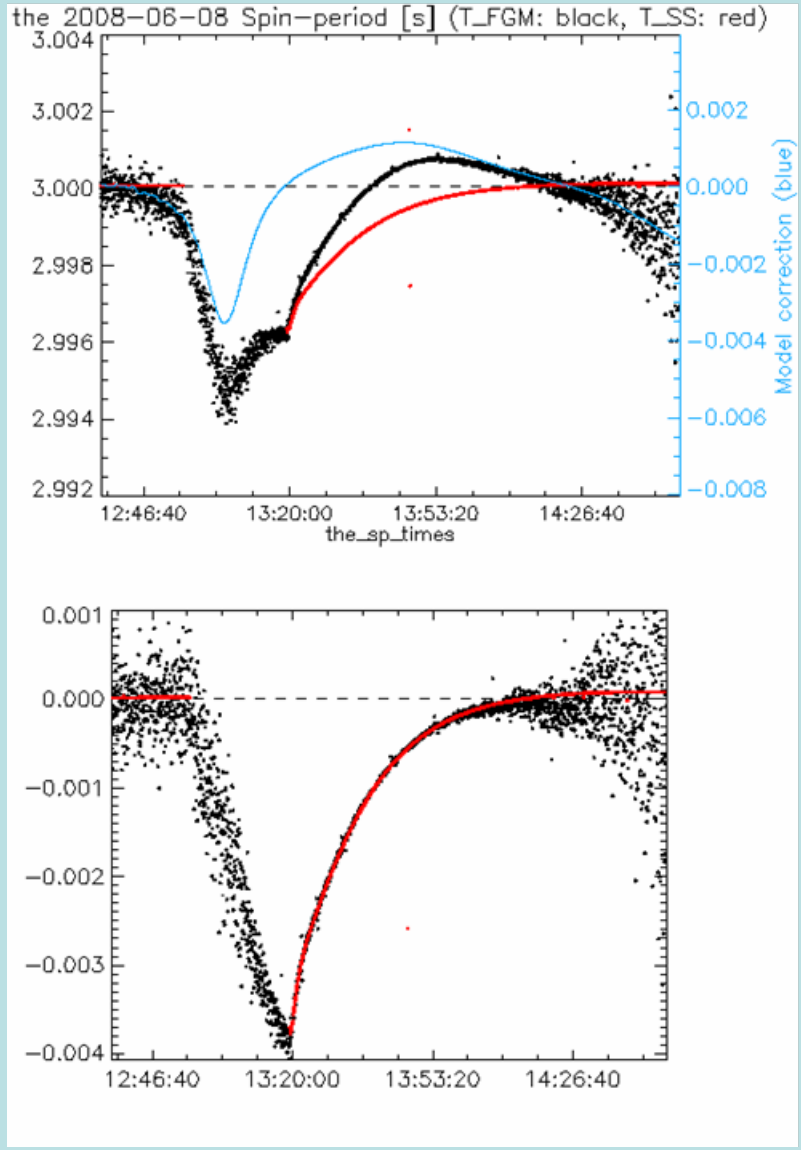
eclipse

2.2 Example of spin behaviour in eclipse

THEMIS

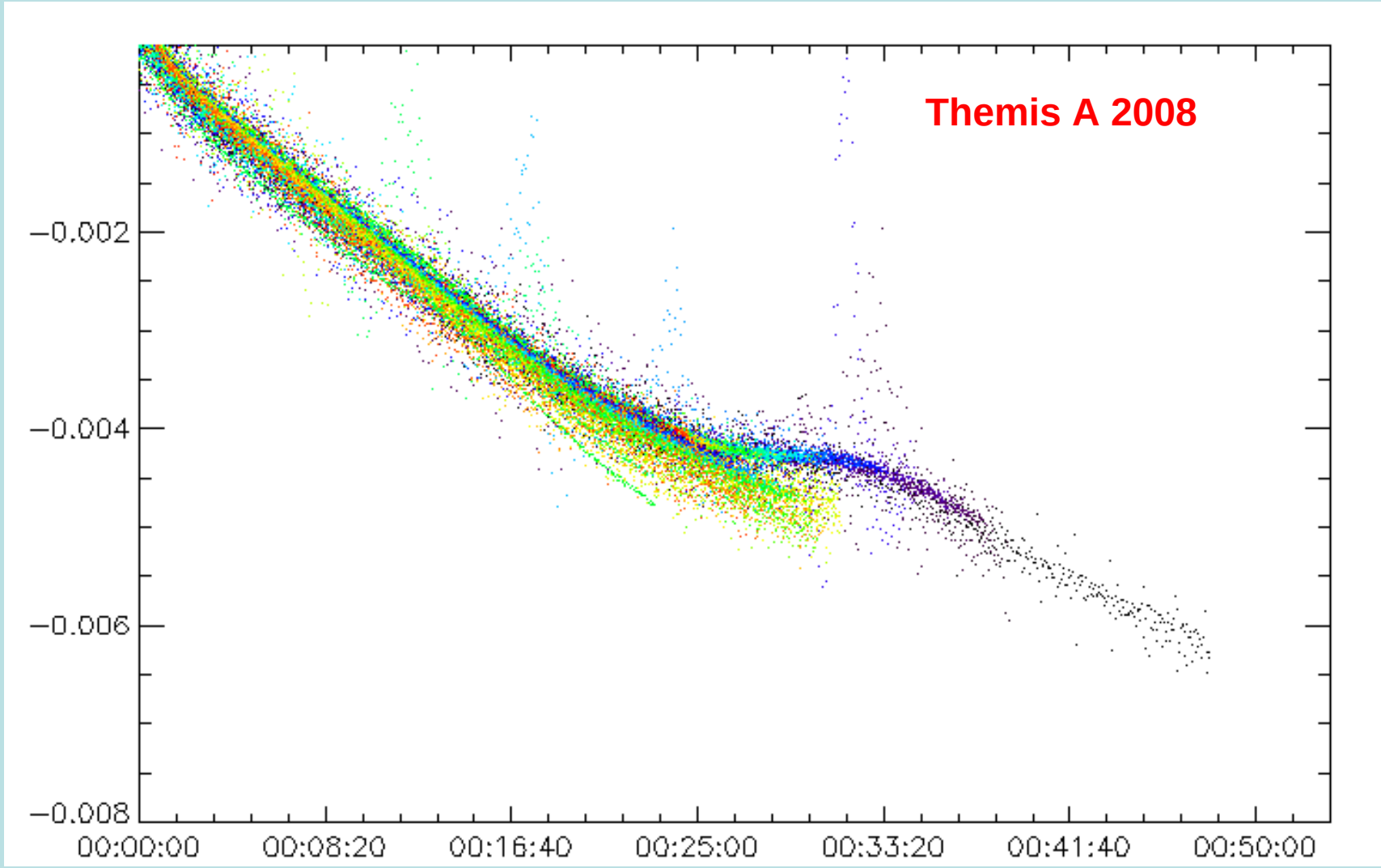


tha 2008-06-10



the 2008-06-08

2.3 Eclipse database & superposed epoch analysis



3. Eclipse-Spin model (ES model)

Database

- **T_SS** = spin period from Sun Sensor
- **T_FGM** = spin period from a spin plane component of the magnetic field in a rotating spacecraft frame (Cluster: FSR, Themis: SSL)
- **B_model** = model magnetic field in a non-rotating spacecraft frame (Cluster: SCS, Themis: DSL) from IGRF + Tysganenko'96; uses position from state file

Procedure to reconstitute the spin period in eclipse

a. Build eclipse database:
 - find eclipses in T_SS
 - get T_FGM and correct with model magnetic field at perigee

b. Superpose eclipse data and fit

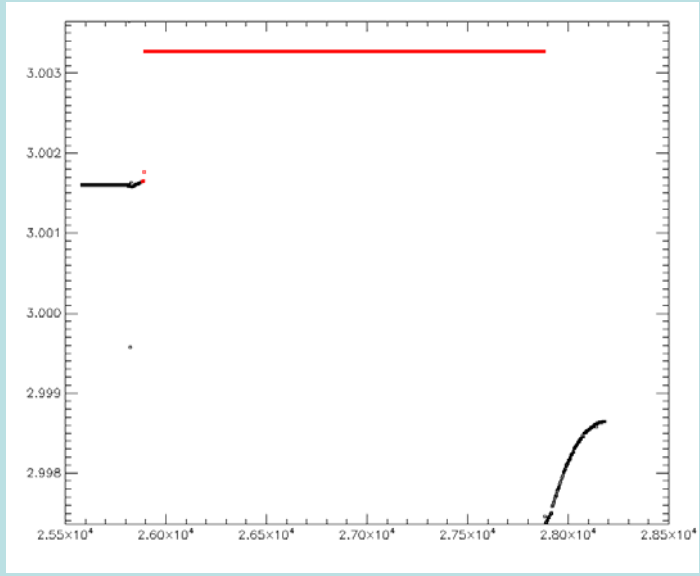
c. Check ES model with single eclipse

3.1 Find eclipses in T_SS

Eclipse time intervals are defined using the spin period data delivered by the Sun Sensor (Cluster: STEF files used)
T_SS: Difference between two subsequent spin start times (see-sunpulse times)

Eclipse recognition routine (semi-automated procedure)

- Build histogram of the values using bins of 0.0001 s.
- The „fake“ eclipse-period is defined as the distinct secondary maximum.
- The data are searched for „jumps“ and each interval between two jumps is compared with the eclipse-period; if it corresponds then the time interval is plotted and recorded (red is the selected eclipse)
- The determined eclipses have been compared to a geometrical model of F. Plaschke for Themis



3.2 Create FGM database: T_FGM and Bmodel

Experimental data:

T_FGM = spin period from calibrated **FGM** data in a spinning spacecraft frame

Procedure to obtain T_FGM:

- One spin plane component is separated into intervals containing one period of a sine
- Each interval is fitted with a linearly varying amplitude sine function:

$$Yfit = (a[0]+a[1]*t)*\sin(2*\pi*t/a[2]-a[3])$$

T_FGM = a[2] is recorded and the middle of the time interval (t_FGM)

Model magnetic field data:

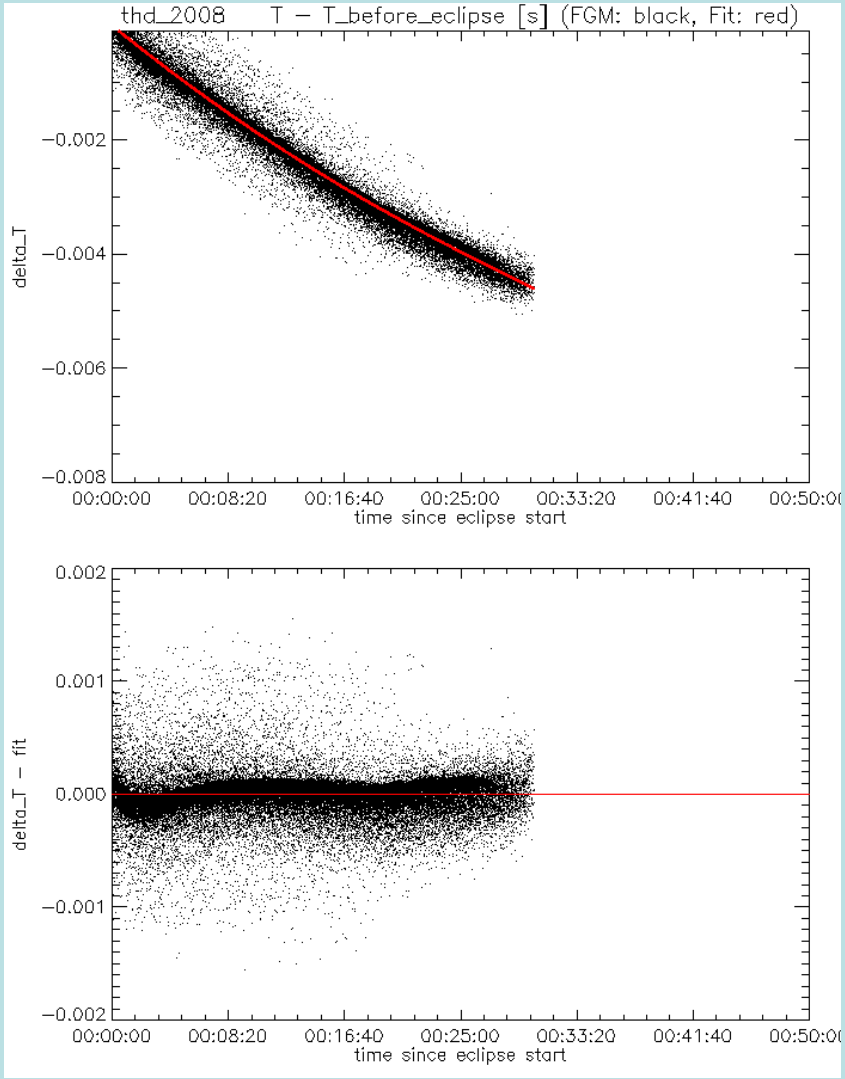
B_model in a non-rotating spacecraft frame (SCS, DSL)

- Uses **position** from state file and **Tsyganenko 96** to produce model field in GSM
- This is transformed using **attitude** the spacecraft frame and spline-interpolated to t_FGM

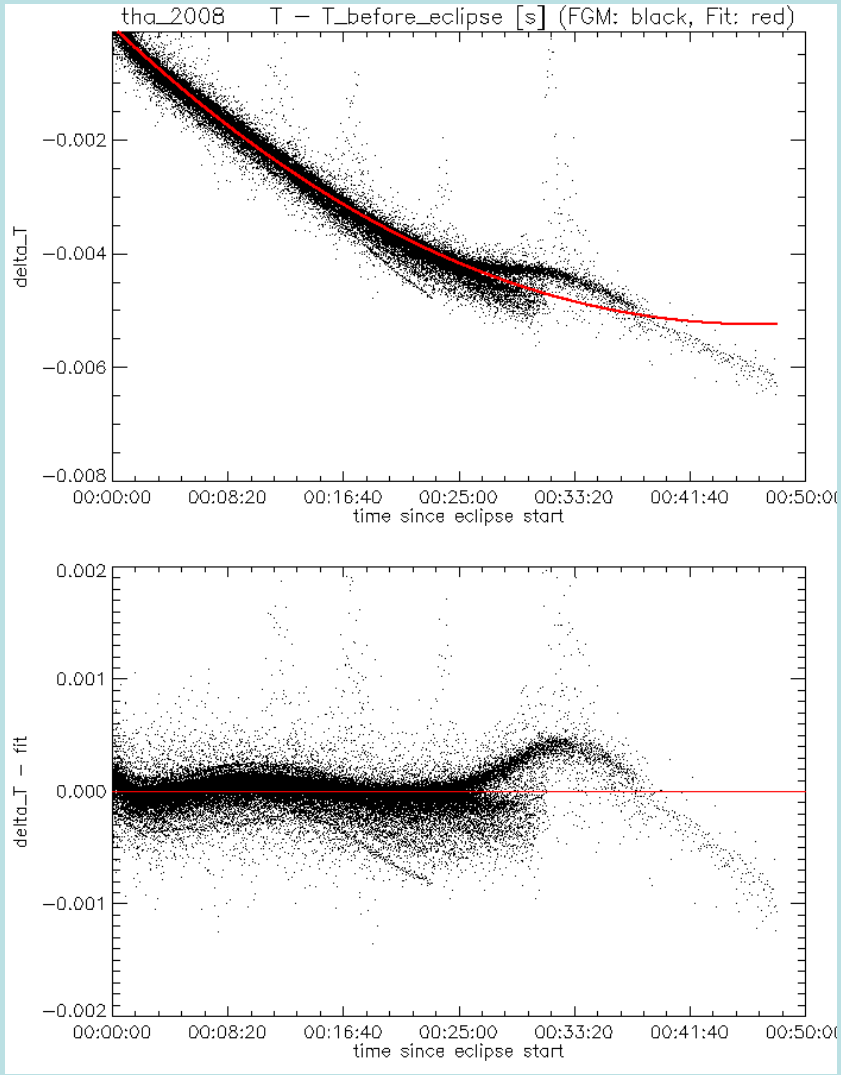
$$Clocka = atan(B\_model\_y\_DSL / B\_model\_x\_DSL)$$

3.3 Fit superposed eclipse data

Fitfunct = a[0]*exp(a[1]*t)+t*(a[2]*t+a[3]*t)

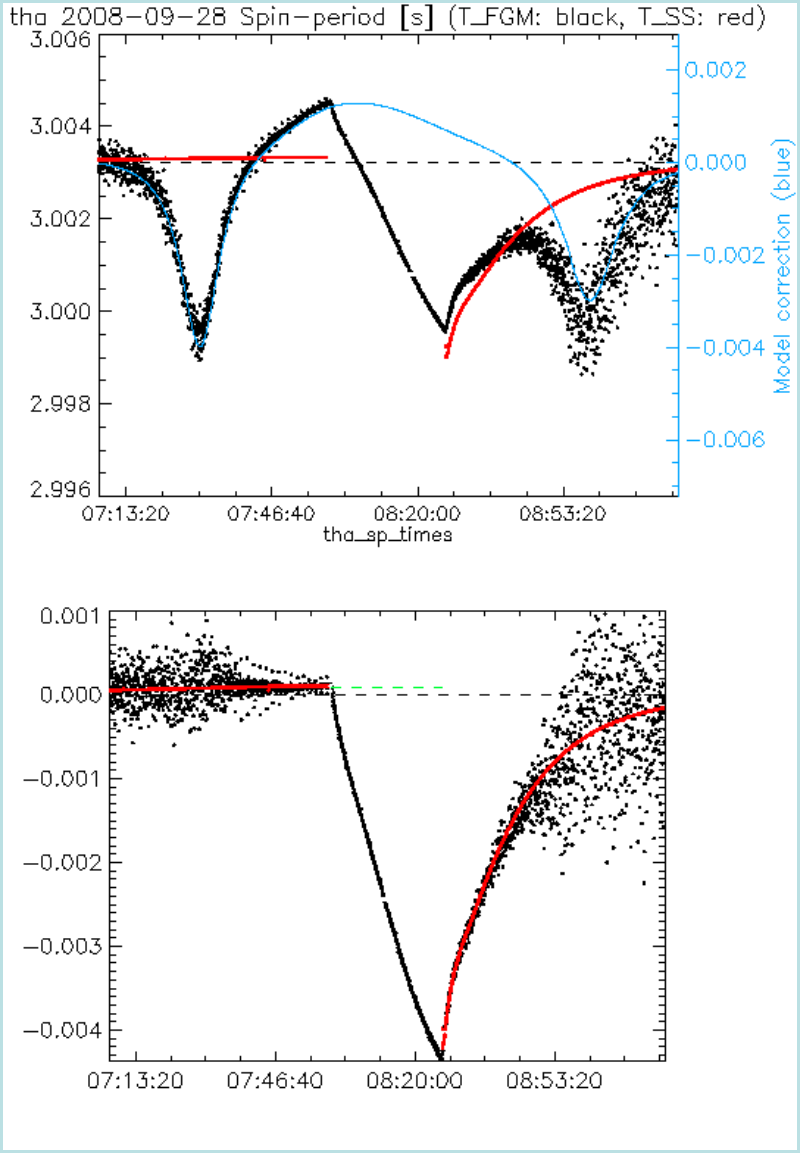


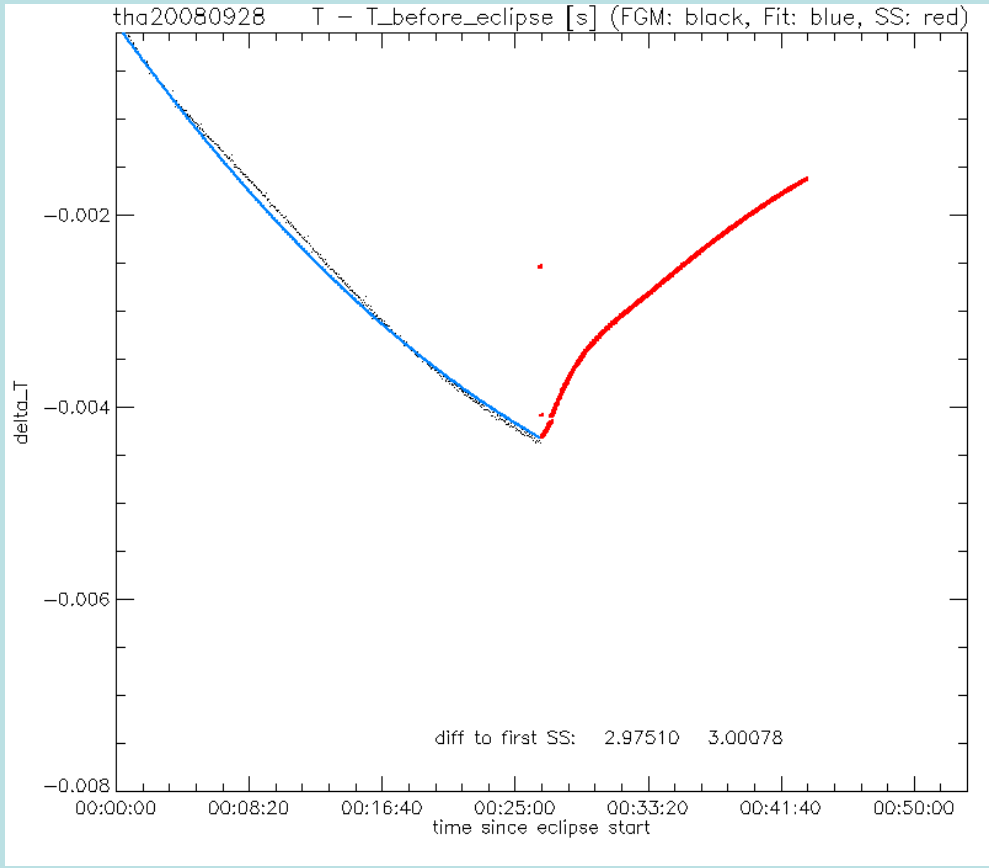
thd 2008



tha 2008

3.4 Check ES model with single eclipse

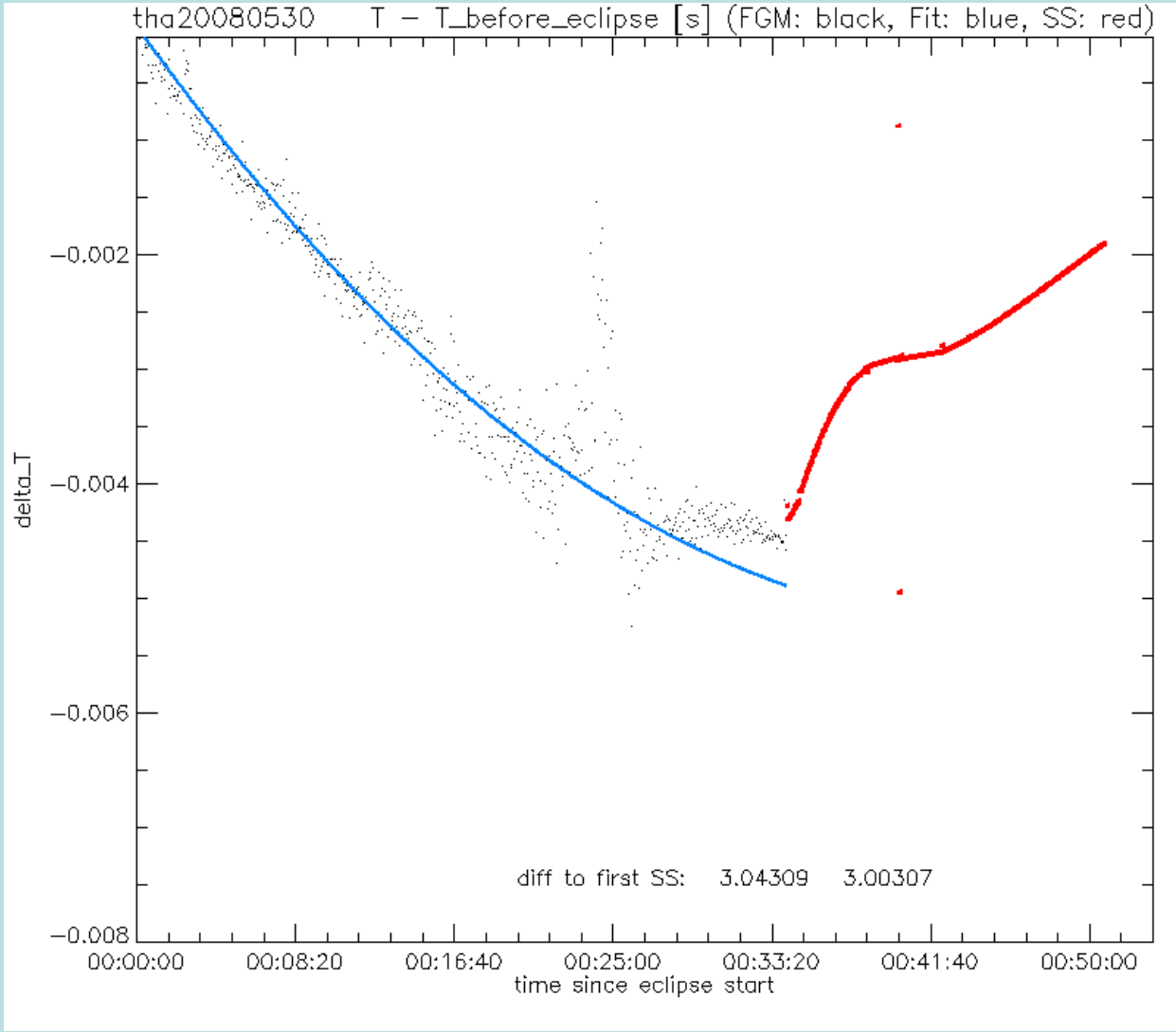




Good agreement for short eclipses

Eclipse duration < = 25 min

3.5 Check ES model with longer eclipse (> 25 min)



Discrepancy when the eclipse is longer (1% after 5 min)
Difference between last model spin period and first after eclipse one

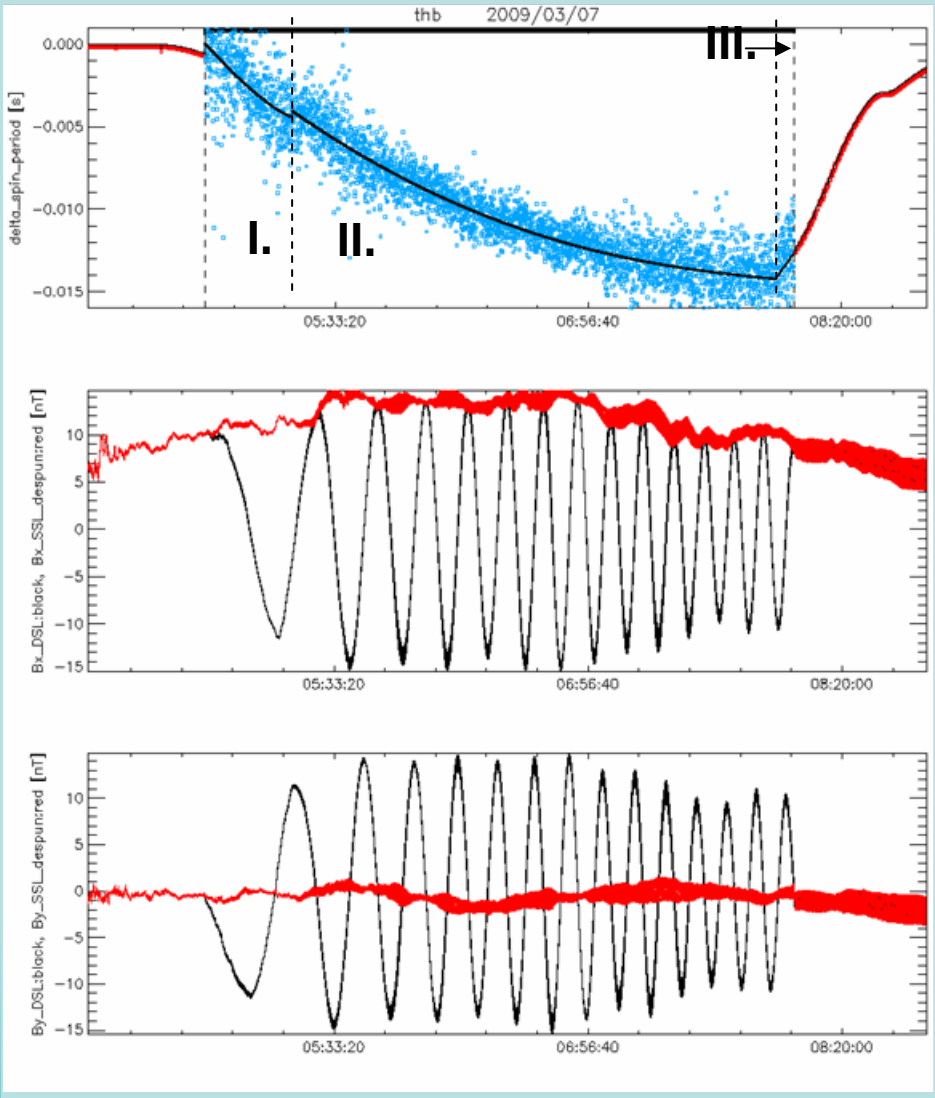
4. Extend Eclipse-Spin model for long eclipses

- Eclipses close to perigee where model magnetic field is well defined are „short“
- The fit to the superposed epoch data describes well these ones
- Long eclipses in quasi-constant magnetic field are required to extend the eclipse-spin model

Procedure for extending the ES model:

- determine eclipse time interval and get corrected T_FGM
- divide the eclipse spin-period data (blue points in Fig. 4.1 a) into 3 parts:
  (I.) “short” eclipse: from start to the first inflexion point (up to 25 min from eclipse start)
  (II.) “long” eclipse: from first inflexion to spin-period minimum
  (III.) “penumbra”: approx. 5min before T_SS present again
- use short-eclipse model for the first 25 min (I.)
- fit similar function for the data of section II.
- fit a line to III.
- select data points of the three sections (Fig. 4.2 b: red squares)
- spline interpolate to 1 s (Fig. 4.2 b: red line)
- save as **„eclipse-spin model“**

4.1 Long eclipse in constant B field



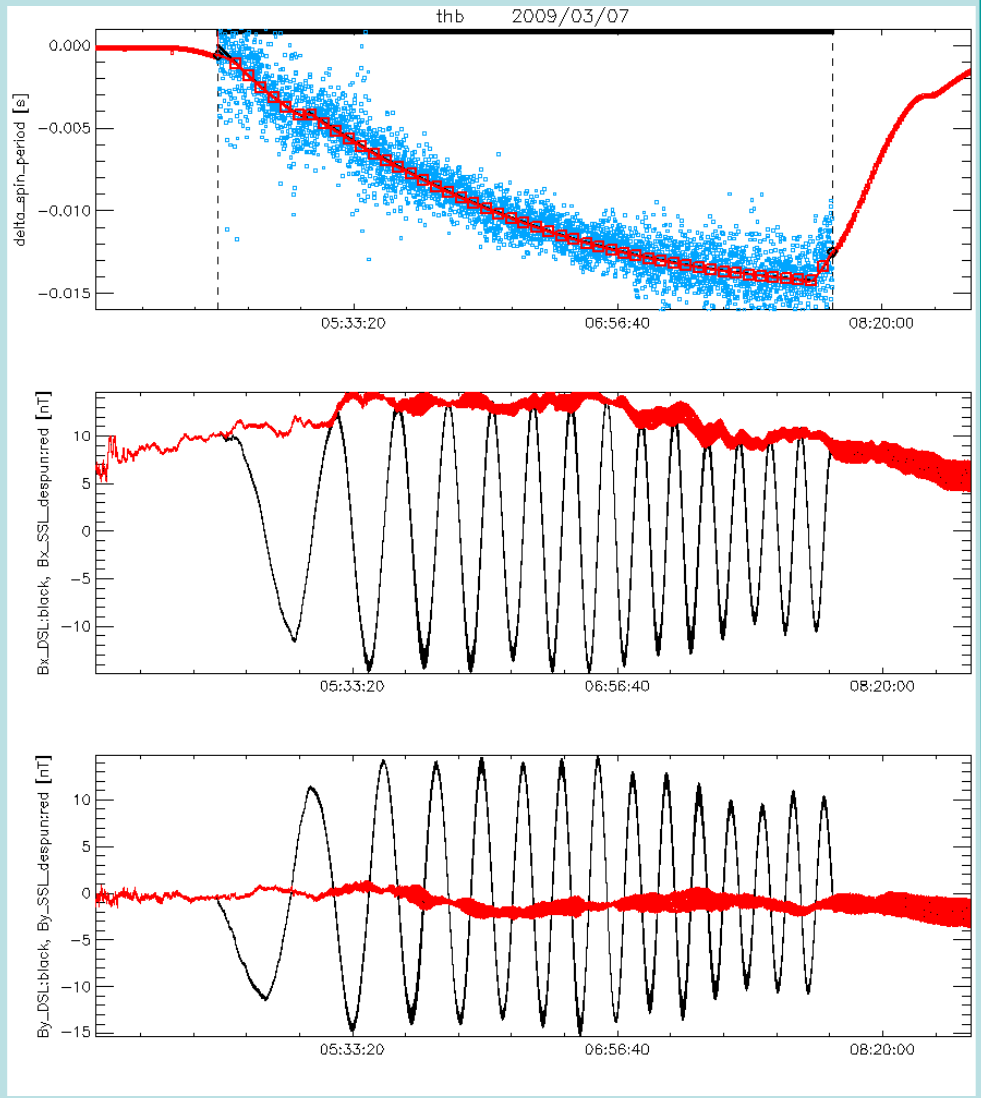
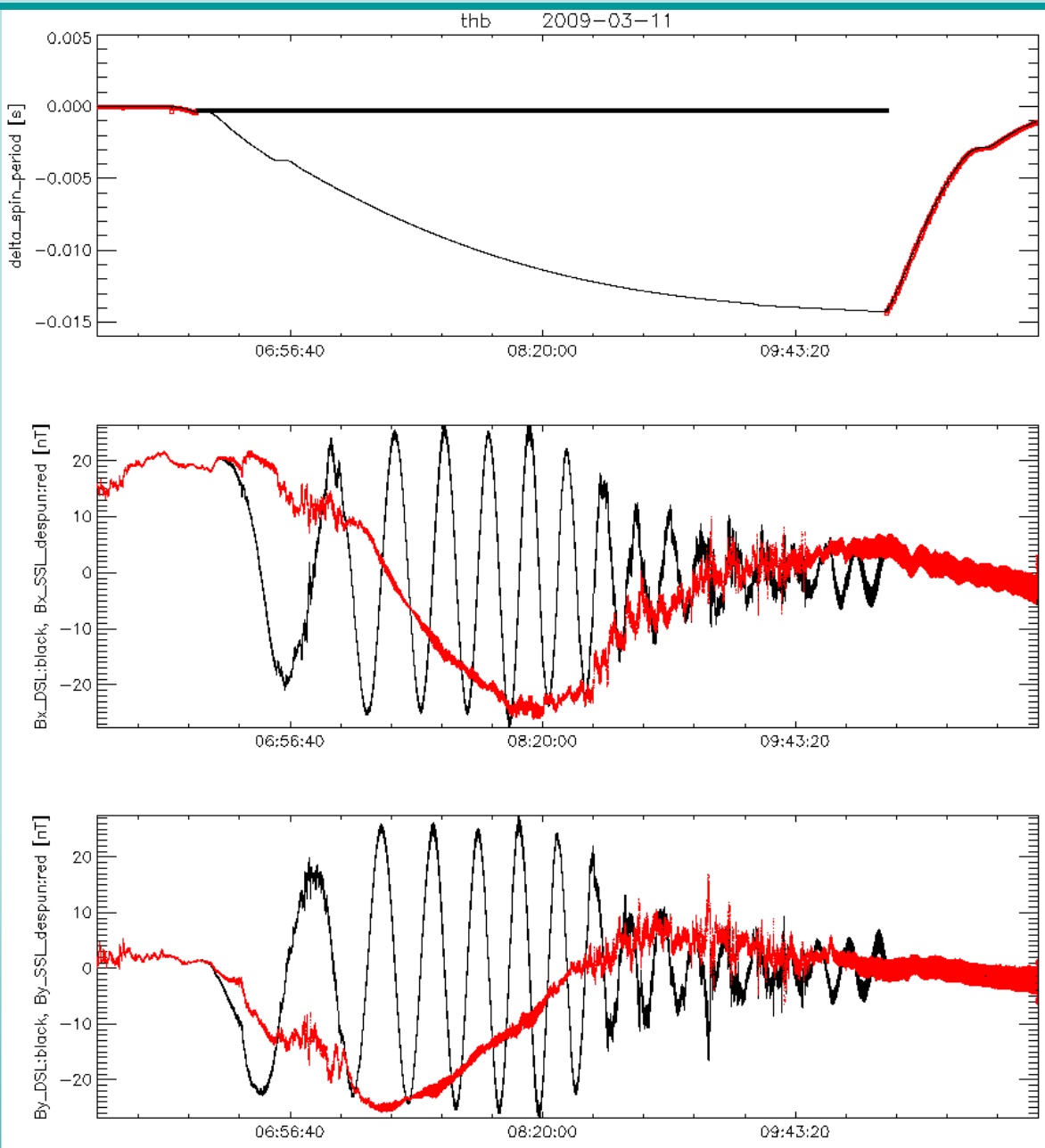


Fig. 4.1 a **thb 2009-03-07** **Fig. 4.1 b**

Upper panel: T_SS(red, black in eclipse), corrected T_FGM (blue points) & model

Lower panels: Spin-plane components despun using T_SS:black & the ES model: red

5. Apply eclipse-spin model



thb 2009-03-11

eclipse duration:
03:47:05.250

model eclipse duration:
03:13:53.478

6. Conclusion

The spacecraft spin behaviour in the eclipse is characteristic for each spacecraft and reflects the dependence of the moment of inertia on temperature

An “eclipse-spin model“ for the spacecraft spin period behaviour using magnetic field vector measurements was developed.

The ES model compensates for the lack of experimental spin phase information from the sun sensor, such that satellite experiments, depending on correct spin phase information, can deliver science data even during eclipses.

The application of the method to CLUSTER and THEMIS data confirm the validity of the assumption and good results for the spin period reconstitution.