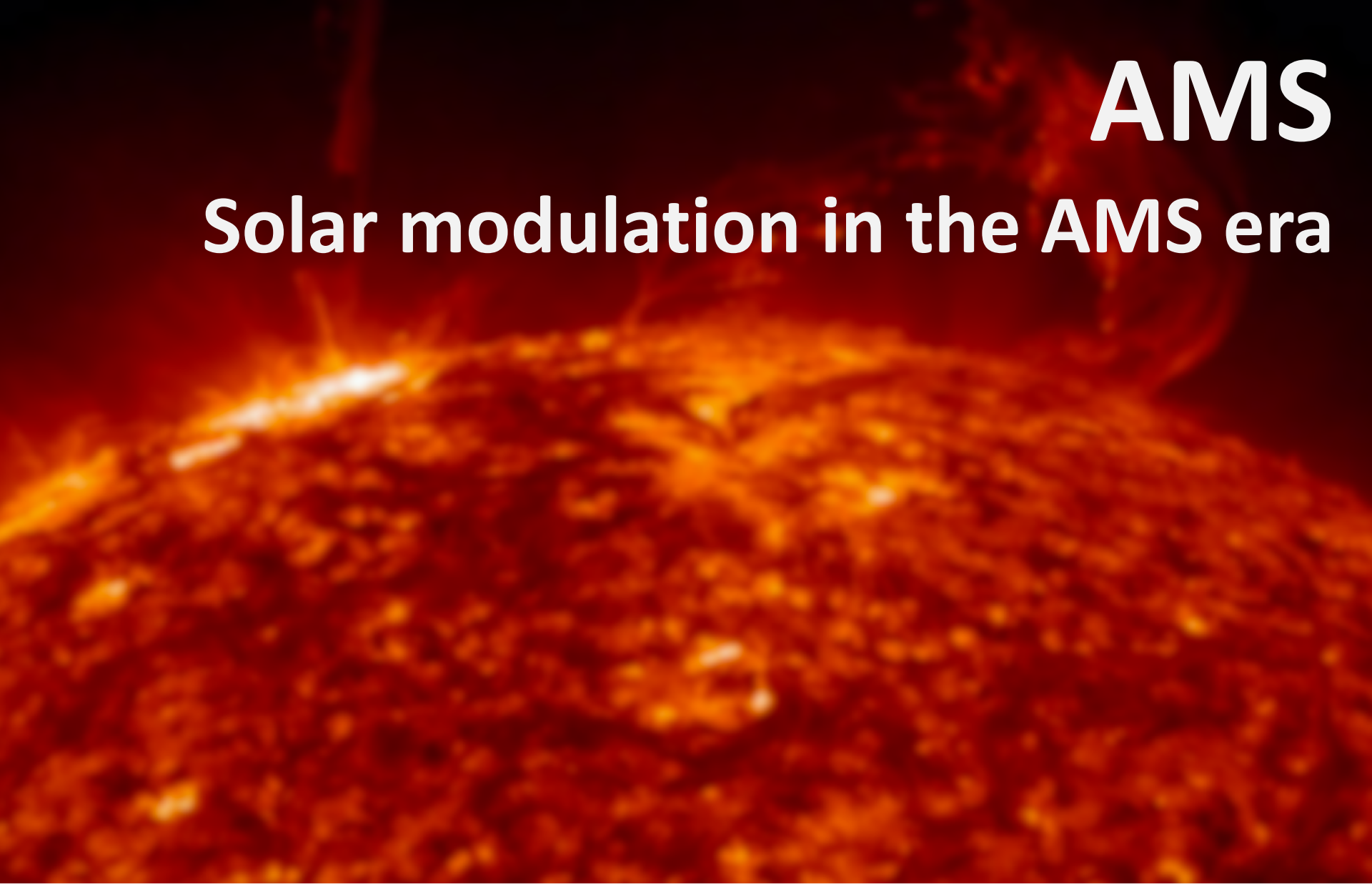


AMS

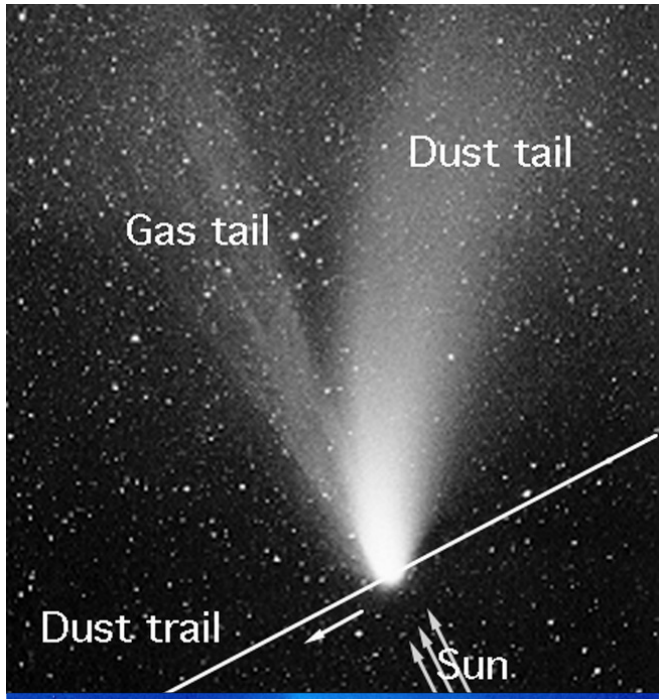
Solar modulation in the AMS era

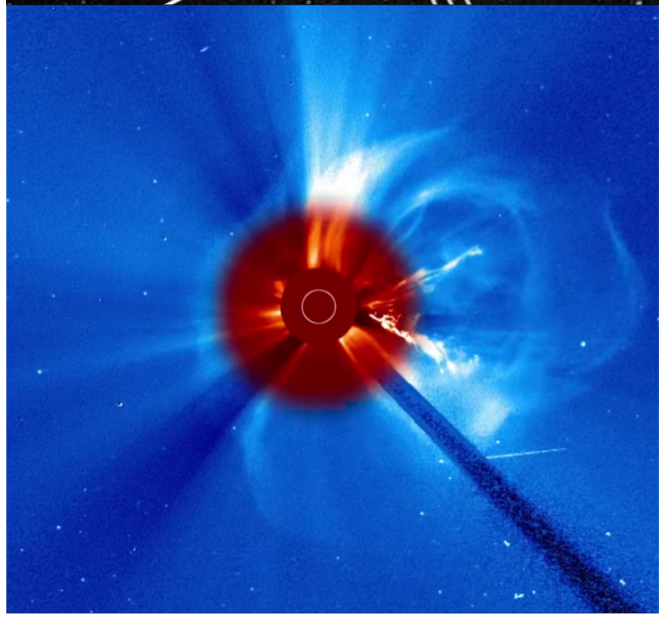
M. Orcinha, Jornadas LIP 2018 (Évora)

SOLAR WIND

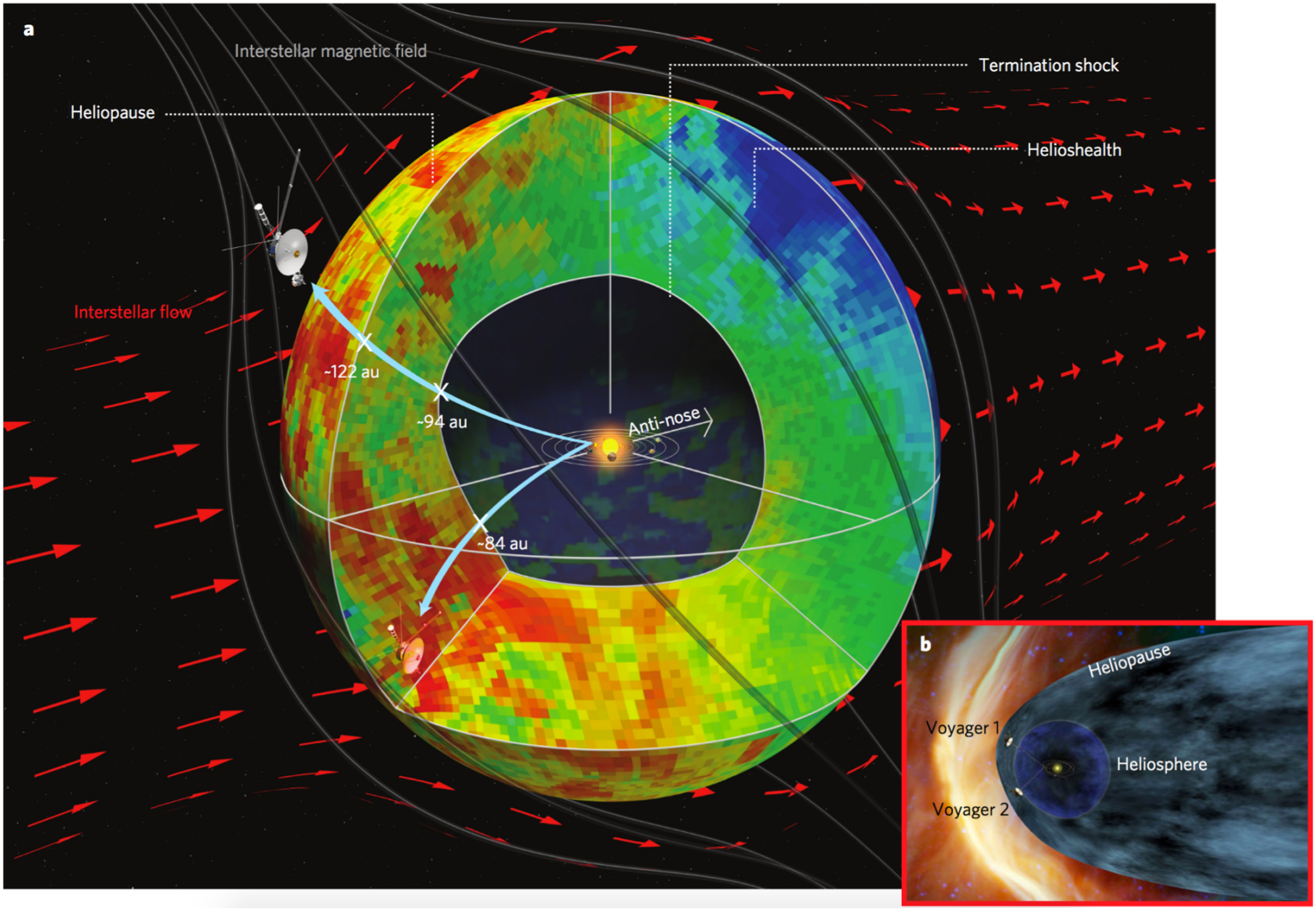
First observations:
Biermann (1951) – observing comet tails, reported that their odd shape should be due to a gas streaming outwardly from the Sun, at around 500-1500 km/s.

Theoretical interpretation:
Parker (1958) – showed that there should be no hydrostatic equilibrium solution for the Solar wind and looked into the Solar corona as a source for this Wind.

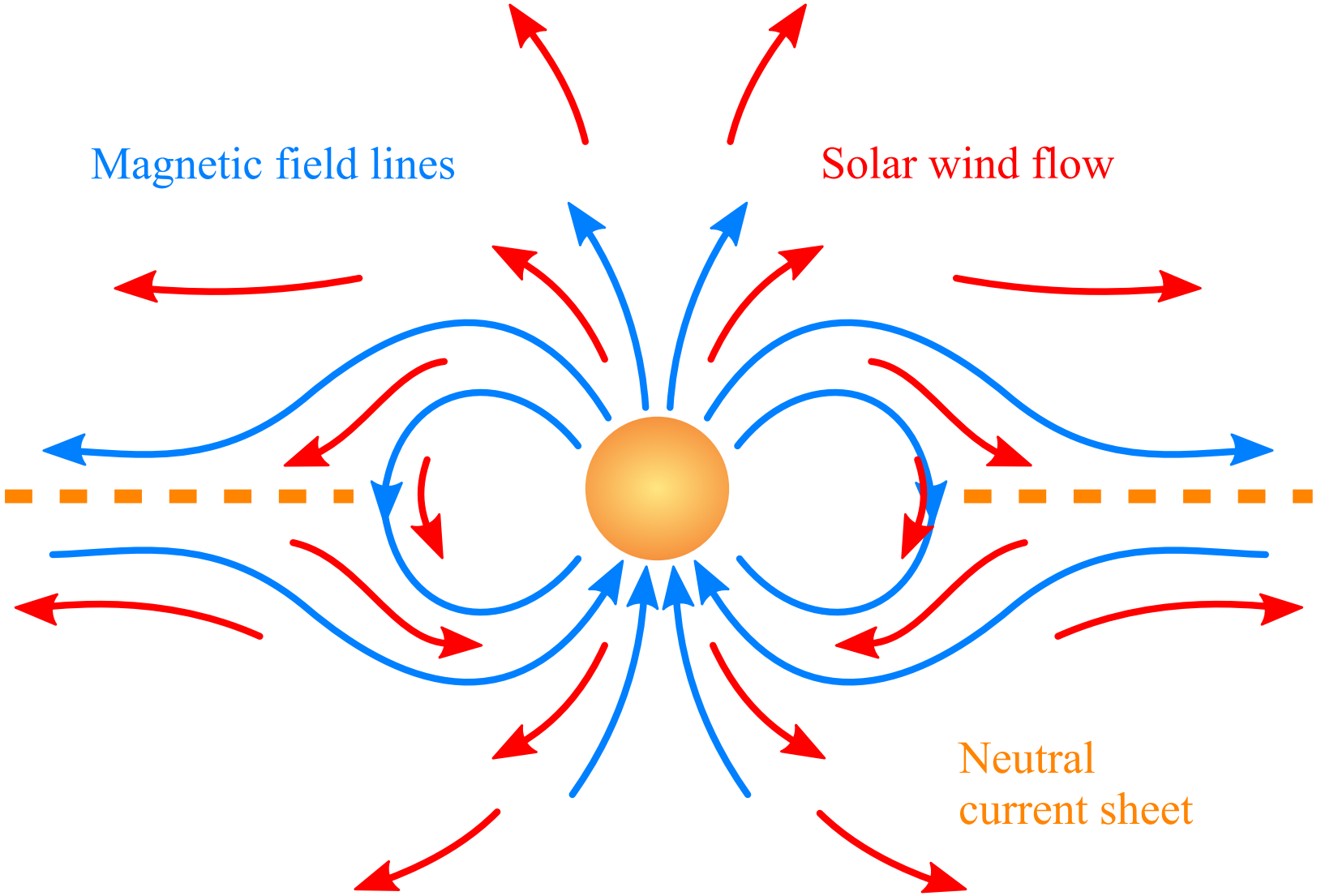




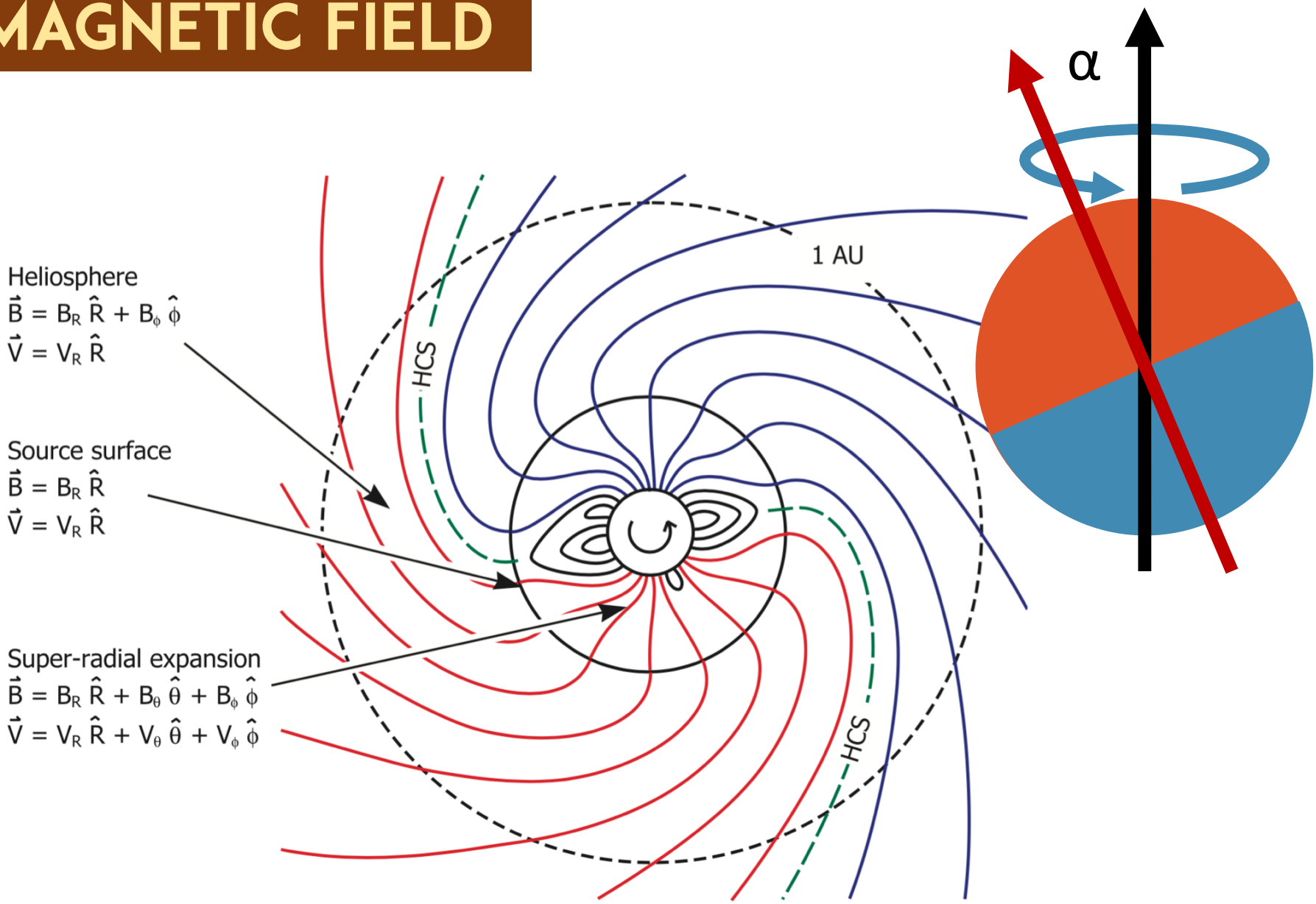
HELIOSPHERE



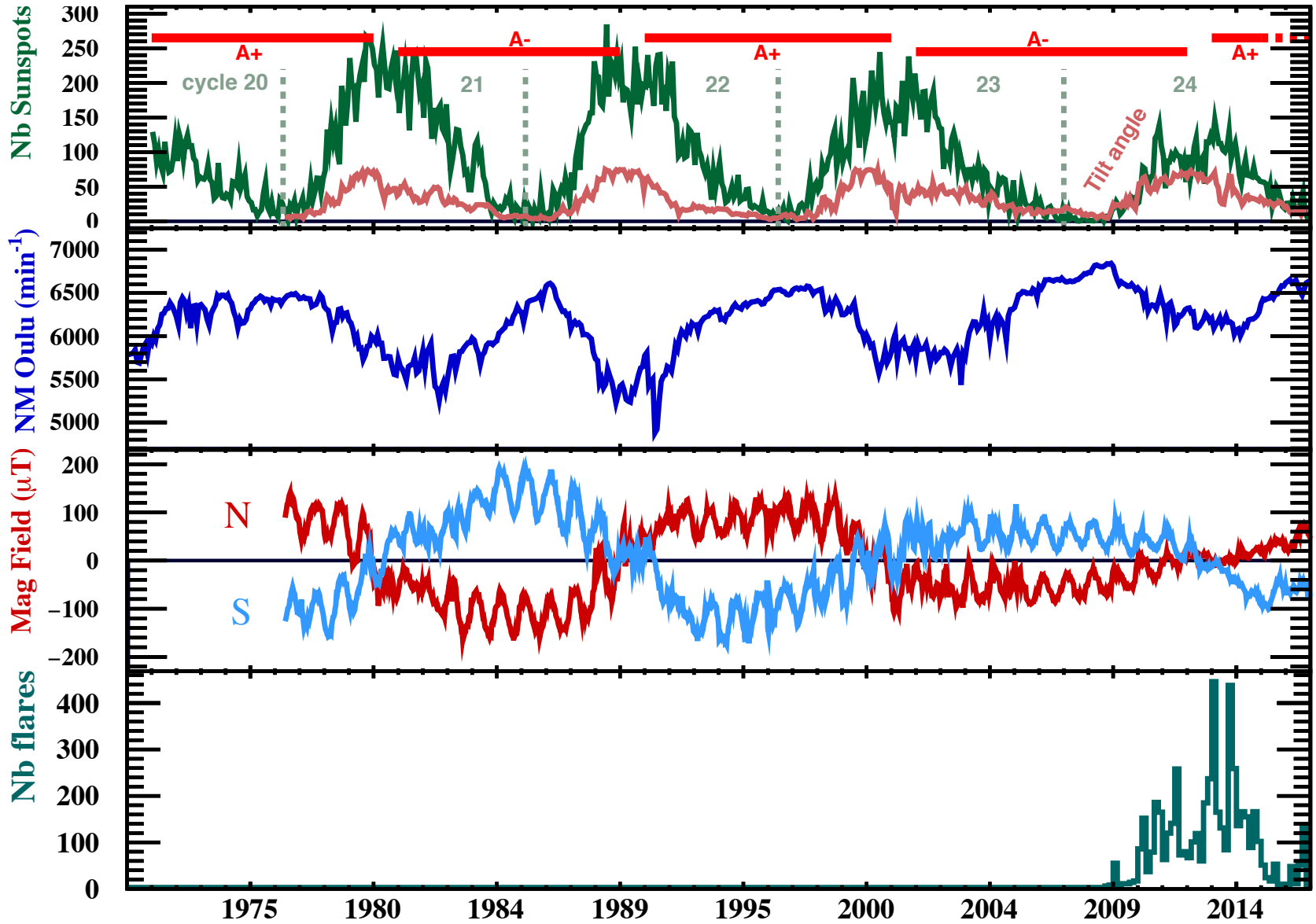
MAGNETIC FIELD



MAGNETIC FIELD

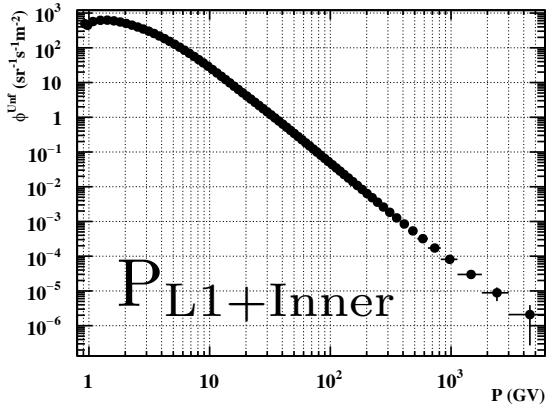


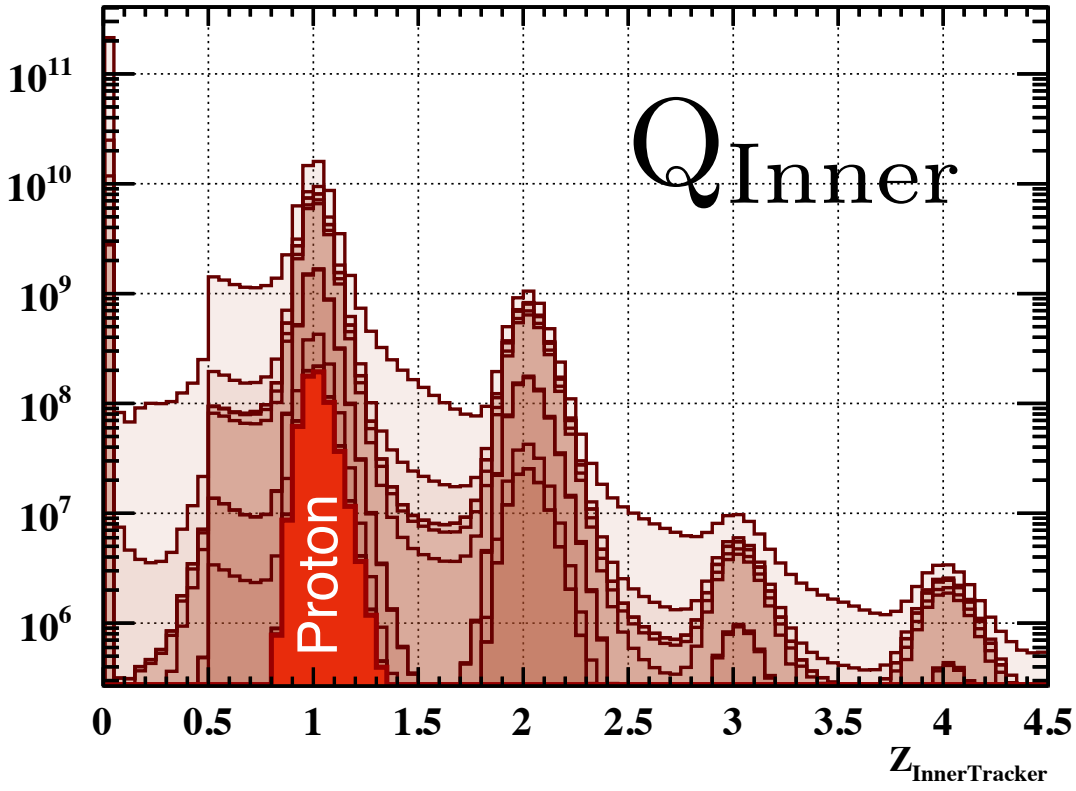
SOLAR ACTIVITY

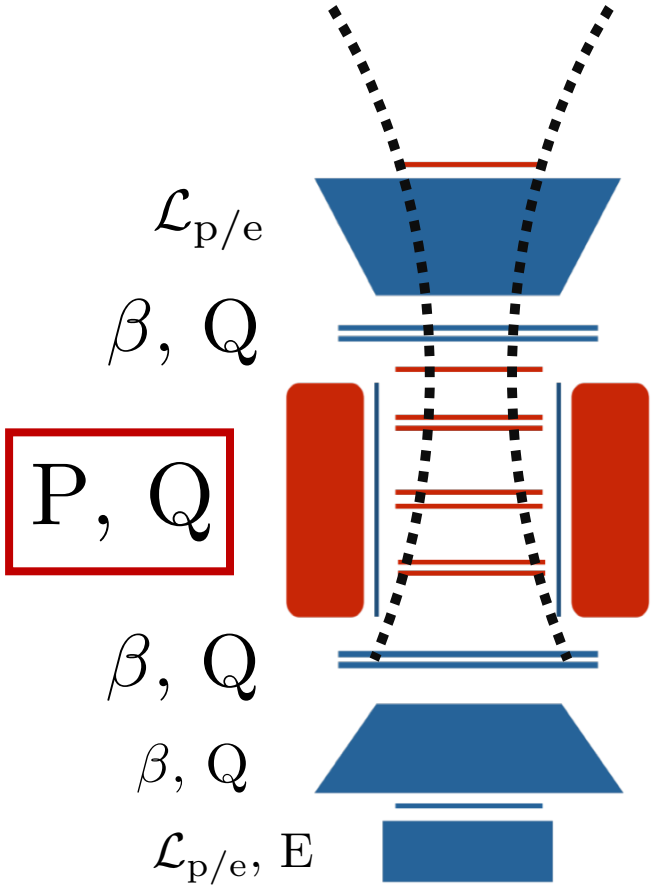


PROTON FLUX

$$\phi(P) = \frac{N_{\mathrm{part}}(P)}{\Delta t(P)\,\varepsilon(P)\,Acc_{\mathrm{MC}}\,C_{\mathrm{MC}}^{\mathrm{Data}}(P)\,\Delta P}$$

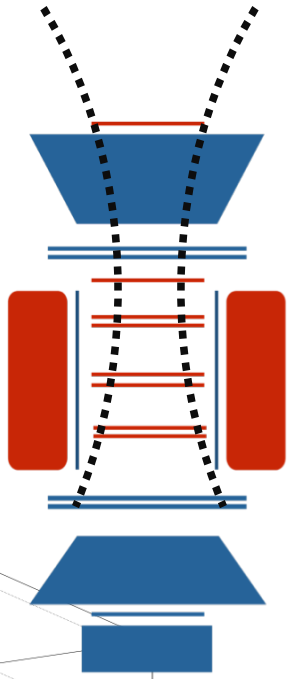


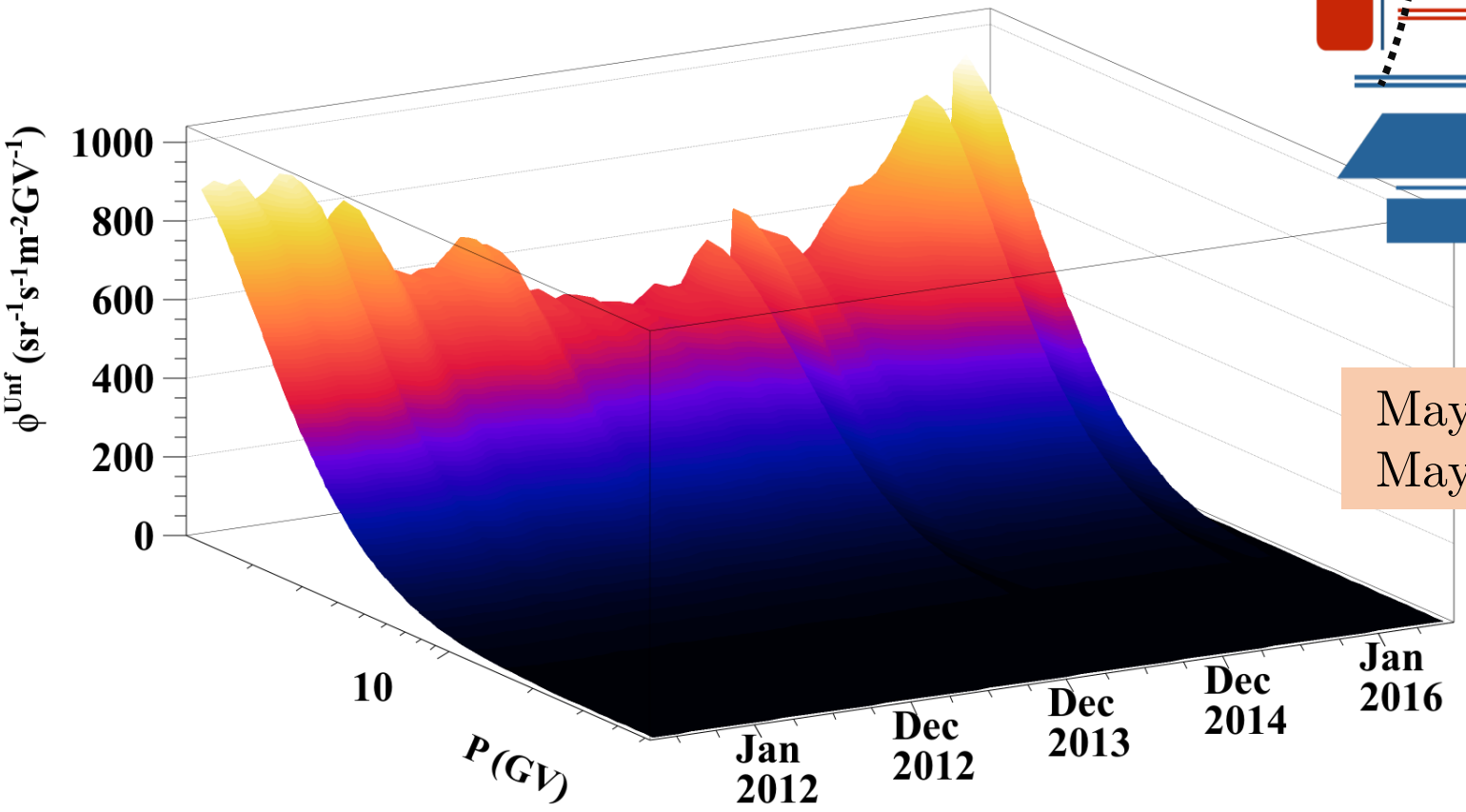




MONTHLY PROTON FLUX

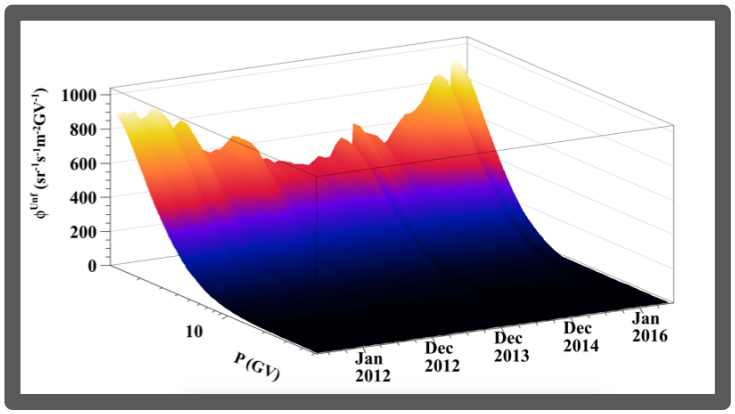
$$\phi(P) = \frac{N_{\mathrm{part}}(P)}{\Delta t(P)\,\varepsilon(P)\,Acc_{\mathrm{MC}}\,C_{\mathrm{MC}}^{\mathrm{Data}}(P)\,\Delta P}$$

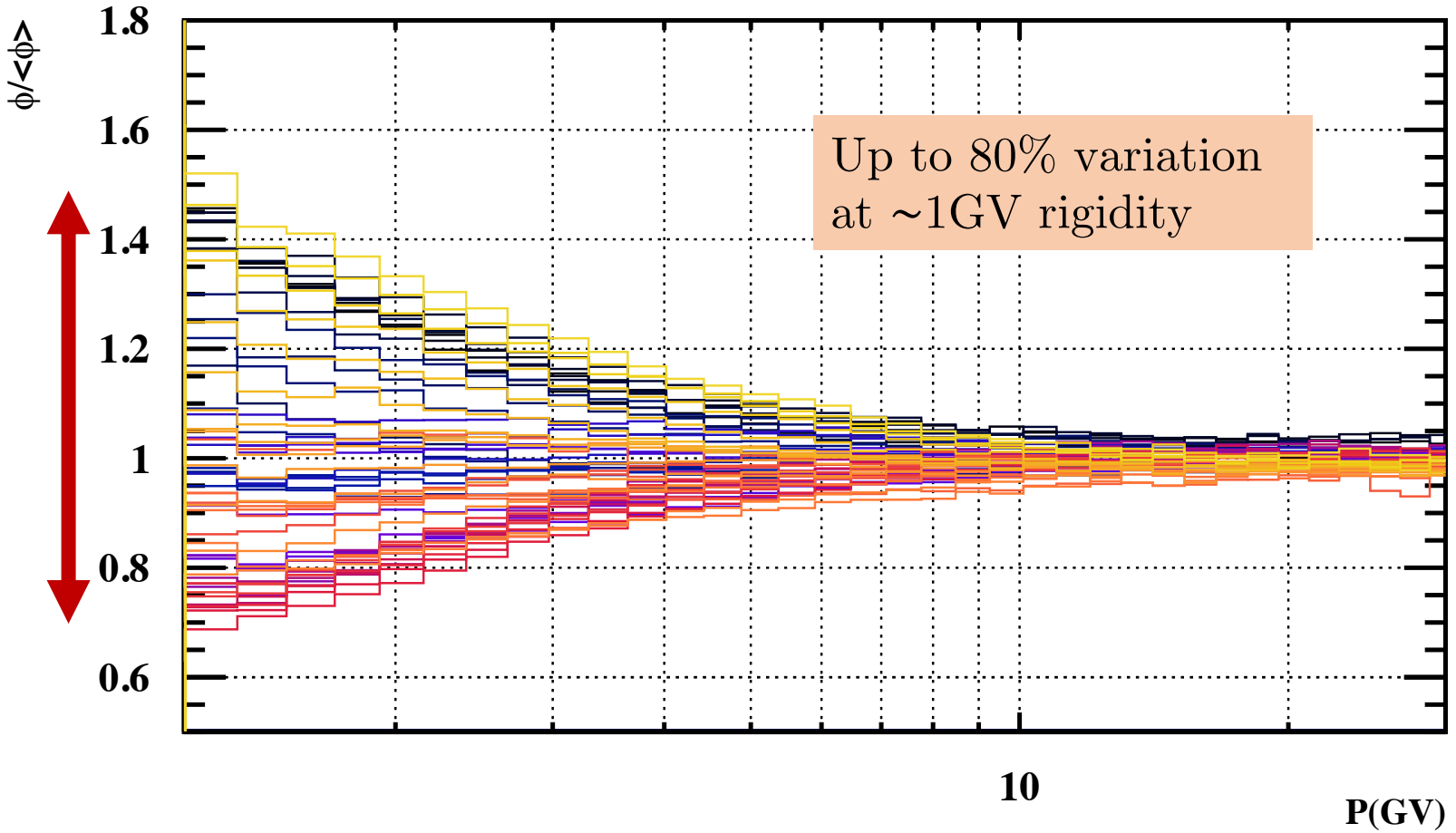




May 2011
May 2016

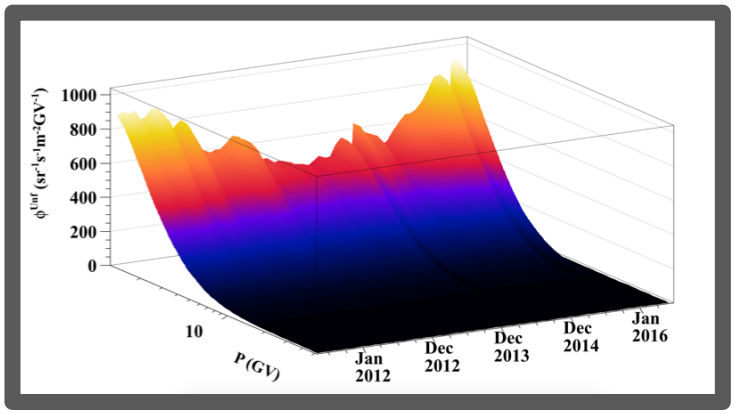
PROTON FLUX

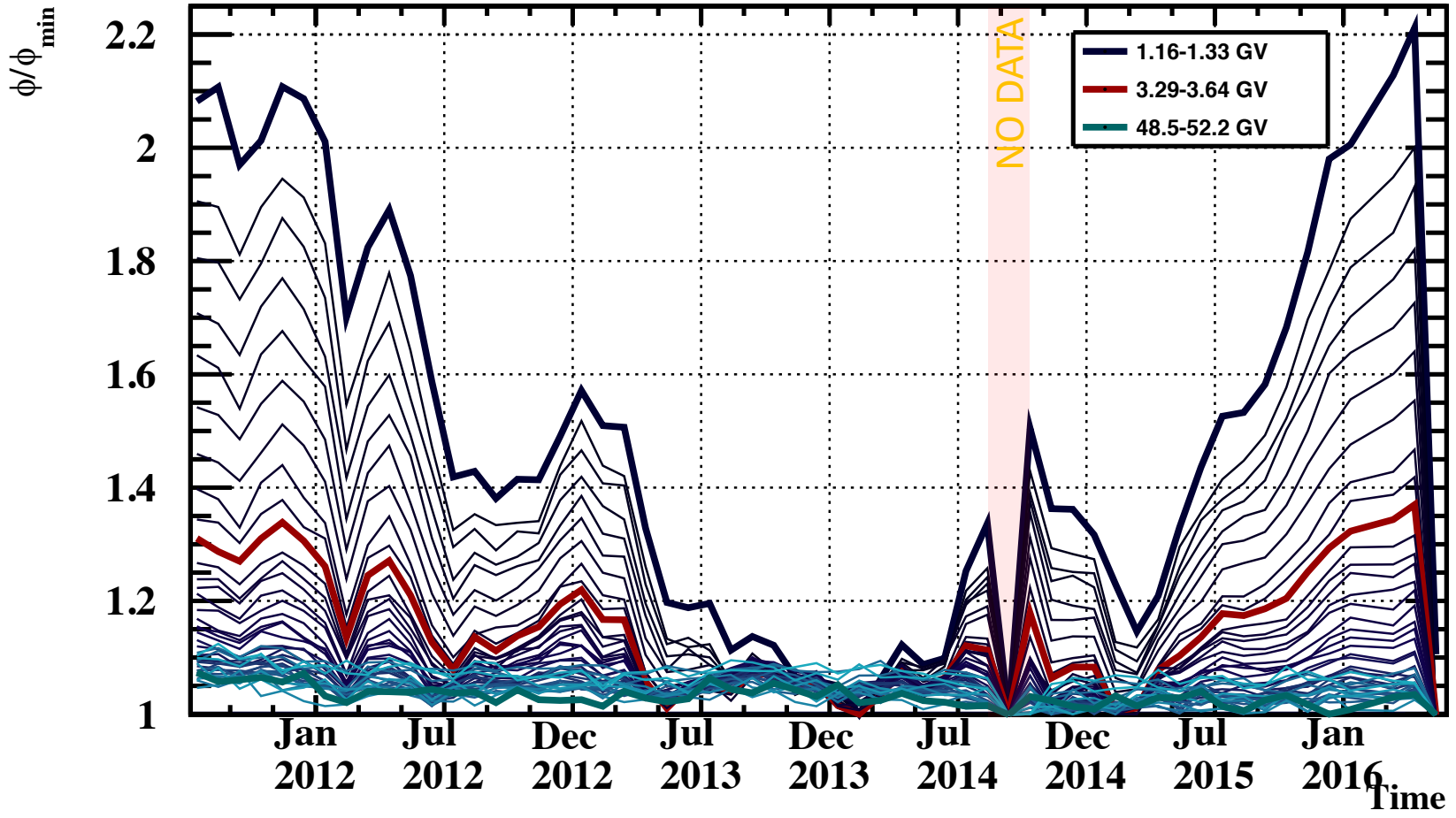

1000
800
600
400
200
0
10
P(GV)
Jan 2012
Dec 2012
Dec 2013
Dec 2014
Jan 2016


ϕ/<ϕ>
1.8
1.6
1.4
1.2
1
0.8
0.6
Up to 80% variation
at ~1GV rigidity
10
P(GV)

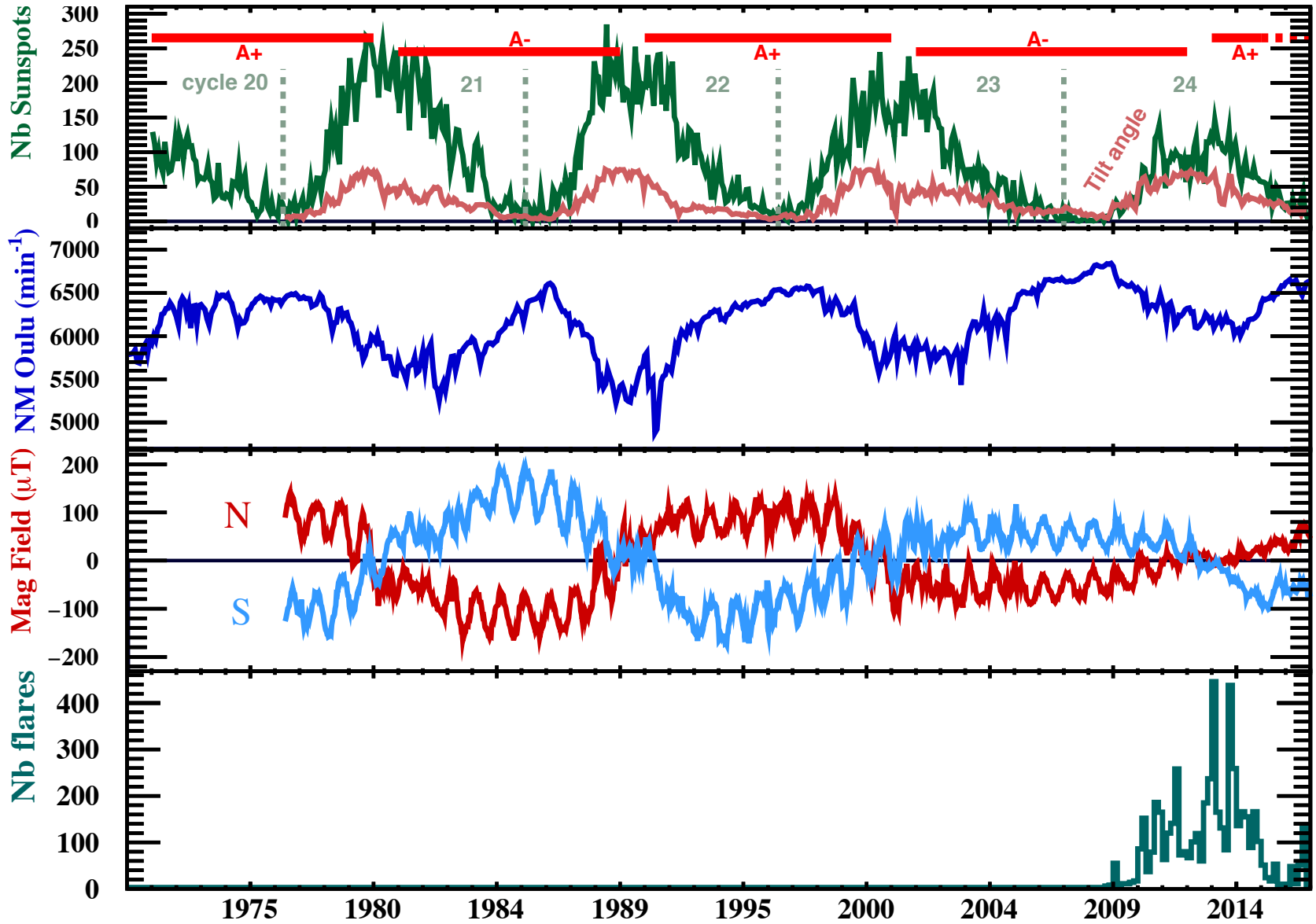
TIME VARIABILITY

Solar modulation is prevaling up to 30 GV

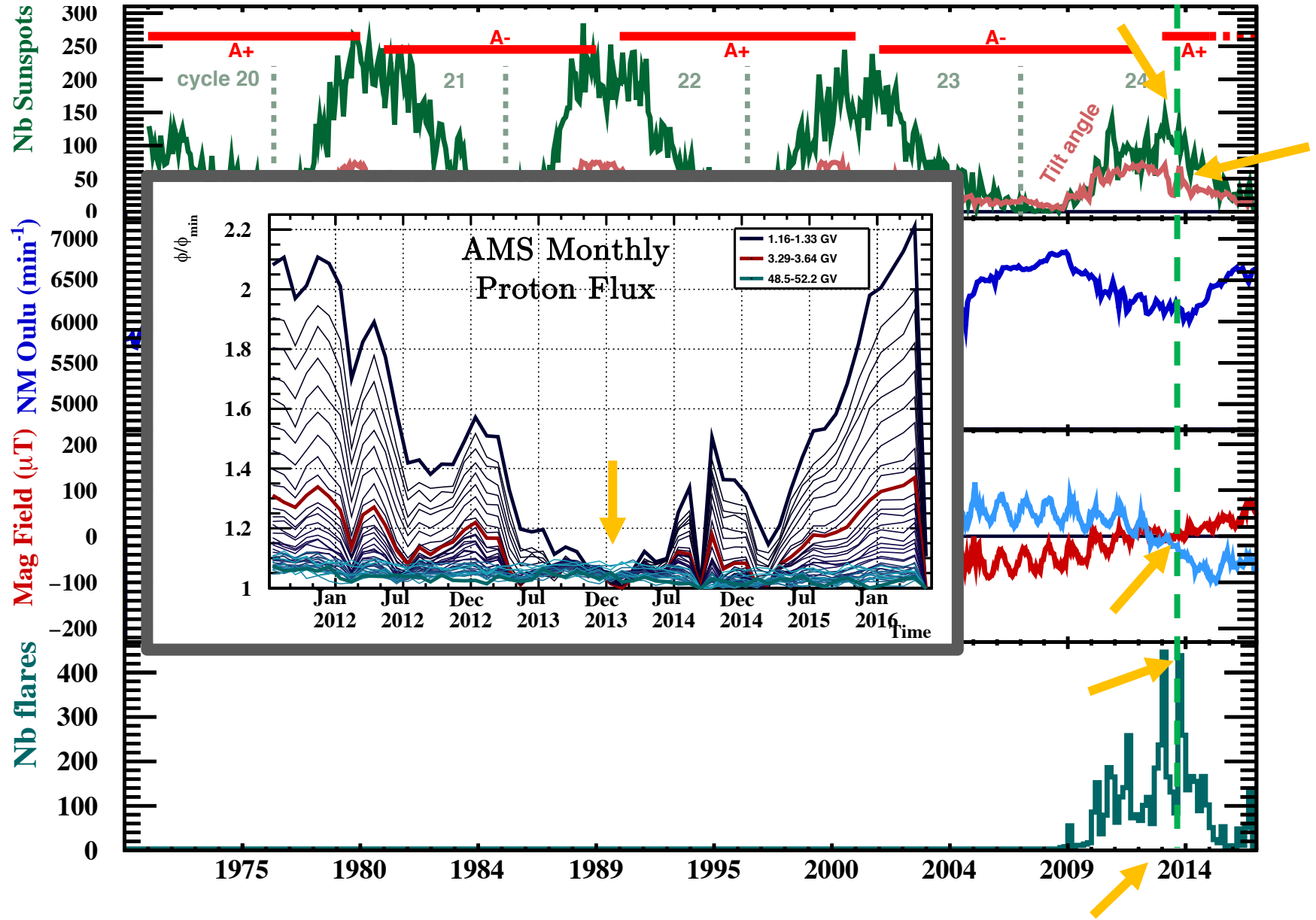




SOLAR ACTIVITY



SOLAR ACTIVITY



PARKER'S EQUATION

$$\frac{\partial f}{\partial t} = \underbrace{\nabla \cdot (\mathbf{K}_{\rm s} \cdot \nabla f)}_{\text{diffusion}} - \underbrace{(\mathbf{V} + \langle \mathbf{v}_{\rm dr} \rangle) \cdot \nabla f}_{\text{convection and drift}} + \underbrace{\frac{1}{3} (\nabla \cdot \mathbf{V}) \frac{\partial f}{\partial \ln P}}_{\text{adiabatic energy loss}}$$

Solar modulation is:

- Time dependent
- Space dependent
- Energy dependent
- Particle dependent

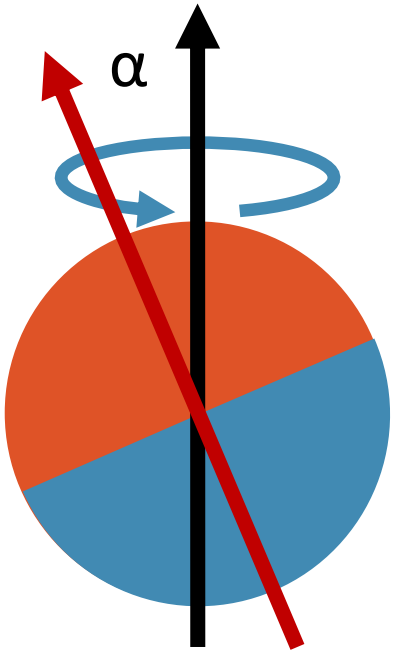
$$\left| \begin{array}{l} K_{\perp} = 0.02 K_{\parallel} \\ K_{\parallel} = k_0(t) \dfrac{A}{3B} \beta \, (P/1\,\mathrm{GV}) \\ \langle v_{\rm dr} \rangle = \dfrac{\beta \, (P/1\,\mathrm{GV})}{3} \nabla \times \dfrac{\boldsymbol{B}}{B^2} \\ B = B(r, \theta, \phi, \alpha(t)) \end{array} \right.$$

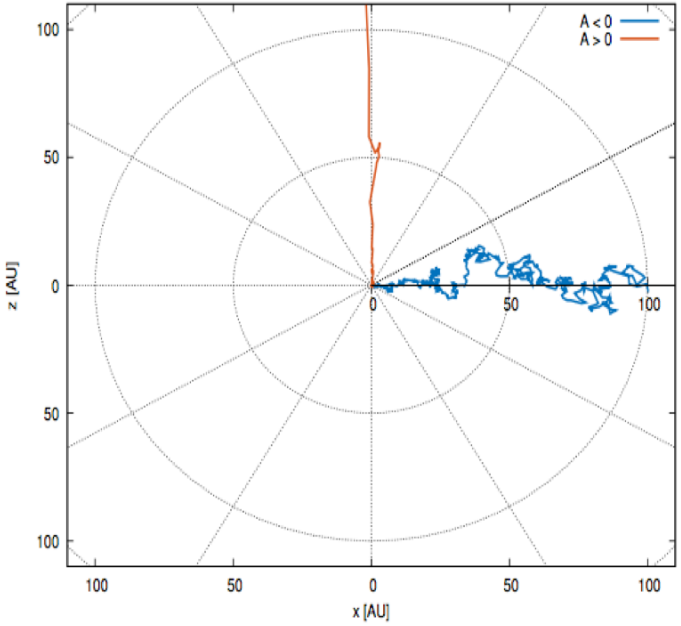
STOCHASTIC APPROACH

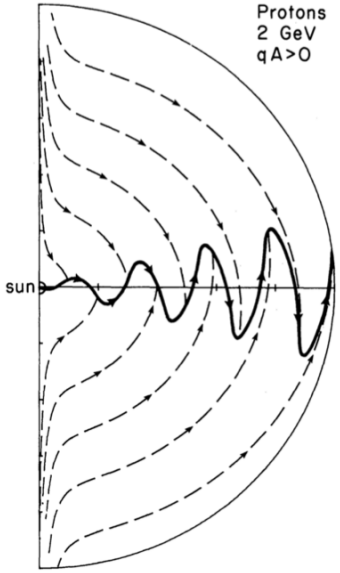
$$\Delta r = \left(-V - V_{\mathrm{D,r}} - V_{\mathrm{HCS,r}} + \frac{1}{r}\frac{\partial r^2 k_{rr}}{\partial r}\right)\Delta t + \sqrt{2k_{rr}\Delta t}\,\mathrm{d}w_r$$

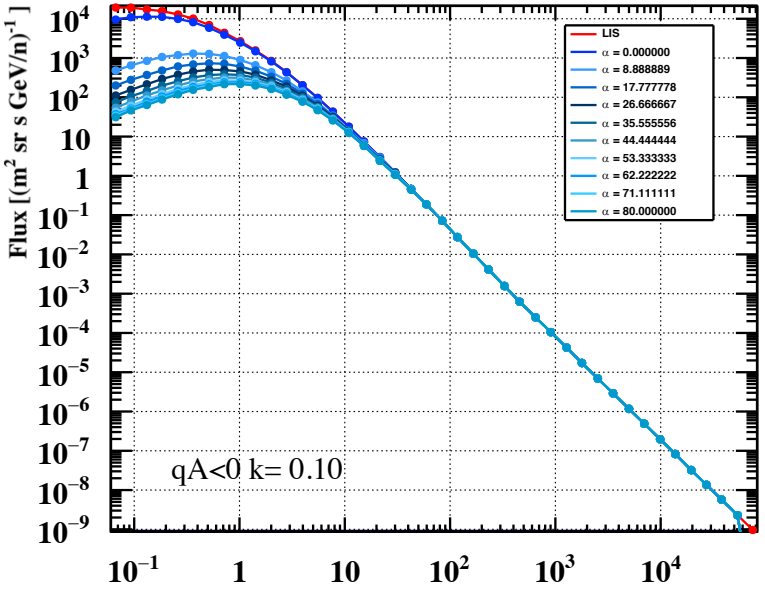
$$\Delta\theta = \left(\frac{-V_{\mathrm{D},\theta}}{r} + \frac{1}{r^2 sin\theta}\frac{\partial sin\theta k_{\theta\theta}}{\partial\theta}\right)\Delta t + \frac{\sqrt{2k_{\theta\theta}\Delta t}}{r}\mathrm{d}w_\theta$$

$$\Delta T = \frac{2V}{3r}\frac{T^2 + 2Tm}{T+m}\Delta t$$









DATA AGREEMENT

The key ingredients for the simulation are:

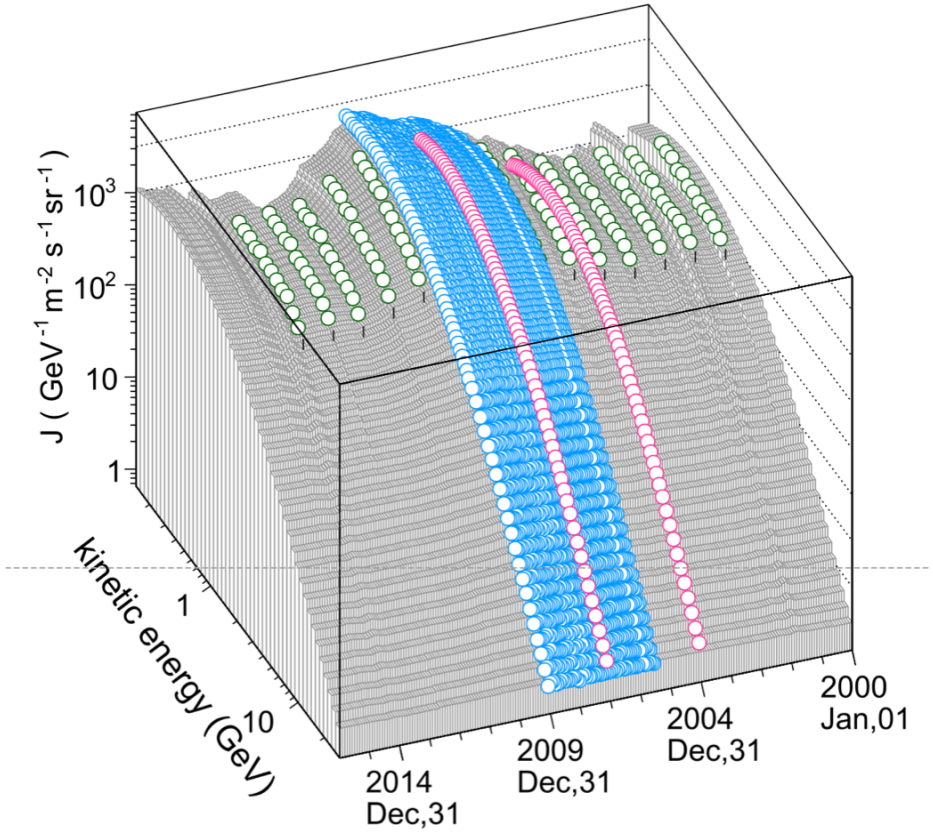
k_0 – Diffusion coefficient

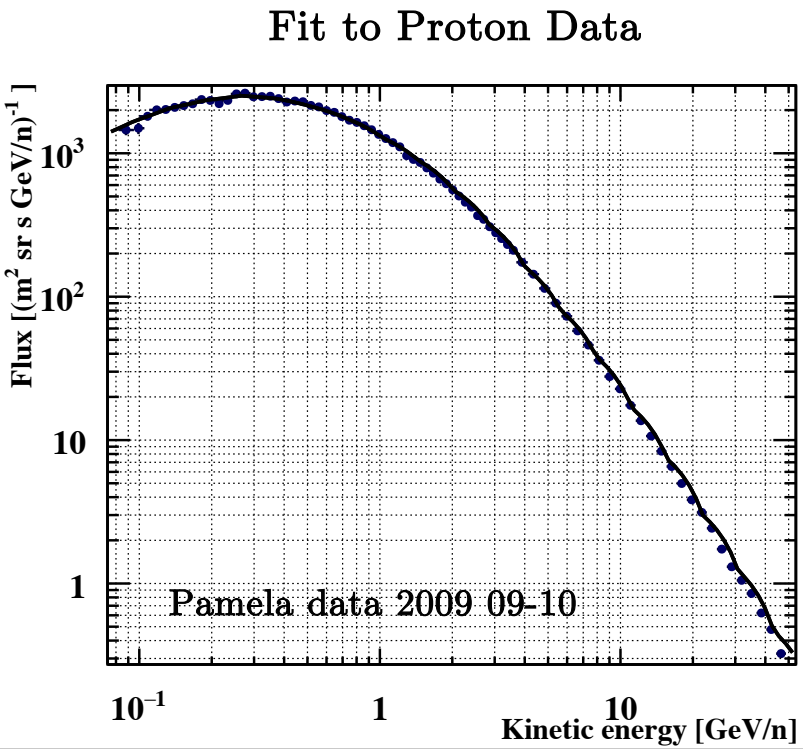
α – Solar dipole inclination (tilt angle)

A – Polarity of the magnetic field

Q – Charge and sign of particle

m – Mass of particle





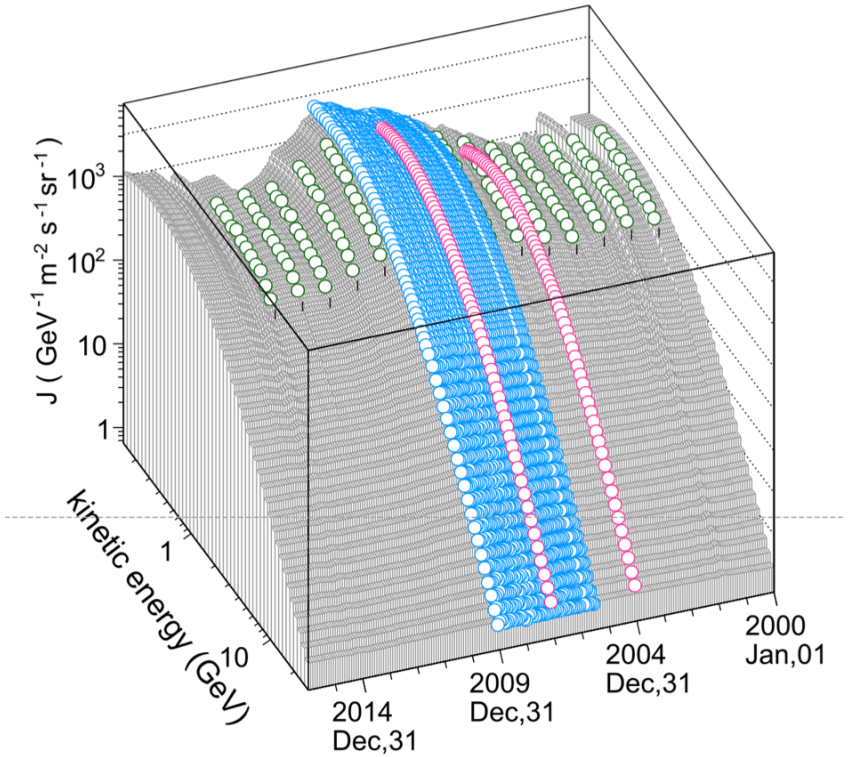
Fitting scheme

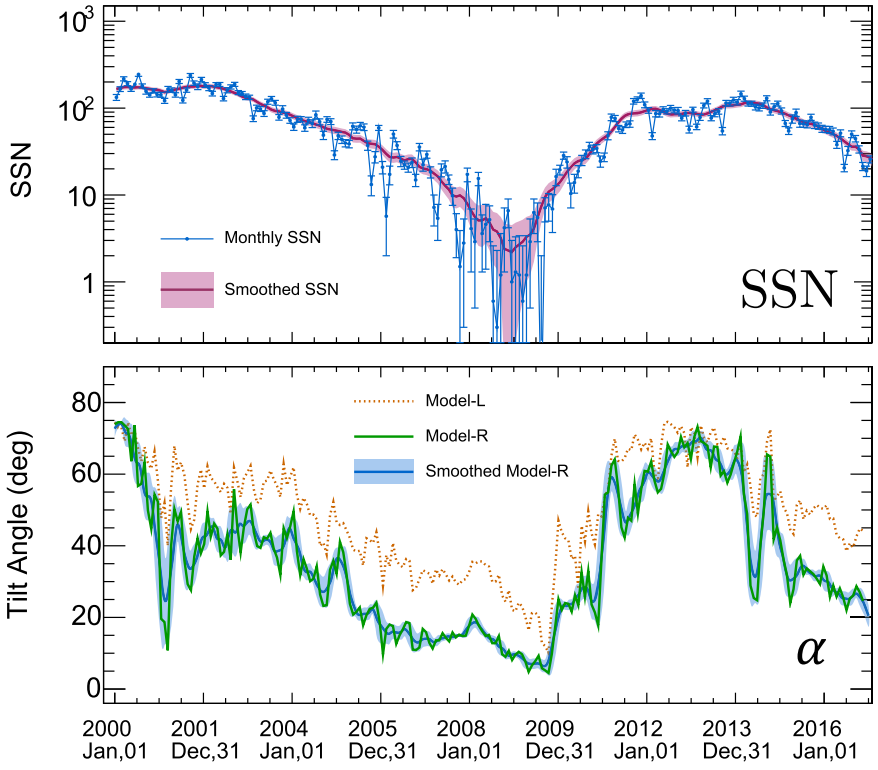
$$\phi^{\text{data}}(E,t) \quad \text{Experimental data}$$

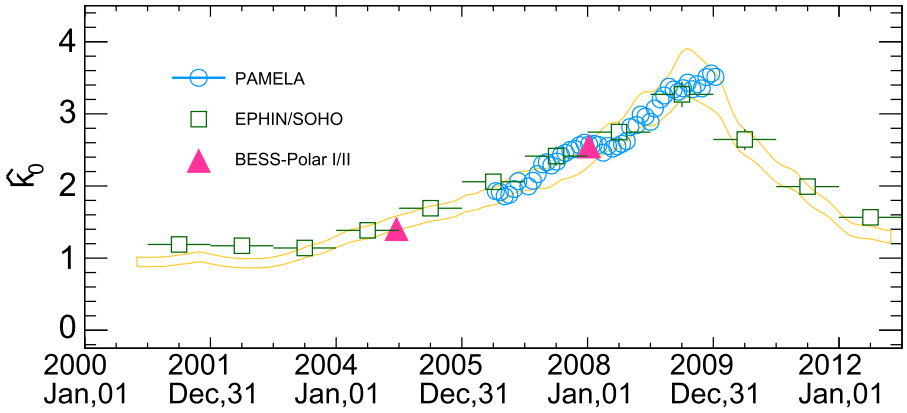
$$\phi^{\text{sim}}(E) = \phi^{\text{sim}}(E;\, k_0, \alpha)$$

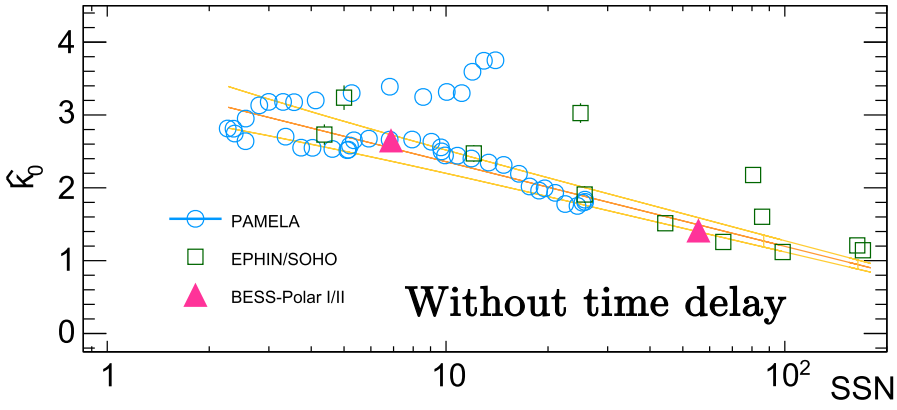
$$\chi^2 = \sum_E \left[\frac{\phi^{\text{sim}}(E;\, k_0, \alpha) - \phi^{\text{data}}(E,t)}{\sigma(E,t)} \right]$$

SOLAR OBSERVABLES

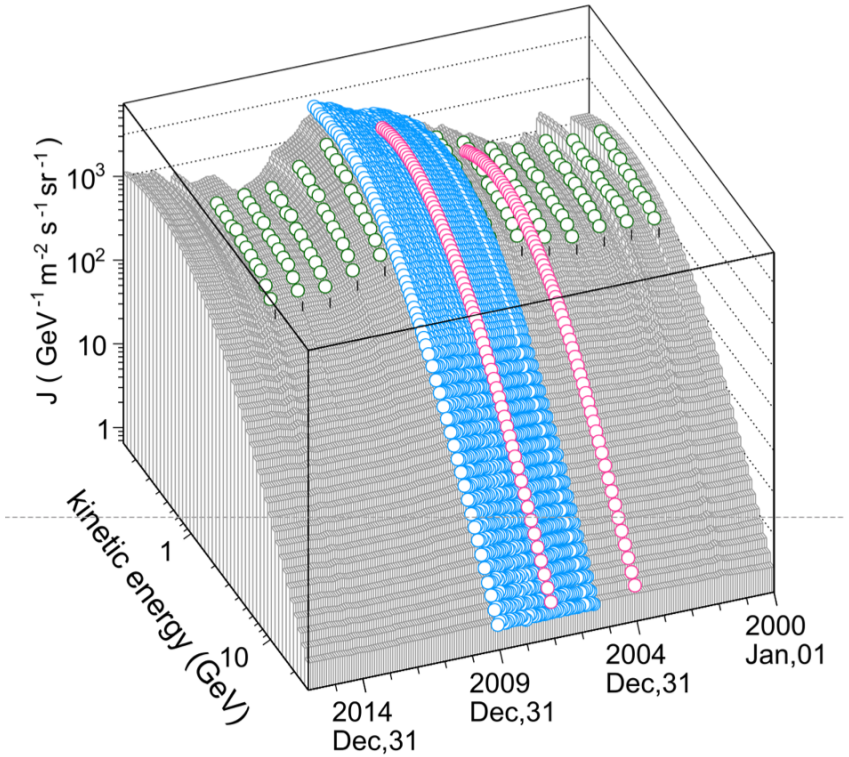


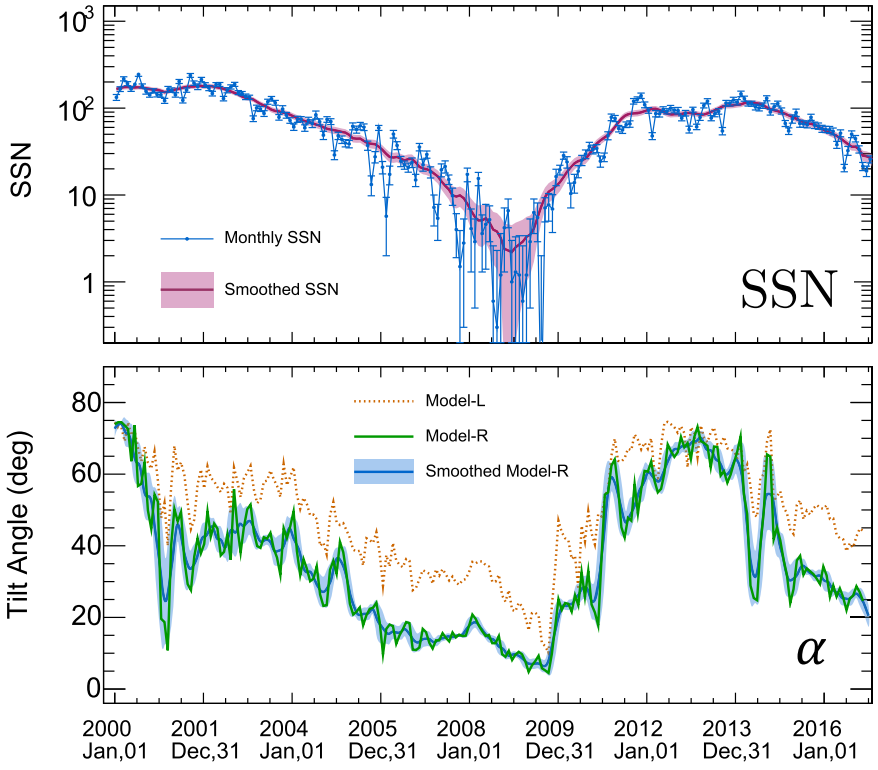


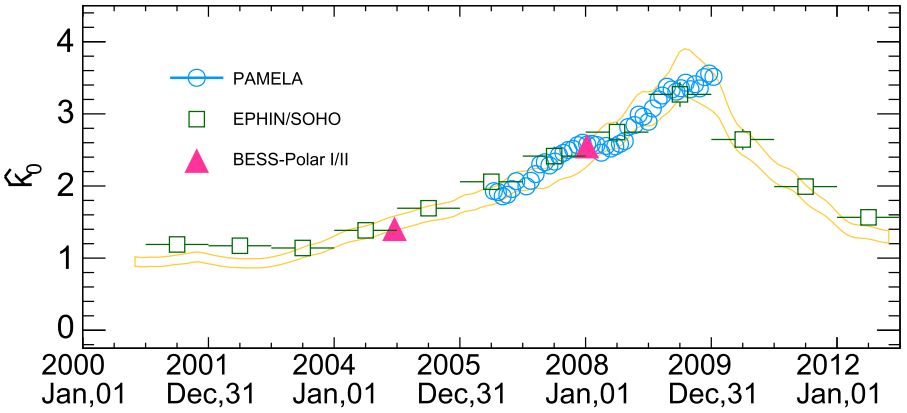


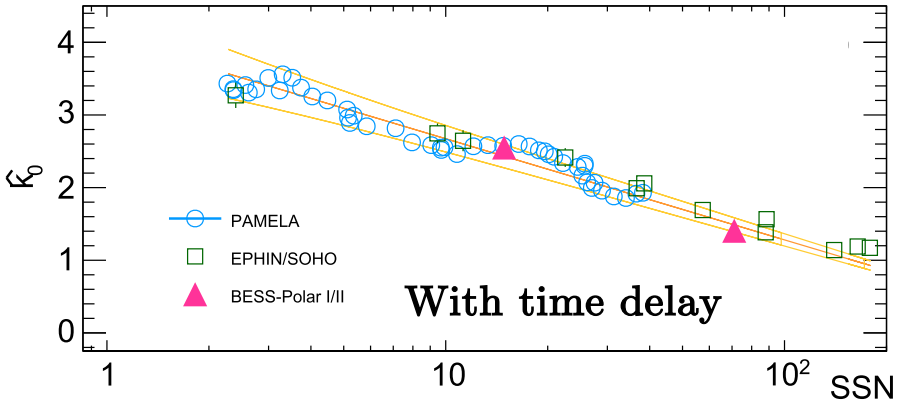


SOLAR OBSERVABLES

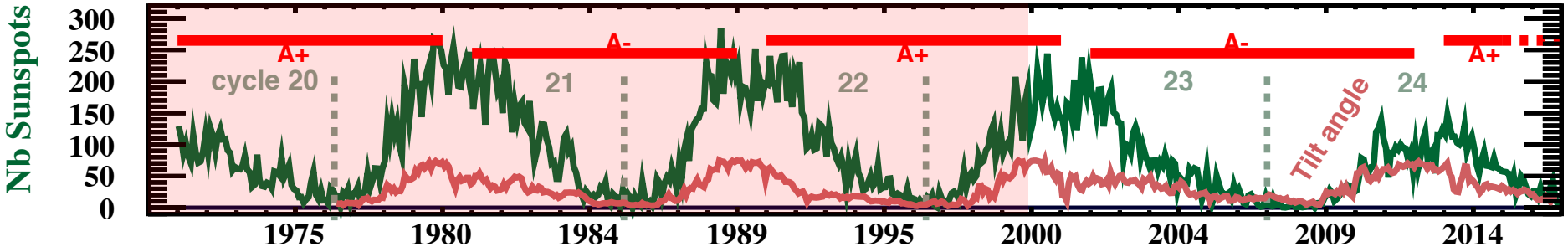








EVIDENCE OF A TIME DELAY



Model Parameters

$$\alpha(t),\ \mathrm{SSN}(t) \quad \text{Direct observation}$$

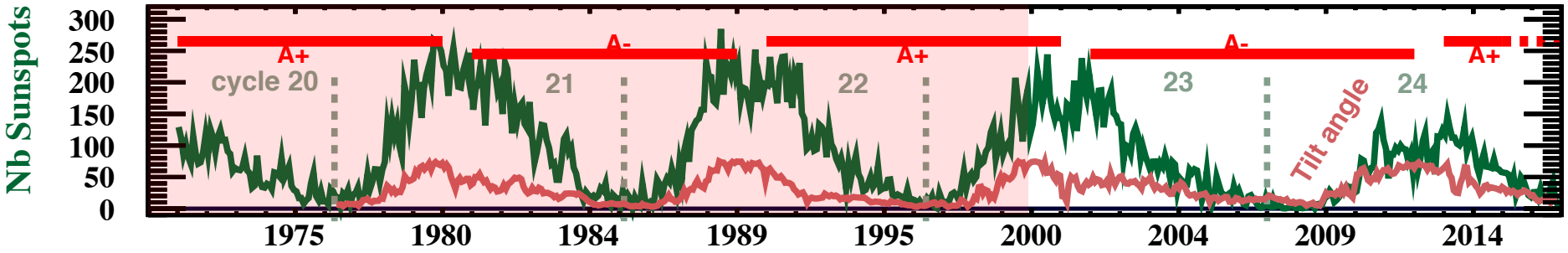
$$k_0(t) = a\ \log_{10}(\mathrm{SSN(t)}) + b$$

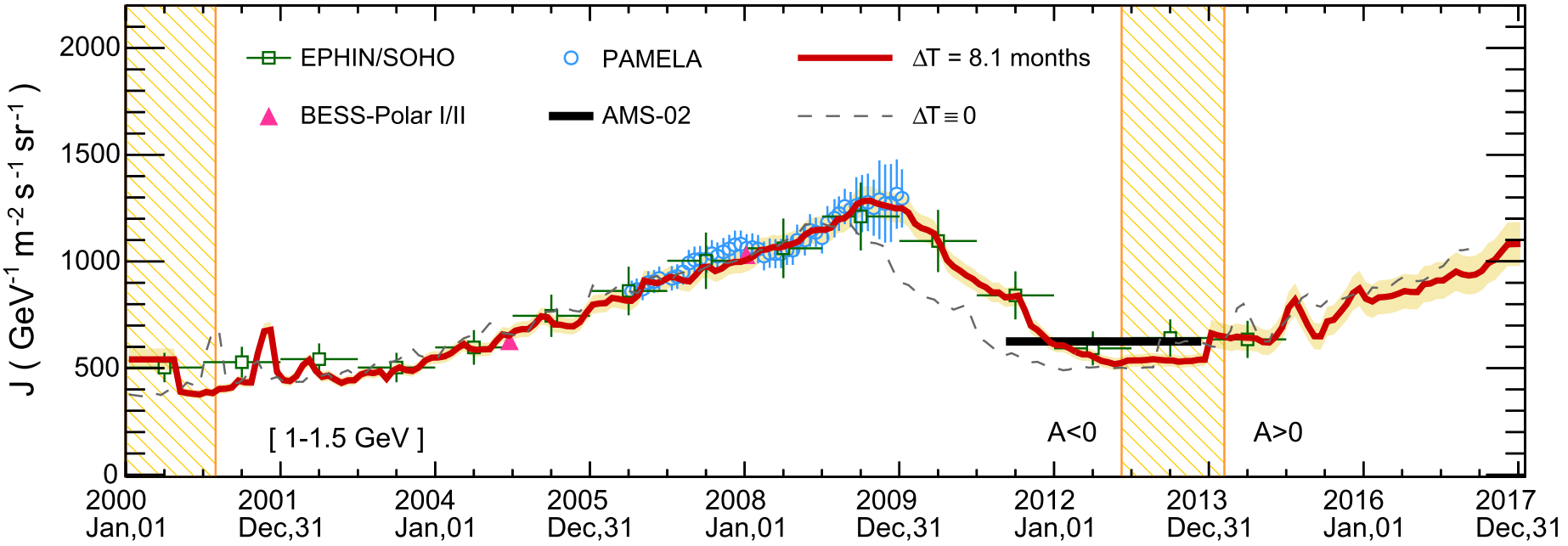
$$\phi^{\mathrm{sim}}(E,t) = \phi^{\mathrm{sim}}(E;\ k_0(t), \alpha(t))$$

Fitting procedure

$$\chi^2 = \sum_t \sum_E \left[\frac{\phi^{\mathrm{sim}}\left(E, t - \Delta t\right) - \phi^{\mathrm{data}}(E,t)}{\sigma(E,t)} \right]$$

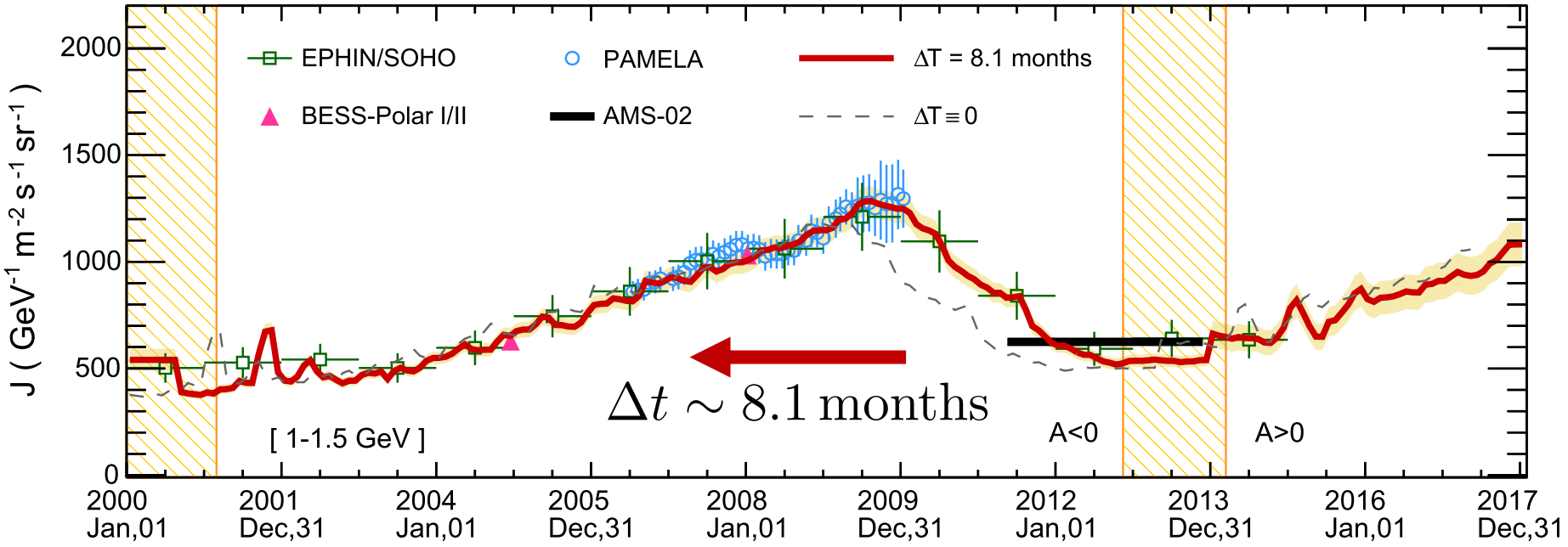
EVIDENCE OF A TIME DELAY





$$\Delta t \sim 8.1 \text{ months}$$

EVIDENCE OF A TIME DELAY



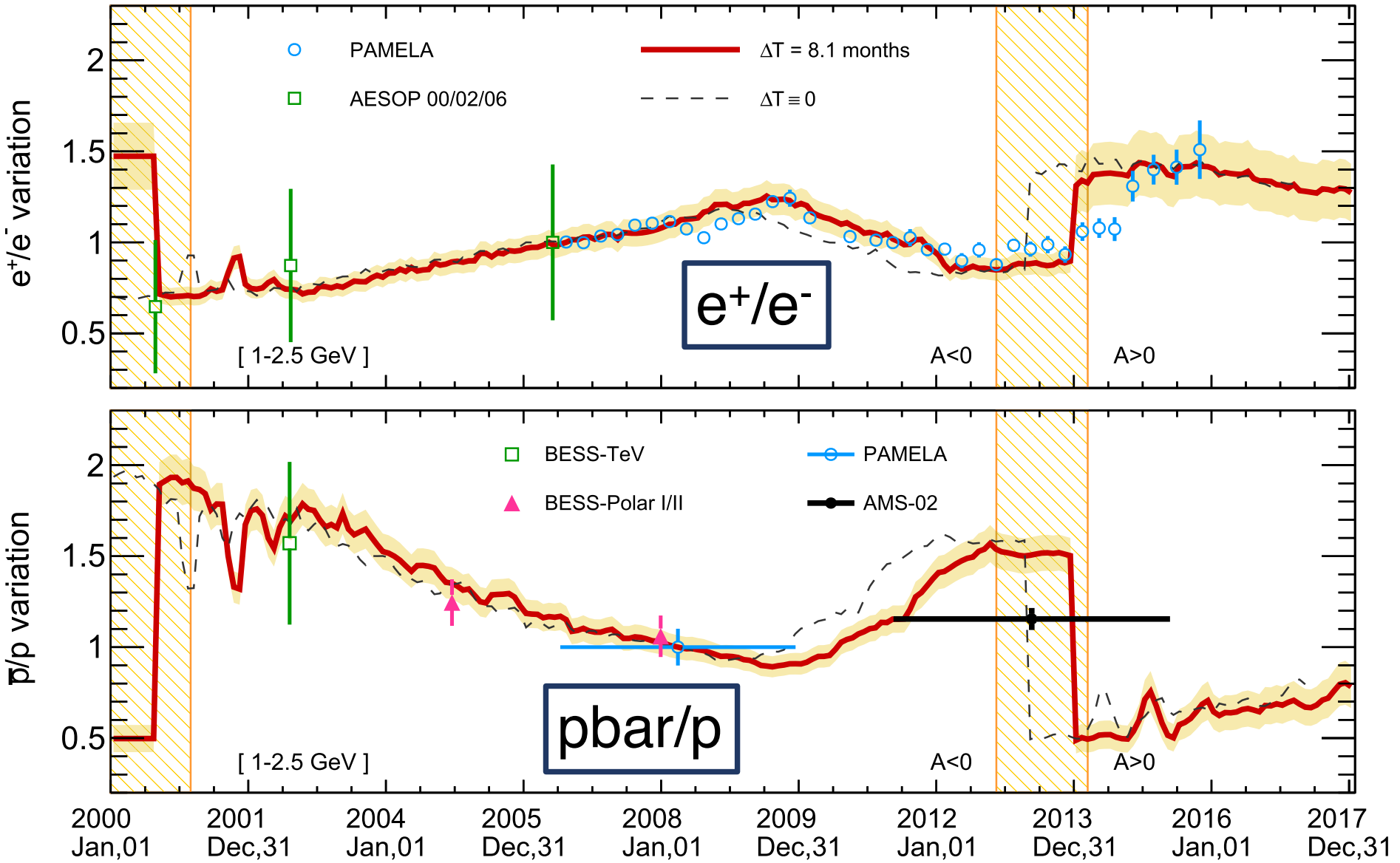
Directly observable solar parameters are delayed, only affecting the cosmic ray flux 8.1 months later.

$$\phi^{\mathrm{data}}(t) \sim \phi^{\mathrm{sim}}(\alpha(t-\Delta t),\, k_0(t-\Delta t))$$

Evidence for a Time Lag in Solar Modulation of Galactic Cosmic Rays

Nicola Tomassetti[1], Miguel Orcinha[2], Fernando Barão[2], and Bruna Bertucci[1]
[1] Università degli Studi di Perugia and INFN-Perugia, I-06100 Perugia, Italy; nicola.tomassetti@cern.ch
[2] Laboratório de Instrumentação e Física Experimental de Partículas, P-1000 Lisboa, Portugal
Received 2017 June 28; revised 2017 October 11; accepted 2017 October 12; published 2017 November 8

EVIDENCE OF A TIME DELAY



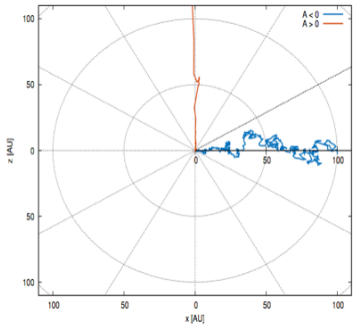
PROSPECTS

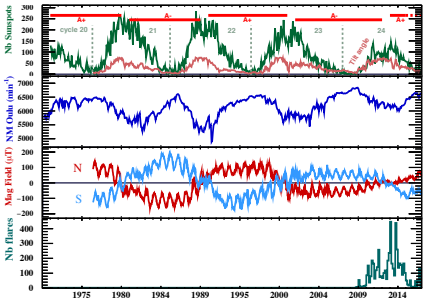
Flux estimation

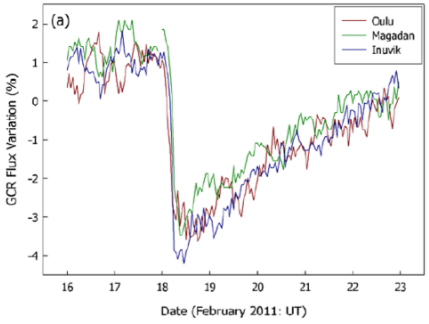
- Electron / Positron flux
- Characterization of charge-sign effects
- Frequency analysis
- Short time event

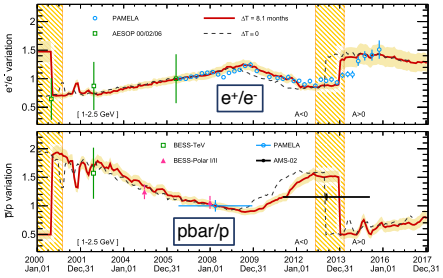
Time analysis

- Time-delay on AMS monthly proton flux
- Time-delay for different particles
- Parametrization consistency per epoch










LIP


TÉCNICO
LISBOA

THANK YOU!


FCT
Fundação
para a Ciência
e a Tecnologia


POCH


PORTUGAL
2020


UNIÃO EUROPEIA
Fundo Social Europeu