Tracking streamers in solar synoptic maps

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Outline

- Solar streamers and synoptic maps
- Streamer tracking in the low activity period
- Streamer tracking in the high activity period
- Conclusion and perspectives
The 11 years of Sun activity cycle

- **Minimum of activity**
- **Maximum of activity**
From k corona images to “synoptic maps”

Synoptic maps are circular profiles at a given radius centered on the Sun and stacked in time.

Series of coronal images $\rightarrow$ *circular sampling* $\rightarrow$ stack maps

Stack maps $\rightarrow$ *regularization of time axis* $\rightarrow$ synoptic maps
The mean Sun rotation period is 27.4 days, streamer will oscillate centered on N and S pole lines. This period is defined as Carrington rotation.
The angle between the Sun axis and the plane of view oscillates of $\pm 7.15^\circ$ during the year. Streamers included in the zone of $\pm 7.15^\circ$ show apparent N to S crossings two times a year.
Evolution of 2 streamers (to $-3^\circ$ and $+3^\circ$ of latitude) during ~10 months (280 days). Streamers included in the zone of $\pm 7.15^\circ$ show two times a year N to S apparent crossings.
The synoptic maps model

\[ l = \phi(t-\Delta t, \lambda) \]

\[ Bk(l, t) = \sum_j \sum_i A(t, \lambda_j) \cdot g \left( l - \varphi(t - \Delta t_i, \lambda_j) \right) ; A(t, \lambda_j) \approx A_n(\lambda_j) \text{ for } t = \{t_n, t_n + T\} \]

\[ Bk(l, t, n) = \sum_j \sum_i A_n(\lambda_j) \cdot g \left( l - \varphi(t - \Delta t_i, \lambda_j) \right) \]
The analysis schema

The model

\[ Bk(l, t, n) = \sum_j \sum_i A_n(\lambda_j) \cdot g(l - \varphi(t - \Delta t_i, \lambda_j)) \]

\[ g(.) \approx \delta(.) \]

\[ D(\Delta t_i, \lambda_j, n) = \left\langle Bk(l, t, n), g(l - \varphi(t - \Delta t_i, \lambda_j)) \right\rangle_n \]

\[ \sim A_n(\lambda_j) \left\| g(l - \varphi(t - \Delta t_i, \lambda_j)) \right\|^2 \]

The analysis

\[ E(\Delta t_i, \lambda_j, n) = \left\langle Bk(l, t, n), \delta(l - \varphi(t - \Delta t_i, \lambda_j)) \right\rangle_n \]
Streamer tracking in the low activity period
A year of synoptic maps (may 1997 to may 1998)

3D restitution of the current sheet encircling the Sun (not shown here)
A year of synoptic maps (May 1997 to May 1998)

3D restitution of the current sheet encircling the Sun (not shown here)
Observed intensity profile along a streamer track (+5°)
Map of observed intensity profiles for a large set of streamer tracks (from -40° to +40°)

\[ \text{dT} = 0 \text{ jours} \]
Image of observed intensity profiles along a large set of streamer tracks (from -40° to +40°)

Phase shift $dT = 0$ days

Latitude of streamers

1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935
Phase shift $\Delta t = 0$ days

Phase shift $\Delta t = 7$ days

Phase shift $\Delta t = 14$ days

Streamers Latitude

Time (Carrington rotation)
The “cube” of responses to “streamer wave”

\[ B_k(l, t, n), \delta(l - \varphi(t - \Delta t_i, \lambda_j)) \]
Detection process

\[ E(\Delta t_i, \lambda_j, n) = \left< Bk(l, t, n), \delta(l - \varphi(t - \Delta t_i, \lambda_j)) \right>_n \]
Integration / Carrington rotation*0.5

\[ E(\Delta t_i, \lambda_j, n) = \left( B_k(l, t, n), \delta(l - \varphi(t - \Delta t_i, \lambda_j)) \right)_n \]
Streamer map

\[ B_k(\theta(t), \lambda, r) \text{ map,} \]
\[ \theta(t), \text{ longitude function of time} \]
\[ \lambda \text{ latitude} = \{-40^\circ \ldots 40^\circ\} \]
\[ r = 3R_\odot \text{ (sun radius)} \]
Streamer tracking in the high activity period
A year of synoptic maps (mars 2000 to feb 2001)

3D restitution of the current sheet encircling the Sun (not shown here)
A year of synoptic maps (mars 2000 to feb 2001)

3D restitution of the current sheet encircling the Sun (not shown here)
Map of intensity profiles of streamers

Latitude of streamers

Time

Phase shifts

0 days
7 days
14 days
Detection maps

$\Delta t = 0$ days

$\Delta t = 7$ days

$\Delta t = 14$ days
Streamer map

$B_k(\theta(t), \lambda, r)$ map,

$\theta(t)$, longitude function of time

$\lambda$ latitude = {-40°...40°}

$r = 3R_o$ (sun radius)
Streamer map

$$B_k(\theta(t), \lambda, r)$$ map,

$$\theta(t)$$, longitude function of time

$$\lambda$$ latitude = {-40°...40°}

$$r = 3R_o$$ (sun radius)
Conclusion and perspectives

- “Streamers tracking” reveals as a potential method in order to characterize the middle term, great scale variations of the solar corona during the solar activity cycle.
- Is insensitive to missing data (in a moderate amount).
- The resolution in time and angle can be increased.
- The quantitative analysis remains to be theoretically and practically improved.
Thanks for your attention