The Evolution of important Magnetic Bright Point Parameters

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Abstract: The activity of the Sun is caused by the magnetic field dynamics. The stronger and more extended field elements have played a key-role in solar research over the last centuries. Due to newly installed ground-based and space-borne telescopes (such as NST, Hinode, Sunrise), it became possible to study magnetic fields on ever smaller scales reaching nowadays down to hundreds of km in diameter and making it possible to resolve single flux tubes.

Good candidates for such isolated magnetic flux tubes are so-called magnetic bright points (MBPs). These features have been studied since the 70´s of the last century concentrating mostly on photometric parameters like size and brightness. In the current study we will use the Sunrise/IMaX and Hinode/SOT instruments to investigate spectro-polarimetric data as well as their inversions done by SIR and MERLIN code, respectively. The temporal evolution of important parameters is studied then to shed more light on the physics of MBPs.

Introduction:

Small-scale magnetic fields are attracting more and more attention due to the improvement in observations as well as computer simulations. Among the found features are so-called magnetic bright points (MBPs). While a theoretical concept for their emergence (convective collapse process, e.g, Spruit 1979) exists, not as much and detailed theoretical as well as observational theories and facts are known about the rest of their evolution. Therefore it is necessary to study the evolution of important MBP plasma parameters to gain a deeper understanding of the processes happening after their formation. This will enable us to answer questions like: are MBPs stable features? On what time-scales and how are they stabilized? How are they dissolved and what happens to the magnetic field and energy stored?

Data Sets:

We used data from the IMaX/Sunrise mission (Barthol et al. 2011). Taken during the first stratospheric flight (~30km high) on the 9th of June 2009. The instrument used the V5-6 mode (vector mode; smpling the Fe 5250.2 Å line 5 times during 6 acquisition cycles). The usable FOV is about 43 by 43 arcsec^2, the pixel sampling about 0.055 arcsec/pixel and the temporal cadence about 32 s. The data have been inverted by SIR with an easy atmospheric model using one node for: magnetic field, LOS velocity, microturbulence and 3 nodes (parabolic perturbations) for temperature (see Fig.1).

In addition Hinode/SOT data (Kosugi et al. 2007, Tsuneta et al. 2008) have been used (quiet sun taken on the 2nd of June 2007 by SOT/BFI in G-band and Ca II-H as well as by SOT/SP; data have been MERLIN inverted -> level 2 data).

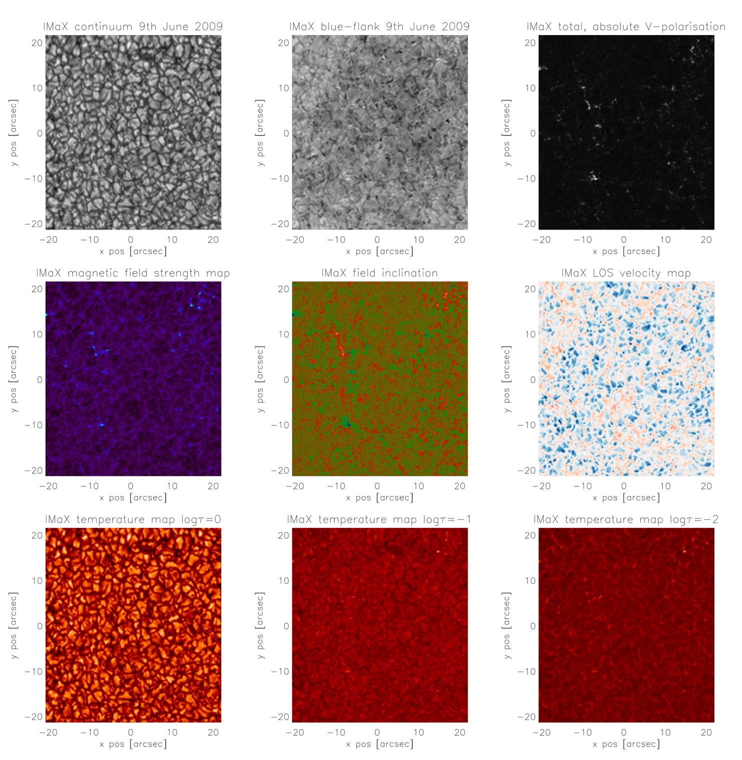


Fig.1: Image examples of the analysed IMaX/Sunrise data set and its SIR inversions. Shown in gray color are the non inverted data (first row, from left to right): a continuum intensity (227 mÅ) map; a blue-line flank (-40mÅ) intensity map and a total V polarisation map. Inversion results are shown in the second and third rows: magnetic field strength, inclination, line-of-sight velocity map, and temperature at log τ=0, -1, -2.

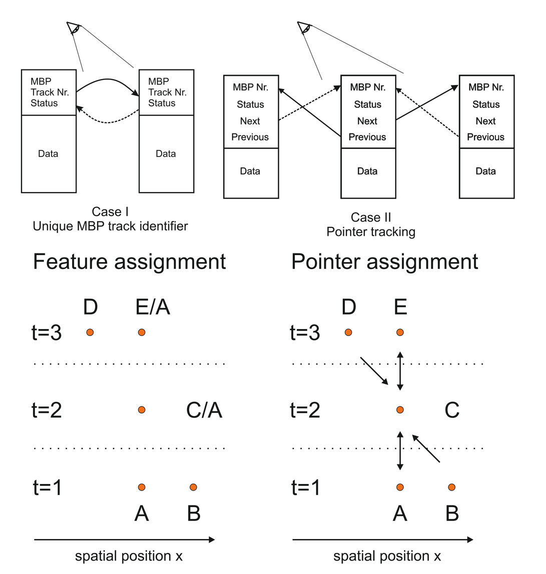


Fig.2: Upper row: 2 possible tracking approaches. On the left, the unique MBP track identifier approach. An MBP is assigned with an unique identifier during the identification process. This number is then assigned also to the closest MBP realised in the next image. On the right, the pointer-tracking approach. Here additionally added pointer link the previous and next realisation to the current MBP. 2nd row: On the left the unique MBP track identifier approach is shown applied to a practical example. On the right the same example from the viewpoint of the pointer approach. Different outcomes can be observed.

Analysis:

The data were calibrated and reduced with standard SSW IDL routines or pre-reduced by the mission team. The Inversions were carried out by SIR (IMaX) and MERLIN code (Hinode). The identification of MBP features were done by an automated segmentation, identification and tracking code (Utz et al. 2009, 2010) applied in the case of IMaX to the blue line-flank intensity sample (-40 mÅ) and in the Hinode case on G-band data. The Hinode BFI and SP data have been carefully co-aligned (necessary due to different spatial resolutions and sampling; see e.g. Kühner et al. 2010). After the identification the tracking of MBPs have been done by a pointer-tracking approach (see. Fig. 2). The rest of the analysis consisted of selecting several evolutionary tracks for a case study and applying statistical tools for a gerneral description of the evolution.

Results for IMaX data:

Figure 3 shows the evolution of one of the tracked MBPs in different plasma parameter maps. The evolution of the parameters can be seen more clearly in Fig. 4, while Fig. 5 gives some statistical results:

- *Magnetic field strength:* Initial field strengths around equipartition (~ 400G), maximum values 2 to 3 times higher and at dissolution lower than the equipartition one.
- *LOS velocities:* Initial velocities consist of weak downflows around 1km/s, maxima of up to 6 km/s and at the end still downflows (generally no flow reversals).
- *Inclinations:* Initially quite horizontal, during some point of the evolution more vertically inclined and at the end again more horizontally.

Figure 6 and 7 show in more detail statistical results about the field strength, LOS velocity as well as the inclination.

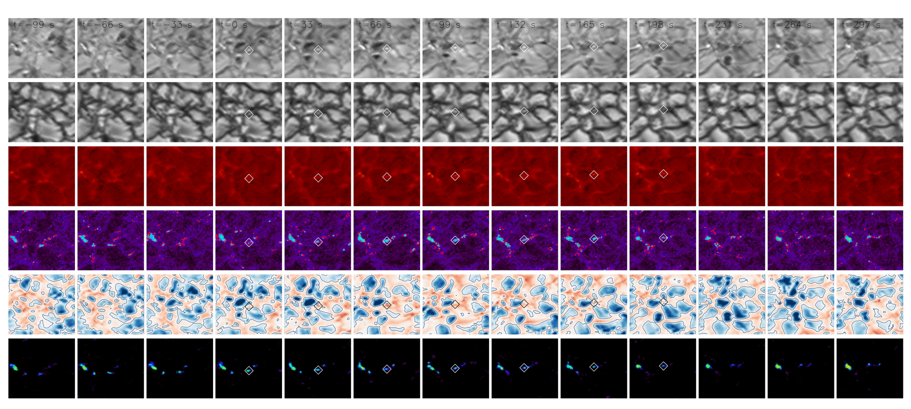


Fig.3: Tracking example of an MBP within maps obtained by IMaX. From top to bottom: blue line-flank used for the identification, continuum wavelength, LOS velocity, line-flank intensity, size, and temperatures at log τ=-2, magnetic field strength, LOS velocity, and inclination map.

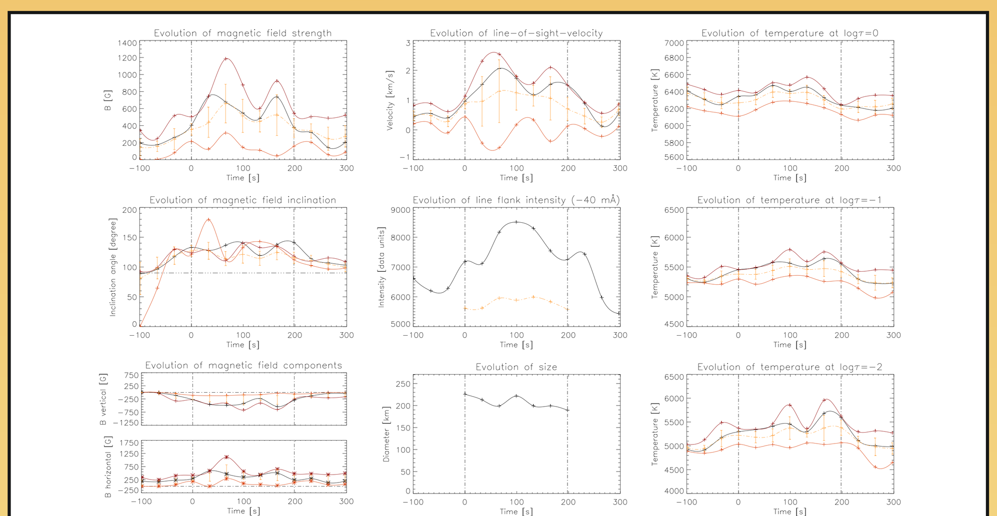
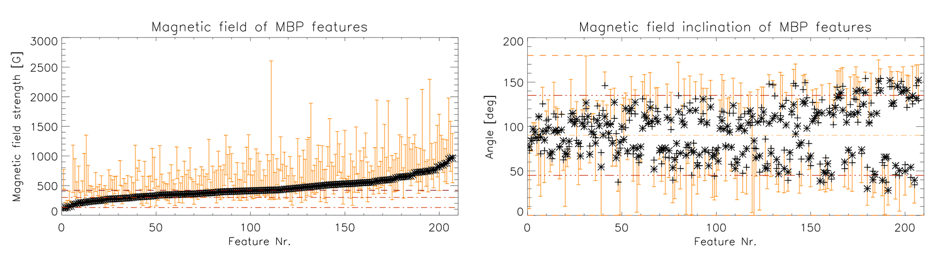


Fig.4: Evolution of plasma parameters of a single MBP evolutionary track. From top to bottom (left to right): The magnetic field strength, inclination, components, LOS velocity, line-flank intensity, size, and temperatures at log τ=0, -1, -2; black, red, orange, and yellow lines correspond to barycentre, maximum, minimum and average values (± rms value) in a 5 by 5 pixel^2 box around the barycentre.



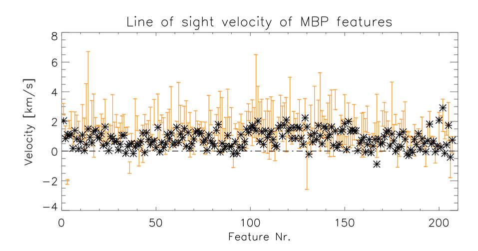


Fig.5: Statistics for the MBPs tracked in the IMaX/Sunrise data. Left top: the magnetic field strength distribution (sorted by initial field strengths); left bottom: the LOS velocity and right top: the Inclination angles; the error bar gives maximum and final values for each MBP track.

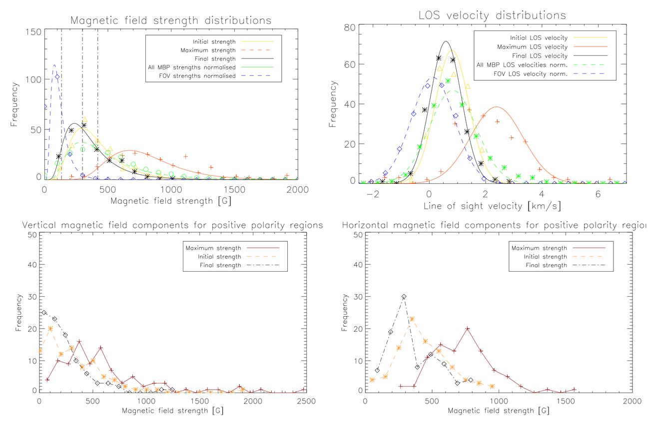
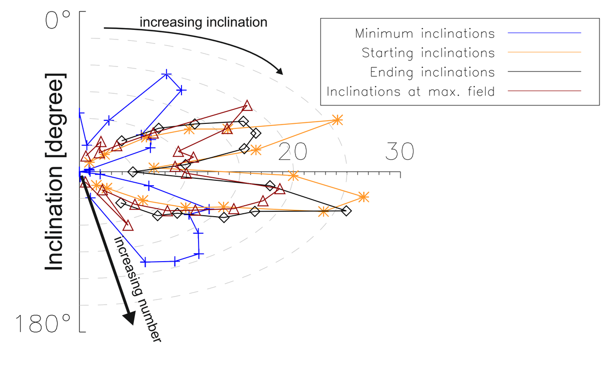


Fig.6: More statistical results; top row: left, the magnetic field strength distributions and right the LOS velocity distributions for characteristic time instances during the MBP evolution. Bottom row: the magnetic field components distribution for MBPs identified in a positive polarity region (negative polarity regions show similiar trends).

Fig.7: The MBP inclinations during characteristic time instances. Interestingly most of them show fairly horizontal magnetic fields -> indication that the tracked features might not be „classical" MBPs created by a convective collapse.



Hinode Comparison & Outlook:

For an evaluation of the results, the algorithm and analysis were also applied to Hinode data. See Figs. 8, 9, 10; Generally the results agree with the previous IMaX results. The main difference is that vertical inclinations can be well observed in the case of Hinode while in the case of IMaX the fields seem to be more horizontal. This has to be investigated in the future in more detail and might have to do with the different inversions, different data sets or due to the different identification criteria (blue line-flank of the Fe line compared to the G-band -> different kind of features?). In the future the analysis should be extended to magnetic flux analysis covering e.g., the following questions: How much magnetic flux is needed to form a MBP. Is it conserved during the formation and/or are they formed in unipolar regions?

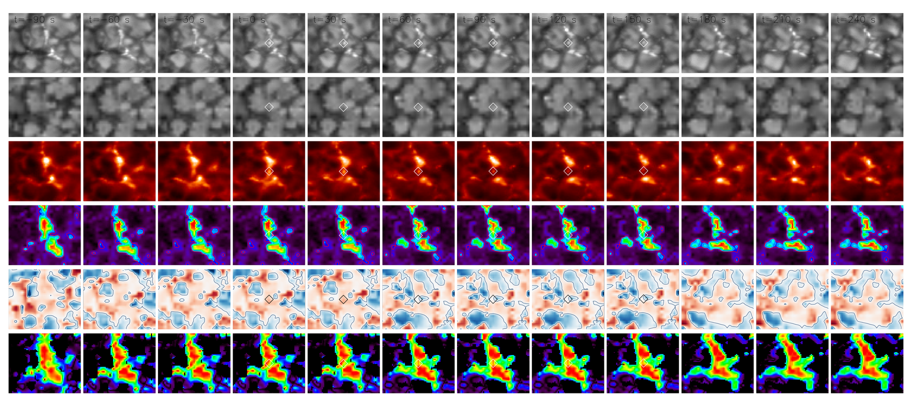


Fig.8: Similar to Fig. 3 but for a tracked MBP in the Hinode data. The field of view is a bit smaller with roughly 3 by 3 arcsec^2 compared to 3.3 by 3.3 arcsec^2. The shown data are (from top to bottom): the G-band (used for identification), the continuum image, the Ca-II H response of the chromosphere, the magnetic field strength map, the LOS velocity map, and the inclination map.

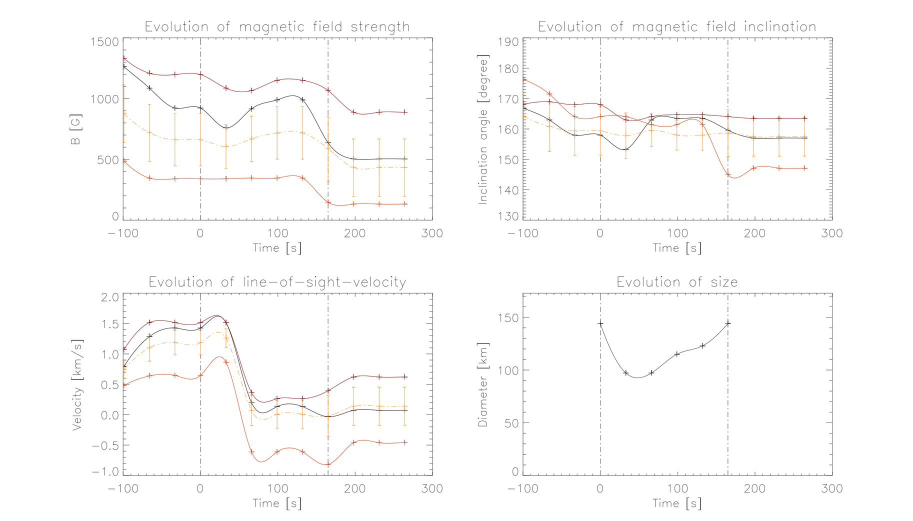
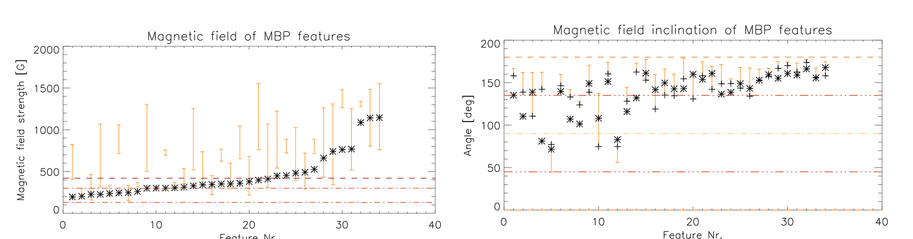


Fig.9: Similar to Fig. 4 but for one of the MBPs tracked in the Hinode data set. Furthermore partly different plasma parameters are shown due to the different inversion codes (MERLIN compared to SIR) applied. For this case the magnetic field strength, the LOS velocity as well as the magnetic field inclination and size are plotted.



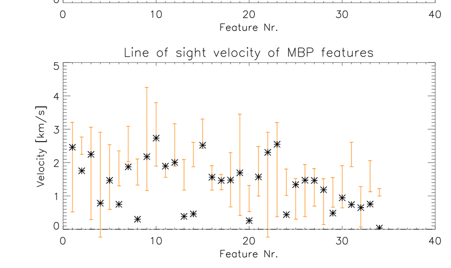


Fig.10: Same as Fig. 5 for the tracked MBPs in the Hinode/SOT data.The same trends can be observed even though the amount of data is limited due to the smaller FOV (less MBP track candidates).

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Acknowledgements:

This work was supported by FWF grant: J3176 and P23618. Hinode is a Japanese mission developed and launched by ISAS/JAXA, with NAOJ as domestic partner and NASA and STFC (UK) as international partners. It is operated by these agencies in co-operation with ESA and NSC (Norway). Partial funding has also been obtained from the Spanish Ministerio de Economía through Projects AYA2011-29833-C06 and AYA2012-39636-C06, including a percentage of European FEDER funds. The German contribution to Sunrise is funded by the Bundesministerium für Wirtschaft und Technologie through Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Grant No. 50OU 0401, and by the Innovationsfond of the President of the Max Planck Society (MPG). The HAO contribution was partly funded through NASA grant NNX08AH38G.