Group session 5

AST5770

Solar and stellar physics

Sven Wedemeyer, University of Oslo, 2026

Evaluation criteria

Final assignment

Content of the individual sections***	30%
Title & Abstract Page	Meaningful title; The abstract should be concise and comprehensive and clearly communicate the essence of the article.
Introduction	Introduces the topic of your work and puts it into of the current state of knowledge in the field, motivation and leading to the addressed scientific question and how the presented work contributes towards answering it. An overview of the structure and content of the paper is provided. The introduction stays concise and balanced and should not be expanded into a complete review over many pages.
Data & Method	A description of the data set(s) and methods used in the study to a level of detail that would allow any reader with access to the described data, methods and resources to reproduce the results (reproducibility!). Addresses how data was obtained/produced (e.g., instrumentation/code, observational/numerical technique), processed (if applicable: e.g., post-processing/adjustment incl. noise reduction, rescaling, filtering etc.), analysed (analysis steps that are central for the presented data analysis). The choice of data with respect to the scientific aim should also be evident.
Analysis & Results	Detailed but yet focused description of the new results found in this study as derived thorough analysis of the introduced data, using the introduced methods. The presented results should be connected to and supported by good and meaningful figures (and tables if applicable).
Discussion	Thorough interpretation of the new results, setting them into context and comparing them to results in the literature (and possibly complementary data). The limitations (data/methods/analysis) and implications of the study are typically addressed. In case of inconclusive results, the likely reasons for the inconclusiveness (and possibly future mitigation strategies) should be discussed.
Conclusions	The essence and take-away message. The conclusion section is not a complete summary but briefly highlights the most important results and conclusions!

*** Please see the lecture handouts for more details regarding how the individual sections should be built up and what content is expected. Please also see regular journal articles for guidance and inspiration.

Evaluation criteria

Final assignment

Writing and format	10%
Writing Style	Well-formulated text with a formal, professional tone (and no colloquial language), suitable for journal publication with a
Conciseness	Concise, accurate and to the point, finding the right balance between level of detail and number of words.
Format & Appearance	Formal appearance including the use the template with correct font, font size, line spacing, and border areas. The overall layout (placement of figures and tables) should look professional.
Spelling, Grammar, and Punctuation	Well written text with no (insignificant number of) grammatical, punctuation and spelling errors. Easy and interesting reading text with clear evidence of regular revision and proofing.

Data and methods (Assignment III)

Data and methods - Assignment III

- **Section typically follows the introduction**
- **Requirements:** 1500 - 3000 words and at least one figure illustrating the used data set(s).
- **Content:** Please describe the data set(s) and methods used in your scientific study.

- **Method(s)** with which the data was
  - obtained/produced *(e.g., instrumentation/code, observational/numerical technique)*
  - processed *(if applicable: e.g., post-processing/adjustment incl. noise reduction, rescaling, filtering etc.)*
  - analysed *(analysis steps that are central for the presented data analysis — as being presented in the next assignment)*.

- **Aim - REPRODUCIBILITY:** This section should allow any reader with access to the described data, methods and resources to **reproduce** the results (to be) reported in your paper! *(However, trivial/unimportant details are usually left out.)*

- Remember: You are supposed to deliver a **tentative draft** of this section that reflects your current ideas and plans.
  - You will get ideas how to adapt/update/improve this part as you work on the data analysis during the next weeks. Updated version as part of the final project assignment.

Data and methods - Assignment III

- **Level of detail: Describe on a lower level than in a real scientific article.**
  - Examples:
    - If you use data from a telescope (SST, SDO, etc)., then please **outline** how the telescope (and instrument) works: Principle of the employed telescope and instrument (not every optical component).
    - If you use numerical data, then please describe the basic workings the numerical code(s): General numerical approach/method used (but not all details of its implementation).

- Please let us know if you are missing information regarding how the data was produced!
- **Typical details** provided:
  - Type of region observed/simulated, set into context with additional data (if applicable)
  - Size of the field-of-view or computational domain, duration of used time series, time & date … (if applicable)
  - Resolution (in relevant domains) and other fundamental parameters (especially for simulations)
- Please have a look at data/method section of scientific articles to check the extent and level of detail of the typical content and how it is typically structured and presented.

Data and methods - Assignment III

- **Section structure:**
  - Typically divided into subsections dealing with different stages (e.g. observation, post-processing, analysis methods…)

- **Figure:**
  - At least 1 figure (and preferably not more than 3) that illustrate(s) the properties of the data (and method(s) if applicable).

- **References**
  - Known/standard methods can be addressed with the proper reference and a short summary (to extent useful for the reader to understand what you are doing)
  - Example: You would explain briefly how the equation of state is handled in the simulation code but not how the Fast Fourier Transform algorithm is implemented

Results (Assignment IV)

Results - Assignment #4

- The part of a paper, in which the **new results are presented in detail**.
- This section typically follows the data & method section.
- **Describe** the results and leave any detailed interpretation (and comparison to the literature) for the discussion section!
- It should not be a (random) collection of all facts and things you found out.

  ➡ **Select** the results that serve a purpose in exploring and addressing the scientific question/topic of your paper!
- Be **concise and focused but yet consistent and complete**.

Results	Discussion	Conclusion
• Detailed but yet focused **description** of the **new results** found in this study • Thorough analysis of the introduced data, using the introduced methods • Results presented with good figures (and tables if applicable)	• **Interpretation** of the new results (described in the previous section), setting them into **context** / comparing them to results in the literature (and possibly complementary data)	• The **essence** and take-away message • **Brief** summary of the most important results and conclusions!

Avoid details and repetitions!

Results - Assignment #4

How to start?!

1. **Get familiar with the data.**
   - Start with the data analysis by plotting different aspect of your data — use standard tools like profiles, maps, histograms etc.
   - Do you see any trends/properties of the data that might be relevant with regard to your science question?
2. **Initial detailed data analysis.**
   - Try to split the scientific question into small steps/aspects and investigate in detail.
   - How can you check these sub-questions by plotting the data in different ways?
   - Find good ways to visualise your findings. Make preliminary plots/tables (simple, do not yet use much time on making them "pretty").
3. **Collect, sort, and filter your findings and plots so far.**
   - Pre-select material (your "puzzle pieces") and start with the most important ones (as far as you can tell at this point)
   - Now put your findings and material into order (in your tentative manuscript)
   - Describe the figures/tables in detail in your text.
4. **Connect the dots.**
   - Put the results into a logical order and create a "story" with a "red thread".
5. **Polish — Make the text, figures, table nice and consistent**
   - Go through the text again and again and make sure it connects well and that all figures and tables are referred to and made good use of. You may want to update your figures to emphasise your findings.

Results and beyond

Results

- The part of paper, in which the **new results are presented in detail**.
- **Describe** the results and leave the detailed interpretation (and comparison to literature) will be done in the discussion section!
- It should not be a (random) collection of all facts and things out find out.

  ➡ **Select** the results that serve a purpose in exploring and addressing the scientific question/topic of your paper!
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Results	Discussion	Conclusion
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Avoid details and repetitions!

Results and beyond

How to start?!

1. **Get familiar with the data.**
   - Start with the data analysis by plotting different aspect of your data — use standard tools like profiles, maps, histograms etc.
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   - Go through the text again and again and make sure it connects well and that all figures and tables are referred to and made good use of. You may want to update your figures to emphasise your findings.

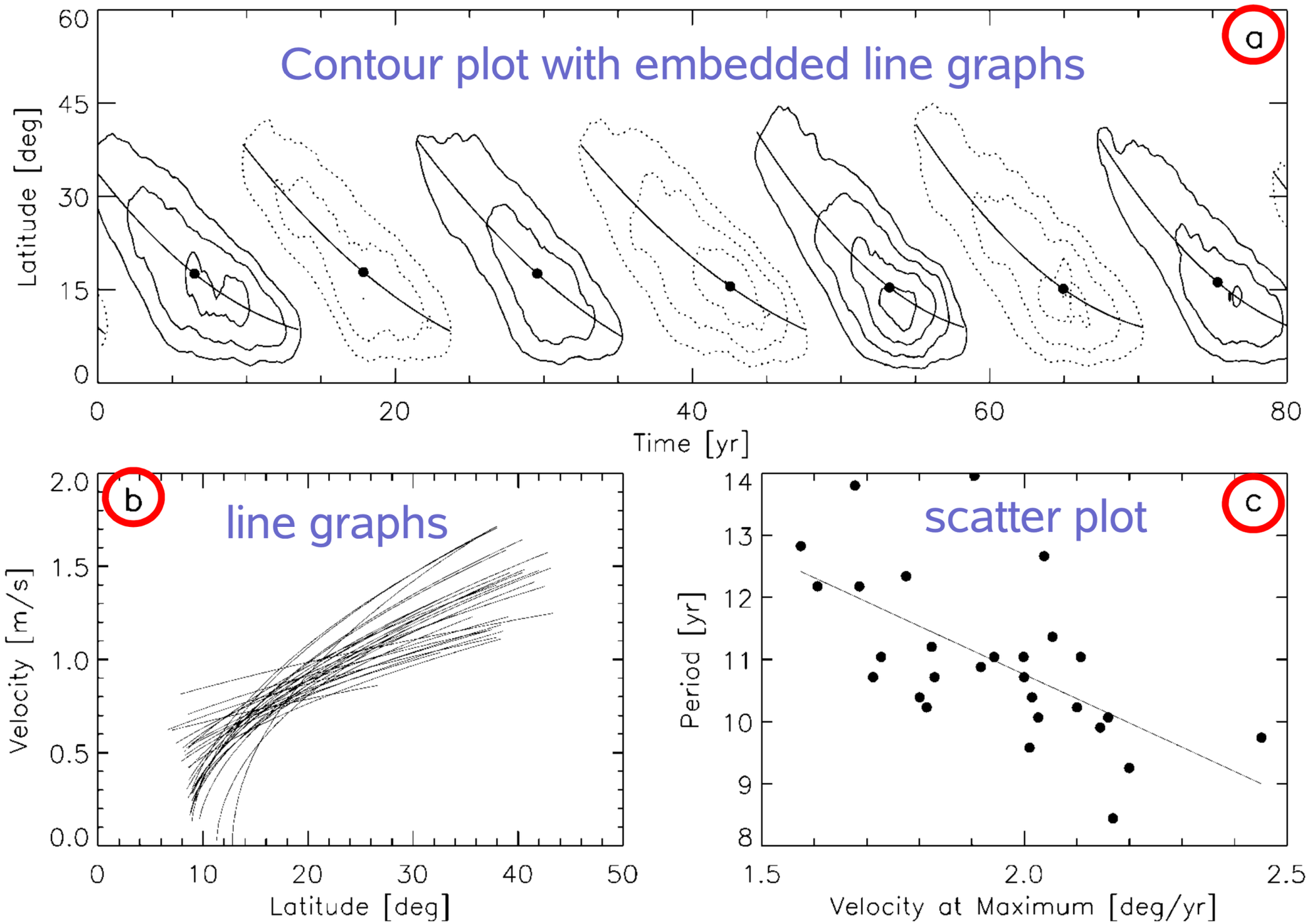
Results and beyond

Figures

- **Important:**
  - Each figure must be **referred** to in the text.
    - Figures are typically set in the order they are referred to in the text (it starts with Fig. 1)
  - Each figure must have a **caption.**
    - Captions are short but self-explaining. It should be possible to interpret a figure just by looking at it and reading the caption (without the main text). What does the figure show?
    - All graphical elements should be explained in the caption (symbols, different lines, colors).
    - Captions **describe what is plotted**. Any interpretation is done in the main text.
  - Make it easy for the reader to navigate the figure. Use letters to identify panels so that they can be referred to as, e.g. "Fig. 1a and Fig. 3c"
  - *It can be possible to use/reproduce figures from other publications if really necessary/useful. That usually requires explicit consent of the authors and journal and of course a proper reference/acknowledgment.*

Results and beyond

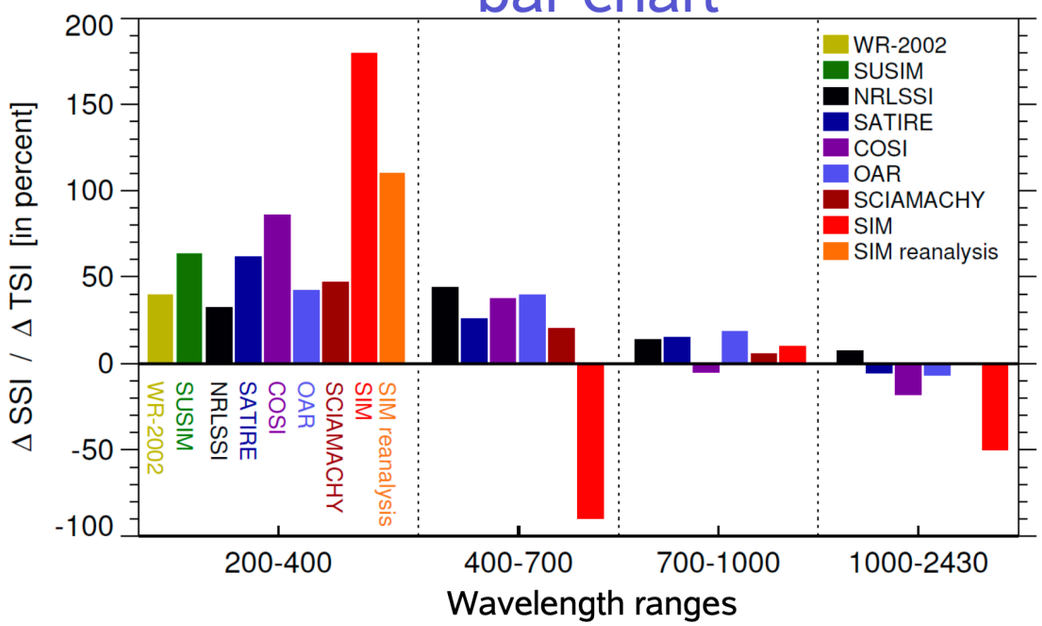
Figures - Examples



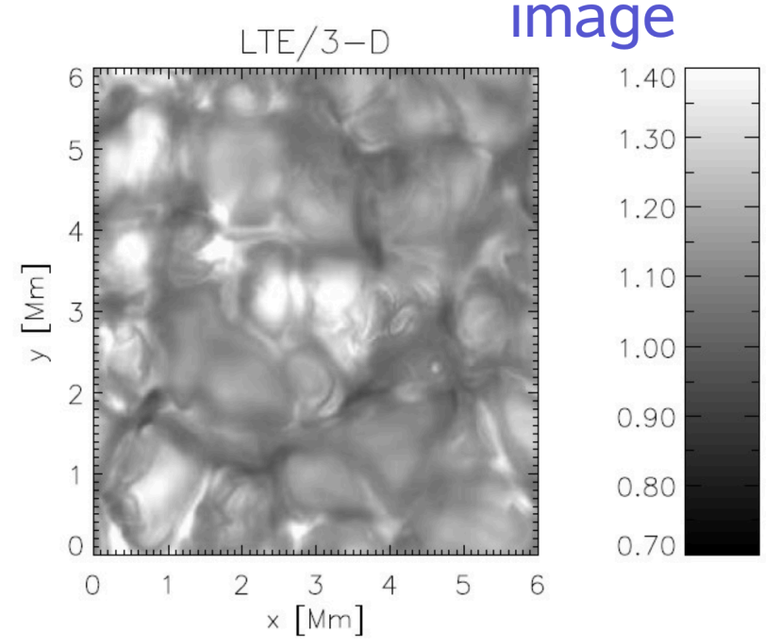
Results and beyond

Figures - Examples

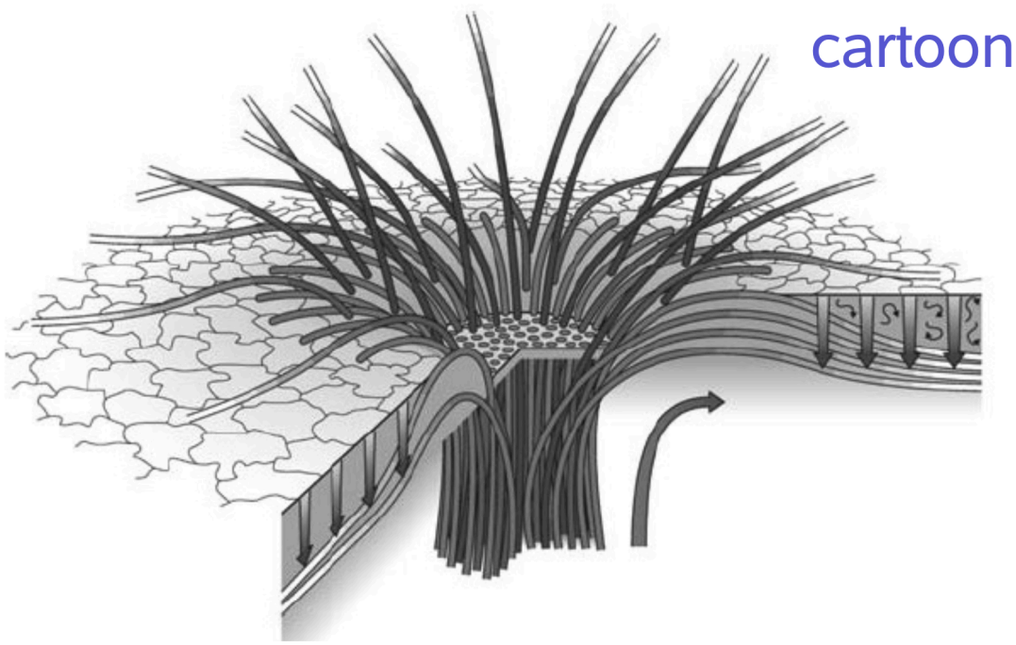
bar chart



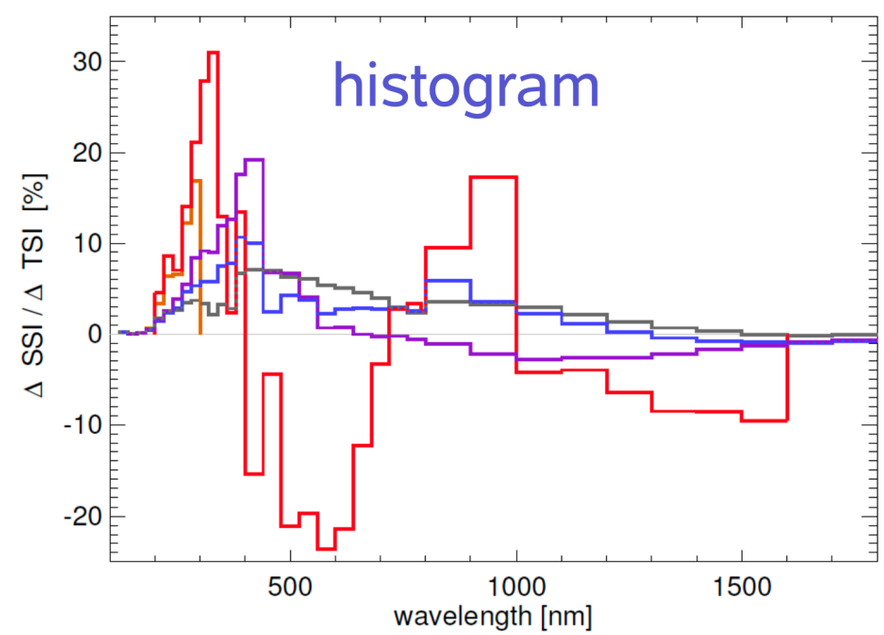
image



cartoon



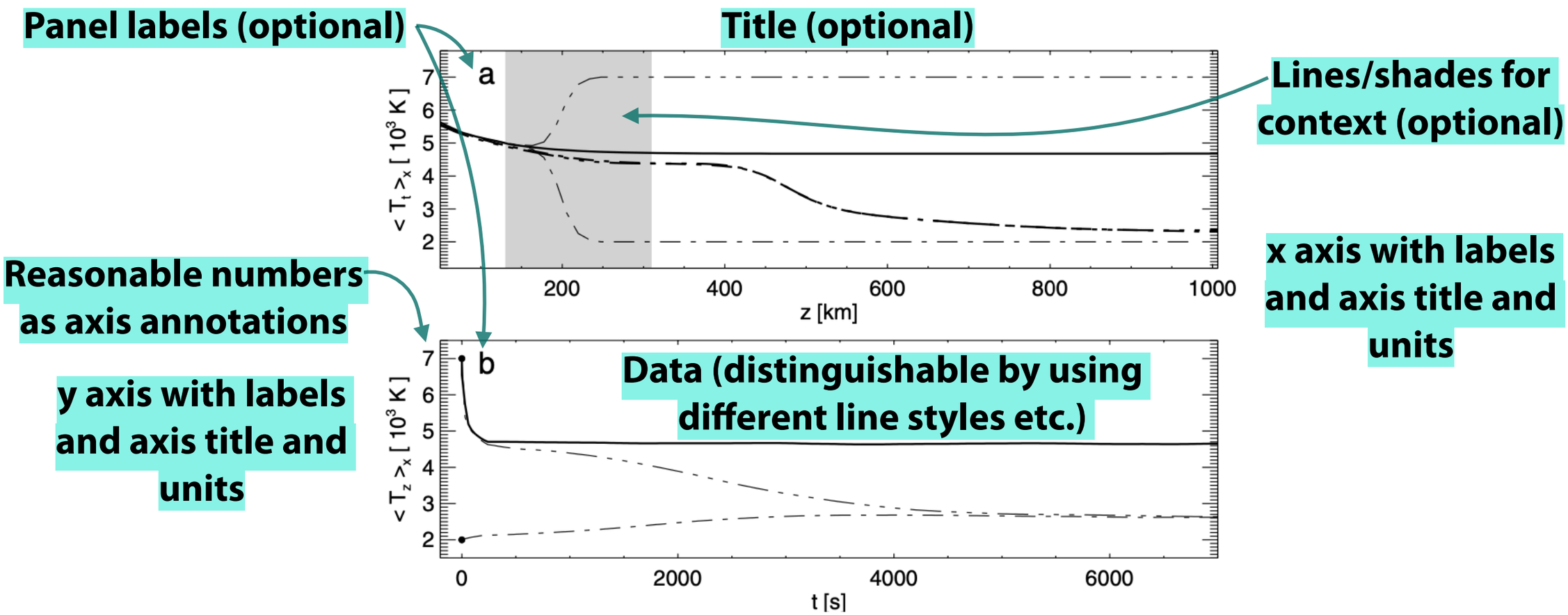
histogram



Results and beyond

Components of a professional figure

- The caption starts by stating what is plotted.
- All graphical elements are described: dots and the line.



Caption **Fig. 3.** Time evolution towards radiative equilibrium (RE) for simulations without (solid) and with CO line cooling for different initial chromospheric temperatures of 2000 K (dot-dashed) and 7000 K (triple-dot-dashed): **a)** horizontally averaged temperature stratification for initial time step (thin) and after 10 000 s (thick) and **b)** time evolution of the horizontally averaged temperature at $z = 650$ km. The shaded area marks the transition layer for artificial damping of velocity fluctuations.

A&A 462, L31–L35 (2007)
DOI: 10.1051/0004-6361:20066173
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Results and beyond

Figures

- **Readability:** Make sure that all graphical elements and text are clearly visible/readable.
  - Line thickness, image resolution, labels
  - Font size not too small, best about the same as in the figure caption (must be clearly readable) — Careful: Check this once it is in your document as the figure might be scaled.
  - Number and size of major and minor ticks
- Meaningful axis ranges (round numbers, fill the frame), linear/log scale
- **Do not overload figures** (do not plot too many different quantities)
  - Consider splitting figures into panels or repeating them on a linear or log/log scale or different axis ranges or different subsets — Whatever makes most sense when describing the results in the text.
- Make sure **all quantities can be distinguished**.
  - If two lines are essentially identical so that only one is visible, try different line styles (one solid, one dashed?), colors, etc. to make both visible
  - Provide a legend if you use many symbols (either in plot and/or in caption)

Results and beyond

Tables

- When to use a table?
  - Many numbers that cannot be presented in a meaningful figure.
  - Exact numbers are needed (which is difficult to infer from a figure). Can be in addition to figure.
  - Overview over data properties, especially when several sets are used.

- Note:
  - Figures are easier to interpret than tables.
  - Tables need a caption that explains all content.
  - The table must be referred to in the text (in the order of them being first referred to in the text).

Exercises

Exercises

Practice bulleting out key takeaways from abstracts, results and conclusions

NANOFLARES AND THE SOLAR X-RAY CORONA[1]

E. N. Parker
Enrico Fermi Institute and Departments of Physics and Astronomy, University of Chicago
Received 1987 October 12; accepted 1987 December 29

ABSTRACT

Observations of the Sun with high time and spatial resolution in UV and X-rays show that the emission from small isolated magnetic bipoles is intermittent and impulsive, while the steadier emission from larger bipoles appears as the sum of many individual impulses. We refer to the basic unit of impulsive energy release as a *nanoflare*. The observations suggest, then, that the active X-ray corona of the Sun is to be understood as a swarm of nanoflares.

This interpretation suggests that the X-ray corona is created by the dissipation at the many tangential discontinuities arising spontaneously in the bipolar fields of the active regions of the Sun as a consequence of random continuous motion of the footpoints of the field in the photospheric convection. The quantitative characteristics of the process are inferred from the observed coronal heat input.

Subject headings: hydromagnetics — Sun: corona — Sun: flares

- What is the **main message**? What is the **new** here?
- What would be **keywords** / tags I would assign? (How do I sort this into my library?)

➡ Is it worth a more thorough read?

➡ Should I cite this paper? How can it back up my research results?

- **Exercises:**
  1. Read the abstract of an article and try to summarise the most important statement in your own word in 1-3 sentences (can be bullet points).
  2. We discuss our summaries and try to improve them

Published: 14 November 2002

Exercise 1

Dark cores in sunspot penumbral filaments

Göran B. Scharmer, Boris V. Gudiksen, Dan Kiselman, Mats G. Löfdahl & Luc H. M. Rouppe van der Voort

Nature **420**, 151–153 (2002) | Cite this article

580 Accesses | **193** Citations | **1** Altmetric | Metrics

Abstract

Sunspot umbrae—the dark central regions of the spots—are surrounded by brighter filamentary penumbrae, the existence of which remains largely inexplicable[1]. The penumbral filaments contain magnetic fields with varying inclinations[2] and are associated with flowing gas[3,4,5], but discriminating between theoretical models[6,7,8] has been difficult because the structure of the filaments has not hitherto been resolved. Here we report observations of penumbral filaments that reveal dark cores inside them. We cannot determine the nature of these dark cores, but their very existence provides a crucial test for any model of penumbrae. Our images also reveal other very small structures, in line with the view that many of the fundamental physical processes in the solar photosphere occur on scales smaller than 100 km.

THE ASTROPHYSICAL JOURNAL, 481:500–514, 1997 May 20
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Exercise 2

FORMATION OF SOLAR CALCIUM H AND K BRIGHT GRAINS

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Received 1996 September 17; accepted 1996 December 16

ABSTRACT

We have simulated the generation of Ca II H_{2V} bright grains by acoustic shocks. We employ a one-dimensional, non-LTE radiation-hydrodynamic code, with six-level model atoms for hydrogen and singly ionized calcium. We drive acoustic waves through a stratified radiative equilibrium atmosphere by a piston, whose velocity is chosen to match the Doppler shift observed in the Fe I 396.68 nm line in the H line wing, formed at about 260 km above $\tau_{500} = 1$.

The simulations closely match the observed behavior of Ca II H_{2V} bright grains down to the level of individual grains. The bright grains are produced by shocks near 1 Mm above $\tau_{500} = 1$. Shocks in the mid-chromosphere produce a large source function (and therefore high emissivity) because the density is high enough for collisions to couple the Ca II populations to the local conditions. The asymmetry of the line profile is due to velocity gradients near 1 Mm. Material motion Doppler-shifts the frequency at which atoms emit and absorb photons, so the maximum opacity is located at—and the absorption profile is symmetric about—the local fluid velocity, which is shifted to the blue behind shocks. The optical depth depends upon the velocity structure higher up. Shocks propagate generally into down-flowing material, so there is little matter above to absorb the Doppler-shifted radiation. The corresponding red peak is absent because of small opacity at the source function maximum and large optical depth due to overlying material. The bright grains are produced primarily by waves from the photosphere that are slightly above the acoustic cutoff frequency. The precise time and strength of a grain depend upon the interference between these waves near the acoustic cutoff frequency and higher frequency waves. When waves near the acoustic cutoff frequency are weak, then higher frequency waves may produce grains. The "5 minute" trapped *p*-mode oscillations are not the source of the grains, although they can slightly modify the behavior of higher frequency waves.

Subject headings: hydrodynamics — methods: numerical — shock waves — Sun: granulation

More exercises

Practice bulleting out key takeaways from abstracts, results and conclusions

Science AAAS

Chromospheric Alfvénic Waves Strong Enough to Power the Solar Wind
B. De Pontieu *et al.*
Science **318**, 1574 (2007);
DOI: 10.1126/science.1151747

REPORT

Chromospheric Alfvénic Waves Strong Enough to Power the Solar Wind

B. De Pontieu,[1]* S. W. McIntosh,[2,3] M. Carlsson,[4] V. H. Hansteen,[4,1] T. D. Tarbell,[1] C. J. Schrijver,[1] A. M. Title,[1] R. A. Shine,[1] S. Tsuneta,[5] Y. Katsukawa,[5] K. Ichimoto,[5] Y. Suematsu,[5] T. Shimizu,[6] S. Nagata[7]

Alfvén waves have been invoked as a possible mechanism for the heating of the Sun's outer atmosphere, or corona, to millions of degrees and for the acceleration of the solar wind to hundreds of kilometers per second. However, Alfvén waves of sufficient strength have not been unambiguously observed in the solar atmosphere. We used images of high temporal and spatial resolution obtained with the Solar Optical Telescope onboard the Japanese Hinode satellite to reveal that the chromosphere, the region sandwiched between the solar surface and the corona, is permeated by Alfvén waves with strong amplitudes on the order of 10 to 25 kilometers per second and periods of 100 to 500 seconds. Estimates of the energy flux carried by these waves and comparisons with advanced radiative magnetohydrodynamic simulations indicate that such Alfvén waves are energetic enough to accelerate the solar wind and possibly to heat the quiet corona.

More exercises

Practice bulleting out key takeaways from abstracts, results and conclusions

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E. N. PARKER
Enrico Fermi Institute and Departments of Physics and Astronomy, University of Chicago
Received 1987 October 12; accepted 1987 December 29

ABSTRACT

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This interpretation suggests that the X-ray corona is created by the dissipation at the many tangential discontinuities arising spontaneously in the bipolar fields of the active regions of the Sun as a consequence of random continuous motion of the footpoints of the field in the photospheric convection. The quantitative characteristics of the process are inferred from the observed coronal heat input.

Subject headings: hydromagnetics — Sun: corona — Sun: flares

More exercises

Practice bulleting out key takeaways from abstracts, results and conclusions

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STATISTICAL PROPERTIES OF THE DISK COUNTERPARTS OF TYPE II SPICULES FROM SIMULTANEOUS OBSERVATIONS OF RAPID BLUESHIFTED EXCURSIONS IN Ca II 8542 AND Hα

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Received 2012 February 15; accepted 2012 April 12; published 2012 June 4

ABSTRACT

Spicules were recently found to exist as two different types when a new class of so-called type II spicules was discovered at the solar limb with the Solar Optical Telescope on board the *Hinode* spacecraft. These type II spicules have been linked with on-disk observations of rapid blueshifted excursions (RBEs) in the Hα and Ca II 8542 lines. Here we analyze observations optimized for the detection of RBEs in both Hα and Ca II 8542 lines simultaneously at a high temporal cadence taken with the Crisp Imaging Spectropolarimeter at the Swedish Solar Telescope on La Palma. In this study, we used a high-quality time sequence for RBEs at different blueshifts and employed an automated detection routine to detect a large number of RBEs in order to expand on the statistics of RBEs. We find that the number of detected RBEs is strongly dependent on the associated Doppler velocity of the images on which the search is performed. Automatic detection of RBEs at lower velocities increases the estimated number of RBEs to the same order of magnitude expected from limb spicules. This shows that RBEs and type II spicules are indeed exponents of the same phenomenon. Furthermore, we provide solid evidence that Ca II 8542 RBEs are connected to Hα RBEs and are located closer to the network regions with the Hα RBEs being a continuation of the Ca II 8542 RBEs. Our results show that RBEs have an average lifetime of 83.9 s when observed in both spectral lines and that the Doppler velocities of RBEs range from 10 to 25 km s^{-1} in Ca II 8542 and 30 to 50 km s^{-1} in Hα. In addition, we automatically determine the transverse motion of a much larger sample of RBEs than previous studies, and find that, just like type II spicules, RBEs undergo significant transverse motions of the order of 5–10 km s^{-1}. Finally, we find that the intergranular jets discovered at Big Bear Solar Observatory are a subset of RBEs.

Key words: Sun: atmosphere – Sun: chromosphere – Sun: corona

Solar Flares: Magnetohydrodynamic Processes

Living Rev. Solar Phys., **8**, (2011), 6
http://www.livingreviews.org/lrsp-2011-6

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Abstract

This paper outlines the current understanding of solar flares, mainly focused on magnetohydrodynamic (MHD) processes responsible for producing a flare. Observations show that flares are one of the most explosive phenomena in the atmosphere of the Sun, releasing a huge amount of energy up to about 10^{32} erg on the timescale of hours. Flares involve the heating of plasma, mass ejection, and particle acceleration that generates high-energy particles. The key physical processes for producing a flare are: the emergence of magnetic field from the solar interior to the solar atmosphere (flux emergence), local enhancement of electric current in the corona (formation of a current sheet), and rapid dissipation of electric current (magnetic reconnection) that causes shock heating, mass ejection, and particle acceleration. The evolution toward the onset of a flare is rather quasi-static when free energy is accumulated in the form of coronal electric current (field-aligned current, more precisely), while the dissipation of coronal current proceeds rapidly, producing various dynamic events that affect lower atmospheres such as the chromosphere and photosphere. Flares manifest such rapid dissipation of coronal current, and their theoretical modeling has been developed in accordance with observations, in which numerical simulations proved to be a strong tool reproducing the time-dependent, nonlinear evolution of a flare. We review the models proposed to explain the physical mechanism of flares, giving an comprehensive explanation of the key processes mentioned above. We start with basic properties of flares, then go into the details of energy build-up, release and transport in flares where magnetic reconnection works as the central engine to produce a flare.