

Summary of the 7 July 2021, Videocon

Attendees were:

Jørgen, Jesper, Kiran, Rachel, Rafa, Reger, Sarbani, Sergei, Sylvain B, Sasha, Sushant, Jason

Meeting started with a discussion on the time span of the time series to be included in Paper II. This was in response to **Sushant**'s email sent out a few days prior to the meeting. Note that the Paper II will include data from all existing sources to understand the systematics and data processing related biases. A strategy on how to combine splittings from different instruments will also be included in the paper. All participants agreed on using the same time span as in Paper I, i.e.

2010.07.11_00:00:00 to 2016.10.30_23:59:59 (2304 days)

There was also a discussion if longest possible time series might be better in this work, however it would be restricted by the computation power, especially for intermediate-degree modes. **Sushant** will work on GONG data and see if existing pipeline can be successfully used to compute splittings for 6 years long timeseries. **Rafa** mentioned that the errors in a few low-degree modes computed from different instruments/projects were significantly different. **Rachel** had suggested using simulations to see their effect on torsional oscillations. Rafa further pointed out that the error distribution in low-degree modes from integrated-light and spatially resolved observations were different, and one had to look at the details of systematics. **Rafa** recalled comparison of $\ell = 1$ & 2 modes computed from two different types of observations. He also referred to Jesper's work from early 2000 along the same lines; however, this had to be revisited for a better understanding.

***Post meeting addition by Kiran:** Rafa has done some work on this aspect as a part of this project and details (including 4 figures) can be found at*

https://www.dropbox.com/home/Rotation%20Project%20Meeting%20Notes?preview=summary_200701.pdf

You may also find results on Jesper's fittings with an emphasis on low-degree and low-frequency modes at

https://www.dropbox.com/home/Rotation%20Project%20Meeting%20Notes?preview=summary_200803.pdf

and more details were mentioned in subsequent meetings' summaries.

In addition, latest 6, 18, and 36 a-coefficient fits for the 2304d HMI timeseries computed by Jesper/Larson are available at

https://www.dropbox.com/home/Rotation%20Project%20Paper%201/Intermediate-degree_Frequency_Tables_HMI_2304d

Sylvain K. had also uploaded coefficients for 2304-d from his fittings at

<https://www.dropbox.com/home/Solar%20Splittings/SylvainKorzennik/19115>

README files are also available in both areas. Since these data sets were specially produced for this project, you are encouraged to directly contact the relevant person, if you use them in any other work.

Jørgen sent out another version of Paper I to those members that typically attend the meeting, a week prior to the meeting; this was another topic in the meeting agenda. He invited comments from the participants. There were suggestions on the text to be included in “Section 1: Introduction”, where the amount of material reviewing the status of the field was found perhaps to be excessive. The current (tentative) plan is to submit this paper to ApJS since it primarily contains technical details of different inversion methods and a comparison between them using Sasha’s models and HMI observations.

There was also a detailed discussion on various figures presented in the paper. **Jørgen** emphasized on including complete description on all inversion methods; so far the focus is on RLSF analyses with the Schou & Howe (SH), Antia & Basu (AB), and Korzennik & Eff-Darwich methods. He had carried out a detailed comparison between AB and SH inversions and found some discrepancies that need to be sorted out: Choosing SH parameters to match the standard deviation and FWHM in radius for an AB solution often leads to an FWHM in latitude substantially larger than the AB value. This is specifically discussed in the Paper I draft in the results presented in Figure 12 (page 20), Figure 14 (page 22), and Table 3 (page 21). **Rachel** thinks that it could be a labeling issue only that she will investigate (Task A.68). One needs to check inputs for the differences in Figure 14.

The lack of a clear relation between the fitted SH results in the lower panel of Figure 12 and the original AB parameters in the top panel raised the question of how to carry out a systematic comparison. **Jesper** suggested to use the AB weight functions in the SH technique. **Jørgen** supported the suggestion but noted that the different form of the derivatives made this more complicated. He suggested simple experiments with 1D inversions in latitude to test the effect of different forms of the regularization.

Roger shared his results on the torsional oscillations obtained from the observations using 5250 and 5895 Å lines (A.33). It is hoped that this will be described in a short document (A.33a)

Rachel reported that she had completed full set of inversions for noisy artificial data.

Next meeting will be held in late August or early September.

Action Items:

Since we have started identifying various tasks by the item numbers, it is decided to keep the same numbering as we move forward. Now onwards, the action item list will have all old and new tasks.

Note: Actions have already been taken on the highlighted items. No further work is required.

Carryover action item list

A.1: Use fixed and reasonable plot limits in plots of inversion result differences (JC-D)

A.2: Investigate causes of excessive error estimates in inversions of individual splittings (SGK, AE-D)

A.3: Inversion results for artificial data on standard form (RH)

A.4: More extensive results on standard form (SV)

A.5: Consider determination of statistical errors and centres of gravity of averaging kernels (SB, HMA)

A.6: Find optimal inversion parameters and produce results on standard form (all inverters)

A.7: Include measures of inversion resolution in radius and latitude in numerical output (all inverters)

February 13, 2020

A.8: Consider ways of displaying resolution results (JC-D)

A.9: Analysis of averaging kernels, determination of radial and angular extent (JCD, RH)

A.10: [Duplicate of A.7]

A.11: Understand differences found by Sarbani and Antia in a coefficients, relative to Sasha's (SB, HMA, AK)

March 17, 2020

A.12: Input for the paper based on the work discussed at the meeting (SB, HMA) (included in meeting summary)

A.13: Format for averaging kernels in (x, y) grid (JCD)

A.14: Notes on today's (March 17, 2020) discussion (SVV) (included in meeting summary)

April 22, 2020

A.15: Compare and consolidate treatment of background in analyses of GOLF and BiSON data (RH, RAG)

A.16: Analyze SOLA inversion results with different trade-off parameters, attempting higher resolution at the expense of higher errors (RH, JCD)

A.17: Surface rotation results to be provided in numerical form (RKU)

Of course A.2 still needs action from Antonio, and for A.9 I hope to get a representative selection of averaging kernels for the SOLA inversions from Rachel.

May 27, 2020

A.18: Compare different determinations of degree 1–3 splittings, including spatially resolved data (RG, RH, SK, JS, TL)

A.19: Compare torsional oscillations in Mt Wilson surface rotation observations with helioseismic results (RU, RH)

A.20: Test analyses of averaging kernels with well behaved (e.g., double Gaussian) artificial kernels (JCD)

A.21: Provide averaging kernels from SK–AE-D inversions (SGK) This is added to Task A.55.

A.22: Results from SK–AE-D inversions to be uploaded before next meeting (SGK)

A.23: Upload the updated summary file on calculating the properties of averaging kernels (SB)

July 1, 2020

A.24: Re-compute splittings for Sun as a star observations using background similar to RG/AMB (RH)

A.25: Investigate the differences between two leakage matrices (JS, SGK)

A.26: Investigate the differences between the zonal flows from Roger's data and the helioseismic method (RH)

A.27: Validate averaging kernels near or at the equator (JCD)

A.28: Averaging kernels to be sent to JCD for the action item A.27 (SB and RH).

August 3, 2020

A.29: Analysis of resolution in averaging kernels as a function of trade-off parameters (RH, JCD)

A.30: Fits from Sun as a star observations to be uploaded to Dropbox (RAG)

A.31: Low-degree mode fits using Rafe's frequencies as initial guesses (JS)

A.32: Notes on the analysis of averaging kernels to be uploaded to Dropbox (JCD).

September 9, 2020

A.33: Analyze rotation rate from observations using different spectral lines (RKU)

A.33a: Create a short document on the results of A.33 (RKU)

A.34: Obtain insight on the HMI observables and their data quality (RH to discuss with JS)

A.35: Combined with A.30.

A.36: How the smoothing parameter is used in the inversion code? (RH)

A.37: Another set of averaging kernels to be sent to JCD (RH)

A.38: Inversions for non-optimal parameters to be sent to JCD (SB/HMA)

A.39: Notes of the averaging kernels analysis discussed at the meeting to be uploaded to Dropbox (JCD).

October 14, 2020

A.40: Hare and hound results with normal smoothing (SB, HMA).

A.41: Upload all low-frequency tables to the Dropbox (KJ).

A.42: plots of the cuts of averaging kernels for $\mu = 1$ to be included in the document (JCD).

A.43: Averaging Kernels for Model 2 to be sent to JCD (RH).

November 25, 2020

A.44: Draft of Paper II by next meeting (RAG).

A.45: Introduction: a few lines on surface differential rotation and why it is important (RKU).

A.46: Introduction: reference(s) for the first evidence of sub-surface zonal flows and their time-dependence (JS).

A.47: Introduction: a short paragraph on core and the radiative zone (RAG).

A.48: Results on the RLS inversion using his code (JS)

A.49: Convert JS results to a standard format for comparison (RH)

A.50: Comparison between different RLS results (JCD)

A.51: Mode set for core inversion below $0.2 R_{\text{sun}}$ (RAG)

A.52: Incorporate suggestions in Paper I (JCD)

A.53: Some details of the Antonio's code for the paper (SGK)

January 12, 2021

A.54: Upload plots from modified SGK/AED code (SGK/KJ): Link is included in the meeting summary.

A.55: Averaging kernels and the solutions to be sent to JCD for comparison (SGK)

A.56: Details of the two RLS methods (SB/HMA, JS/RH)

A.57: Discussion on low-degree modes (RAG, RH, AMB, JS, SM, SGK)

February 17, 2021

A.58: Coordinate with concerned persons for various data sets to be included in Paper II (RAG)

A.59: Discussion with Antia on AB formalism (Sarhani)

A.60: Upload results on the comparison of AB and SH averaging kernels (JCD)

March 17, 2021

A.61: Jørgen and Rachel to discuss off-line the issues with Model 2 solution.

April 17, 2021

~~A.62: Send the link of frequency tables from Jesper's fitting (KJ)~~

A.63: Eigenfunctions to be sent to Jørgen for comparison (AGK)

A.64: Jørgen to communicate directly with Antia/Sarbani for their results to complete A.38.

A.65: Share draft/outline of Paper II on overleaf (RAG).

~~A.66: Share latest version of Paper I (JCD)~~

May 25, 2021

~~A.67: Share latest results (JCD)~~

July 7, 2021

A.68: Check input for differences in figures on page 22 in Paper I draft version. (RH and JCD)
