B. Witschas 22.12.2021

The valuable comments given by the anonymous Referee #1 (received on 29 November 2021, shown in black) are highly appreciated. The corresponding answers of the authors, indicated in blue color, as well as the related changes in the manuscript, indicated in green color, are given below.

Interactive comment on "Spectral performance analysis of the Aeolus Fabry-Pérot and Fizeau interferometers during the first years of operation" by B. Witschas et al.

(Reviewer comments) (Author response) (changes in the manuscript)

As noted in lines 250-255, this is a complex system where the behavior of one interferometer impacts the downstream performance of the others. As such, this detailed description is helpful and insightful (and necessary). In fact, I would argue this is an important piece of work to have documented for posterity, particularly the mathematical descriptions of the specific Aeolus interferometer implementation and the detailed on-orbit operational performance. The mathematical approach appears correct and robust.

Doppler lidar is challenging because so many effects can appear as Doppler shifts. Changes in laser frequency, thermal shifts, plate spacing – all can appear as Doppler shifts and have to be separated from the actual atmosphere-induced Doppler shift. There is a comment early in the manuscript about thermal impacts on the telescope. Are there any thermal impacts being noted on the interferometers?

Indeed, thermal impacts are not only observed on the telescope but also on the rest of the ALADIN instrument. In the bottom panel of Fig. 7, the drift of the spectral spacing (black circles) as well as the temperature measured at the ALADIN detection electronic units (DEU) is shown whereas the latter serves as a proxy for the ambient temperature within the instrument. From this figure it can be seen that the instrument temperature changes by several Kelvin throughout the annual cycle, depending on the position of the sun with respect to the satellite. For this reason, the FPIs and the polarizing beam splitter block (Fig. 1, PBSB) are placed in a thermal hood to reach a long-term temperature stability of +/- 10 mK. On a short-term (hours), the temperature stability is better than 3 mK. Considering the temperature sensitivity of the Rayleigh channel of 455 MHz/K (81 m/s/K), 3 mK temperature fluctuations correspond to 0.2 m/s. However, as the internal reference signal is usually used for the wind retrieval, only temperature fluctuations that occur within one observation (12 s) are of relevance and are observed to be even smaller than 3 mK. In order to clarify this issue, we added the following paragraph to the manuscript:

Following line 115: "As the FPIs are rather temperature sensitive (≈ 455 MHz/K which corresponds to ≈ 81 m/s/K), they are enclosed in a thermal hood to reach a long-term temperature stability of about ±10 mK. On the short time scale of a wind observation (12 s), the temperature stability is even better than 3 mK, which translates to wind speed variations of less than ≈0.2 m/s".

In discussing the results shown in Figure 4 (e.g., manuscript lines 351-364), it would be helpful to know, from forward modeling, how good the fit has to be to maintain bias at <1 m/s, <5 m/s, <10 m/s, etc. In my experience, the absolute wind determination is highly sensitive to the FPI fit. Thus, even the small amount of variability as shown in Figure 5, for example, can have large impact on the wind retrieval. This manuscript does a good job of explaining and quantifying the measured instrument response. What is not answered is the question, "Is this good enough?" In other words, perhaps add a succinct description of how well the errors have to be minimized to have less than X m/s impact on the final product. This would help the reader understand how close the team is to best possible performance, or if this is best possible and is at the limit of noise.

This question is rather complex to answer, as a lot of steps are performed in the Aeolus processor to derive HLOS winds. Thus, a forward modelling of the induced systematic error is out of scope for this publication as much more detailed information about the wind processing and corresponding calibration procedures have to be addressed in advance. In particular, there is only one step in the processing chain where the FPI transmission curve fits are used, namely the so-called Rayleigh-Brillouin correction (Dabas et al., 2008, Dabas and Huber, 2017), where the impact of temperature and pressure differences in various altitudes on the receiver response is considered. To perform this correction, the fits are convolved with Rayleigh-Brillouin spectra calculated for different temperatures and pressures, and the derived response change is used for correction. However, as the atmospheric channel has different optical properties than the internal reference channel, further modifications have to be performed. In particular, the fits of the internal reference FPI transmission curves is convolved with a tilted top-hat function to consider any etendue effects. The accuracy of this procedure cannot be well assessed, as there is no possibility to measure the FPI transmission curves via the atmospheric channel with the needed accuracy. Among others, this is the reason why additional bias corrections based on ground return or ECMWF-model data are performed to obtain a wind product with a small systematic error of e.g. < 1 m/s. This bias correction is extensively explained by Weiler et al., 2021. Furthermore, as the width of the Rayleigh-Brillouin spectrum is rather broad (i.e. about 3 to 4 GHz for a laser wavelength of 355 nm and atmospheric pressures from 0 hPa to 1013 hPa and temperatures from 220 K to 330 K), the response of the Rayleigh channel is insensitive to small scale details as observed for the FPI transmission curve residuals. In order to clarify this issue, we add the following explanations to the manuscript: Following line 358: "It is also worth mentioning here, that the shown deviations cannot directly be related to a potentially origination systematic error, as several steps are performed during the wind processing chain. The only processing step that directly applies FPI transmission fit curves is the RBC that considers the impact of different atmospheric temperatures and pressures on the receiver response (Dabas et al., 2008; Dabas and Huber, 2017). Within the RBC, the FPI fit curves are convolved with Rayleigh-Brillouin spectra of different temperatures and pressures, as well as with a tilted top-hat function to consider optical differences between the internal reference and the atmospheric path. The particular accuracy of the latter procedure cannot be well assed, as there is no possibility to measure the FPI transmission curves via the atmospheric path with the needed accuracy. Among others, this is the reason why additional bias corrections based on ground return signals or ECMWF-model data are performed to obtain a wind product with a small systematic error of e.g. ≈ 1 m/s. This bias correction is extensively explained by Weiler et al. (2021b). Additionally, as the width of the RB spectrum is rather broad (i.e. 3 to 4 GHz for a laser wavelength of 355 nm and atmospheric temperatures and pressures), the response of the Rayleigh channel is insensitive to small scale details as observed for the FPI transmission curve residuals.". Furthermore, the following references were added:

- Dabas, A. and Huber, D.: Generation and update of AUX CSR, AE.TN.MFG-L2P-CAL-003, p. 43, https://earth.esa.int/eogateway/news/announcement-of-opportunity-for-aeolus-cal-val, 2017
- Rennie, M., Tan, D., Andersson, E., Poli, P., Dabas, A., De Kloe, J., Marseille, G.-J., and Stoffelen, A.: Aeolus Level-2B Algorithm Theoretical Basis Document (Mathematical Description of the Aeolus Level-2B Processor), ECMWF, https://earth.esa.int/eogateway/documents/20142/37627/Aeolus-L2B-Algorithm-ATBD.pdf, 2020.

There must have been an initial expectation of controlling instrument parameters to some limits, to maintain wind error less than some specified amount. How well did the initial expectation or modeling match the measured results?

The specifications for the spectrometer parameters that are available are indicated in Table 1. For an easier comparison with the determined parameters from the ISR measurements, we added the corresponding specifications including their margins to Table 3, which shows the fit results of one of the first ISR measurements that was performed on 10 October 2018.

Table 3. Fit parameters according to Eq. (9), Eq. (11) and Eq. (12). The given uncertainty of the fit values denotes the standard error derived by the fit routine.

Parameter	Unit	Dir. ch. $\mathcal{T}_{\mathrm{dir}}(f)$	Ref. ch. $\mathcal{T}_{\mathrm{ref}}(f)$	Specification
$\mathcal{I}$	LSB	3765 ± 3 (3722 ± 4)	3209 ± 2 (3120 ± 2)	-
$\mathcal{I}$ ratio (integral)	-	0.85 (0.84)		-
R	-	0.649 ± 0.001 (0.651 ± 0.001)	0.653 ± 0.001 (0.652 ± 0.001)	$0.65 \pm 1\%$***
σ_g	MHz	138 ± 6 (147 ± 7)	156 ± 6 (147 ± 7)	-
f_0	GHz	-1.236 (-1.239)	4.220 (4.217)	-
Spacing	MHz	5456 (5456)*	5490 (5490)	5477 ± 120 $(2.3 \pm 0.05$ pm)**
Γ_{FSR}	MHz	10946 (fixed)	10946 (fixed)	10955 ± 48 $(4.6 \pm 0.02$ pm)**
Q	-	-	0.93 ± 0.01 (0.92 ± 0.01)	-
$\mathcal{I}_{\mathrm{Fiz}}$	-	0.144 ± 0.003 (0.141 ± 0.006)	0.136 ± 0.003 (0.141 ± 0.004)	-
$f_{0_{\mathrm{Fiz}}}$	GHz	-2.689 (-2.691)	-2.582 (-2.573)	-
$\Gamma_{\mathrm{FSR_{Fiz}}}$	MHz	2202 ± 8 (2205 ± 6)	2177 ± 6 (2175 ± 3)	2191 ± 24 $(0.92 \pm 0.01$ pm)**
d_{Fiz}	-	0.5 (fixed)	0.5 (fixed)	-
$\mathrm{FWHM_{ref}}$	MHz	1519 ± 4 (1508 ± 3)	1496 ± 3 (1500 ± 3)	1516***
$\mathrm{FWHM_{def}}$	MHz	325 ± 14 (347 ± 16)	368 ± 15 (345 ± 17)	695***
$\mathrm{FWHM_{tot}}$	MHz	1591 ± 4 (1589 ± 6)	1587 ± 5 (1580 ± 6)	1667 ± 7 $(0.70 \pm 0.003$ pm)**
$\mathrm{Finesse_{tot}}$	-	6.88 ± 0.02 (6.89 ± 0.02)	6.90 ± 0.02 (6.93 ± 0.02)	6.6**

The fit values in brackets denote the one retrieved from the energy drift corrected data set (see also Sect. 3.2).
* Direct channel is at lower frequencies. The second cross point is calculated by considering the measured FSR.
** Values as given by Reitebuch et al. (2009).
*** Values taken from internal documents of the manufacture that are not available for public.
n/a = no specification available.

Additionally, a comparison of the determined parameters and the corresponding specifications is given at the respective position within the manuscript:

- In line 330 we modified the sentence according to "The given uncertainty of the fit values denotes the standard error derived by the fit routine and the last column indicates the specification values for comparison".
- Following 342 we add the following sentence: "Furthermore is can be seen that the derived spectral spacing on both sides of the filter curves is well within the specification of (5477 ± 120) MHz."
- Following 346 we add the following sentence: "…when neglecting the imprint of the reflection on the Fizeau interferometer and are smaller than the specified value of (1.667 ± 7) GHz.".

Minor point: Figure 4 is referenced in line 183, well before it appears in the document and before Figure 3. Best practice is to have the figures in the order they are referenced.

We removed the ling to Fig. 4 here and just referenced the section were this topic is further discussed. The sentence now reads: "This is especially obvious from the tilt that is visible in the relative residuals as discussed later in Sect. 4.3.".

Grammatical issue: The authors use the phrase "in order to" nearly 40 times in this manuscript. Use of "in order to" is poor grammar. It's one of the few useful things I retain from grammar school, but "in order to" should never be used. Instead, just "to." For example, "In order to provide valuable input data…" is more appropriately simply "To provide valuable input data…"

We revised the manuscript regarding your suggestion and replaced "in order to" throughout the manuscript.