Subtraction of the continuum contribution in the narrowband filters of PROBA-3/ASPIICS

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Spectral contributions on the detector

- Contributions considered as additive:

  - F Corona
  - K corona

  Ideally, measured in the Wide Band Filter (WBF)

  - Emission lines

  Ideally, measured in the Narrow Band Filters (NBF):

  - **He I D3** **(587.72 nm)**
  - **Fe XIV "green line"** **(530.45 nm)**

  - Stray light

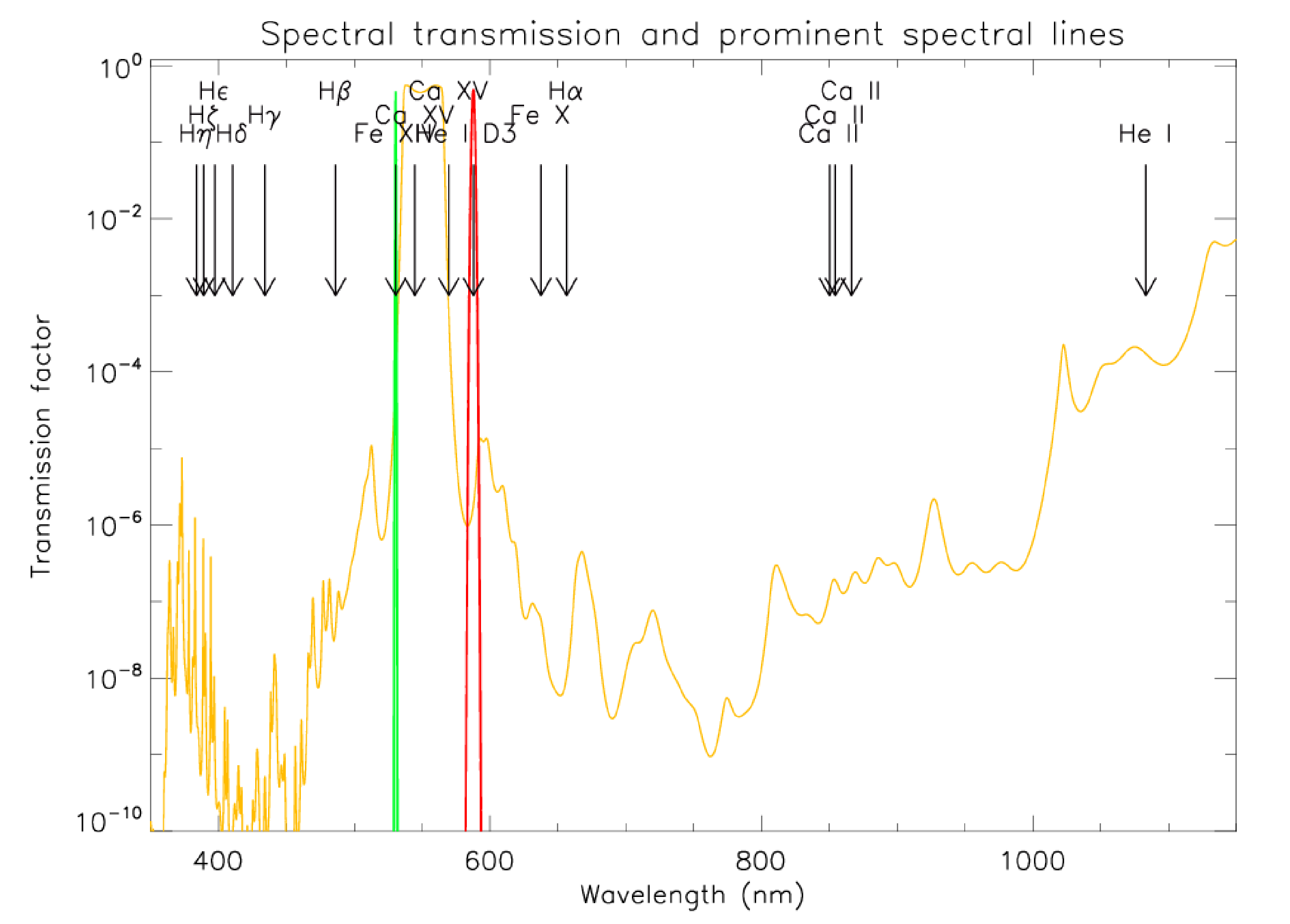
In reality: cross-contaminations

- Continuum is present in every passband
- Emission lines in the WBF:
  - Fe XIV on the blue edge

    Also measured in the green line filter

  - Ca XV in the main profile and on the red edge

    No independent measurement, but contributes only in case of hot material (>3-4 MK)



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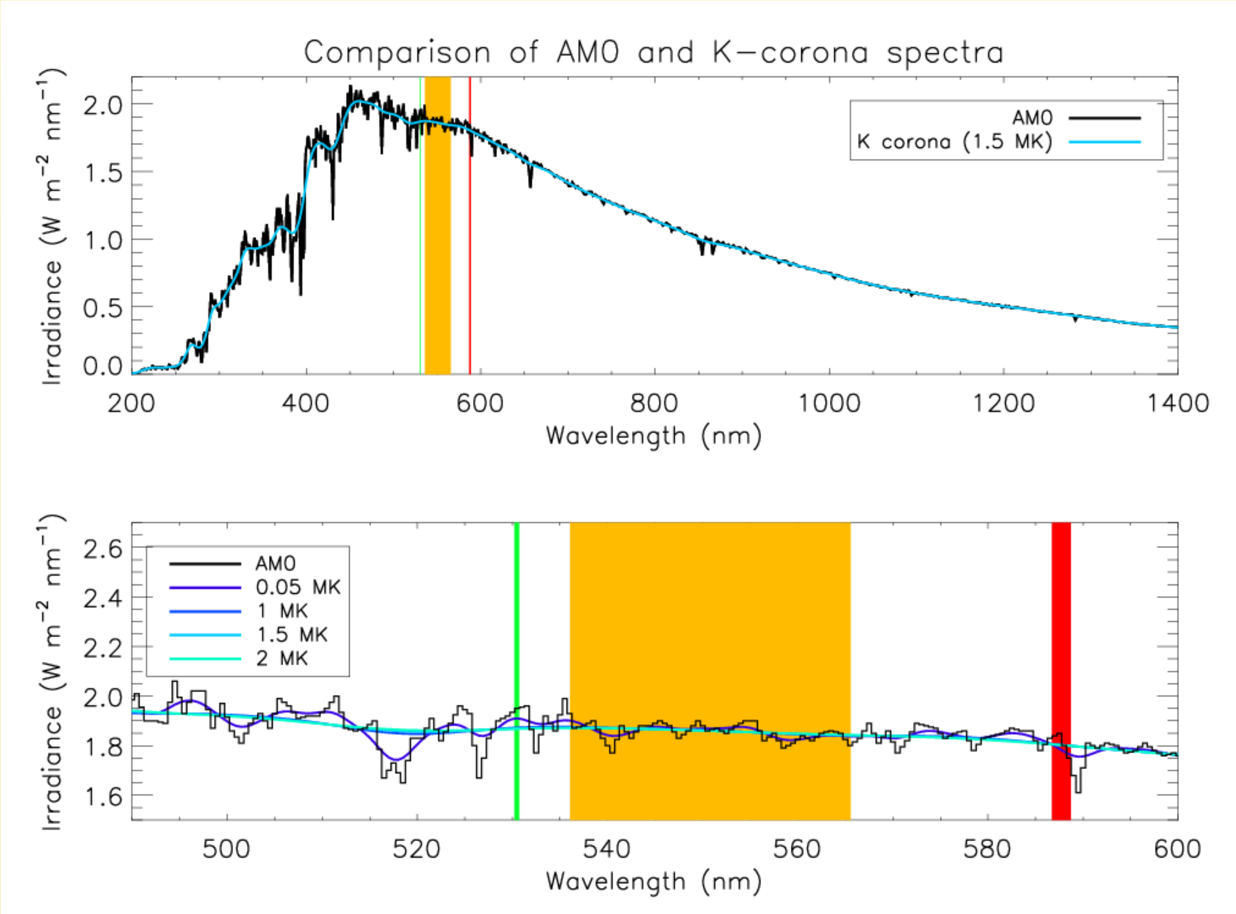
“On-Band Calibrator”

- Level-3 correction that is applied after:
  - Detector and optical effects
  - Stray light subtraction
  - Multiple exposures assembled in one image
  - Images of different passbands co-aligned
  - F corona subtracted (can use the same reference spectra as the On-Band Calibrator)
- Corrections consist in linear combinations of the images in the WBF and a given NBF
- Need a model for the spectral profile of the continuum to extrapolate the continuum emission measured in WBF to the continuum emission in the NBF
- **Accurate knowledge of the spectral transmission profile of the filters is essential**

Reference spectrum for K corona



- Obtained by smoothing the AM0 spectrum to reproduce the effect of the widening of spectral features by the thermal velocity of the coronal electrons: ≈ 20 nm FWHM @1.5 MK @530 nm
- AM0: "Air Mass 0" (ASTM-E490)
  - No telluric lines
  - Low resolution (1 nm), but suitable for our purpose (smoothing)
- Temperature for smoothing can be adapted to the observed coronal feature, but not in the automatic pipeline (but variation are small between 1 and 2 MK)
- Case of prominences: adapting the temperature using a mask based on D3 images (prominences)? Anyway, D3 filter is generally less affected by the continuum contribution
- Velocity effects (line shifts) cannot be taken into account in the automatic pipeline

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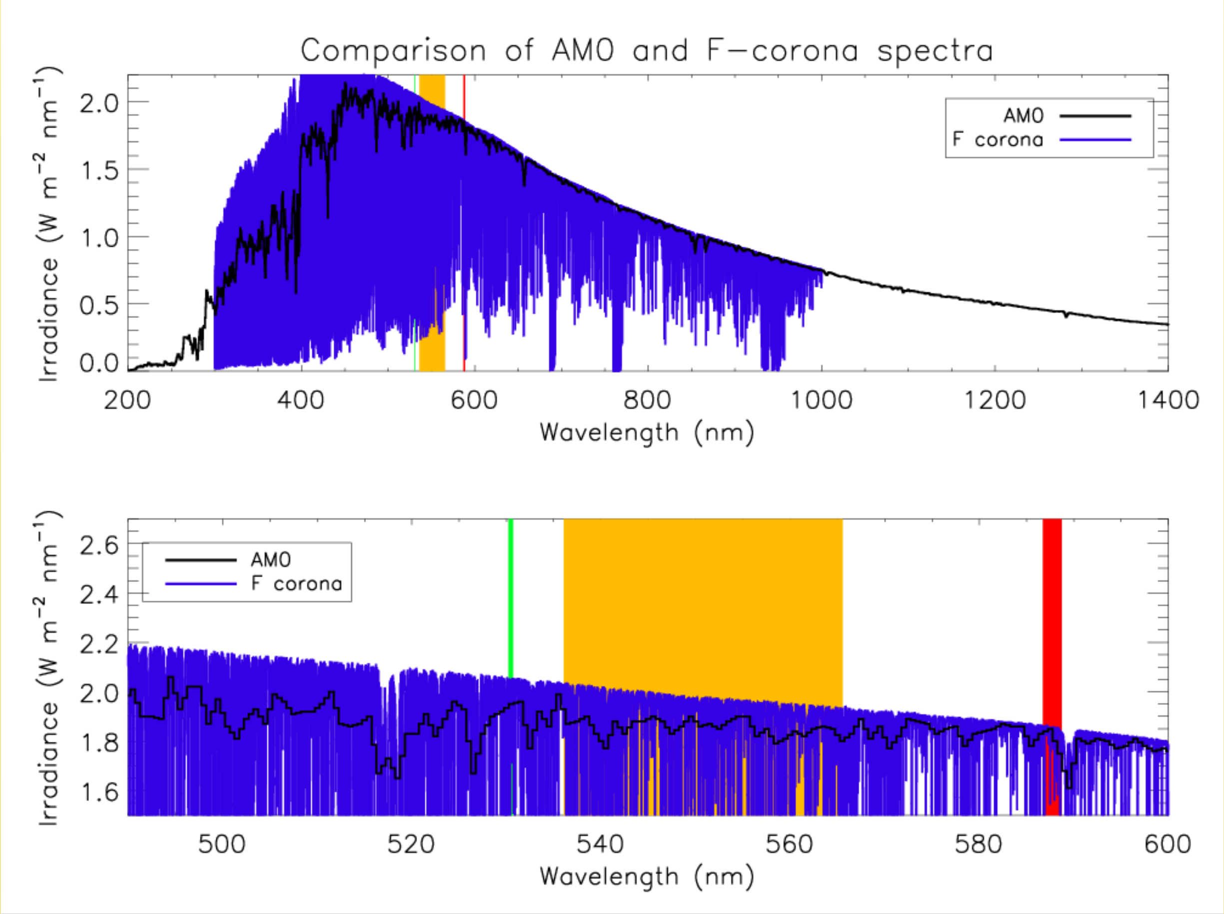
Reference spectrum for F corona



- Retained solution: multiplying the continuum level measured by Neckel & Labs (1984; aka “Hamburg spectrum”) by the spectral relative absorption coefficient of Delbouille et al. (1972, 1981; aka “Liège spectrum”
- Can be used to:
  - Propagate the correction of F corona from WBF to NBFs
  - Correct part of the stray light contribution (e.g. diffraction by occulters)

K-continuum emission for a pixel in a given filter

Calibrated transmission profile

Normalised reference spectrum of K continuum

$$I_{K,filter} = \int R_{filter}(\lambda) \times I_{K,tot} \times S_K(\lambda)\, \mathrm{d}\lambda.$$

$$\Rightarrow \quad I_{K,filter} = I_{K,tot} \times C_{K,filter}.$$

Constant, calibrated coefficient for all pixels (we work after flatfield, etc…)

Spectral line contributions for a pixel in a given filter

- Similarly, one can define calibrated coefficients for the spectral lines, as the integrated product of their (assumed) normalised spectral profile by the filter transmission profile:
  - $C_{\text{green, filter}}$
  - $C_{\text{D3, filter}}$

- Once again, velocity effects cannot be taken into account in the pipeline

Simple case: spectral contributions in the WBF are negligible

- If WBF is according to specifications and in cases no Doppler velocity is expected (quiescent corona):
  - $I_{WBF} = I_{K,WBF} \cancel{+ I_{lines,WBF}} \Rightarrow I_{K,tot} = I_{WBF} / C_{K,WBF}$
  - From which we can extrapolate the continuum emission in the other filters and deduce the total line intensity:

$$I_{green,tot} = \frac{I_{green} \times C_{K,WBF} - I_{WBF} \times C_{K,green}}{C_{green,green} \times C_{K,WBF}}.$$

$$I_{D3,tot} = \frac{I_{D3} \times C_{K,WBF} - I_{WBF} \times C_{K,D3}}{C_{D3,D3} \times C_{K,WBF}}.$$

What if spectral contributions are non negligible in WBF?

- $I_{WBF} = I_{K, WBF} + I_{green, WBF}$ (mostly the green line)

- $I_{green} = I_{K, green} + I_{green, green}$

$\Rightarrow$ One must solve a system of 2 equations with 2 unknown quantities and can get simultaneously $I_{K, tot}$ and $I_{green, tot}$

BUT: uncertainties will increase, all the more when Doppler velocity effects can no longer be neglected (green line moving in intervals where the transmission profiles vary quickly, both in WBF and green line filter).

Conclusions

- Correction can be applied automatically in the ASPIICS pipeline, as a Level3 product

- Limit of validity of the method: “quiescent” corona
  - No velocity along the LOS (no eruption)
  - Ca XV emission neglected (no hot material, i.e. >3-4 MK)

  Out of those conditions, correction will require case-by-case analysis.

- Essential: proper calibration of the spectral transmission profiles of the filters, in particular the edges of the main passband of the WBF