The opacity pipeline: from atomic data to realistic RMHD simulations

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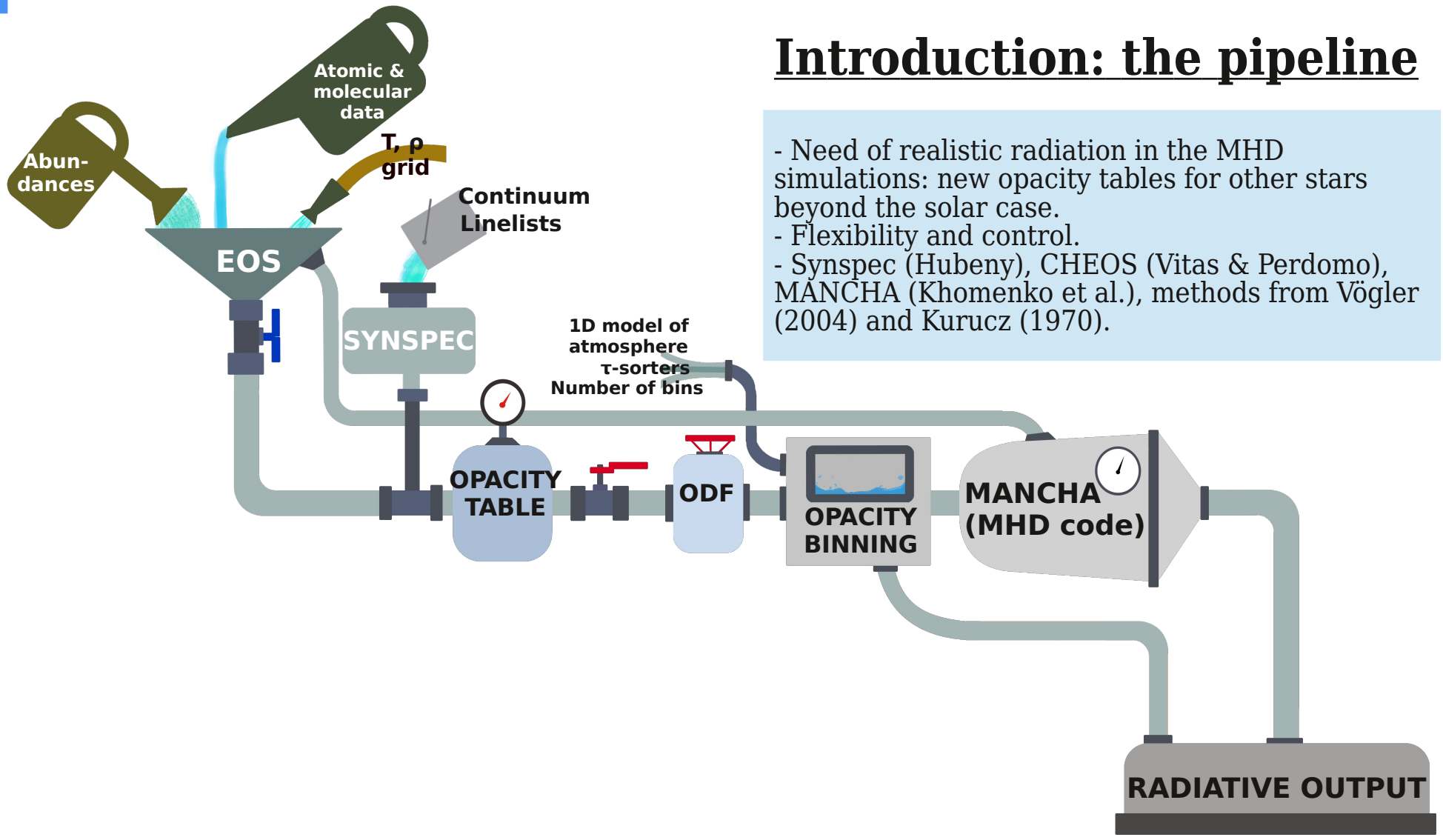
Please, check the related posters:
- Large amplitude longitudinal oscillations [...] (Valeriia Liakh; session 5.3)
- Public version of MANCHA: [...] (Mikhail Modestov; session 5.4)
- From highly-collisional to collisionless fluid models (Peter Hunana; session 5.4)
- Modelling the thermal conductivity [...] (Anamaria Navarro; session 7.1)

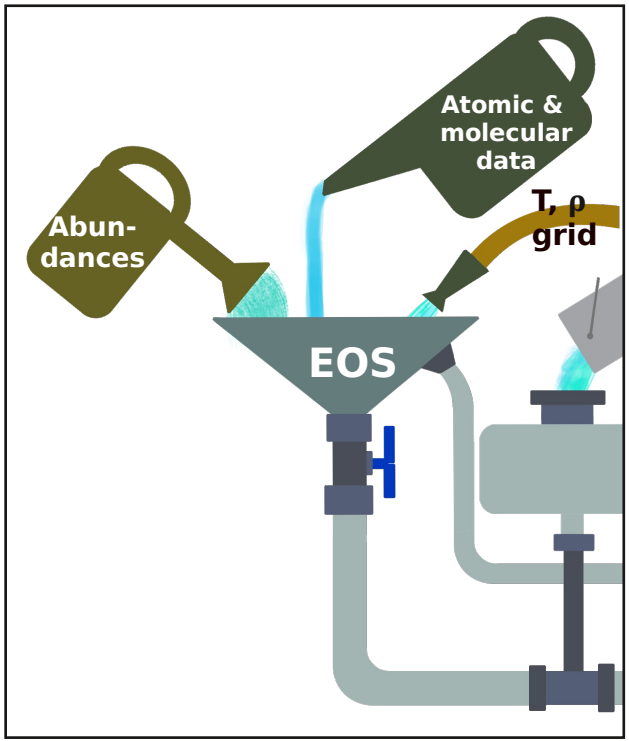
Introduction: the pipeline

- Need of realistic radiation in the MHD simulations: new opacity tables for other stars beyond the solar case.
- Flexibility and control.
- Synspec (Hubeny), CHEOS (Vitas & Perdomo), MANCHA (Khomenko et al.), methods from Vögler (2004) and Kurucz (1970).



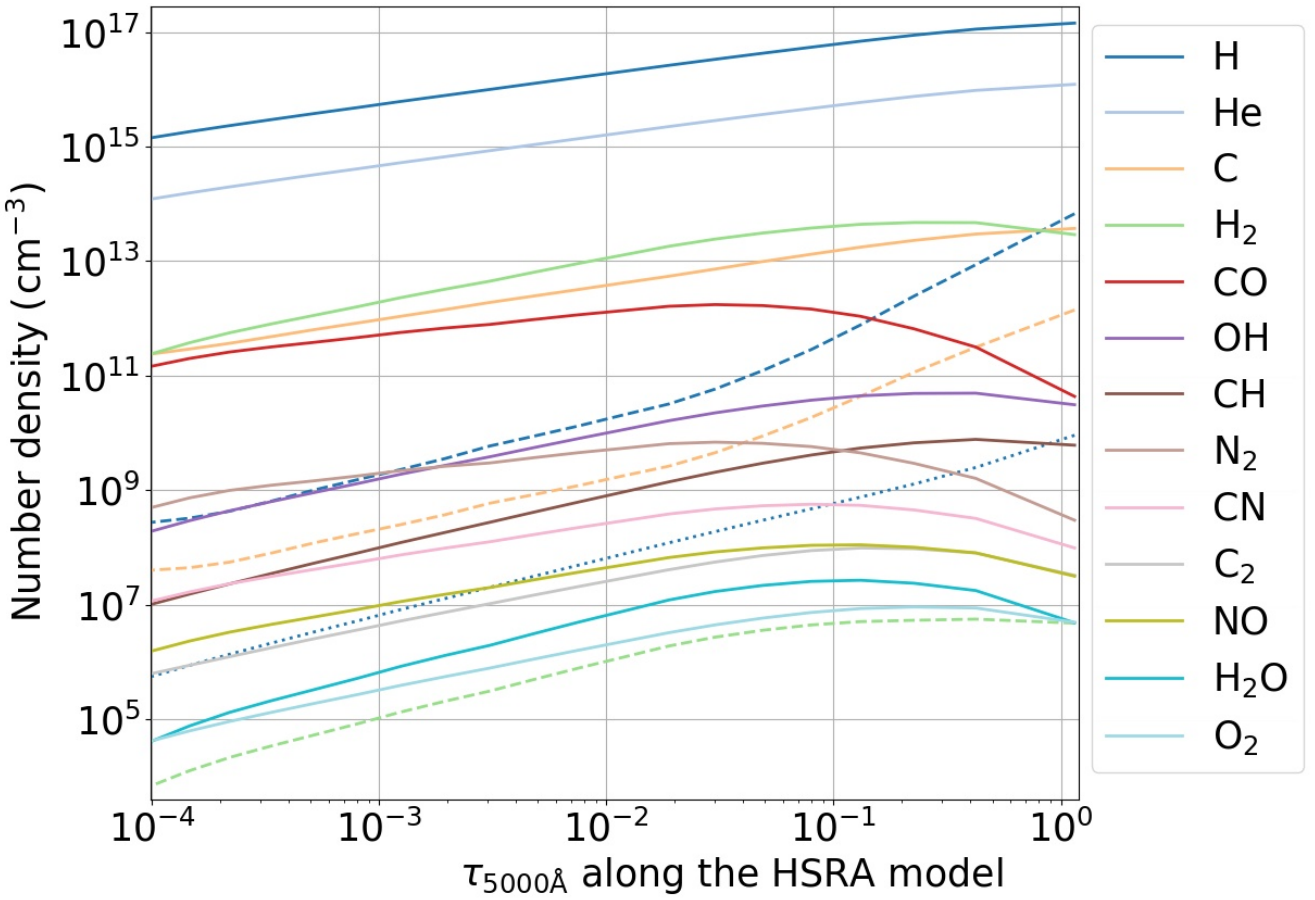
Equation of state (EOS)

Solar abundances (Asplund et al., 2009)

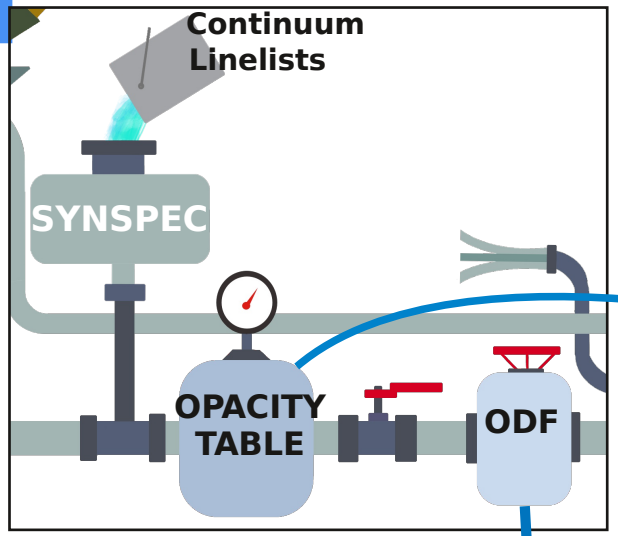


CHEOS EOS ⇔ Synspec EOS

(fully equivalent)

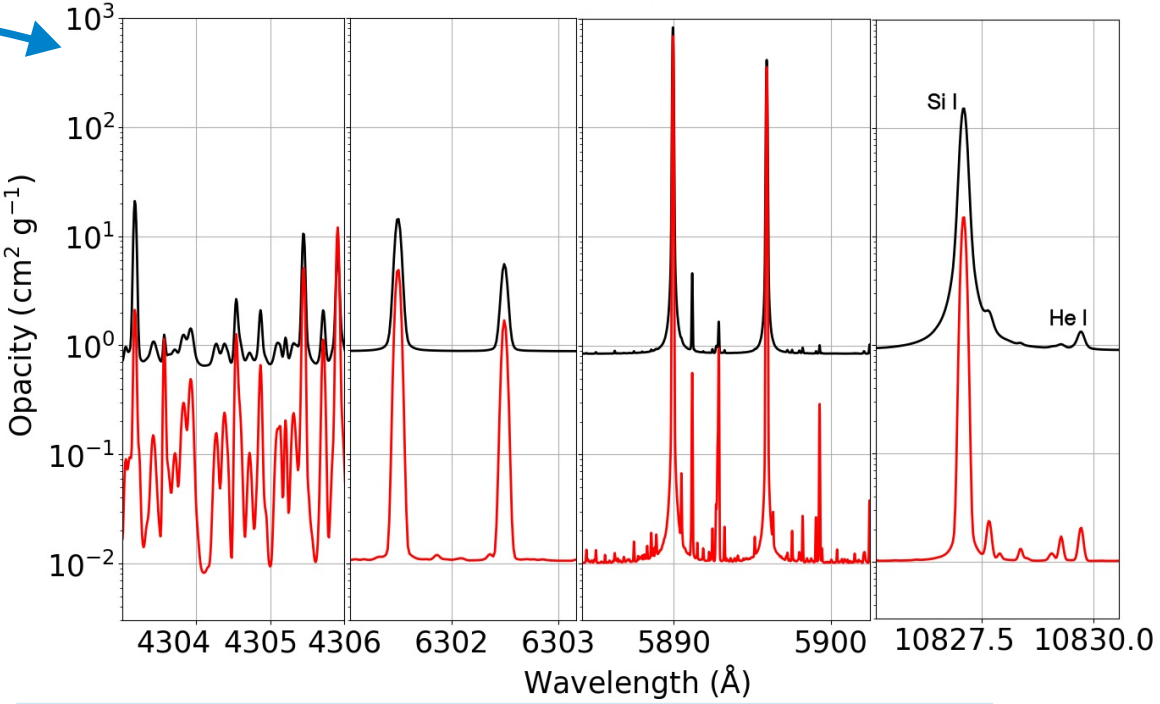


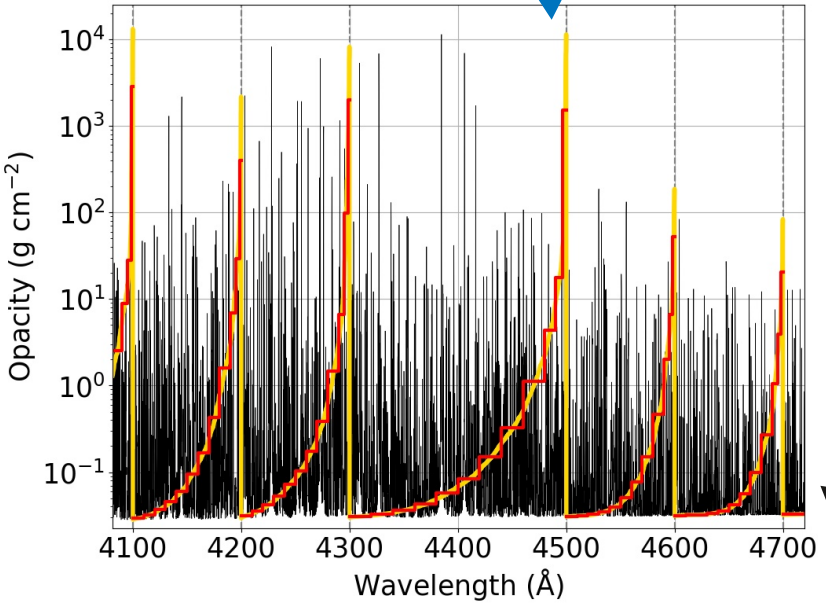
Opacity and opacity distribution function (ODF)



G-band, Fe I lines, Na doublet, Si and He lines around 10830 Å

$(T,\rho) = (6400\ k, 3.0\cdot10^{-7}\ g\ cm^{-3})$; $(T,\rho) = (4300\ k, 7.0\cdot10^{-9}\ g\ cm^{-3})$

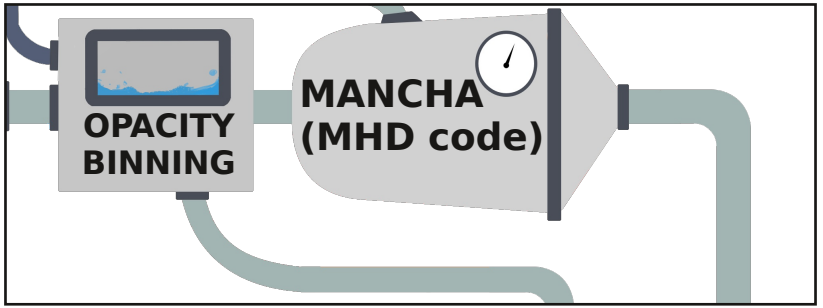


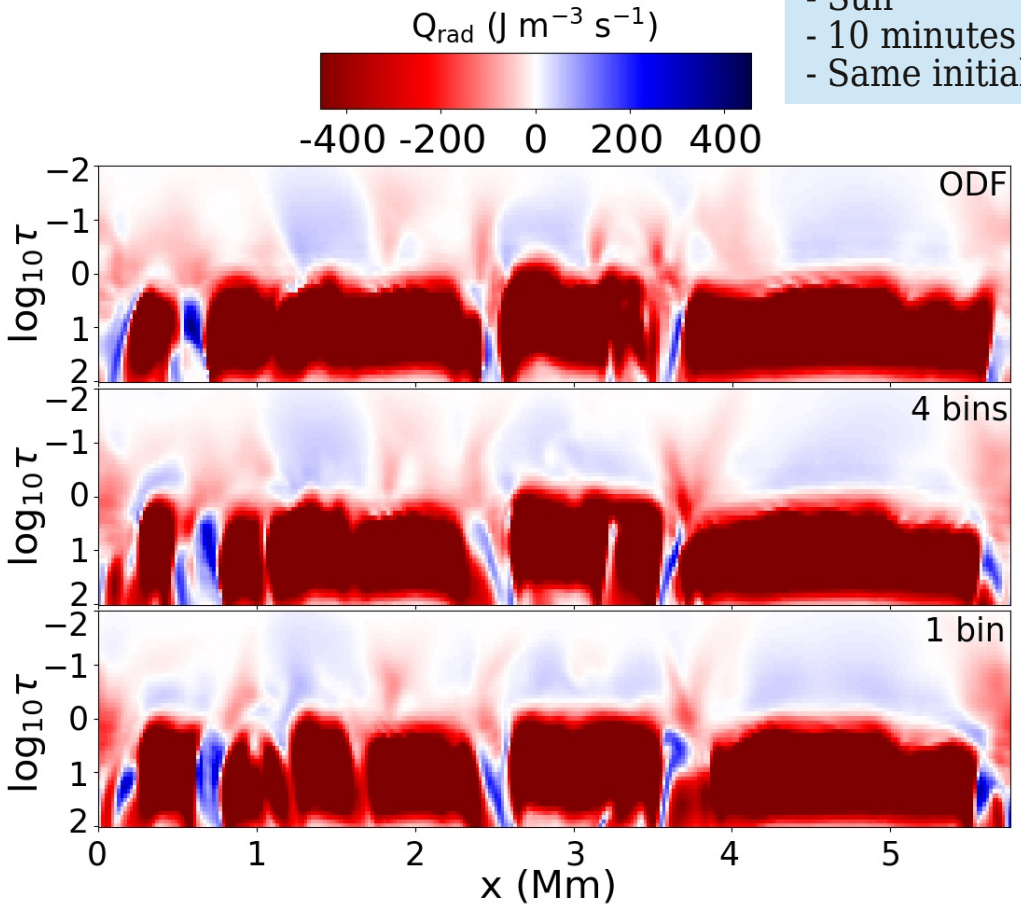


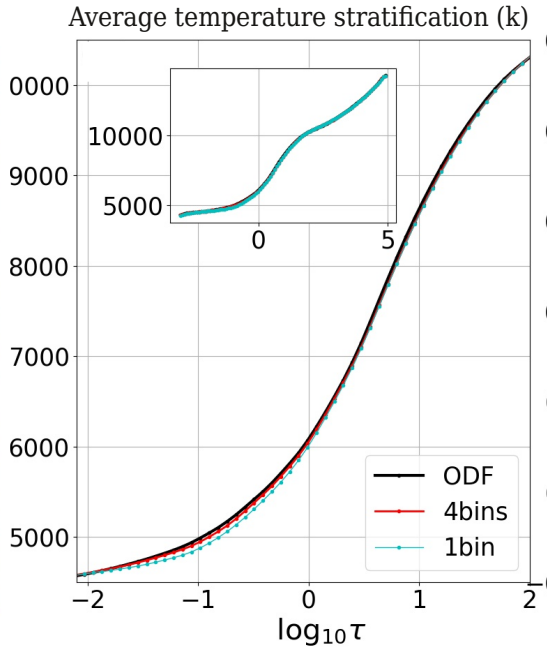
Divide (~100 steps); sort; discretize (sub-steps); weights. Steps and sub-steps from ATLAS (Kurucz), but.... Cernetic et al. (2019), Criscuoli et al. (2020)

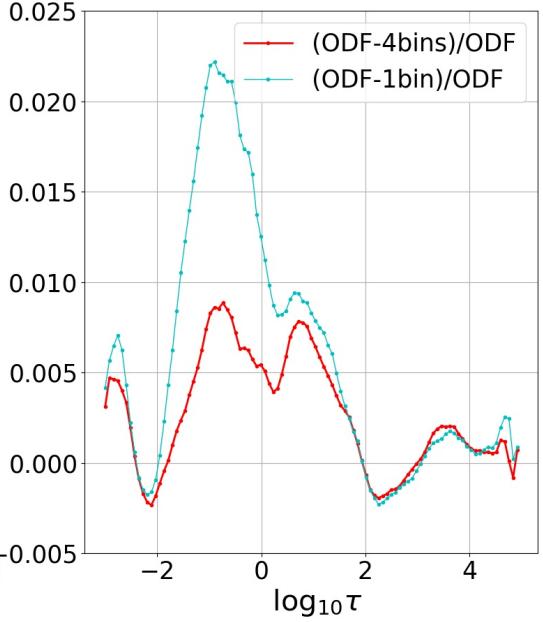
MANCHA (MHD code)

- Sun
- 10 minutes
- Same initial snapshot









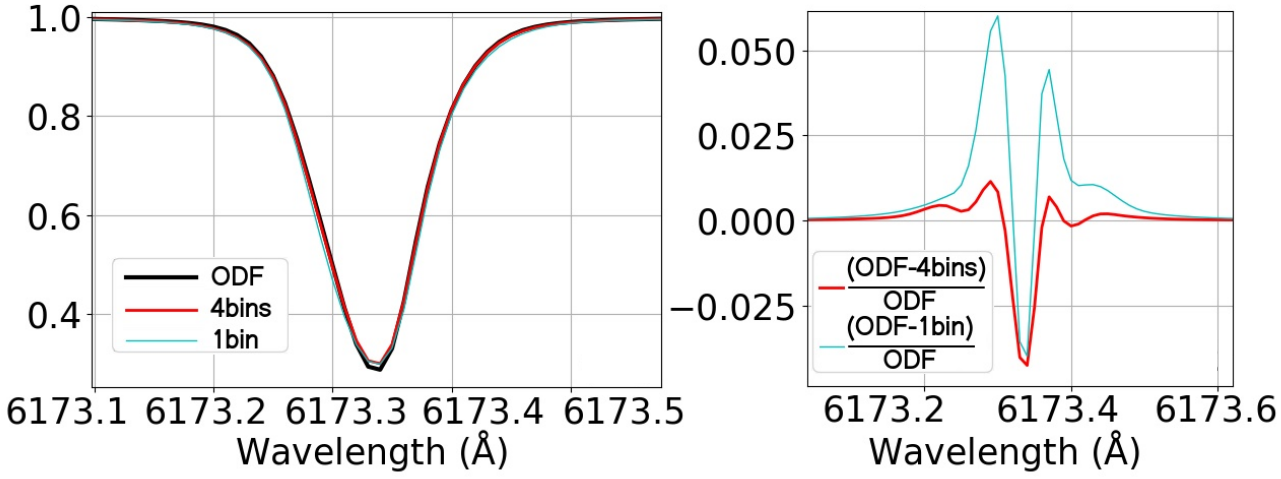
Notice the definition of the structures over τ=1.

Temperature gradient steeper for 1 bin in the line formation region.

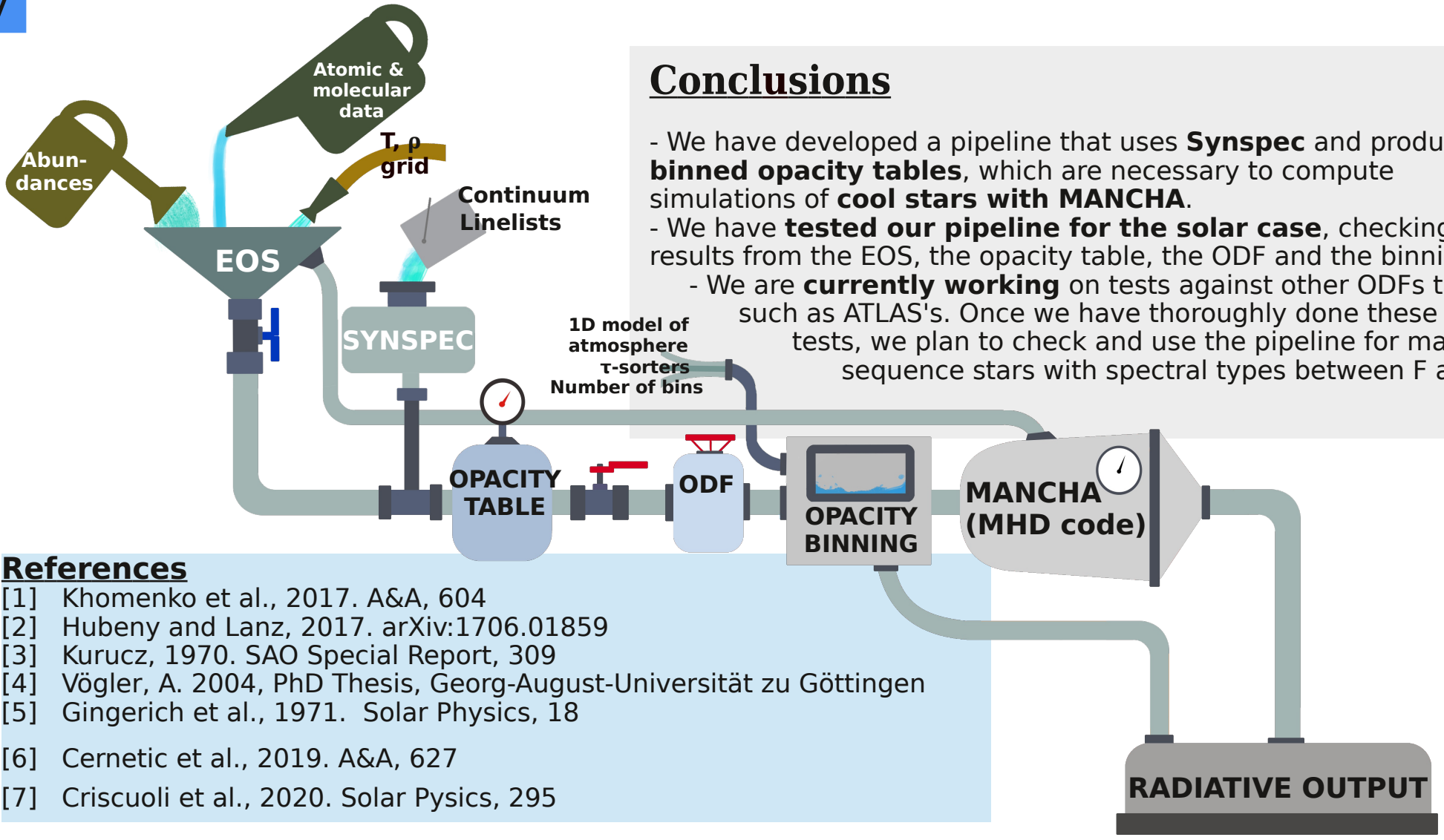
Radiative output

Fe I line at 6173 Å

Specific monochromatic intensity
normalized to the continuum



Line **wings** better reproduced with 4 bins than 1 bin, but not that much difference in the **core**.



Conclusions

- We have developed a pipeline that uses **Synspec** and produces **binned opacity tables**, which are necessary to compute simulations of **cool stars with MANCHA**.
- We have **tested our pipeline for the solar case**, checking on the results from the EOS, the opacity table, the ODF and the binning.
- We are **currently working** on tests against other ODFs tables, such as ATLAS's. Once we have thoroughly done these latter tests, we plan to check and use the pipeline for main sequence stars with spectral types between F and M.

References

[1] Khomenko et al., 2017. A&A, 604
[2] Hubeny and Lanz, 2017. arXiv:1706.01859
[3] Kurucz, 1970. SAO Special Report, 309
[4] Vögler, A. 2004, PhD Thesis, Georg-August-Universität zu Göttingen
[5] Gingerich et al., 1971. Solar Physics, 18
[6] Cernetic et al., 2019. A&A, 627
[7] Criscuoli et al., 2020. Solar Pysics, 295