Comment on acp-2022-55
Anonymous Referee #2


Summary:

The paper presents an literature review about circular polarization. It explains how circular polarization is generated and which aerosols in the atmosphere produce circular polarization. A few radiative transfer simulations are carried out to investigate the sensitivity of circular polarization on aerosol optical thickness and on aerosol composition. The conclusion is that measurements of circular polarization from space could provide additional information on aerosol compared to measurements of intensity and linear polarization only. The literature review is very interesting to read but it does not include new scientific results. The simulation part is very short and also seems to be not correct (see comment below). For these reasons I can not recommend to publish the paper in its current status, in my opinion major revisions are required.

General:

- It is claimed that technical advances have demonstrated the feasibility to measure the full Stokes vector from space. However, this is not discussed in the text in more detail. The literature review and also the simulations show, that circular polarization (CP) is several orders of magnitude smaller than linear (LP). The authors should provide more information about planned passive instruments that could measure CP with such a high precision from space.
- The RT simulations are not convincing, because they do not include absorption by trace gases (e.g. ozone in UV). The results show higher linear polarization for a scattering angle of 160.8° than for a scattering angle of 112°, which is not expected because the maximum polarization for Rayleigh scattering is at 90° scattering angle. The relative sensitivity of CP to aerosol composition is large, but since the magnitude is so small it will still be very difficult to measure it.
Specific comments:

I. 165 ff: "For example, exact solutions can be found for $2pr/l << 1$ and $|mr/l| << 1$ (Rayleigh scattering) ..." -> you are talking here about the scattering matrix elements $S_{4j}$ and $S_{i4}$, which describe circular polarization. For Rayleigh scattering they are exactly 0, because Rayleigh scattering does not cause any circular polarization.

Fig. 3 (caption): "right panel" should be "left panel" and reference to "right panel" is missing

I. 298: "This concept has been applied in astronomy studies where the observations of linear and circular polarization in comets and interstellar dust" -> What is the observed degree of linear/circular polarization in interstellar dust?

I. 325: "Lidars with CP detection capabilities have been proposed for cloud phase" -> How can cloud phase be detected with circular polarization? Please explain.

I. 329: "... (Gilbert and Pernicka, 1967; Lewis et al., 1999) and foggy atmospheres (van der Laan et al., 2017). These studies highlighted the fact that in high- and low-density particle environments, the propagation of circular polarization does not degrade as quickly as linear polarization." -> Why should linear polarization degrade quickly in low-density particle environments? Why does circular polarization degrade slower than linear?

I. 395: "inagreement" -> "in agreement"

I. 395: "Interestingly the distinctive CP found by lidar is inagreement with the theoretical modelling study by Kolokolova & Nagdimunov, (2014) where optically active particles were shown to have non-zero CP and zero linear polarization in the backscattering direction. However, a controlled study (Cao et al., 2011) measuring the degree of LP and CP in pollen backscattering found that both scale with each other following the predictions of Mishchenko & Hovenier, (1995). That study concluded there is no additional aerosol information by measuring both LP and CP. While these two offer somewhat conflicting conclusions, both highlight that indeed biogenic aerosols do produce circular polarization" -> What are the different assumptions in the studies by Kolokolova and Nagdimunov 2014 and Mishchenko&Hovenier 1995? I assume these are theoretical studies, so there should be a simple explanation for the conflicting conclusions?

I. 429: Eq. 4 (circular polarization after 2 scattering events) -> This equation is not very
special (included in all VRT codes handling circular polarization). Why is this equation derived and written down here, it is not used at all in the discussion of the results?

I. 447: "The particle shape is assumed to be spherical." -> In the discussion you highlighted the importance of particle shape and orientation for circular polarization. Then, in the model simulations it is neglected. At least randomly oriented aspherical particles can be handled in most state-of-the-art VRTE models...

I. 449: "The atmospheric column only contains air (i.e., no trace gases)" -> Why modelled without trace gases? Calculations without O3-absorptions are very unrealistic in the UV-range. To my understanding "air" normally includes also the trace gases.

Figs. 7/8: What is the definition of the scattering angle? Normally it is given by \( \cos(\theta_s) = \cos(n_{\text{inc}} \times n_{\text{sca}}) \), where \( n_{\text{inc}} \) and \( n_{\text{sca}} \) are incoming and scattered directions, respectively? I doubt that Fig. 7 is for scattering angle of 160.8 degrees. LP by Rayleigh scattering has a maximum around 90° scattering angle, so I would expect much higher LP in Fig. 8 (scattering angle 112°) than in Fig. 7 (160.8°, backscattering direction).
In the discussion of the modelling results, please discuss also the dependence of LP and CP on scattering angle.

I. 522 "Overall, these plots suggest there is a sensitivity to differences between coarse and fine mode dominated aerosols in both linear and circular polarization." -> Since CP is scaled with 10⁴, I assume that even if the relative sensitivity is higher in CP, it can still be better measured in LP? I can not see the benifit of measuring CP.

Fig.9, labels in right panels: U->V
What is the scattering angle of the simulations shown here?

Author contribution: What is the contribution of KK?