Referee # 2

The authors are grateful to the distinguished referee #2 for reviewing the manuscript and also for him/her valuable comments. We have tried to apply all the comments and answer all the questions that had been asked by the referee #2.

General Comments:

The manuscript by A. Bayat et al. deals with observations performed using a sun photometer in a wonderful and not intensively explored geographical area using ground based remote sensing of the atmosphere. The main message of the manuscript is to show the potential of the polarized phase function (PFF) measured using sun photometer observations. The manuscript needs to be largely improved and I request major revisions. First of all, a general comment related to the relationship between the previously cited manuscript. Li et al. (2004) has many parts in common with your manuscript and also the approach followed by the authors looks mostly the same. A couple of plots presented by the authors have even the same shape though the measurements presented are obviously from two different places (Beijing and Zanjan). The main objective of Li et al. (2004) is to show the value of polarized phase function for the retrieval or aerosol microphysical properties. However, Li et al. (2004) is only mentioned for the cloud clearing algorithm. The structure of the paper is quite disordered. Both the topic and the results of this manuscript are presented like in a short oral communication, many details should be better addressed and quantified, some sentences that should be considered as conclusions of this paper come before the description of some plots. English needs also to be improved.

As it is suggested by the referee the whole manuscript has been revised and we tried to show the propose of this work quite clearly through the manuscript. Even though the technique is very similar to the work by Lie et al, 2004 as already addressed in the manuscript in P2L31 to P2L40, but there are some main differences as:

1. The region is different,

2. The number of measurements are quite larger so as it clear from the graphs and plots, the potential of q_a in categorization of the atmospheric aerosols is quite clear,

3. Correlations that have been appeared in Figs. 5 and 7 as well as behavior of the data points in Fig. 9 very clearly show this potential.

4. The complex refractive indices in Fig. 9, are chosen to much to one of well known aerosol types (i.e., dust, anthropogenic, Southeast Asian) that may have some impact on the region.
5. Classification of different types of aerosols in the atmosphere of Zanjan by using the polarized phase function parameter is the main objective in the manuscript.

We will discuss all these issue in answering to the specific comments.

The General changes in this version of manuscript are listed in the following:

- **Abstract:** Some sentences have been added to the abstract as the referee #1 specific comment.

- **Introduction:** We re-wrote the introduction section as the referees' comments**.**

- **Instrumentation and Data:** This section has been added in P2L64 to P2L98 to gather all the information about the instrumentation and data recordings as the referee #1 specific comment #2.

- **Method:** This section has been changed as follows:
  1. First paragraph has been added for describing aerosol optical depth and Ångström exponent retrievals.
  2. Second paragraph has been changed (P3L27 to P3L41) and added some sentences (P3L41 to P3L48) to insert some descriptions about spheroid model.
  3. Table 1 has been changed (rows #8 and 9).

- **Results and discussions:** The results and discussions merged with together in section 4; Figure 1 has been added to the manuscript to check the aerosol shape sensitivity of the parameters. Also figure 2 has been added to compare AERONET and our retrievals for single scattering albedo. Table 2 has been changed to give more detail information from the measurements and categories what that have been emphasized in the text. The correlation coefficients and equations for the linear fits are added to Figs. 5 and 7. Also, Figure 9 has been changed. Furthermore root mean square distance (RMSD) of data points from the curves in Fig 9 have calculated and summarized in Table 3. Figure 10 has been added to show the sensitivity of the polarized phase function to the imaginary part of the refractive index.

- **Conclusions:** This section has been added to the manuscript in P9L8 to P9L60.

- Finally some references have been added to the manuscript as follows:

1. Basart, S., Pe´rez, C., Cuevas, E., Baldasano, J.M., and Gobbi, G. P.: Aerosol characterization in Northern Africa, Northeastern Atlantic, Mediterranean Basin and Middle East from direct-sun AERONET observations, Atmos. Chem. Phys., 9, 8265-8282, doi:10.5194/acp-9-8265, 2009.

2. Boersma, K. F., Eskes, H. J., and Brinksma, E. J.: Error Analysis for Tropospheric NO2 Retrieval from Space, J. Geophys. Res., 109, D04311, doi:10.1029/2003JD003962, 2004.

3. Boselli, A., Caggiano, R., Cornacchia, C., Madonna, F., Mona, L., Macchiato, M., Pappalardo, G., and Trippetta, S.: Multi year Sun photometer measurements for aerosol characterization in a Central Mediterranean site, Atmos. Res., 104105, 98110, doi:10.1016/j.atmosres.2011.08.002, 2012.

4. Bösenberg, J., and Matthias, V.: EARLINET: a European aerosol research lidar network to establish an aerosol climatology, MPIReport 348, Hamburg, Germany, 2003.

5. Burrows, J. P., Richter, A., Dehn, A., Deters, B., Himmelmann, S., Voigt, S., Orphal, J.: Atmospheric remote-sensing reference data from GOME-2. Temperature-dependent absorption cross sections of O3 in the 231794 nm range, J. Quant. Spectrosc. Radiat. Transf., 61, 509-517, 1999.

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7. Giles, D. M., Holben, B. N., Eck, T. F., Sinyuk, A., Smirnov, A., Slutsker, I., Dickerson, R. R., Thompson, A. M., and Schafer, J. S.: An Analysis of AERONET

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9. Gobbi, G. P., Kaufman, Y. J., Koren, I., and Eck, T. F.: Classification of aerosol properties derived from AERONET direct sun data, Atmos. Chem. Phys., 7, 453-458, doi:10.5194/acp-7-453, 2007.

10. Kalapureddy, M. C. R., Kaskaoutis, D. G., Ernest Raj, P., Devara, P. C. S., Kambezidis, H. D., Kosmopoulos, P. G., and Nastos, P. T.: Identification of aerosol type over the Arabian Sea in the premonsoon season during the Integrated Campaign for Aerosols, Gases and Radiation Budget (ICARB), J. Geophys. Res., 114, D17203, doi:10.1029/2009JD011826, 2009.

11. Kaskaoutis, D. G., Kambezidis, H. D., Hatzianastassiou, N., Kosmopoulos, P. G., Badarinath, K. V. S.: Aerosol climatology: dependence of the °Angstr¨om exponent on wavelength over four 70 AERONET sites, Atmos. Chem. Phys. Discuss., 7, 7347–7397, 2007.

12. Lee, J., Kim, J., Song, C. H., Kim, S. B., Chun, Y., Sohn, B. J., and 75 Holben, B. N.: Characteristics of aerosol types from AERONET sunphotometer measurements, Atmos. Environ., 44, 31103117, doi:10.1016/j.atmosenv.2010.05.035, 2010.

13. Mielonen, T., Arola, A., Komppula, M., Kukkonen, J., Koskinen, J., de Leeuw, G., and Lehtinen, K. E. J.: Comparison of CALIOP level 2 aerosol subtypes to aerosol types derived from AERONET inversion data, Geophys. Res. Lett., 36, L18804, doi:10.1029/2009GL039609, 2009.

14. Omar, A. H., Won, J.-G.,Winker, D. M., Yoon, S.-C., Dubovik, O., and McCormick, M. P.: Development of global aerosol models using cluster analysis of Aerosol Robotic Network (AERONET) measurements, J. Geophys. 5 Res., 110, D10S14, doi:10.1029/2004JD004874, 2005.

15. Russell, P. B., Bergstrom, R. W., Shinozuka, Y., Clarke, A. D., De-Carlo, P. F., Jimenez, J. L., Livingston, J. M., Redemann, J., Dubovik, O., and Strawa, A.: Absorption °Angstr¨om Exponent 15 in AERONET and related data as an indicator of aerosol composition, Atmos. Chem. Phys., 10, 11551169, doi:10.5194/acp-10-1155, 2010.

16. Winker, D. M., Hunt, W. H., and McGill, M. J.: Initial performance assessment of CALIOP, Geophysical Research Letters, vol. 34, no. 19, Article ID L19803, 2007.

Specific comments:

In the following I report the major concerns I have with this paper.

1. **The introduction of the manuscript is mainly focused around passive photometric observations. This is right but other relevant results come from studies performed with other techniques. This should be reported as well. For example, aerosols have been largely studied so far using LIDAR, from ground based and satellites (e.g. CALIPSO). Aerosol does not only mean ground based or satellite photometry.**

   It has been applied in P1L33 to P1L43.

2. **In section 3, the authors describe the correlation between the PFF and the Angstrom exponent as well as the anti-correlation between the PFF and the optical depth. In both cases, the reported plots do not allow the reader to go beyond a qualitative analysis of this correlation. Correlation coefficient should be provided for both the plots 3 and 5 along with the linear fitting parameters (also directly on the plot).**

   It has been applied on the figures and discussed in P5L69 to P5L75 and P5L81 to P5L84.

3. **Sun photometer observations are representative of the full atmospheric column: though I assume the distribution of the aerosol over your site might be clear to you, the authors should comment more about the real value of columnar aerosol measurements for aerosol type also considering the lacking of any characterization of the vertical distribution of aerosol over the observation site.**

   The vertical distribution of aerosols in Zanjan atmosphere for two dust events has been reported in Abdi et al., 2011 and 2012 papers. In current paper the references have been cited in P1L53. Also, the vertical distribution of the aerosol is out of the purposes of the present paper. Therefore, we did not mention the aerosol vertical distribution in this paper.

4. **It is surprising to see that the authors, dealing with generic shape particles and observing their PFF as shown in section 2 and in the form of the scattering matrix considered, use the Mie theory for spherical particles to cluster/type the aerosols. It seems meaningless to me. T-**

Matrix should be used and several codes are easily accessible for free through the web portal: www.scattport.org. The only limit in the use of T-Matrix is related to the trade-off between particle aspect ratios and effective radius, but prolate spheroids up to 7 microns with aspect ratios of 1.4 can be easily simulated (see Wiegner et al., 2009 Tellus-B). Moreover, T-Matrix allows the authors to take advantage of further aspect related to the particle polarization, like particle orientation distribution.

For spherical particles we have used the Mie scattering theory (as we discussed in P3L38 to P3L41 and Table 1) that is quite well known and used by many other authors like Dubovik et al., 2000, Vermulen et al., 2000, Li et al., 2004, and 2006, Masoumi et al., 2013.

Also in this version we referred to the work by Dubovik et al., 2006 to consider also the spheroid shape for particles (P3L41 to P3L49 and Table 1).

The calculated results from using the sphere and spheroid models show that the maximum values of the polarized phase function almost insensitive to the assumed shapes for the particles (Fig. 1).

5. **The huge sensitivity of the results obtained with a scattering code to the variation of the imaginary value of the refractive index, known and shown in several papers, gives less value to the discussion of the results presented in figure 7. The data cluster of figure 7 shows two things. First, given the small difference between the curves describing the relation between PFF and the Angstrom exponent (very small for the values of the refractive index of m=1.45 and m=1.50), the separation among different aerosol types the authors want to introduce is quite forced. Second, the fitted curves show the non-high linearity of the correlation between the PFF and the Angstrom exponent. This could also indicate a limited validity of the authors' hypothesis.**

The sensitivity of the polarized phase function to the variation of the imaginary part of the refractive index has been shown in Figure 10 and discussed in P8L10 to P8L16 also the works by Li et al., 2004 and Dubovik et al., 2006 have been addressed in P9L2 to P9L3.

It should be added that sentences between lines P7L21 to P8L9, are mentioning that, just when $\alpha > 0.6$, the curves in Fig. 9 can distinguish between the particles of different types. It should be added as appeared in lines P7L13 to P7L25, the curves in Fig. 9 are not some fits to the data points but the theoretical calculations of variations of $q_a(60^o)$ versus α for particles of three different refractive indices as depict on this figure. The interesting point is how these curves can categorize the atmospheric aerosols (lines P7L21 to P8L9 and Table 3).

Once more we have to emphasize that the measured data points in Fig. 5 show a strong linear correlation between $q_a(max)$ and α (R = 0.95) this is not a hypothesis but an observation.

Finally, I ask the author to think again about their manuscript and to underline the original aspects they are introducing and the real benefit the retrieval of aerosol microphysical properties can gain from their results. The value of the manuscript could also benefit from the assessment of the relationship between PFF and aerosol intensive properties over a larger dataset.

We hope that the current manuscript almost totally revised and includes lots of changes could fulfill all the mentioned comments and questions.