Workflow and Polarization Reductions with PolSALT

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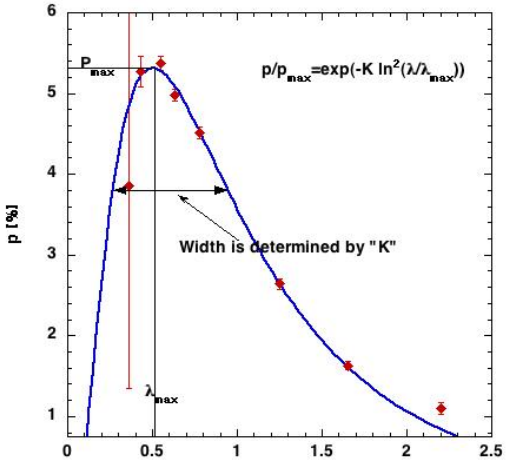
Outline

Science Goals

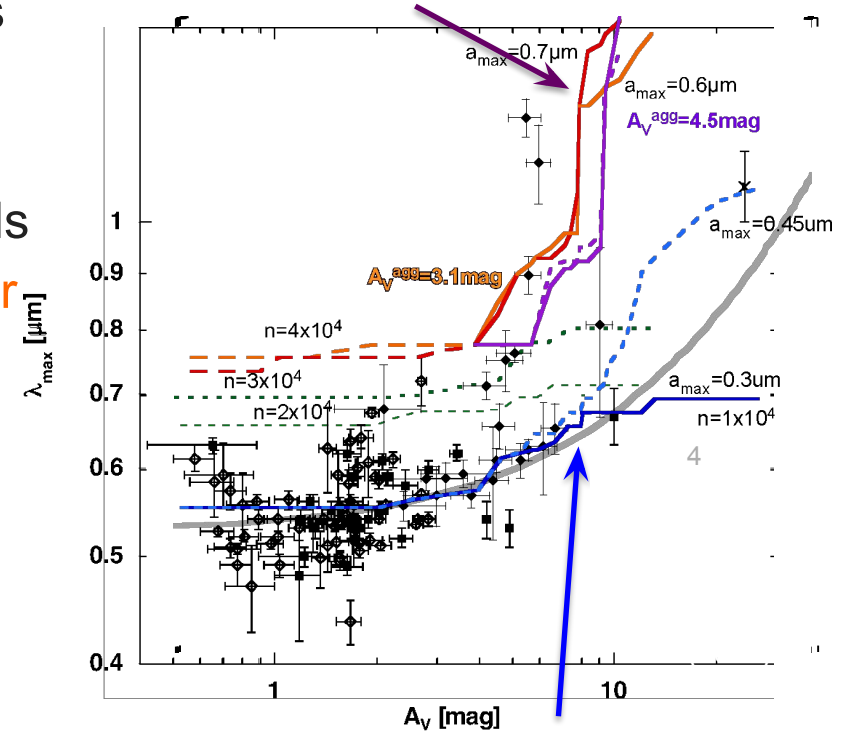
- The recent study of the Taurus cloud (Vaillancourt et al. 2020) showed that optical +NIR spectro-polarimetry can be used to trace grain growth in dense gas.
- We decided to test these results by probing the deep – but still starless – Southern Coalsack cloud, which Jones et al. (1984) surveyed in H-band polarization and we (Andersson & Potter 2005) have in R-band pol.
- Taking advantage of the SAAO telescope and instrument complements we have acquired full optical polarimetry with the 1.9m and SALT of several dozen stars from A_V=1 to >10 mag.

Photo credit: S.B. Potter

The location of the peak-of-polarization (λ_{max}) depends on the underlying grain size distribution and the color of the aligning radiation. Reddening yields a linear rise with A_V. The non-linear rise indicates grain growth.



Evidence for grain growth



Sequence without grain growth

SALT/RSS

- SALT – the South Africa Large Telescope - is a 10m, fixed elevation, telescope based on the HET design.
- The Rob Stobie Spectrograph (RSS) is an optical light, grating spectrograph with polarimetry capability (Half wave plate and Wollaston prism) originally built by Ken Nordsieck at U. Wisconsin

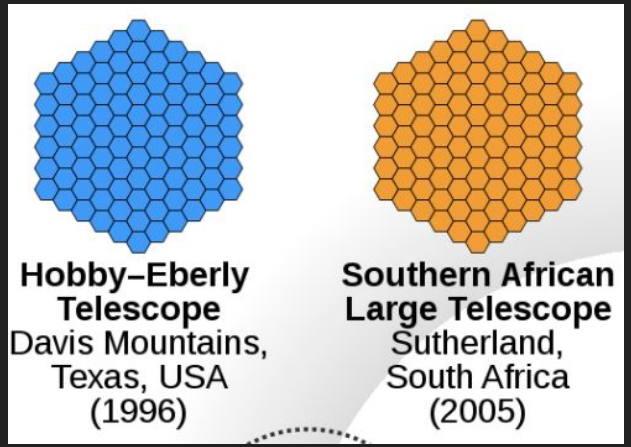
- The large SALT aperture, and careful design and flexibility of RSS, allows broad-band optical polarimetry of faint targets ideal for polarimetry of very heavily extincted stars

What is PolSALT?

- The PolSALT software is used to reduce spectropolarimetric observations taken with SALT (South African Large Telescope)
- Uses PySALT and PyRAF softwares to automate the reduction process
    - PySALT is the primary reduction and analysis software tools for the SALT telescope.
- Open source and downloadable through github
- Originally developed by Ken Nordsieck and currently maintained by Danièl Groenewald

Why it’s used.

- Similar with HET in Texas the mirrors on SALT can act independently.
- In order to properly reduce data collected with SALT and the RSS we use the PolSALT pipeline to allow for accurate processes to be done



Installation

- While there are many dependencies on the installation and usage of PolSALT the most recent version is a Linux docker created by the SALT team.
  - https://github.com/saltastro/polsalt
- I have worked to get both PolSALT and PySALT up to date using updated versions of packages such as PyQt and Numpy. My updated versions can be found at:
  - https://github.com/Richard-Tarbell/polsalt & https://github.com/Richard-Tarbell/pysalt

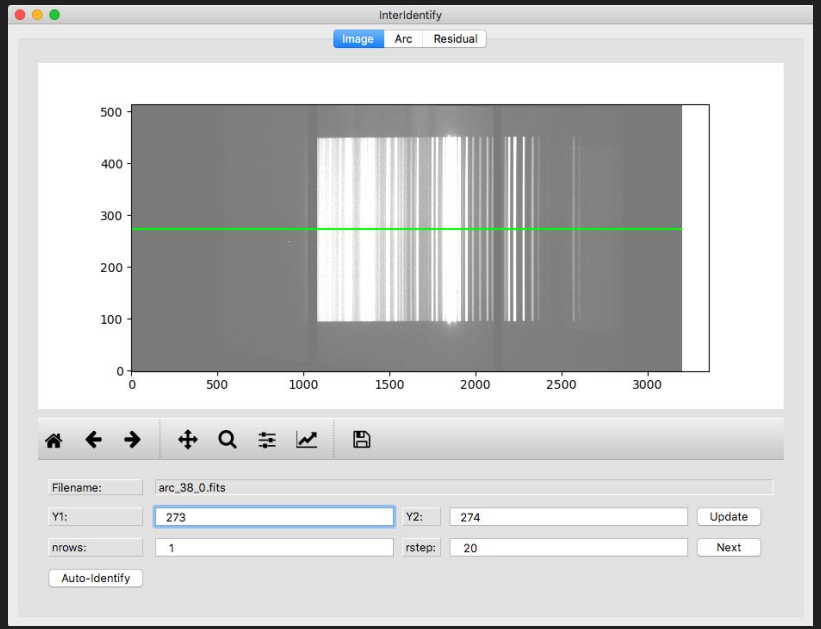
PolSALT steps - Basic Reductions

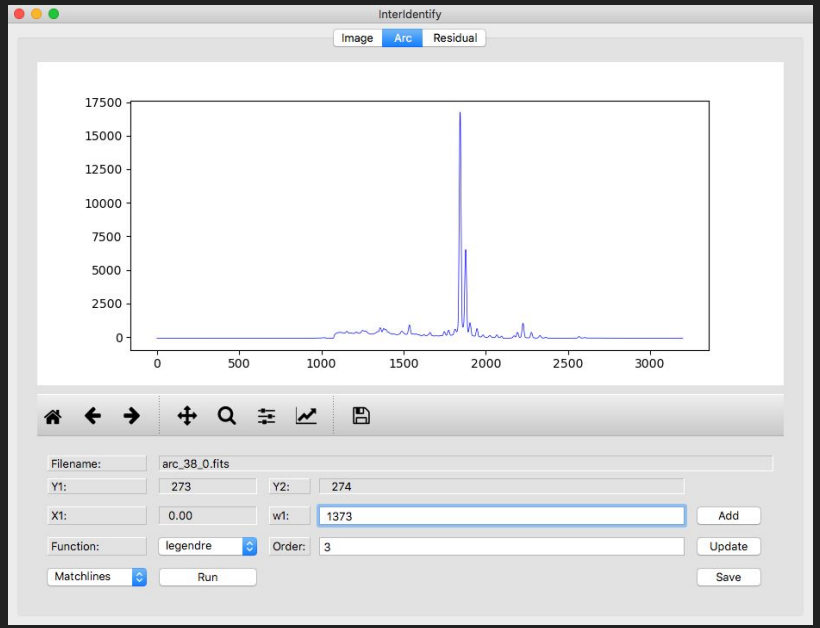
- Basic CCD reductions that include overscan subtraction, gain correction, crosstalk correction, CR cleaning, and geometric corrections.
  - All these steps can be run individually through PyRAF and Pysalt
- This step does produce “mxgbP..fits” files comparable to the reduced files given in the SALT product directory. However the images reduced via PolSALT include addition bad-pixel and variance information necessary for the polarimetric reductions.

# IMAGE	NPIX	MEAN	STDDEV	MIN	MAX
mbxgpP202105030034_SALT.fits[1]	3254472	223.8	409.5	-18.73	98559.
mbxgpP202105030034_Docker.fits[1]	3288572	221.8	408.2	-19.23	98559
mbxgpP202105030034_Beta.fits[1]	3288572	222.1	408.3	-18.73	98559

PolSALT steps - Wavelength Calibration

- Splits the data into O and E beams to allow for separate wavelength calibrations to be done
- The process for identifying lines happens twice (once for O beam and once for the E beam)
- While manual identification is recommended there is the option to Auto-Identify after the lines are identified for the first arc of the image





PolSALT steps - Wavelength Calibration cont.

- This step uses the wavelength solution to determine the wavelength at every good pixel and creates a wavelength map.
- This step should also map out bad areas in the wavelength map either due to being off the edge of the slit or areas of overlap

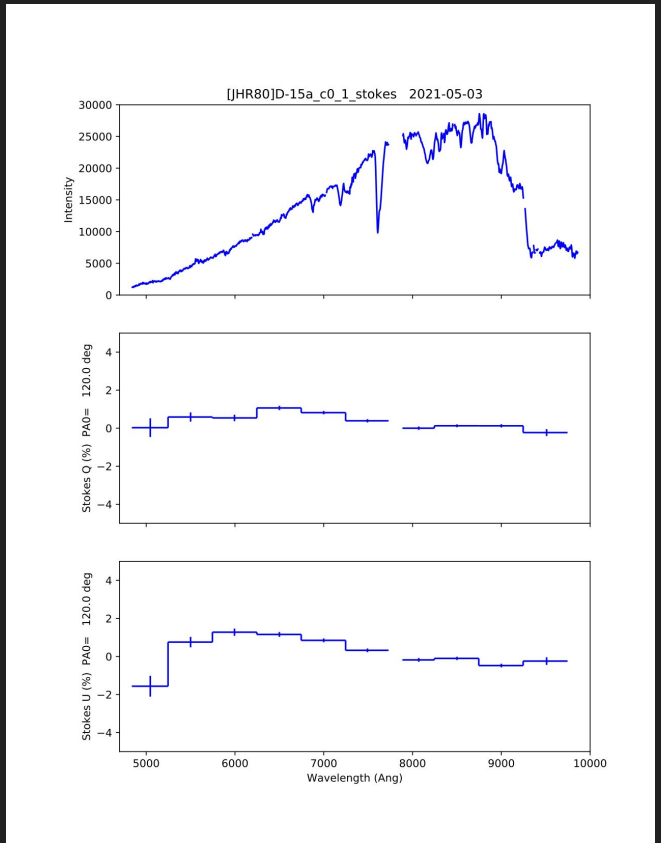
PolSALT steps - Extraction

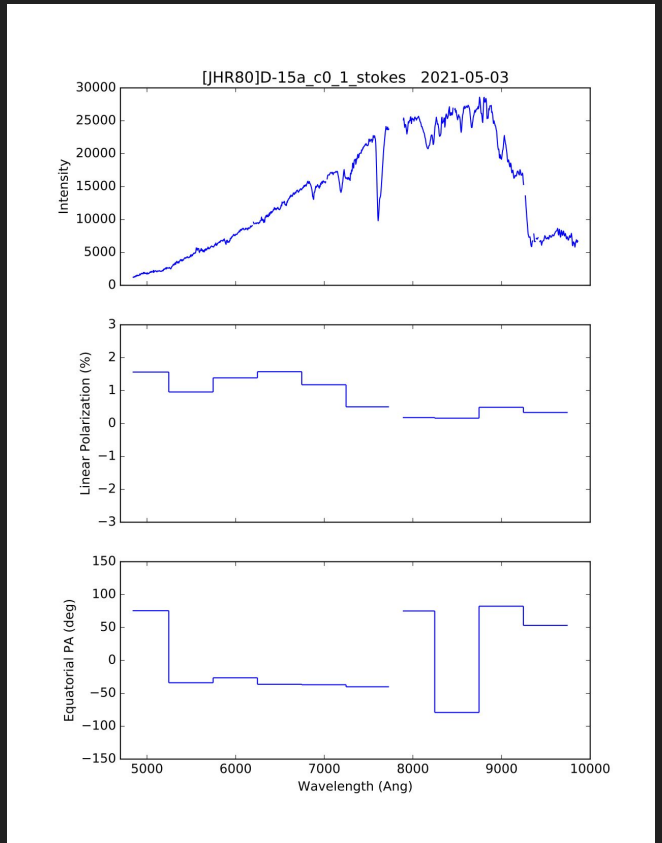
- This step allows for the sky and spectrum to be extracted vs wavelength and creates a 1D image for the extracted O and E spectra.
- The spectrum is extracted and centered on the brightest object in the “window” given. If the Science target is not the brightest in the slit the locate window can be changed to narrow in on the object.
- This does allow the user to select a position angle where a comparison object does fall elsewhere on the slit with the option to extract the comparison object as well.

PolSALT steps - Stokes Calculations

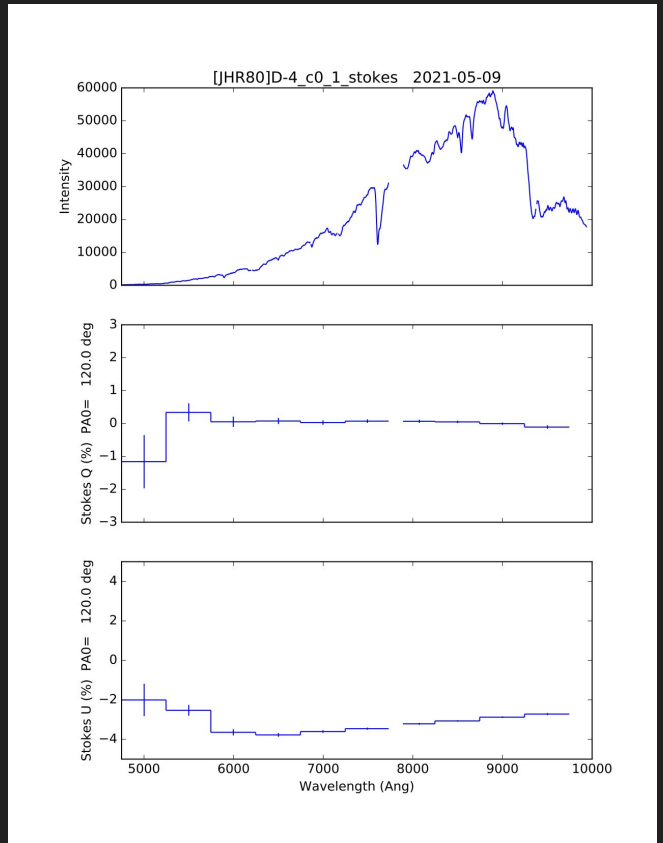
- This step looks for and identifies waveplate position pairs and separates them into single stokes parameters
- For each of these stokes measurements, it produces an output FITS file with the intensity and difference for the pairs measured as a function of wavelength this step also includes the variance and bad pixel maps.
- Applies the zero-point solution, waveplate efficiency, and axis calibrations to give the final stokes parameters

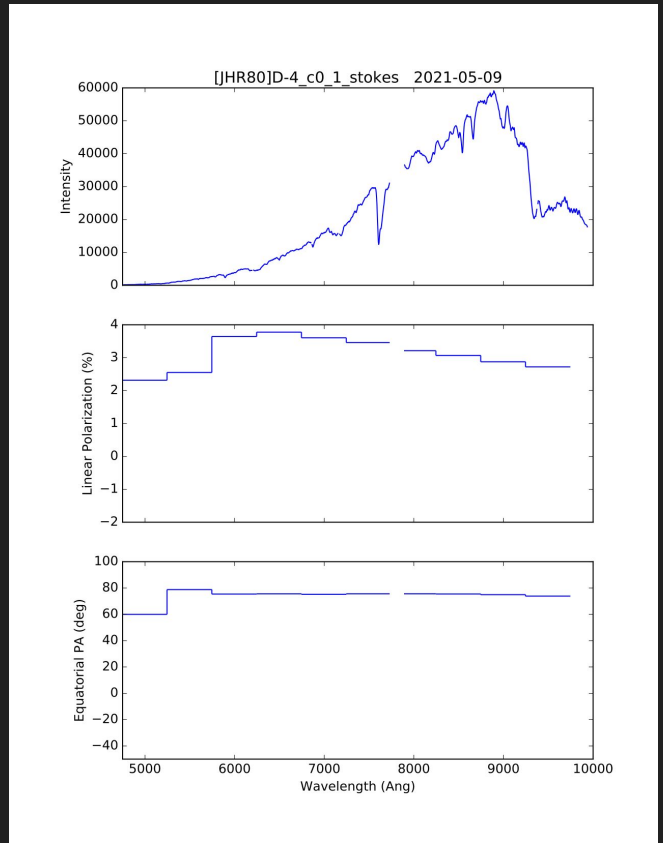
Results


[JHR80]D-15a_c0_1_stokes 2021-05-03
Intensity
Stokes Q (%) PA0= 120.0 deg
Stokes U (%) PA0= 120.0 deg
Wavelength (Ang)

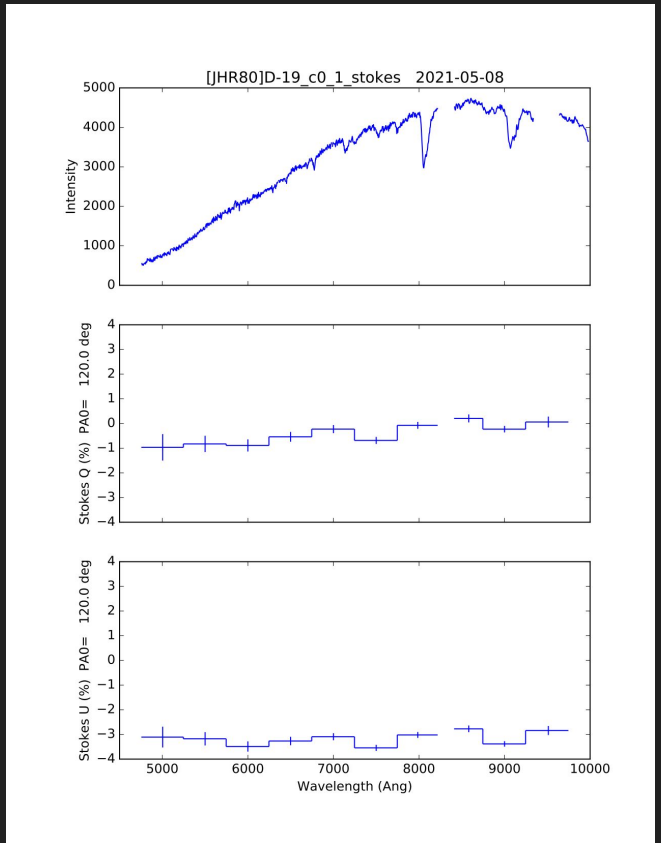

[JHR80]D-15a_c0_1_stokes 2021-05-03
Intensity
Linear Polarization (%)
Equatorial PA (deg)
Wavelength (Ang)

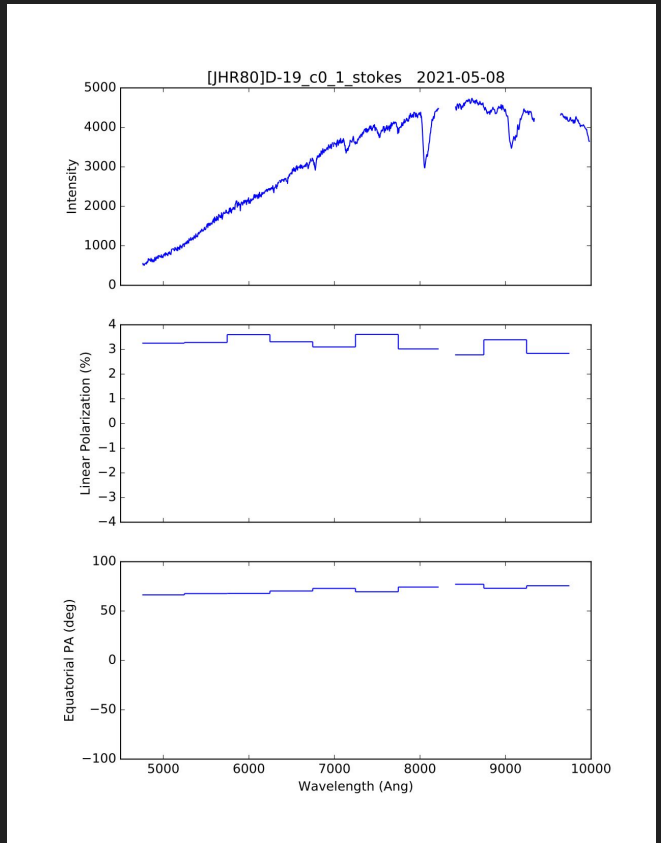
Results Cont;





Results Cont;





Conclusion & Future Work

- PolSALT is an analysis software for RSS spectro-polarimetry
- Each step can be run individually and tweaked to specific needs
- Our group will continue to use the pipeline to reduce the rest of our observations
- Continue to update the MacOS version of PySALT

Thank you

- I would like to thank the mentors of our summer group Dr. B-G Andersson, Dr. Kristin Kulas, and Dr. Archana Soam.
- Big thank you to Dr. Danièl Groenewald and Dr. Ken Nordsieck for answering all my SALT related questions