Improved Rotation-Measure(RM) synthesis technique for extreme Faraday rotation

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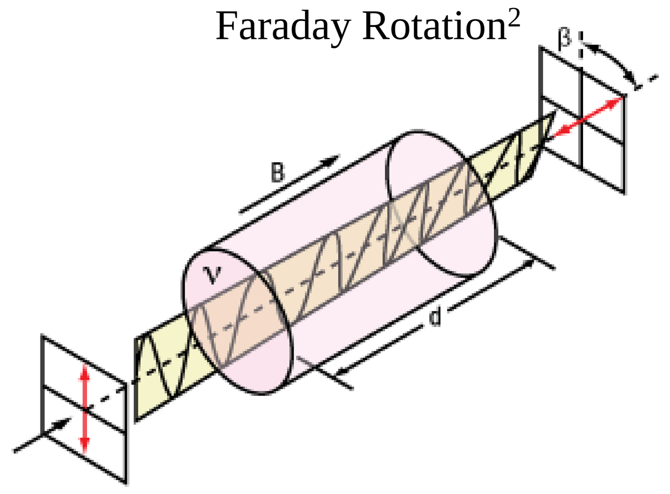
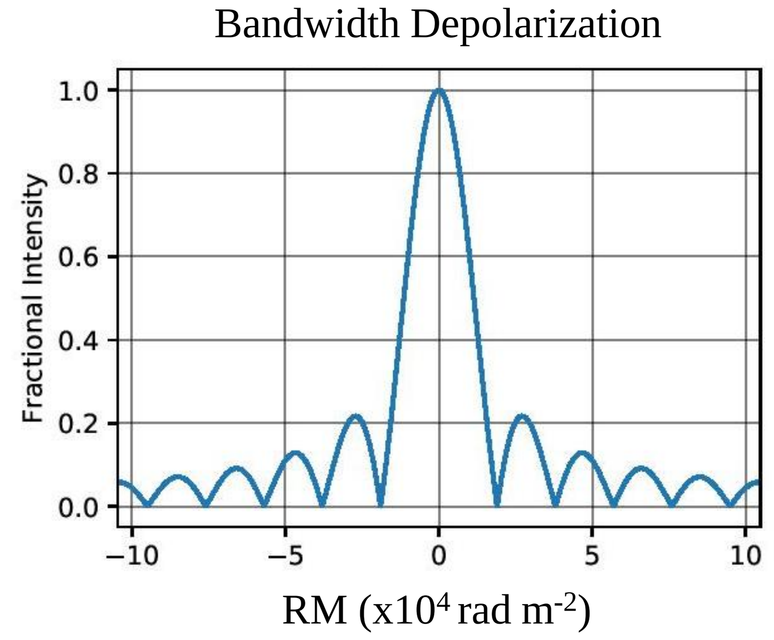
Introduction

Rotation-Measure (RM) synthesis is a technique to determine the Faraday depth for Faraday rotated polarized emission. Current methods of Rotation-Measure (RM) synthesis breakdown for extreme RM values due to bandwidth depolarization.[1] The goal of this project is to find and implement an improved RM synthesis technique for extreme RM values.

Faraday Rotation[2]



Bandwidth Depolarization



Methods

We implemented three new RM synthesis algorithms into the RM-Tools package. These were a direct inverse transform, the Schnitzler & Lee method[3], and an adjoint version. The four methods where then tested with simulated data of a known RM value. Theoretical noise and sensitivity curves were also compared to the results from the simulations.

Classical: $\tilde{P}(\phi)_{\mathrm{dirty}} = K\sum w_i \tilde{P}_i e^{-2i(\lambda_i^2-\lambda_0^2)\phi}$

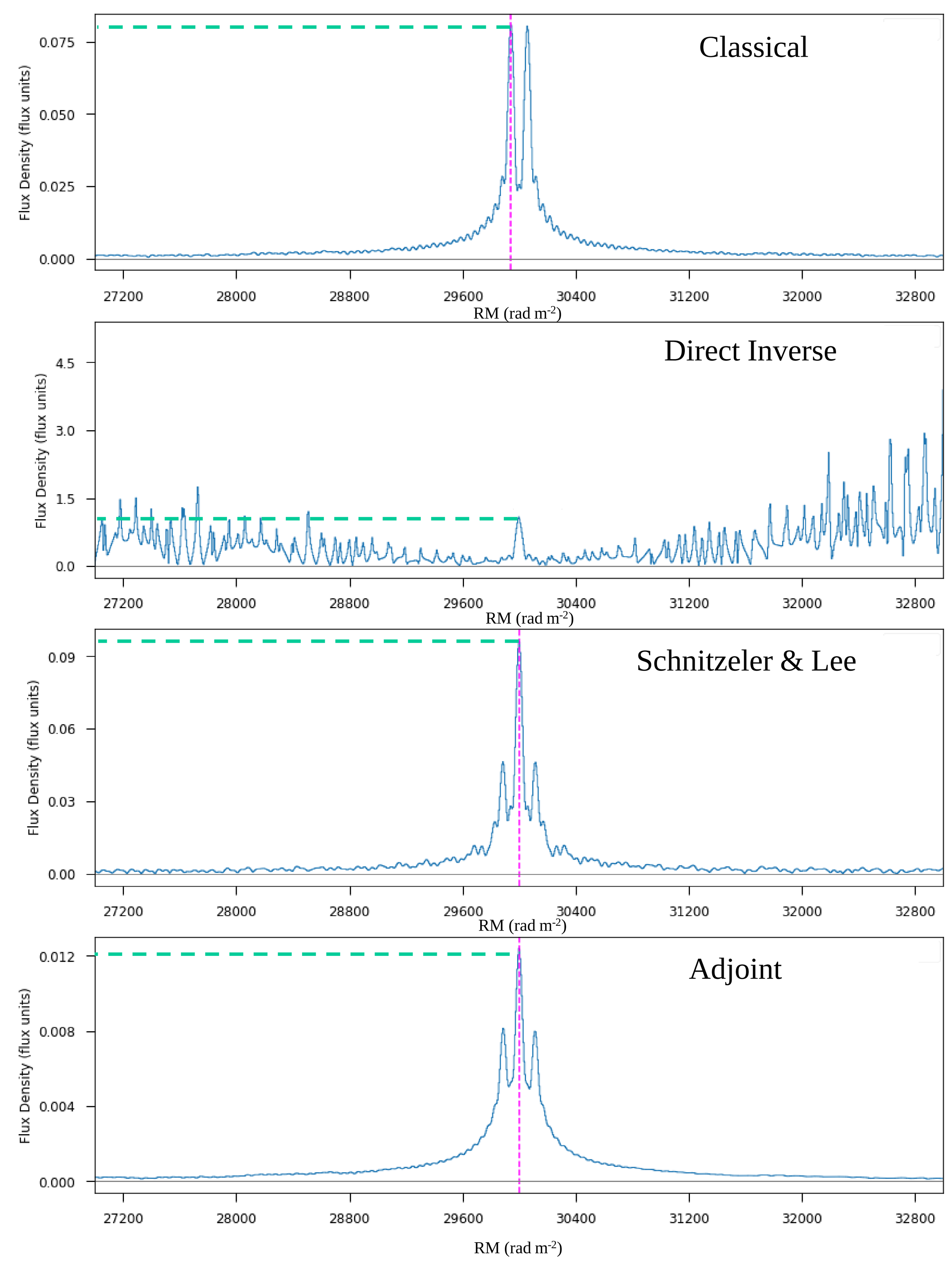
Direct Inverse: $\tilde{P}(\phi)_{\mathrm{dirty}} = K\sum w_i \tilde{P}_i R_i^{-1}$

Schnitzler & Lee: $\tilde{P}(\phi)_{\mathrm{dirty}} = K\sum_i w_i \tilde{P}_i v_i$

Adjoint: $\tilde{P}(\phi)_{\mathrm{dirty}} = K\sum_i w_i \tilde{P}_i R_i^*$

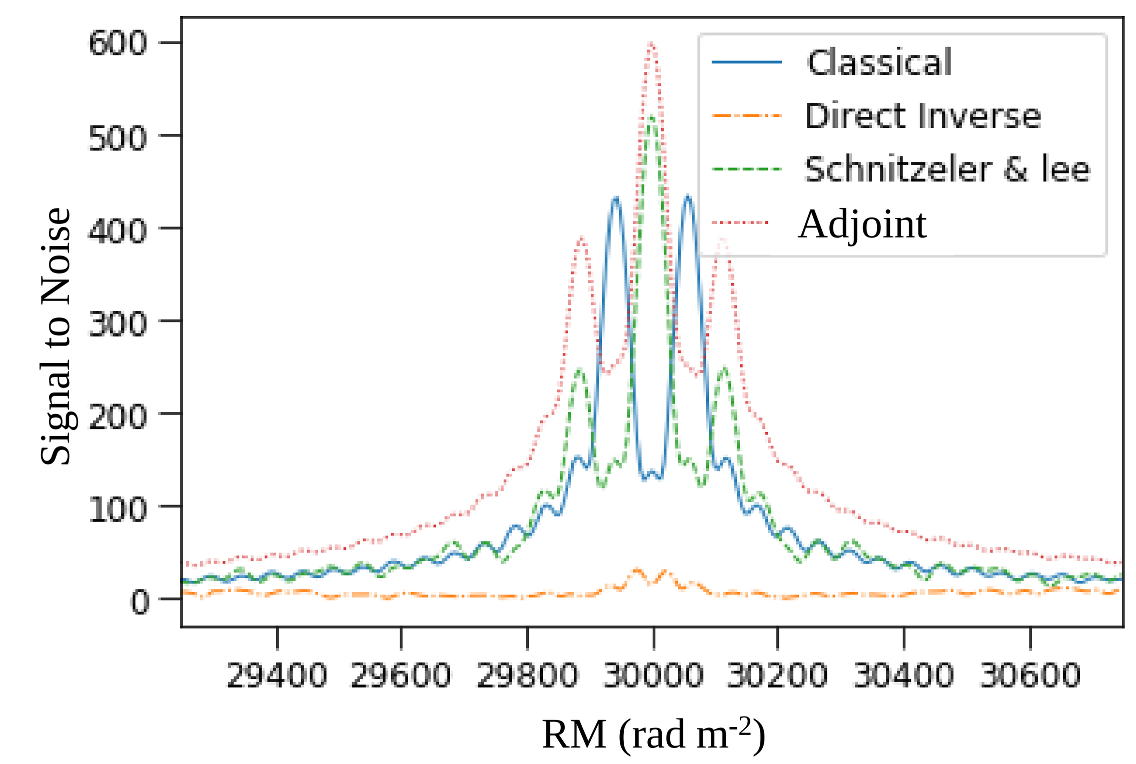
Results

The four methods produce different RM spectra.



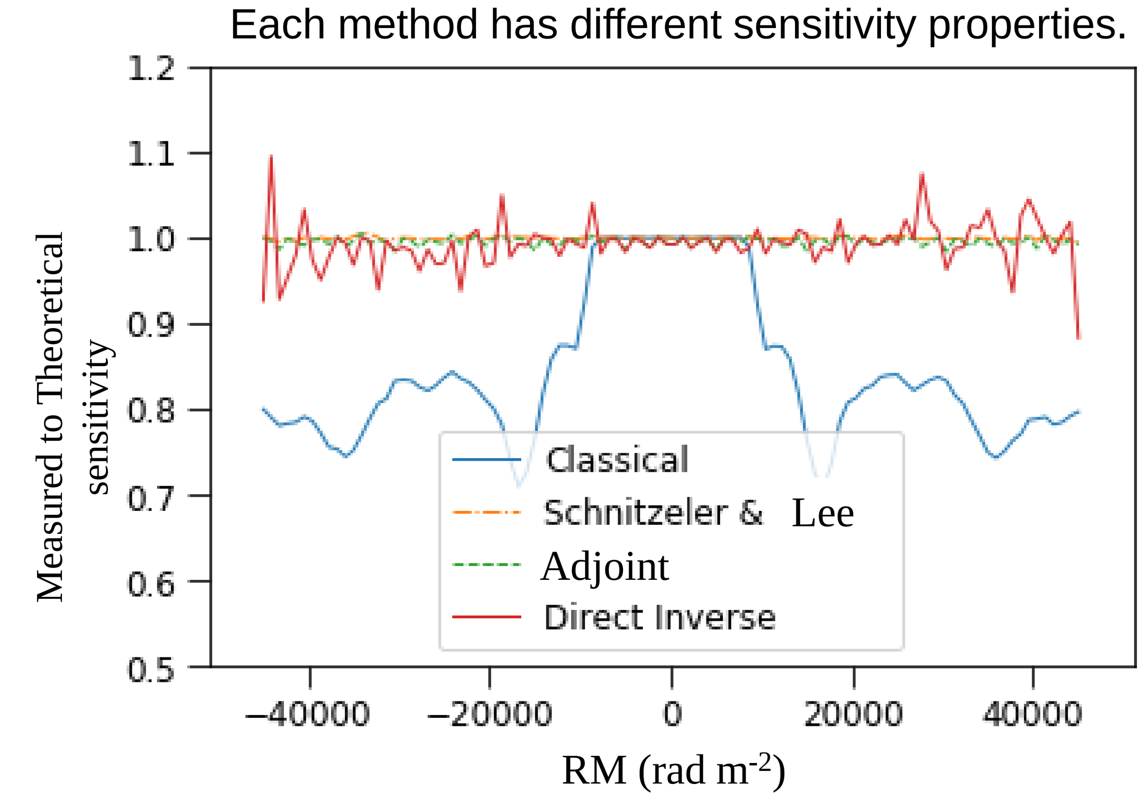
The four FDF's above each indicate the various algorithms strengths and weaknesses. The classical suffers from a twin peak. The direct inverse suffers from increased nose. The adjoint and Schnitzler & Lee methods both have very attractive peaks, and low noise. However, the adjoint versions peak is roughly one order of magnitude lower than the Schnitzler & Lee method.

The signal to noise spectra are very different for each method.



The adjoint has the highest signal to noise; closely followed by the Schnitzler & Lee method, both have improved signal to noise compared to the classical version. For Schnitzler & Lee method and adjoint methods, we can use the signal to noise to find the peak in RM.

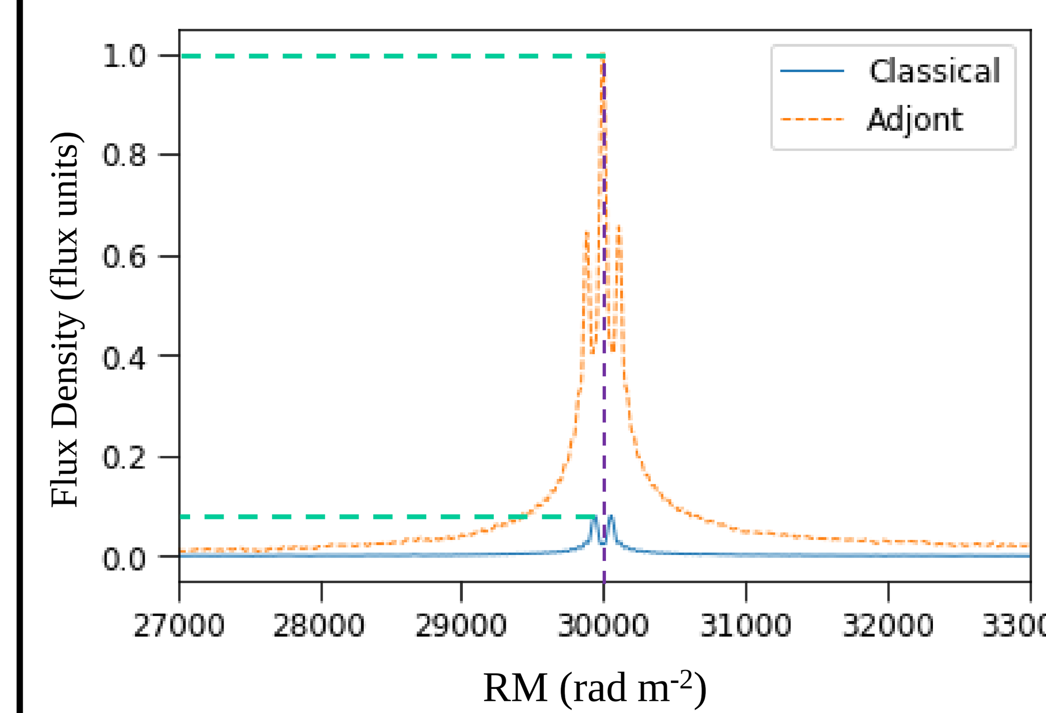
Each method has different sensitivity properties.



The well behaved measured to theoretical sensitivity of the adjoint and Schnitzeler & Lee allows for renormalization of their RM spectra.

Conclusions

The adjoint version is best of the four techniques. The adjoint offers best signal to noise of the four methods, and can be renormalized, using the theoretical sensitivity which allows for the recovery the polarized intensity of the source.
This method is now being implemented into the ***RM-Tools*** package.



A comparison of the Classical method of RM- synthesis and the new adjoint version for extreme Faraday rotation.

Literature cited

1: Brentjens, M. A., and A. G. de Bruyn. "Faraday Rotation Measure Synthesis." Astronomy & Astrophysics 441.3 (2005): 1217–1228.

2: Wikimedia Commons SVG version of Image:Faraday-effect.png By User:Dr.Bob

3: Schnitzeler, D. H. F. M., and K. J. Lee. "Rotation Measure Synthesis Revisited." Monthly Notices of the Royal Astronomical Society: Letters 447.1 (2014): L26–L30.

Acknowledgments

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