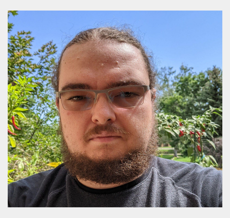

Can We Invert Solar Coronal 3D Magnetic Fields Using IQU-only Spectropolarimetry?

A Prototype Synoptic Application for HAO/MLSO CoMP and uCoMP

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Motivation:

With the upcoming commission of new generation instrumentation coupled with recent advances in understanding the theoretical aspects of solar coronal polarization, the development of new science interpretation and inversion methods for polarized infrared observations is paramount.

Proposed Inversion Framework:

Sufficient but not complete information on the field geometry is encoded in the IQU observables that uCoMP/CoMP can resolve. Θ_B is less constrained and there is no direct access to the magnetic field strength. We propose splitting the problem of inverting coronal vector magnetic fields with no Zeeman effect input data (Stokes V) into two parts:

$$
\begin{aligned}
I_l &\propto k_1 \sigma_{0\,l}^2 \quad (3\cos^2\Theta_B - 1) \\
Q_l &\propto k_2 \sigma_{0\,l}^2 \quad \sin^2\Theta_B \quad \cos 2\Phi_B \\
U_l &\propto k_2 \sigma_{0\,l}^2 \quad \sin^2\Theta_B \quad \sin 2\Phi_B \\
\cancel{V_l} &\cancel{\propto k_4 \sigma_{0\,l}^2 \; \omega_B \; \cos\Theta_B}
\end{aligned}
$$

i. Utilize Stokes IQU observations to disentangle the magnetic field orientation via the newly developed CLEDB inversion code through the saturated Hanle effect. See Judge et. al, 2021 and Paraschiv & Judge 2022.

Invert 6 IQU observables for magnetic Geometry Using CLEDB

ii. Estimate the magnetic field strength via magnetically-induced Doppler oscillations (See Yang et. al, 2020.) and reintroduce this information to partly break degeneracies.

Coronal Seismology inversion of Fe XIII 1074.7 nm intensity to obtain B_{POS}

not consistent with B_{POS}

consistent with B_{POS}

Obtain a set of 2x2 degenerate solutions

GEOMETRICAL SOLUTION A1

GEOMETRICAL SOLUTION A2

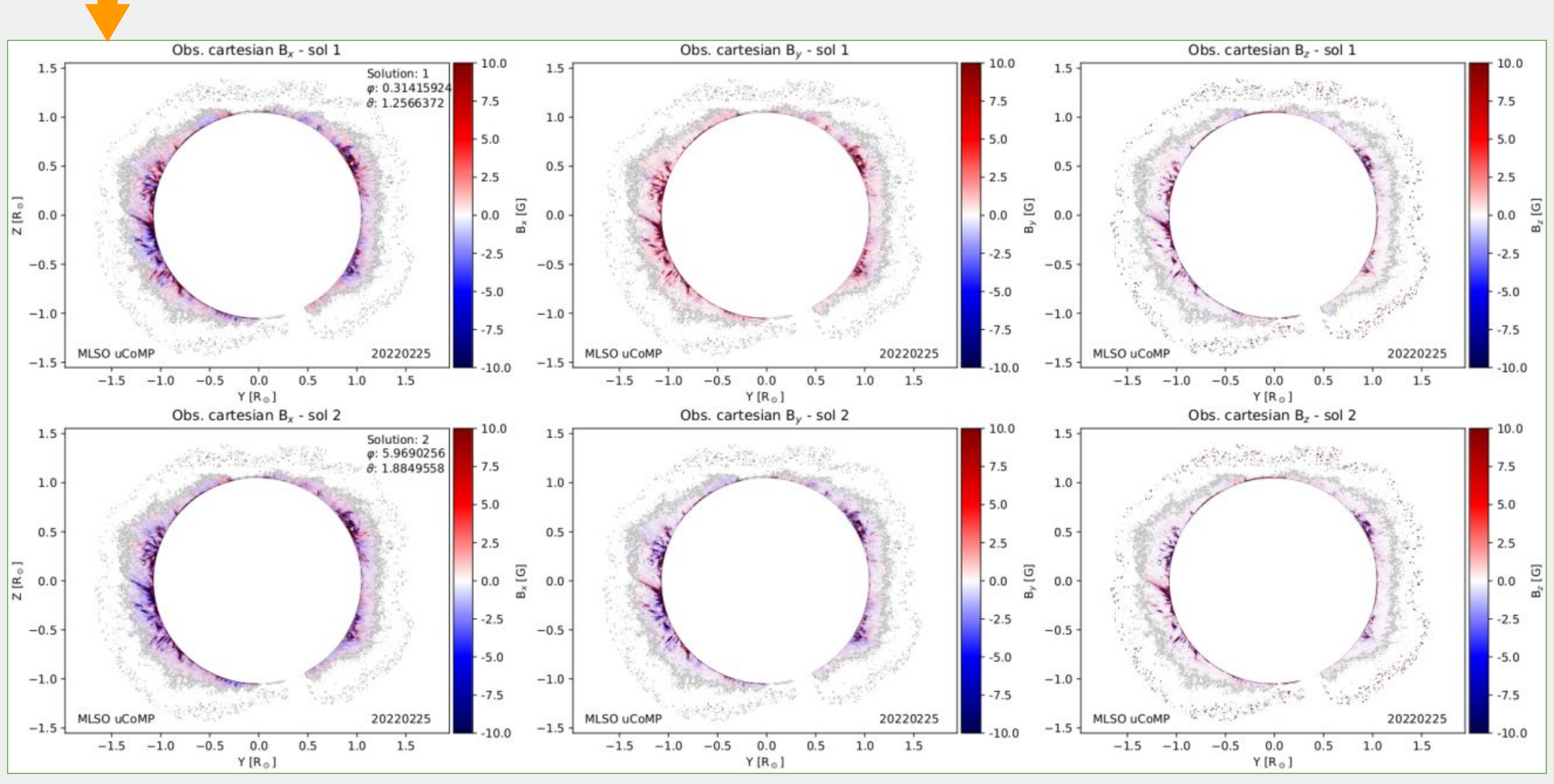
GEOMETRICAL SOLUTION B1

GEOMETRICAL SOLUTION B2

Selects either Ax or Bx sets and then scales the magnetic field strength

FIELD SCALED SOLUTION B2

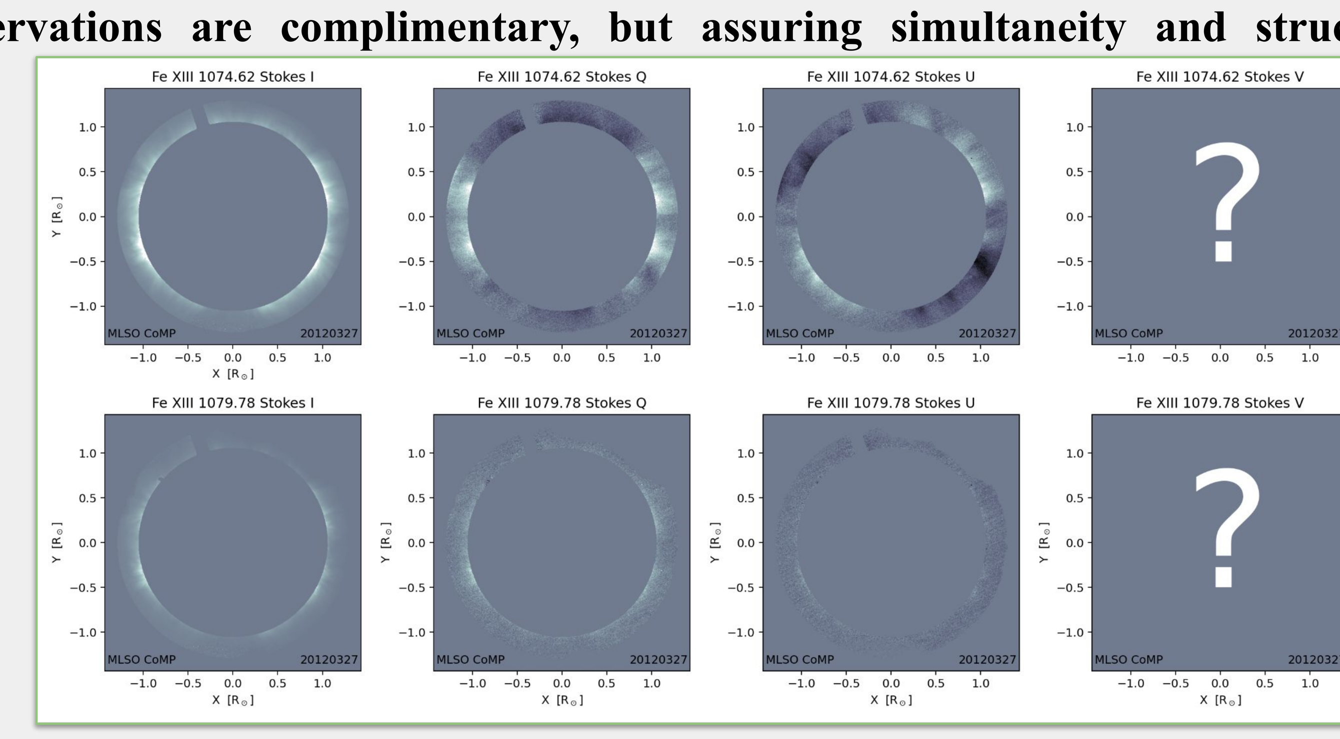
FIELD SCALED SOLUTION B1

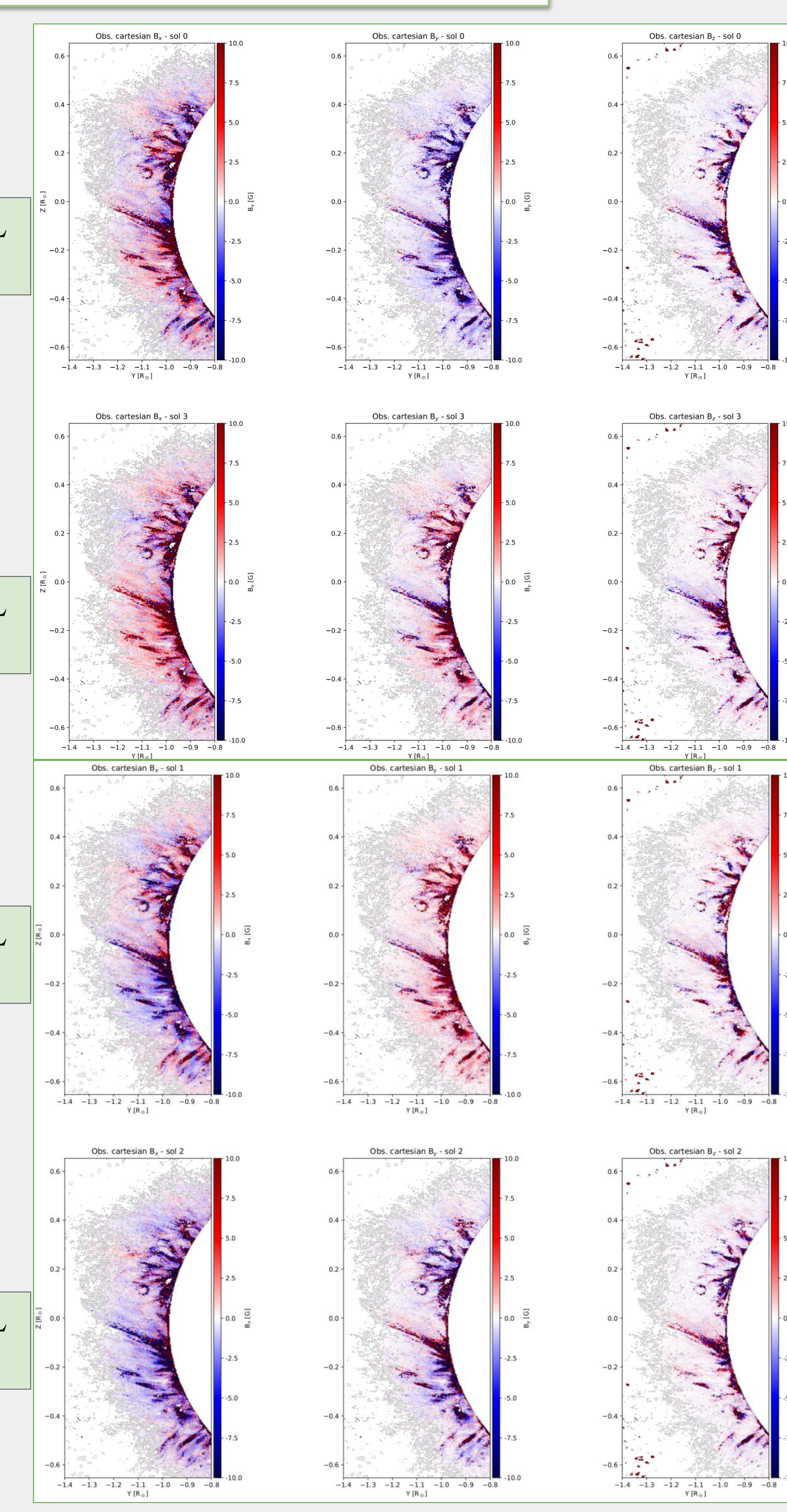


THUS, A VECTOR MAGNETIC FIELD CAN BE INFERRED WITHOUT THE FORMAL NEED OF INCLUDING STOKES V CIRCULAR POLARIZATION.

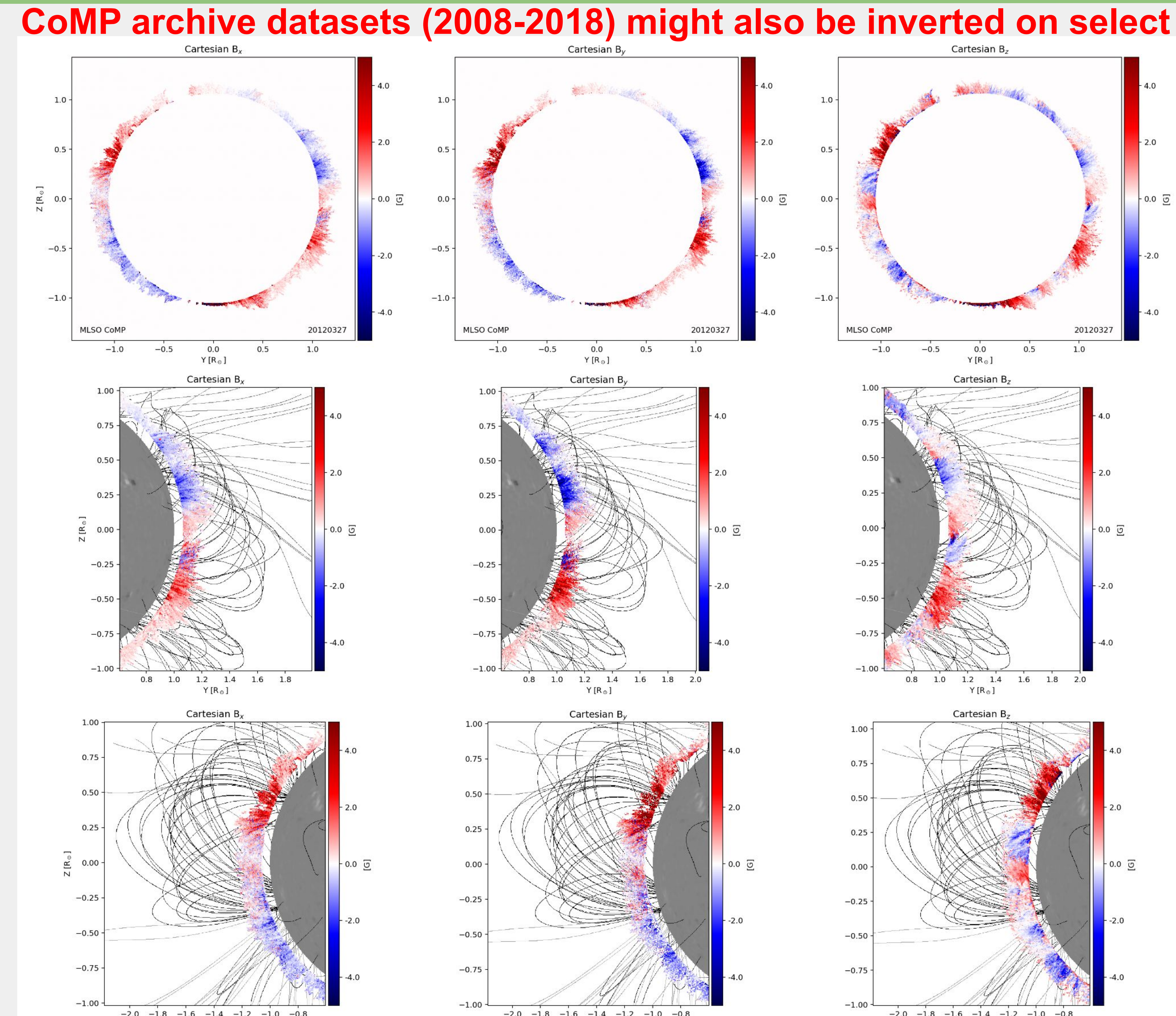
Current State of IR Coronal Magnetometry:

Measuring full Stokes polarization of forbidden IR lines formed in the solar corona is challenging. Radio observations are complimentary, but assuring simultaneity and structure matching is non-trivial.





CoMP archive datasets (2008-2018) might also be inverted on select days.



THE CLEDB INVERSION PACKAGE:

- Designed as a level 2 pipeline for DKIST coronal observations.
- Open source, documented, and publicly accessible code.
- Actively developed and in beta status.
- Parallelized Python implementation.
- Ready to deploy in research computing systems.

GITHUB REPOSITORY | READTHEDOCS DOCUMENTATION | JOURNAL PUBLICATION

https://github.com/arparaschiv/solar-coronal-inversion

https://cledb.readthedocs.io

Paraschiv & Judge, 2022

Assumptions and Caveats:

- The IQU configuration of CLEDB is still an in-development prototype. DKIST observations are required for a fully traceable validation.
- The method requires (Simultaneous) observations of intensity and linear polarization only, of at least two coronal M1 emission lines, like the Fe XIII 1074.68/1079.79 nm pair.
- Observing programs need to accommodate long observing times in order to recover coherent Doppler oscillation and extract wave-related magnetic field strengths.
- This inversion setup is suited for synoptic programs and not so much appropriate for inverting eruptive and/or momentary snapshots.
- The current output products still require disambiguation. Can snapshot tomography help?