

**Advanced three-dimensional modeling of the
magnetic field in active regions on the Sun**

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For ISSI team

Summary

- Sunspots are the hallmark of solar activity. High resolution spectropolarimetry is rapidly progressing toward a better physical understanding of small-scale structures in sunspot penumbra and umbra. However, our understanding of the magnetic structure of sunspots in the chromosphere and corona is lagging behind. In our modeling of magnetic fields in the corona, we still rely on various extrapolation methods, which do not include a realistic atmosphere nor are they constrained by the observations.
- Our ISSI team will explore different approaches to address this deficiency. Nonlinear force-free field reconstructions that employ routinely available full-disk photospheric vector magnetograms as bottom boundary conditions represent the state-of-the-art of coronal magnetic field modeling. Such reconstructions, however, are not unique and suffer from an inconsistency between a force-free coronal magnetic field and non-force-free photospheric boundary condition, from which the coronal reconstruction is performed.
- Realistic time-dependent MHD models could help greatly, but are not expected to be routinely available any time soon. The use of chromospheric vector magnetograms can aid the coronal part of the magnetic model, but does not help to build the magnetic model between the photospheric and chromospheric levels.
- Our ISSI team will use a combination of state-of-the-art modeling with existing and near future high-resolution observations (e.g. from new DK1 4-meter aperture Solar Telescope, DKIST) to evaluate existing approaches in modeling the chromospheric and coronal magnetic fields and identify key failure points in such modeling. The goal is to integrate newly available chromospheric and/or coronal magnetic field data with the vector photospheric magnetograms to improve the magnetic field reconstructions.
- We will select several well-observed active regions, which have both chromospheric and coronal magnetic field diagnostics from optical and radio spectropolarimetry, construct their 3D coronal magnetic field models using various complementary techniques, and validate these models using the observations. As a result of this effort we will create better constrained models of the coronal magnetic field, available for public use in the form of data cubes, codes, and scientific publications.

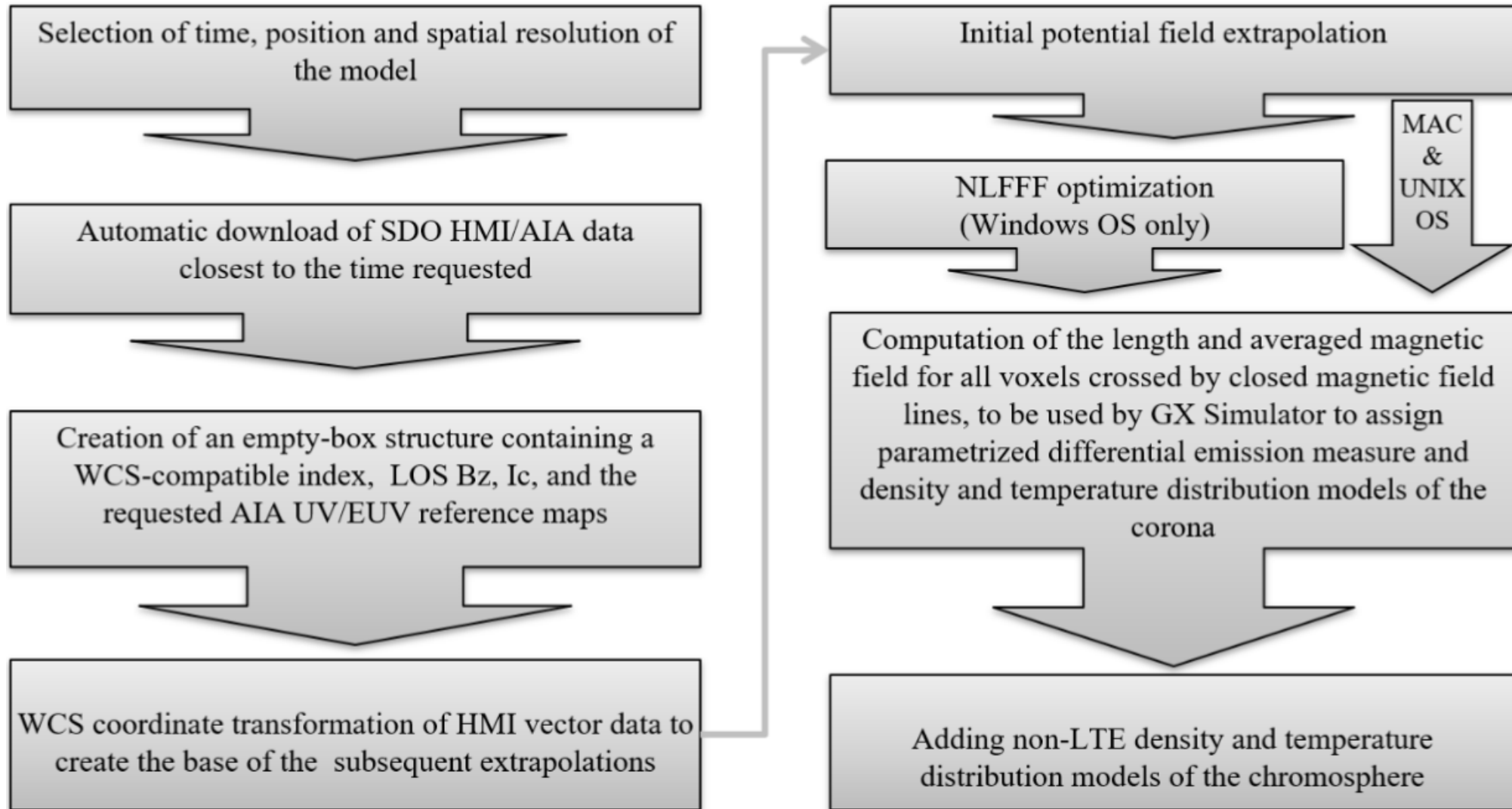
Color code	Monday	Tuesday	Wednesday	Thursday	Friday
Team work	10-12. Fleishman. Opening. Goals of the team meeting. Program. GX Simulator: current state and needed enhancements.	9-10:30 de la Cruz Rodriguez. NLTE inversion methods and magnetic field reconstructions in the chromosphere	9-10 Wheatland. Self-consistency in force-free modelling. Ideas for adding chromospheric B constraints.	9-10 Team work on AR selection and advanced AR modeling.	9-10:30. Fleishman. General discussion on coronal and chromo thermal modeling.
Photospheric science	12-13 Lunch	10:30-12 Pevtsov. Chromospheric B data from optical observations. SOLIS etc.	10-10:15. Lesovoy. SRH. 10:15-12. Anfinogentov. Radio GR diagnostics of coronal B. Current instruments (EOVSA, SRH, etc.)	10-11. Ryan French. Constraining coronal fields with coronagraph measurements	10:30-12. Vrubelskis, Thermal modeling on open field. On open field atmosphere based on the observed reduced microwave brightness temperature in AR 8535.
Chromospheric science	13-14 Photosph. B data: SDO, SST, GREGOR, GST, DKIST (Pevtsov, Kleint etc.)	12-13 Lunch	12-13 Lunch	11-12. Mackay. Data-driven modeling. Approaches to include the coupled evolution of the field at two heights.	12-13. Lunch.
Free time	14-15:30 Wiegelmann. Force-free, magnetostatic and stationary MHD modelling	13-14:30 Kleint. Chromospheric spectropolarimetry	13-13:30. Ryabovs. QT diagnostics of coronal B. On accuracy of circular polarization from QT region	12-13 Lunch	13-17 Team work on AR selection and advanced AR modeling.
Coronal science	15:30-16 Kazachenko. DKIST status and B data	14:30-16 Loukicheva. Free-free (radio) diagnostics of B at the chromosphere. ALMA.	13:30-15 Kaltman. RATAN B diagnostics. RATAN resources and available data. Role of RATAN data in model validation.	13-14 Mackay (cont)	
Evolution; data-driven modeling	16-17. Overview of photo B data. FOVs, resolutions, combining data etc.	16-17 da Silva Santos. Magnetic heating of the active chromosphere (NOAA 12723 on 09/30/2018)	15-17 Stupishin. NLFFF code realization for GX Simulator. Optimization code with added chromo/coronal constraints.	14-15 Team work on AR selection and advanced AR modeling.	
Thermal properties				15-17 Kazachenko. Data-driven modeling.	

GX Simulator: user-friendly tool for 3D modeling

The screenshot displays the GX Simulator interface, which is used for 3D modeling and simulation. The main window is titled "GX SIMULATOR" and contains a central 3D view area. The interface is divided into several sections:

- Top Panel:** Includes a "Help" menu and a toolbar with various icons for navigation and manipulation.
- Left Panel:** Contains view mode selectors: "MAP VIEW", "IMAGE VIEW", and "VOLUME VIEW".
- Right Panel:** Contains the "MODELS" section, which is currently set to "Corona Model 1". It includes a toolbar, a "Dimension" field (set to [81, 81, 81]), a "Resolution" field (set to 0.00205613R), and "Reference Map Actions" (set to Bz) with a "B scale" of 1. There are also checkboxes for "Hide model", "Hide base map", "Hide ROI box", and "Top View". Below these are "EW" (80°) and "NS" (10°) fields, along with "Bline steps" (5000) and "Subgrid steps" (10).
- Flux Tube 1 Section:** Contains a toolbar and tabs for "Geometry", "Thermal electron distribution", "Nonthermal electron distribution", "Electron energy distribution", and "Pitch". It features several parameter fields: p[0] 1, p[1] 1, p[2] 0, p[3] 0; q[0] 4, q[1] 0, q[2] 0; nb= 1e+008cm^-3, s0/l= -0.0978261, and the equation n(x,y,s)=nb*nr(x,y)*ns(s). Below these are two plots: a 2D plot of nr(x,0) and nr(0,y) vs x/a and y/b, and a 1D plot of ns vs s/l.
- Bottom Panel:** Contains a grid of control fields for X (0.9957R), FOV (0.0575R), dS (0.0000R^2), NxNy (729), Y (0.1359R), L (0.0513R), dz (0.0021R), and Nz (24).

Automated Model Production Pipeline (AMPP)



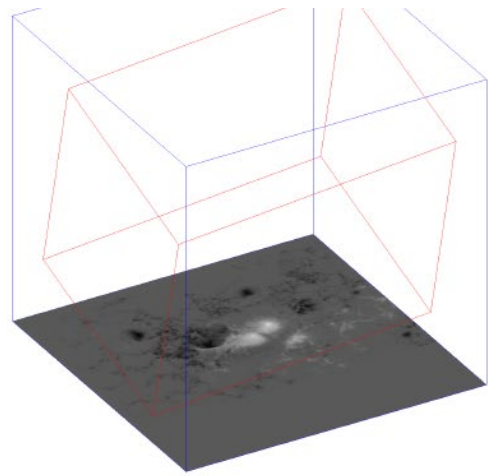
Interface of Automated Model Production Pipeline

The interface displays the following configuration details:

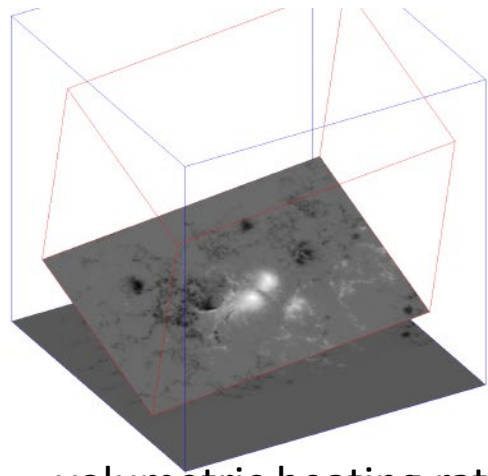
- Automated Model Production Pipeline**: Legacy Magnetic Field Extrapolation Project
- SDO Data Repository**: C:\soc_cache
- GX Model Repository**: C:\gx_models
- External Box path**: [Empty]
- Jump-to Action**: none, potential, nlff, lines, chromo
- Model Time**: 2016-02-20 17:00:00.000
- Model Coordinates**: Xc: -15", Yc: 185", Heliocentric, Carrington
- Model Gridpoints**: X: 64, Y: 64, Z: 64, Resolution: 1400km
- Geometrical Projection**: CEA, TOP
- Pi-disambiguation**: HMI, SFQ
- Buffer Zone Size**: 10% (default, 10% of the box dimensions recommended)
- Options**:
 - Download AIA/UV contextual maps
 - Download AIA/EUV contextual maps
 - Save Empty Box
 - Save Potential Box
 - Save Bounds Box
 - Stop after the potential box is generated
 - Skip NLFFF extrapolation
 - Stop after the NLFFF box is generated
 - Center voxel magnetic field line tracing
 - Do not add Fontenla chromosphere model

Summary: gx_fov2box '20-Feb-16 17:00:00', center_arcsec=[-15,185], size_pix=[64,64,64], dx_km=1400, /cea, /uv, /euv, tmp_dir= 'C:\soc_cache', out_dir= 'C:\gx_models'

Model and synthetic images

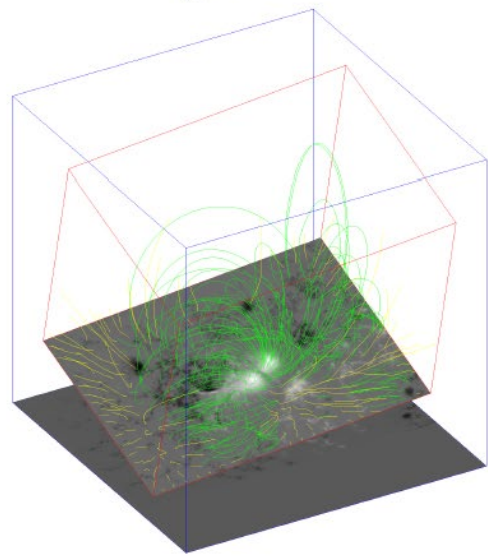


(a)

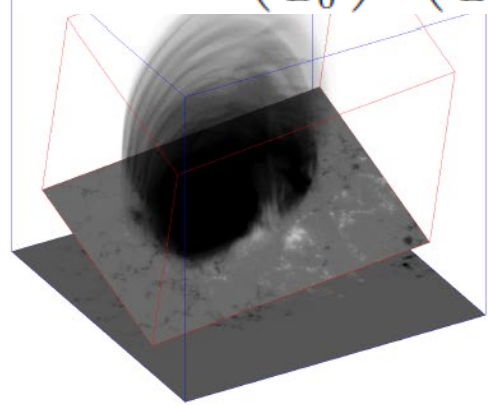


volumetric heating rate (

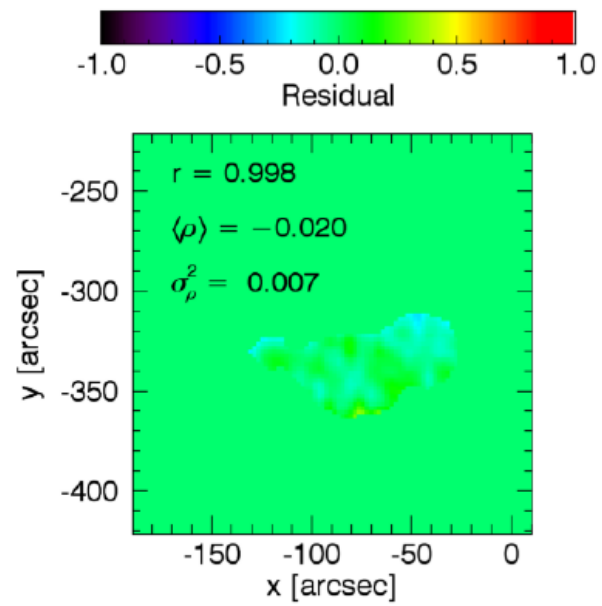
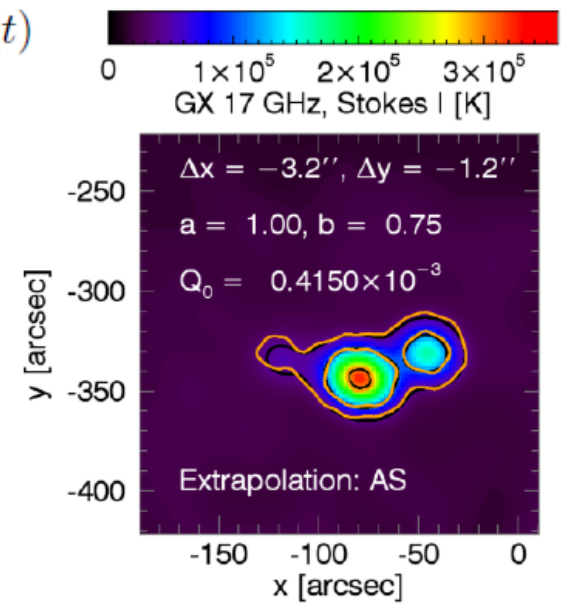
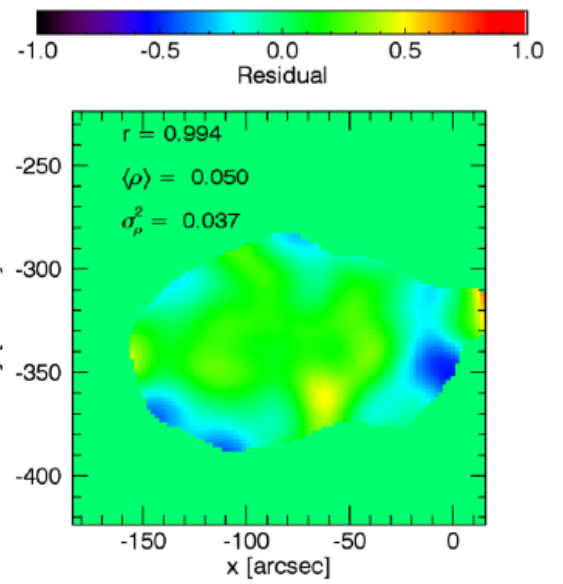
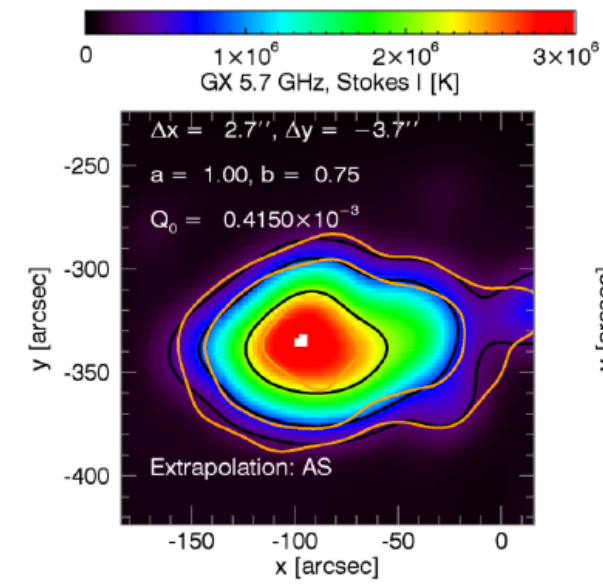
$$Q(t) = Q_0 \left(\frac{\langle B \rangle}{B_0} \right)^a \left(\frac{L_0}{L} \right)^b f(t)$$



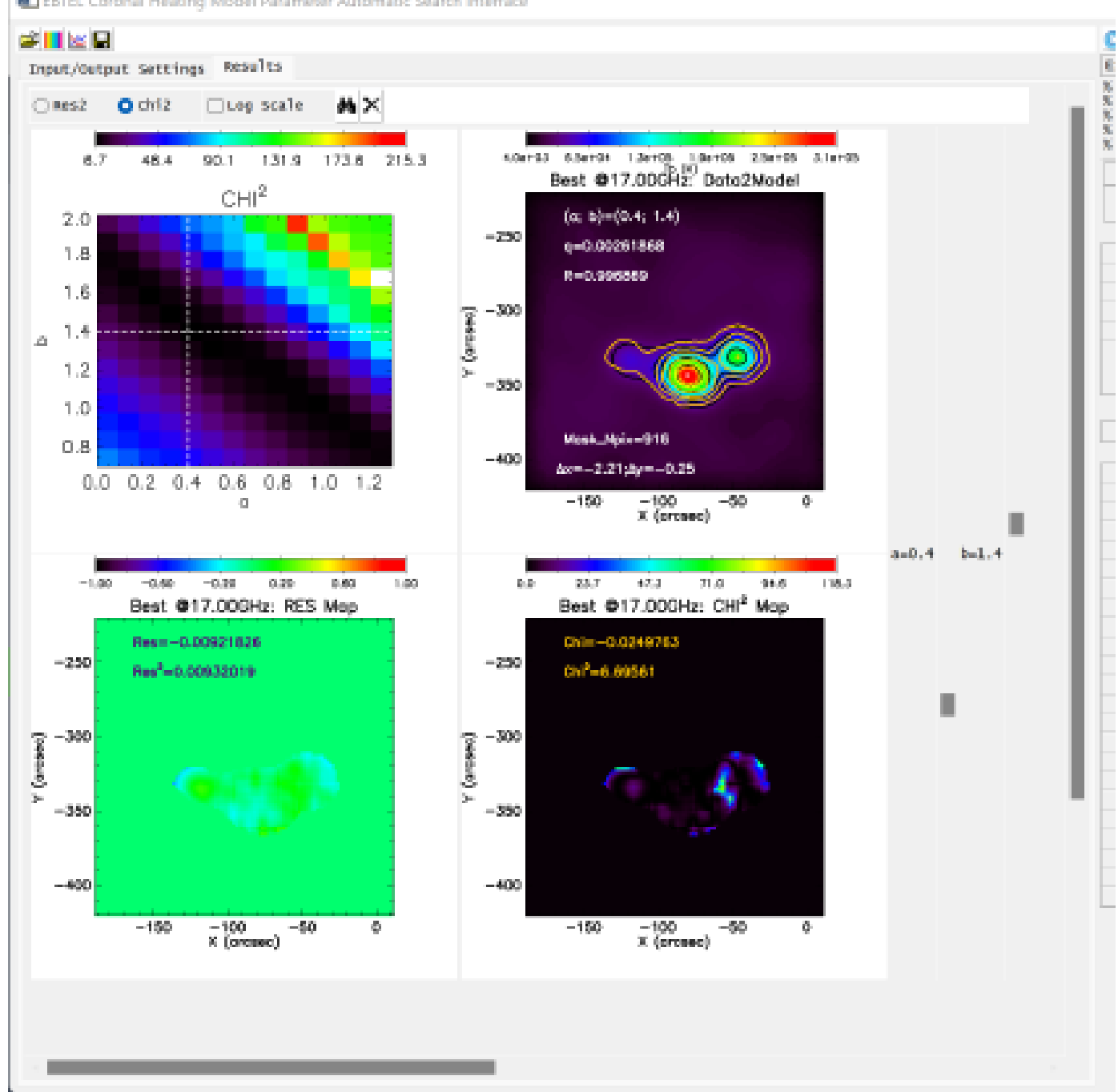
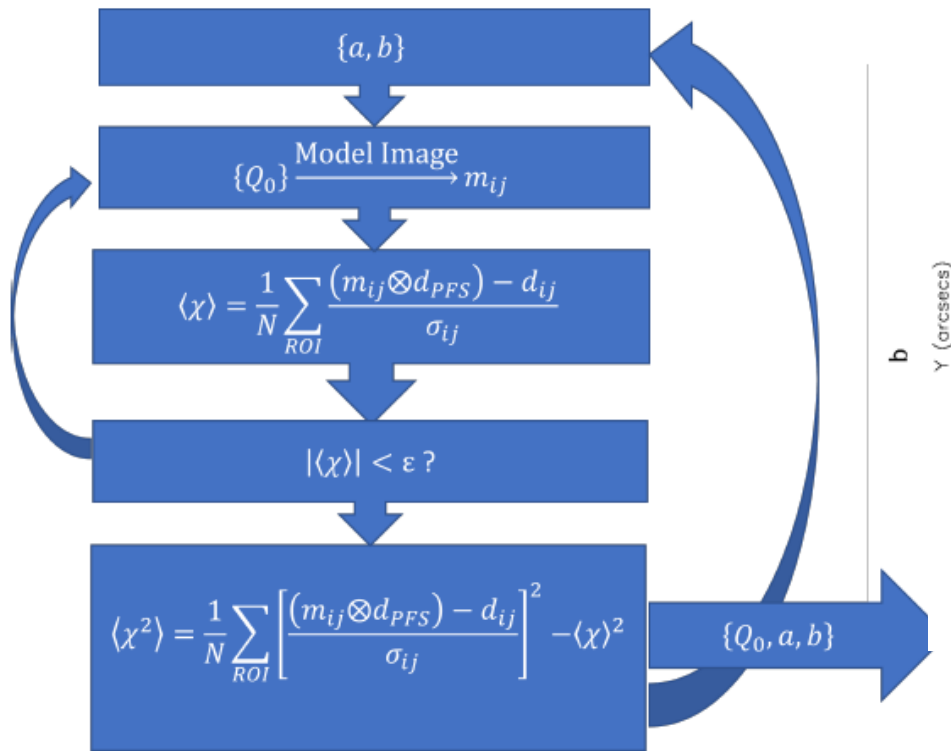
(c)



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Fine tuning therm

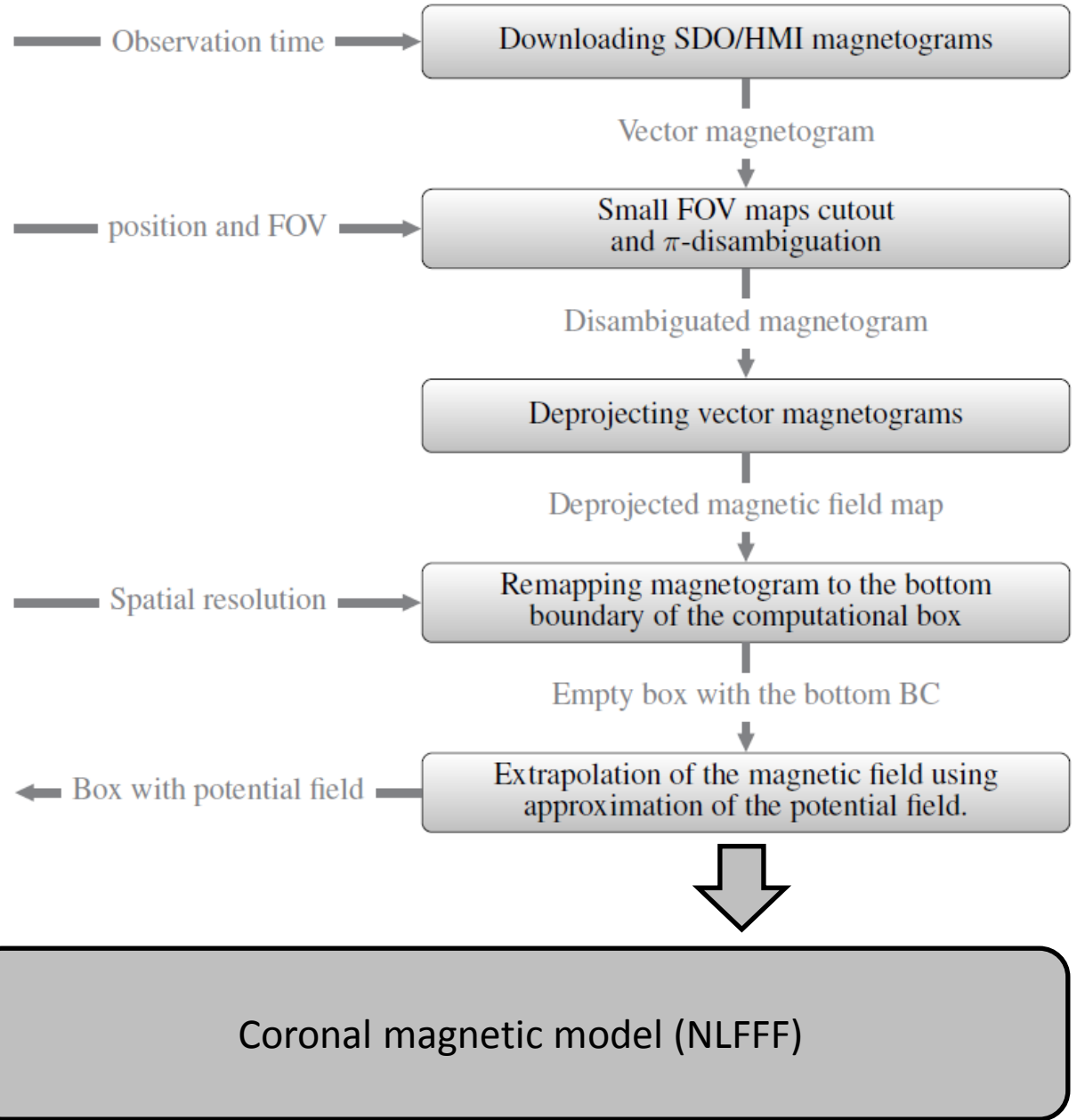


Conceptual view

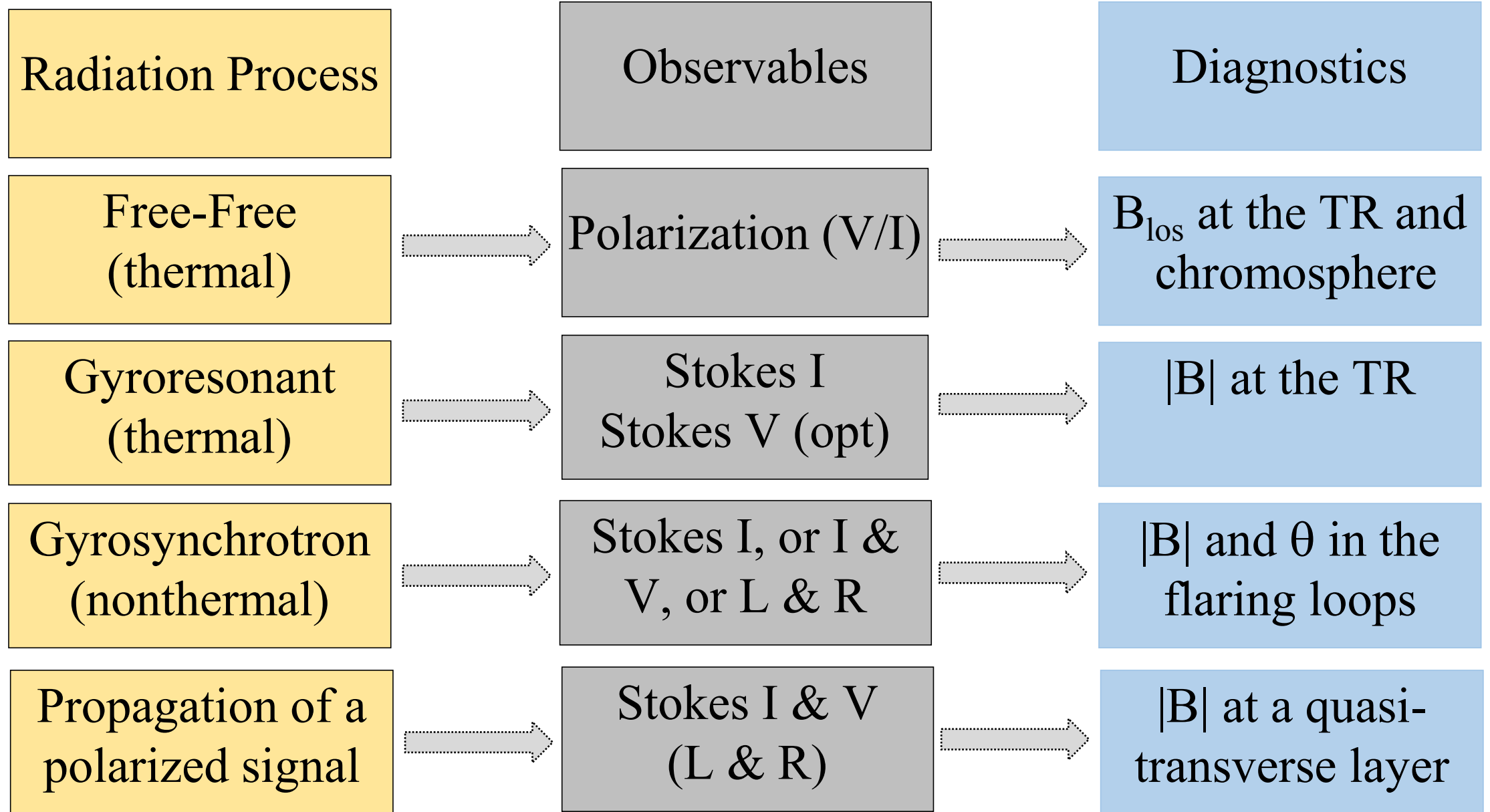
Zeeman chromospheric \mathbf{B} probing
at various heights

Microwave/mm chromospheric B_{los}
probing at various heights (ALMA)

Radio probing of B at various
heights (EOVSA, SRH)



Radio Diagnostics of B



Coronal B Field: Measurements vs Models

