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

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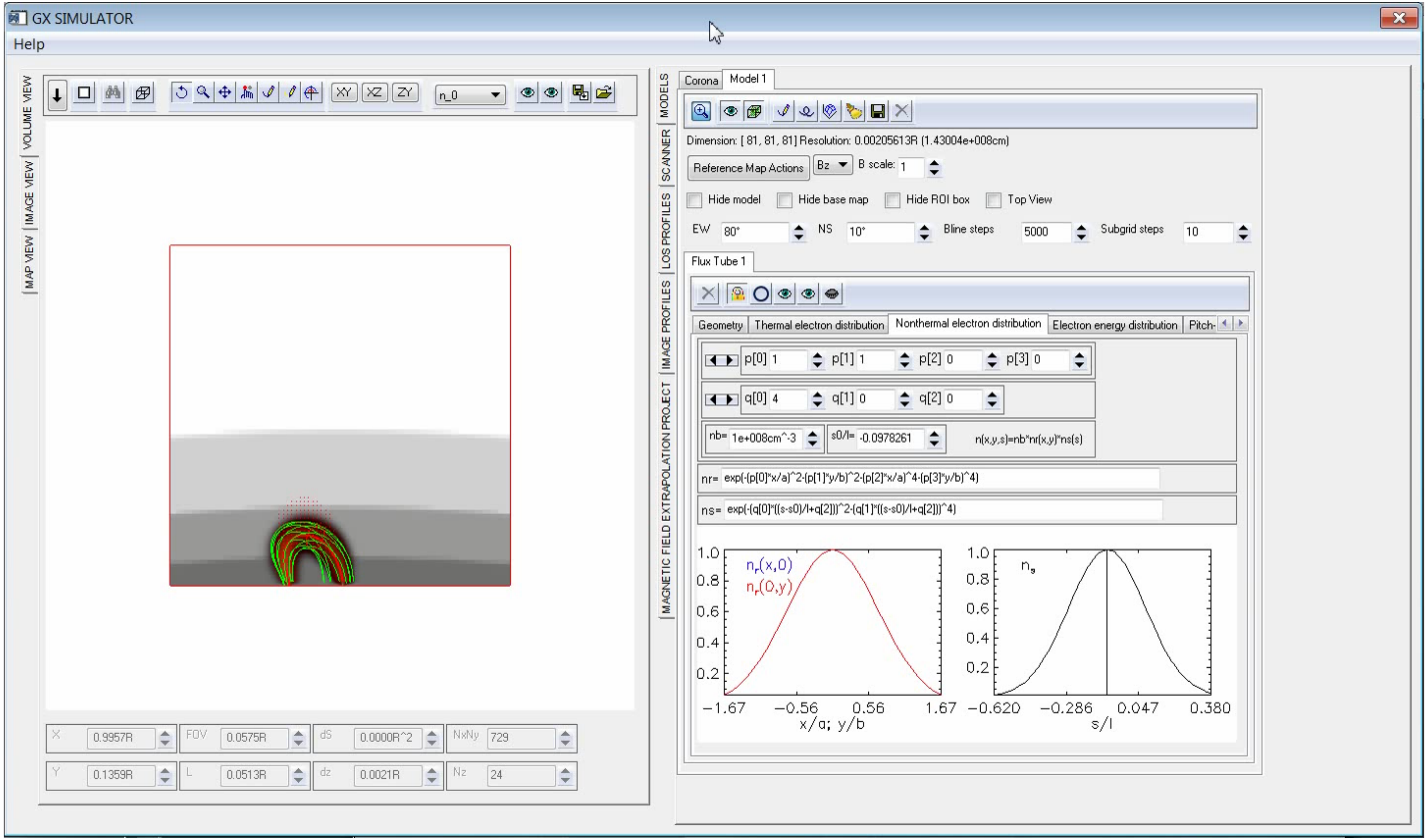
For ISSI team

Summary

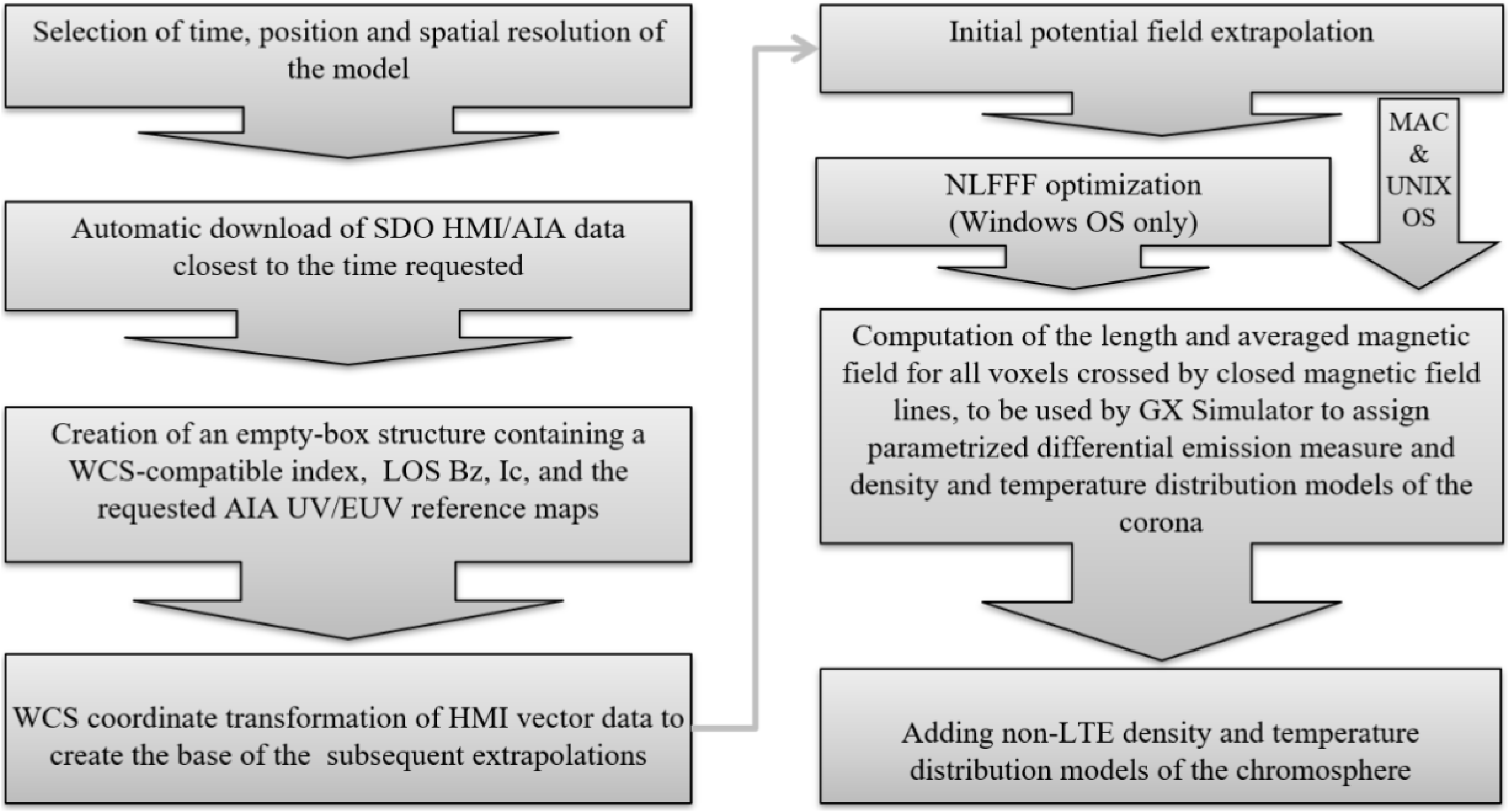
- Sunspots are the hallmark of solar activity. High resolution spectropolarimetry is rapidly progressing toward a better physical understanding of small-scale structures in sunspot penumbra and umbra. However, our understanding of the magnetic structure of sunspots in the chromosphere and corona is lagging 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 rou-tinely 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 DKI 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.	

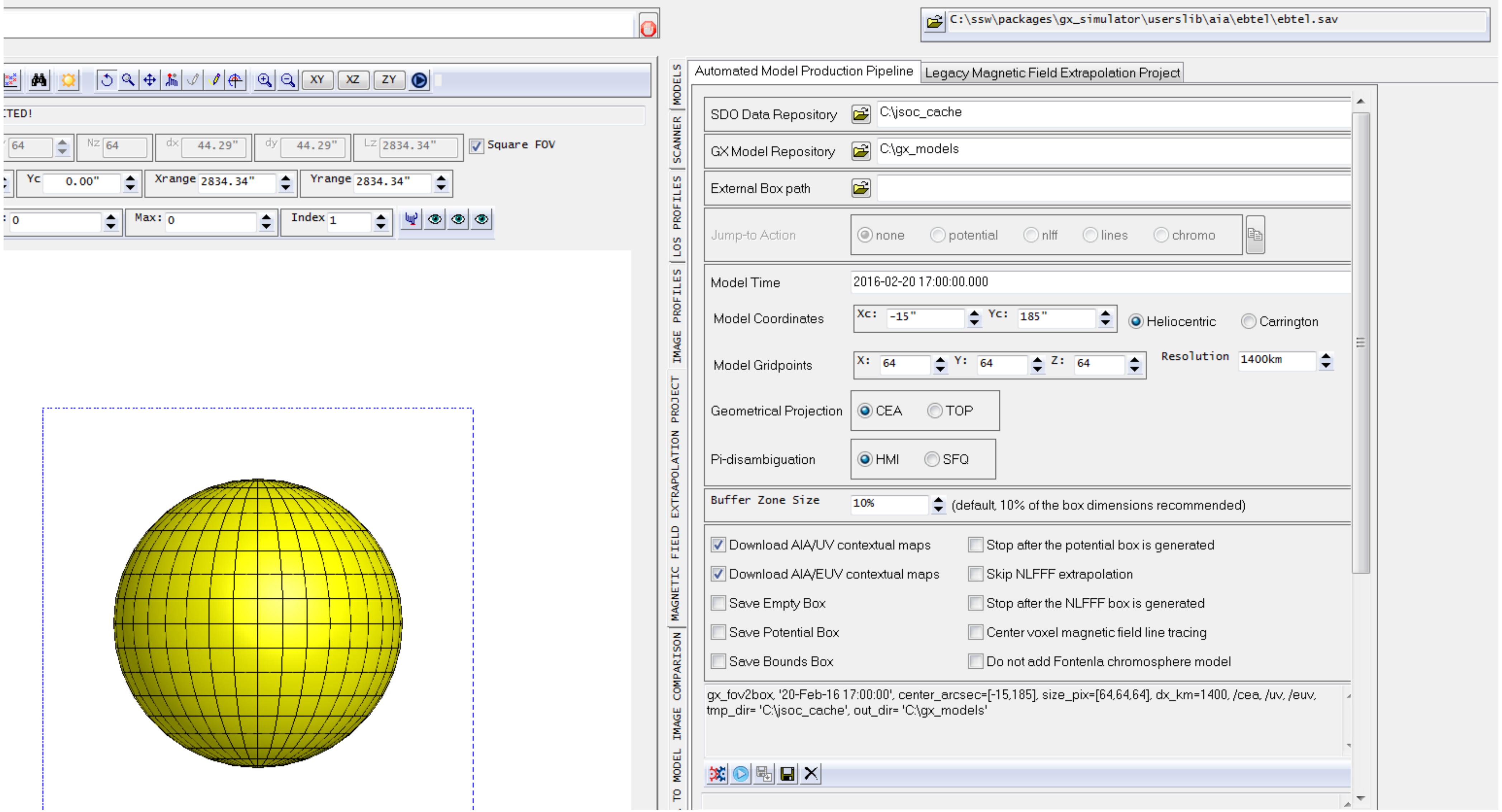
GX Simulator: user-friendly tool for 3D modeling



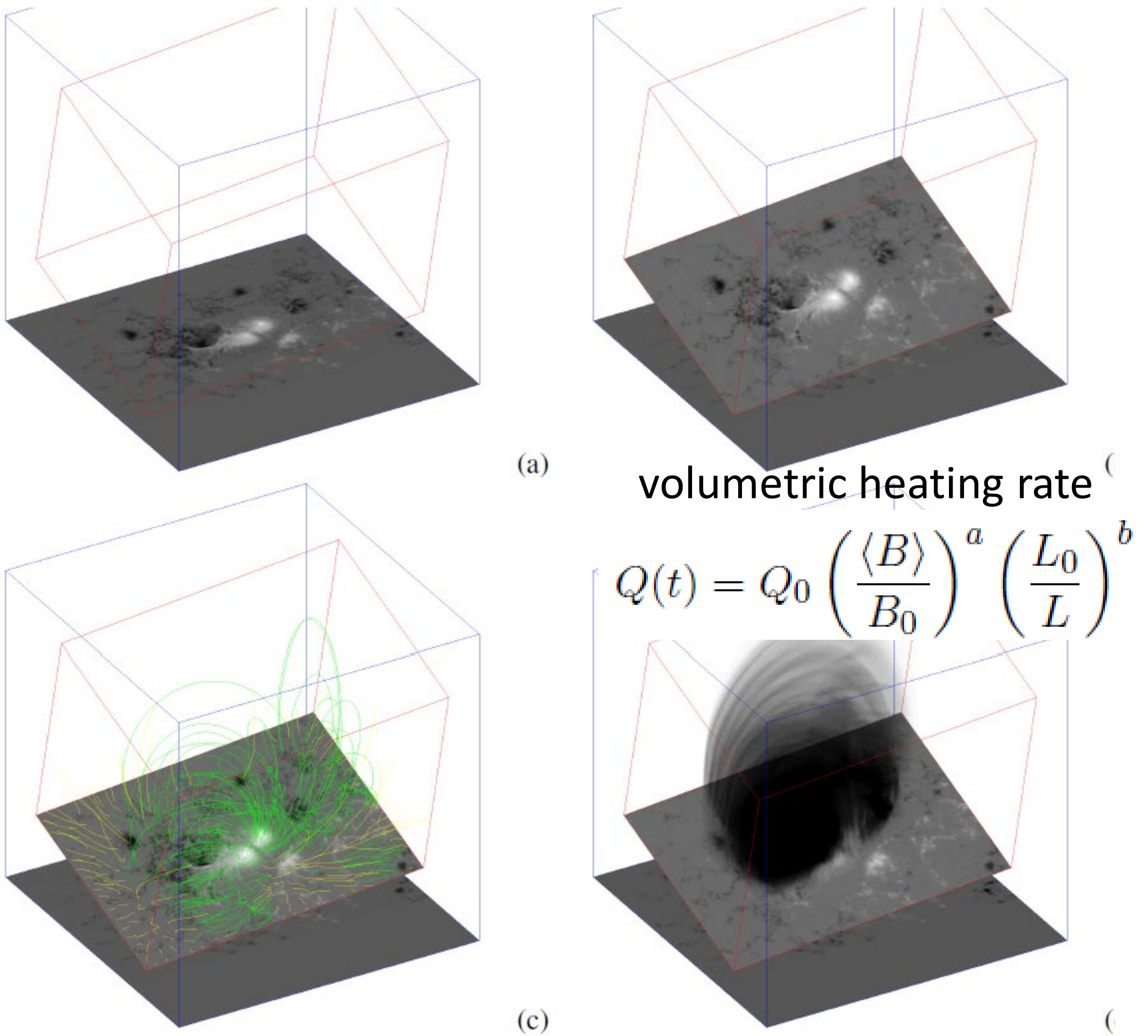
Automated Model Production Pipeline (AMPP)



Interface of Automated Model Production Pipeline

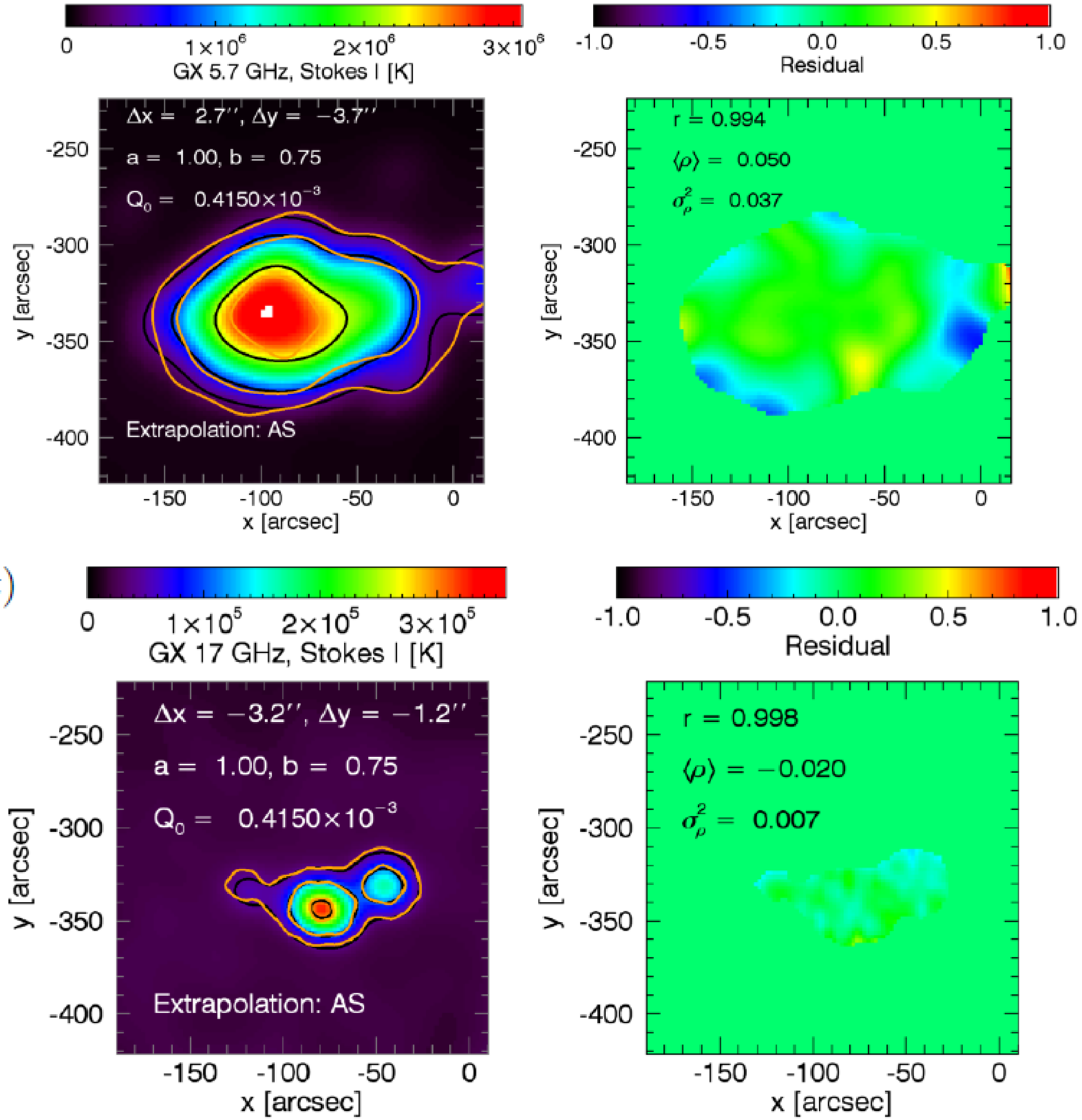


Model and synthetic images

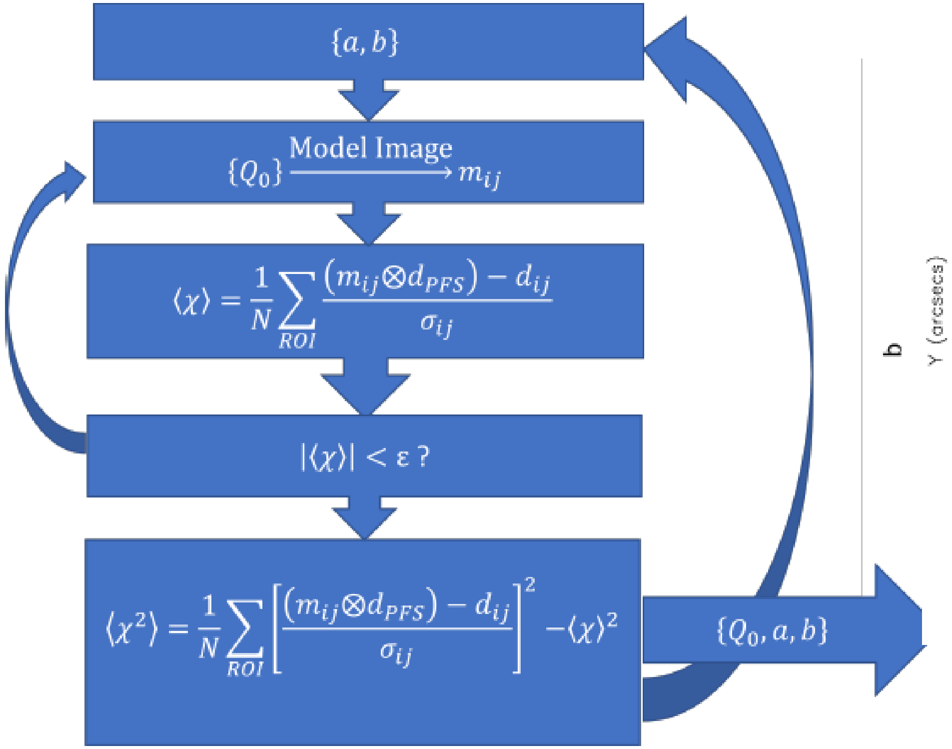


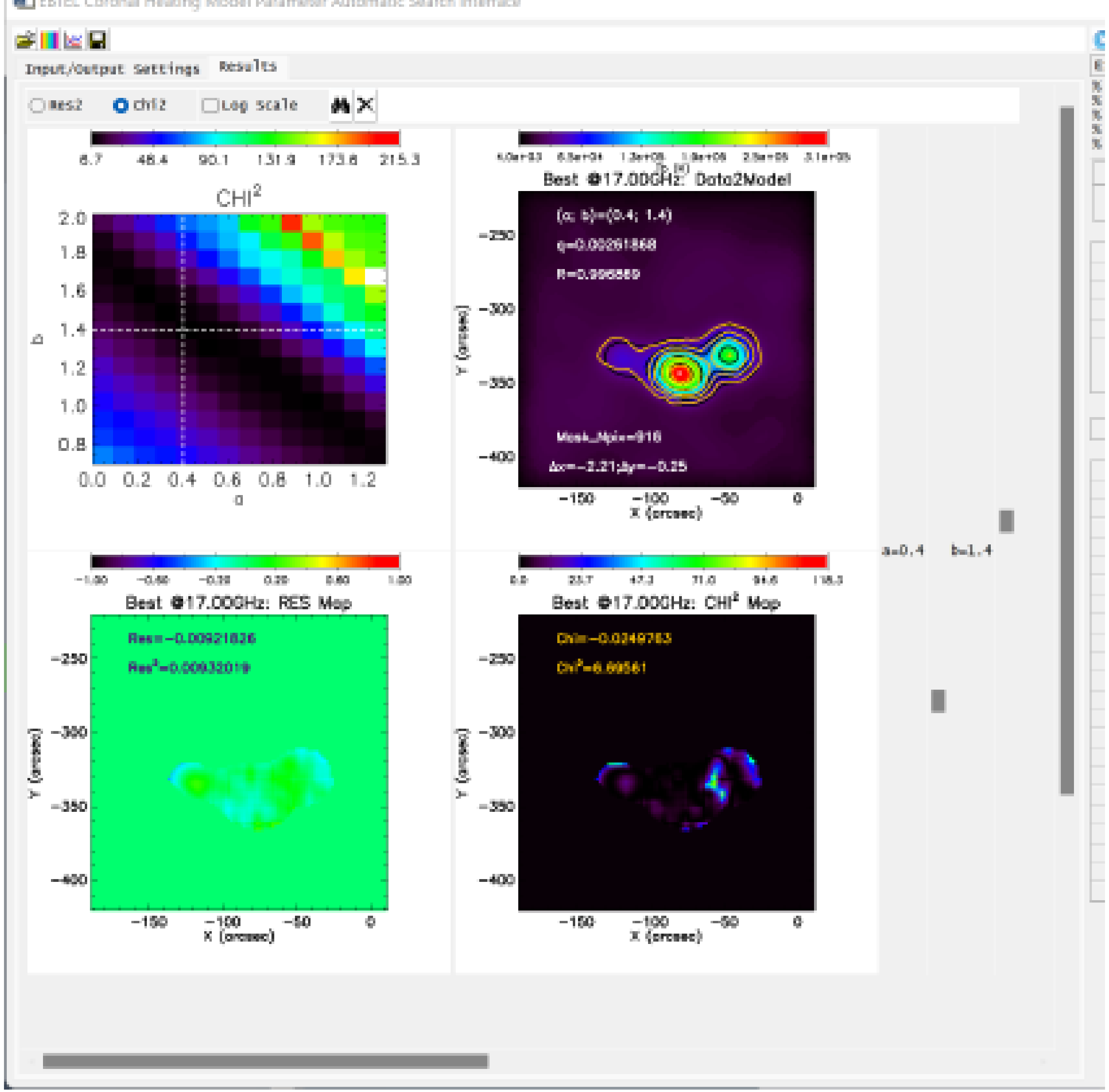
volumetric heating rate

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

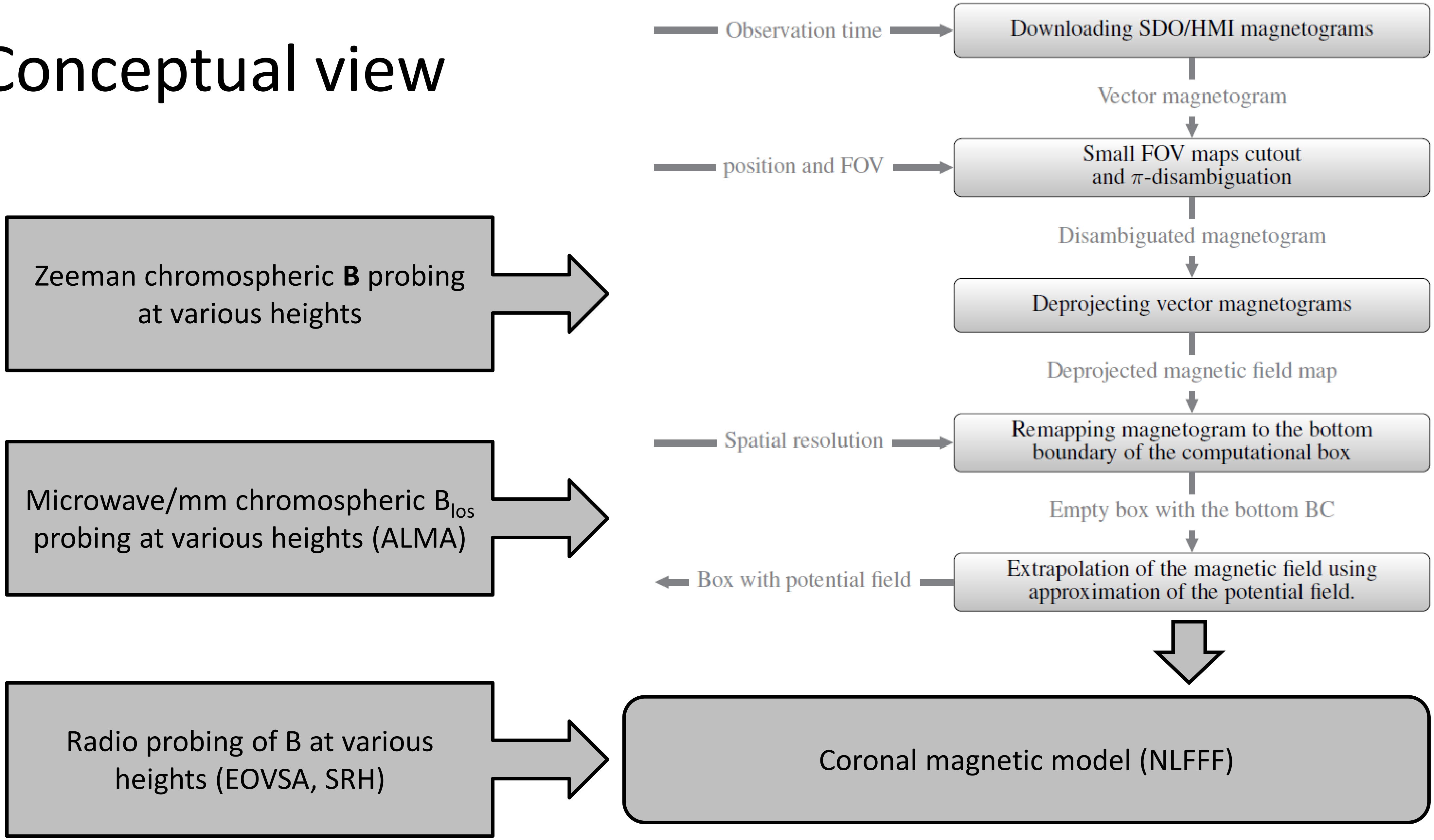


Fine tuning therm





Conceptual view



Radio Diagnostics of B

Radiation Process	Observables	Diagnostics
Free-Free (thermal)	Polarization (V/I)	B_{los} at the TR and chromosphere
Gyroresonant (thermal)	Stokes I Stokes V (opt)	|B| at the TR
Gyrosynchrotron (nonthermal)	Stokes I, or I & V, or L & R	|B| and θ in the flaring loops
Propagation of a polarized signal	Stokes I & V (L & R)	|B| at a quasi-transverse layer

Coronal B Field: Measurements vs Models