



Solar Irradiance and Semi-empirical, Physics Based Modeling

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Abstract

Solar Radiation Physical Modeling (SRPM) is a set of tools designed for studying the solar spectra in terms of the physics of the solar atmosphere. This system can be used for many purposes. One such purpose is the calculation of the solar spectral irradiance (SSI) using a set of semi-empirical models. SRPM takes into consideration physical processes that are well understood within the solar atmosphere. For example, radiative transfer is taken into account with a great level of detail in atomic and molecular species, with many ionization stages, levels, and lines. It applies the full non-local thermodynamic equilibrium (NLTE) calculations where necessary and the effectively thin approach when valid. SRPM can perform calculations for 1- and 3-dimensional structures whenever possible and relevant. To date, the mechanisms for chromospheric and coronal heating are still not well understood. Therefore, empirical forward modeling must be used to determine the temperature structure in these layers of atmosphere. In the photosphere, recent convection simulations yield a more theoretical structure that, despite the approximations made, matches fairly well with previously existent semi-empirical quiet-Sun models. However, magneto-convection simulations are only now becoming realistic enough to potentially replace the semi-empirical modules of the SRPM system.

Using the SRPM set of tools, SSI is computed from the far infrared to the extreme ultraviolet considering the observations of the magnetically heated solar surface features and the physical models built for them. SRPM includes all layers of the solar atmosphere, namely the photosphere, chromosphere, transition region, and corona. This poster provides a description of SRPM application to modeling SSI and discussion of its current results.

Current results (1)

- B & 1001 & Quiet-Sun inter-network
- D & 1002 & Quiet-Sun network lane
- F & 1003 & Enhanced network
- H & 1004 & Plage (that is not facula)
- P & 1005 & Facula (very bright plage)
- S & 1006 & Sunspot umbra
- R & 1007 & Sunspot penumbra

(See Fontenla et al. 2009a)

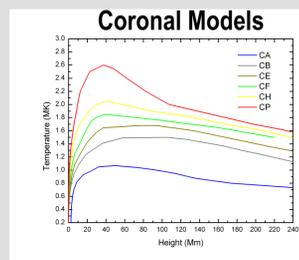
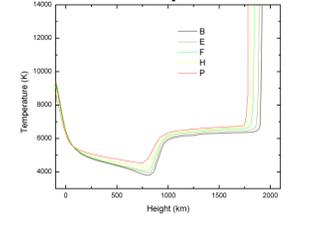
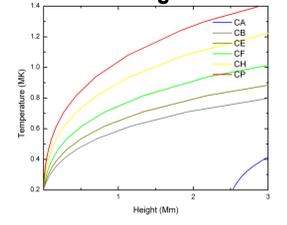


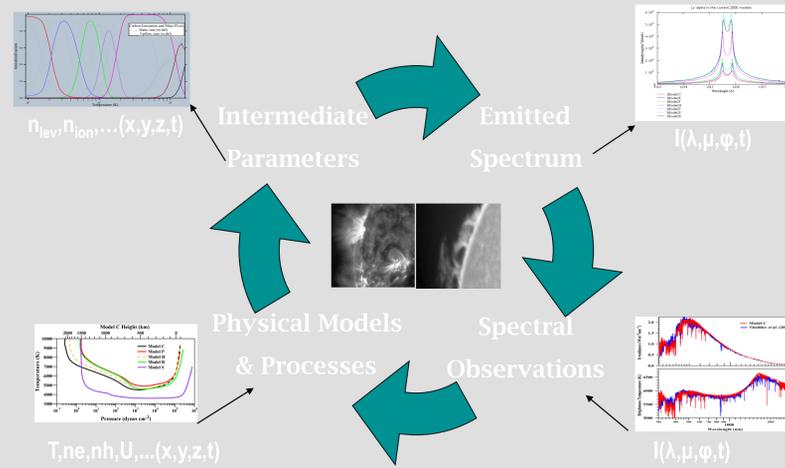
Photo-chromosphere Models



Transition Region Models



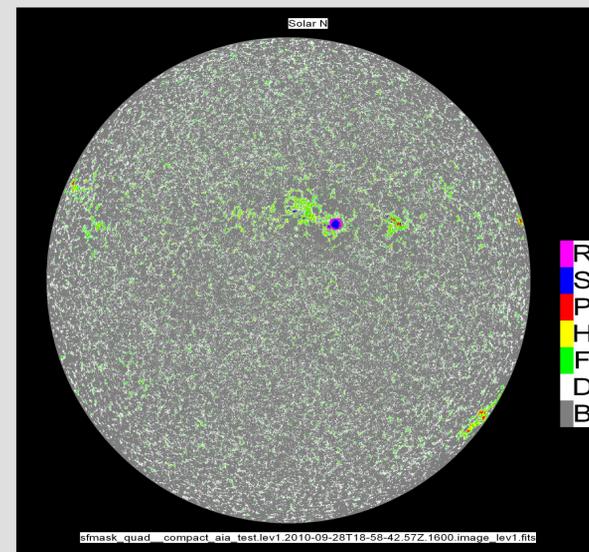
Solar Radiation Physical Modeling (SRPM)



SRPM is a method for understanding the solar atmosphere. The diagram on the left demonstrates the system's logic. Input can take the form of observational or model data, while output can be intermediate parameters or resultant emitted spectra. Comparisons can be made between the calculated and observational spectra.

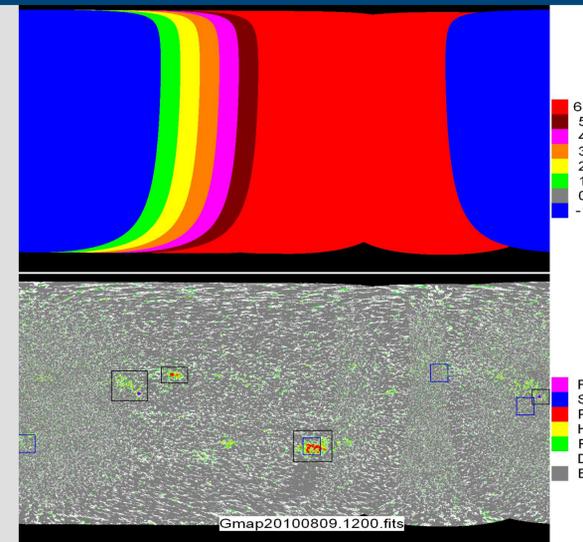
Intermediate parameters (e.g. number density) are generally the output of physical models, which provide a detailed characterization of the solar atmosphere. These parameters can then be used for a variety of purposes, the calculation of the emitted spectrum (Fontenla, Balasubramaniam, and Harder 2007).

Decomposing the Sun: Physical Models



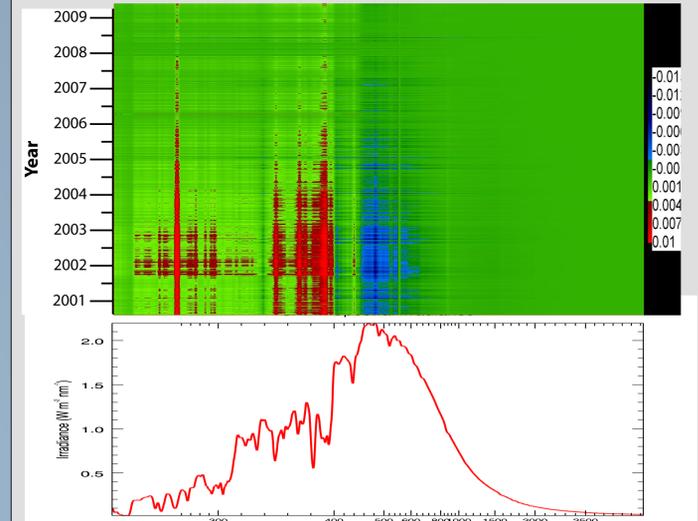
Each solar feature produces its spectral irradiance in a particular way. In order to obtain an irradiance that takes this spatial inhomogeneity into account, physical models for each feature are used to obtain a base set of spectra. These can then be summed for a particular solar observation to generate the emitted spectrum. The above figure shows an example of the solar decomposition into features, using colors to indicate the feature.

Far-Side Tracking and Forecasting



In order to forecast the solar irradiance using the feature models described in the pane to the left, one must know what features are on the back side of the sun. A technique has been developed to do this using helioseismology (Lindsey and Braun, 2000) and Lyman-alpha backscatter (Quémerais and Bertaux 2002). The result of the helioseismology technique is shown above. A synoptic chart is generated with far-side input from helioseismology. The top chart displays how long it has been since a particular section of the chart has been updated (i.e. since the section rotated around the eastern limb). The synoptic chart allows the temporal continuity of AR tracking and thus an uninterrupted forecast for the solar spectral irradiance. Forecasting can be extended to the range of 7-20 days (Fontenla et al. 2009b).

Current Results (2)



Top graph shows calculated irradiance at a particular time in the visible spectrum. The colored chart shows calculated irradiance as a function of time and wavelength. This high-resolution spectrum is calculated from the IR to the EUV and can be used as input to terrestrial climate models (e.g. global circulation models). Comparisons with the Spectral irradiance Monitor (SIM) and the Extreme Ultraviolet Variability Experiment (EVE) observations show very close agreement.

Conclusions and Outlook

SRPM is capable of improving our understanding of the physics in the solar atmosphere, generating SSI/TSI forecasts as far as 20 days out, and providing input to terrestrial climate models. Currently, the models employed for calculating SSI agree fairly well with observations. Many of the detailed difference are understood and the models are being improved accordingly. Some future improvements include updated ionic data, automated forecasts, and generalization to 3D radiative transfer.

References

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