

CHIANTI: An Atomic Database and Software Package for Astrophysical UV Spectroscopy

<https://chiantidatabase.org>

Peter R. Young, Code 671

History

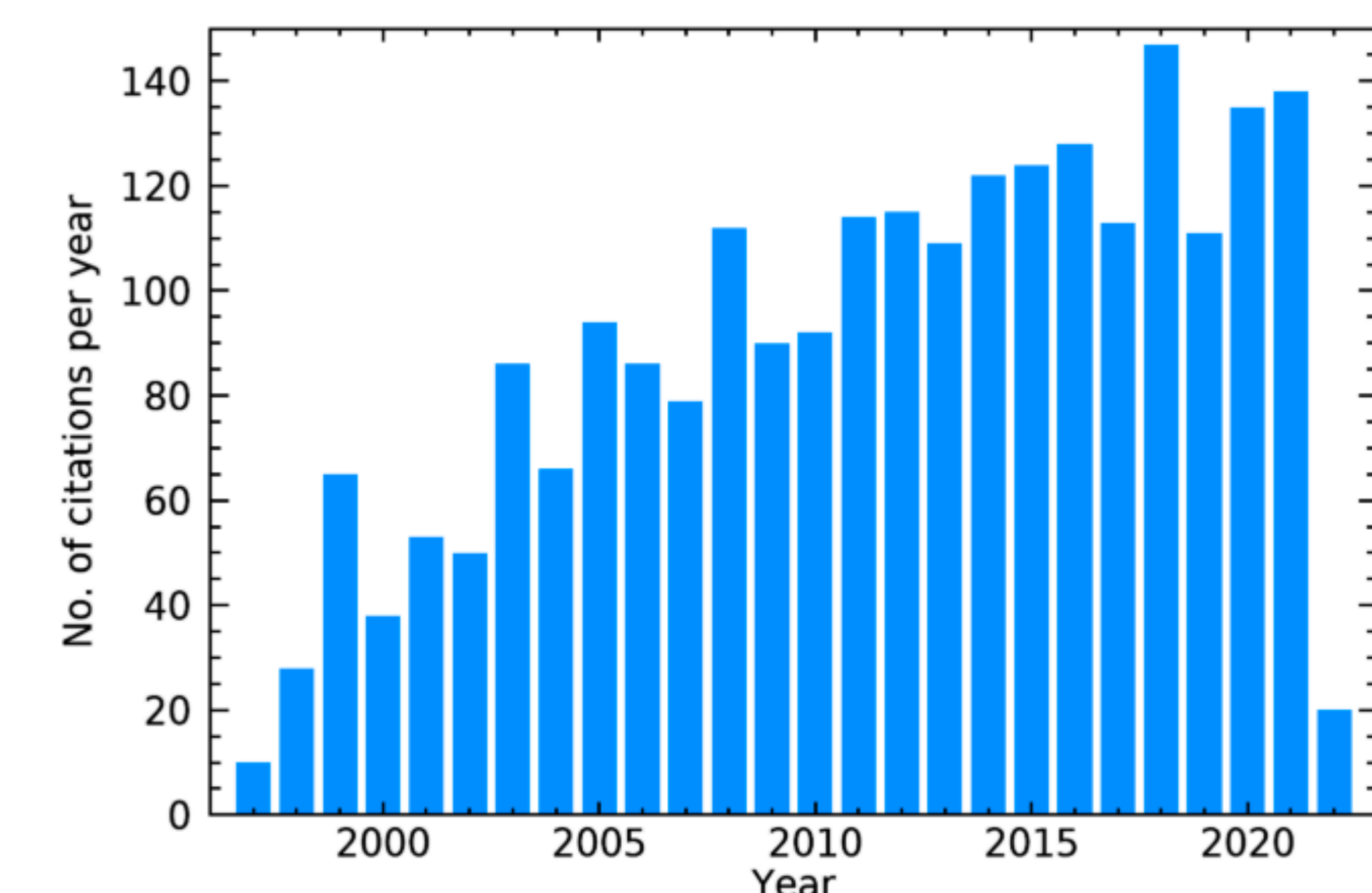
- First released in 1996 as an atomic database and an IDL software package.
- Developed for the UV spectrometers on board the *Solar and Heliospheric Observatory* (SOHO; launched 1995).
- Extension to X-ray region in 2001.
- Ionization and recombination rates added in 2009.
- Python version of software (*ChiantiPy*) released in 2010.
- Version 10 of CHIANTI released in 2020.
- Landmark of 4000 citations reached in 2022.
- Current team members: Peter Young (GSFC), Ken Dere (GMU), Enrico Landi (U. Michigan), Giulio Del Zanna (U. Cambridge).



CHIANTI was named for the wine-growing region in Tuscany, Italy. Arcetri Observatory (Florence) was one of the early collaborating institutes.

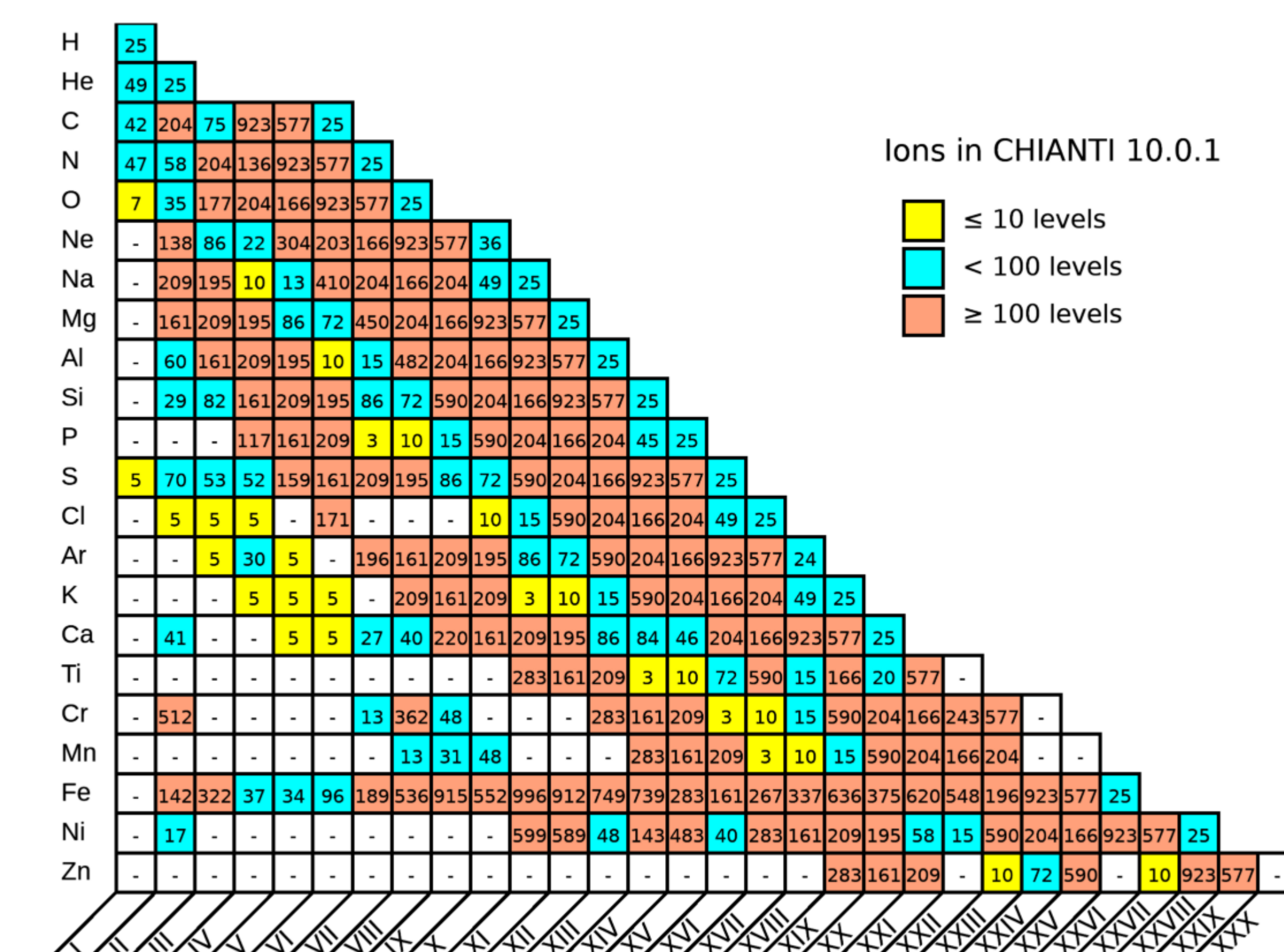
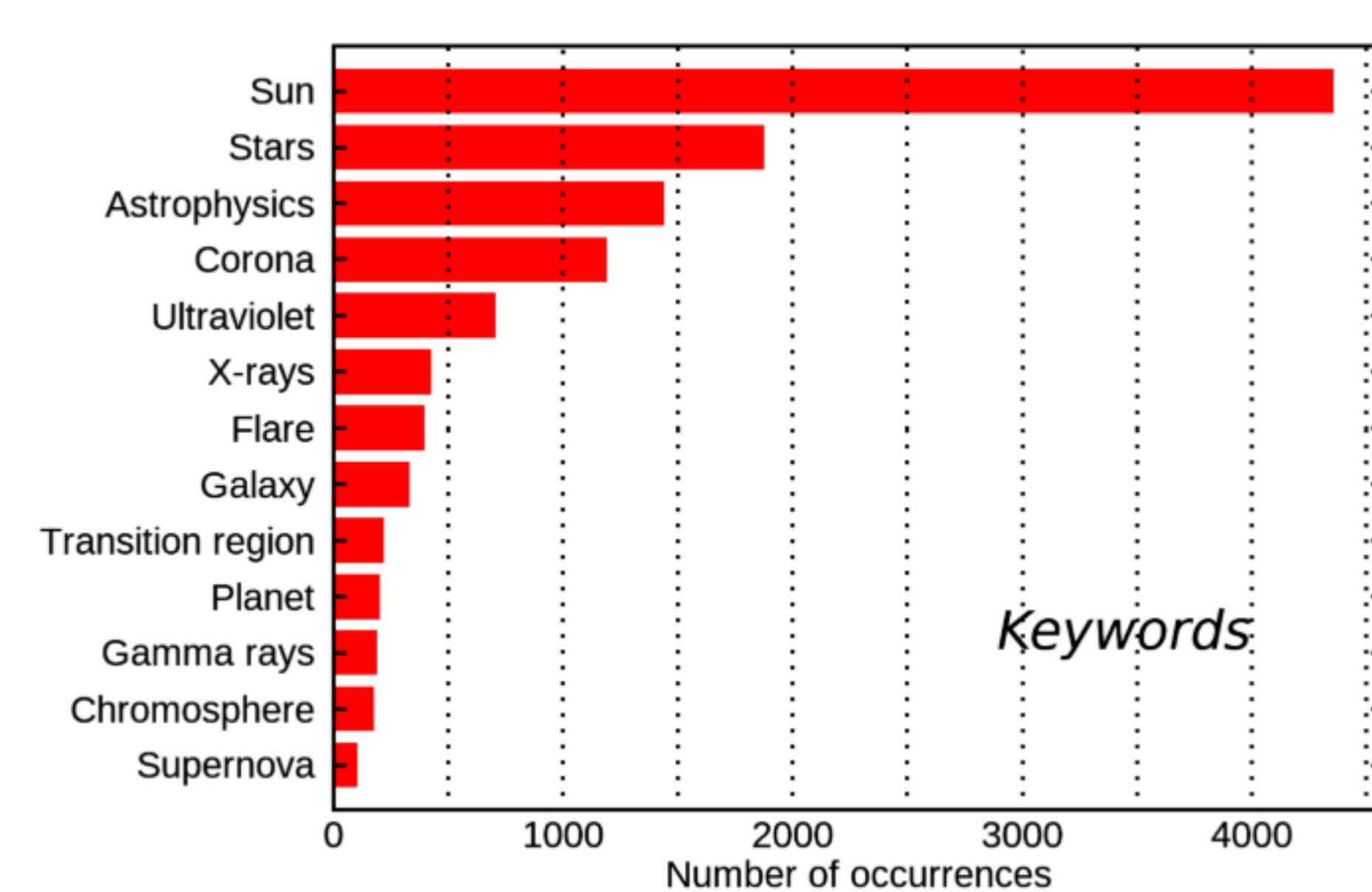
Documentation

- Each version of CHIANTI is described in a refereed journal article, beginning with version 1 (Dere et al. 1997).
- Del Zanna et al. (2021) describes CHIANTI version 10.
- The **CHIANTI User Guide** gives a detailed overview of the database structure and software.
- For specific topics there are **CHIANTI Technical Reports** covering, for example, file formats, level population calculations and continuum calculations.
- All documentation is available on our website at <https://chiantidatabase.org>.



Usage Statistics

- As of 28 March 2022, the CHIANTI papers have received 4038 citations. The chart above shows the change in citations since CHIANTI was released.
- Journal articles contain a set of keywords, and the most commonly-used keywords for articles that cite CHIANTI are given below.
- CHIANTI is widely used in Heliophysics, hence 'Sun' is the most common keyword.
- Other keywords such as 'Stars', 'Galaxy' and 'Planet' highlight the wider use of CHIANTI.

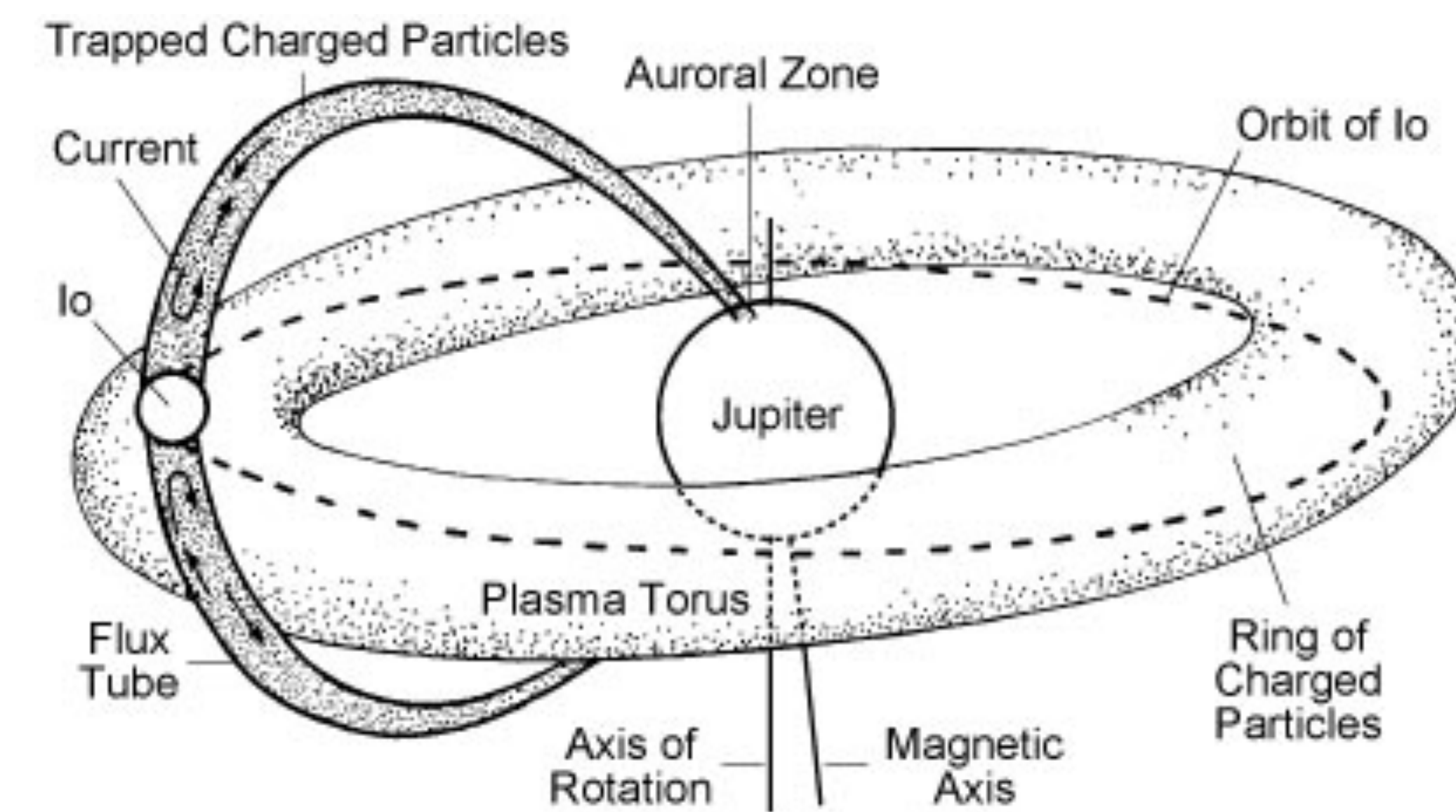


Atomic models and database

- The chart above identifies the ions for which CHIANTI has atomic data. The number in each box gives the number of fine-structure levels for that ion.
- CHIANTI principally developed for hot ($> 10^4$ K), low density ($< 10^{12}$ cm $^{-3}$) plasmas that are ionized through electron collisions (as opposed to photoionization).
- Key datasets:
 - *Experimental energy levels*
 - *Electron excitation rates*
 - *Radiative decay rates*
- Data files provided in ASCII format and freely available.

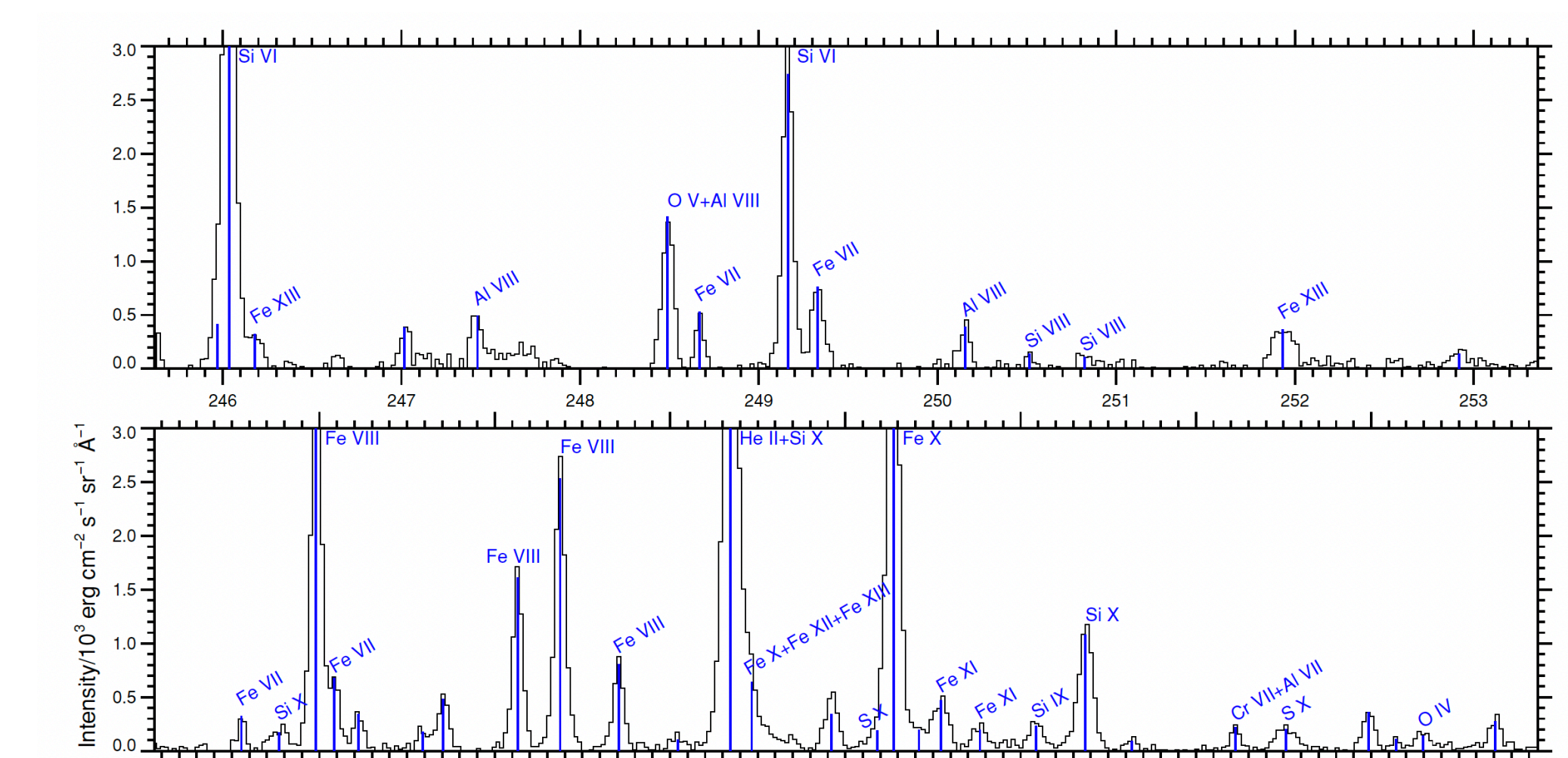
Software

- CHIANTI has an extensive software package written in IDL for performing the following tasks:
 - Creating synthetic spectra.
 - Studying temperature and density sensitive line ratio diagnostics.
 - Deriving the plasma differential emission measure (DEM).
- Two separate *Python* software packages are in development and available on GitHub:
 - *ChiantiPy* (K. Dere)
 - *FIASCO* (W. Barnes)



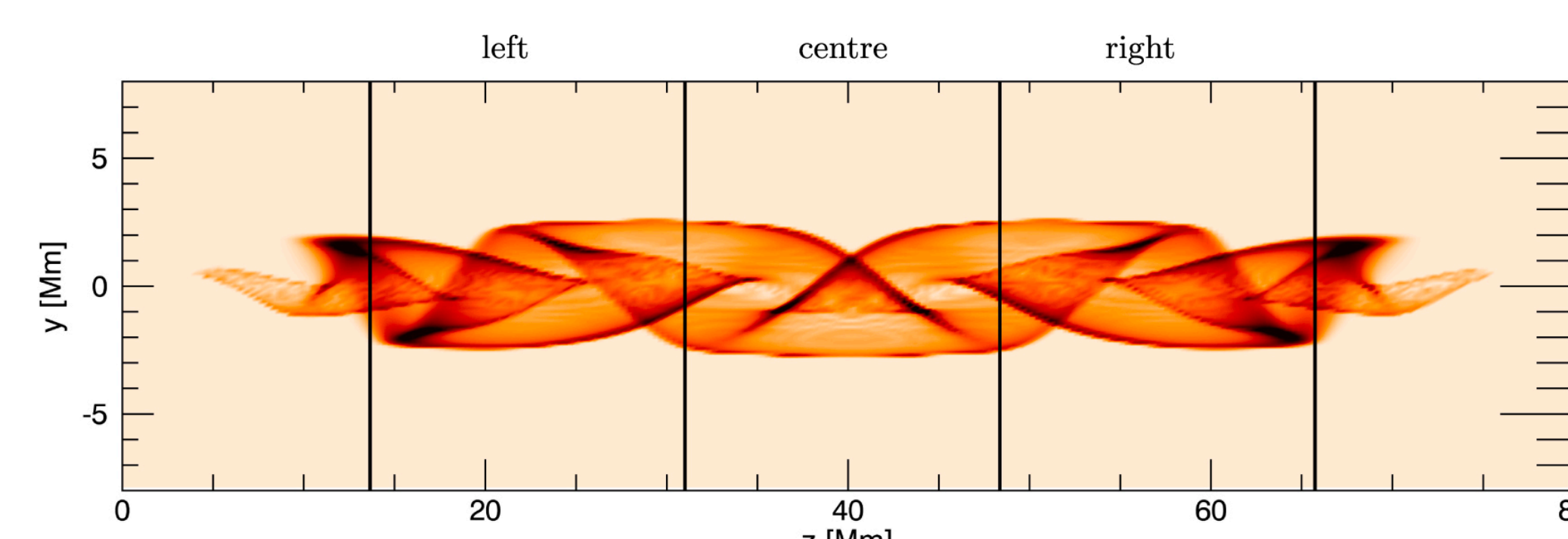
Application: The Jupiter-Io Plasma Torus

- The volcanoes of Io spew out mainly SO $_2$ that becomes ionized and forms a plasma torus along the Io orbit.
- The UV spectrum in the 50-150 nm range is dominated by ion stages +1 to +3 of sulfur.
- CHIANTI is used to model the torus spectrum (Steffl et al. 2004; Yoshioka et al. 2017).



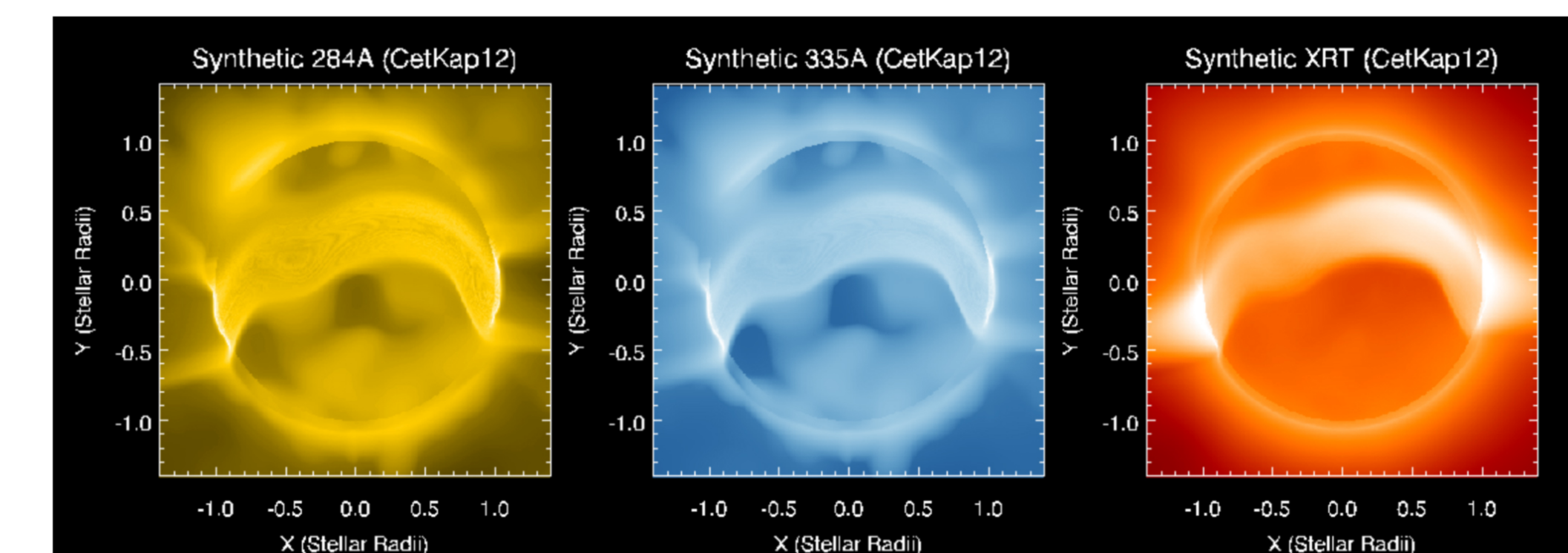
Application: The Solar EUV Spectrum

- The above plot shows two sections of an EUV spectrum from the EUV Imaging Spectrograph (EIS) on board the *Hinode* spacecraft.
- This spectrum was analyzed by Landi & Young (2009) and Young & Landi (2009) using CHIANTI.
- The labels demonstrate the wide range of elements and ions found in the solar EUV spectrum.
- Analysis of the solar EUV spectrum has been critical for motivating new atomic calculations for these ions.



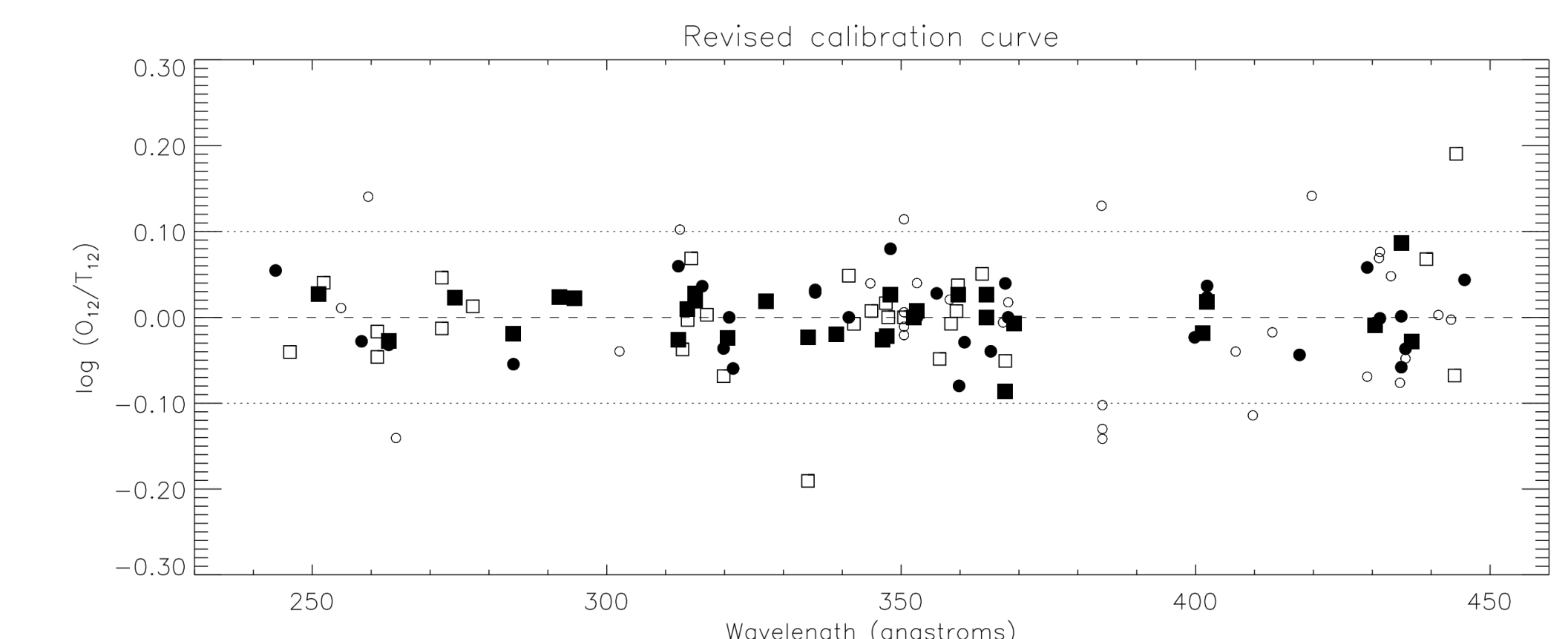
Application: Plasma Modeling Codes

- Many astrophysical phenomena are modeled with magnetohydrodynamic (MHD) codes.
- When coupled with the plasma thermodynamics, the temperature, density and velocity can be predicted at each pixel in the simulation.
- CHIANTI can then be used to predict the emission from the structures in specific atomic transitions.
- The example above shows the predicted emission in the 1.0747 μ m infrared line of Fe XIII from the simulation of a coronal loop by Snow et al. (2018).



Application: Predicting Stellar Coronae Emission

- The above plot shows predicted EUV and soft X-ray images of the corona of κ^1 Ceti (Airapetian et al. 2021).
- Magnetic field measurements of the star are combined with a 3D MHD model and constraints from UV spectra to yield temperature and density in the stellar atmosphere.
- CHIANTI is then used to derive the EUV and X-ray emissions from the star, producing the images shown above.
- Predictions of EUV emission are important for studying atmospheric escape and chemistry of exoplanet atmospheres.



Application: Instrument Calibration

- Rich emission line spectra such as those from the Sun offer many plasma diagnostic opportunities.
- They also present many lines for which the ratios are insensitive to the plasma conditions.
- These can be used to check the radiometric calibration of the instrument.
- The plot above is constructed from insensitive line ratios observed by the SERTS EUV rocket spectrograph (Young et al. 1998).
- The ratios revealed that vignetting was occurring at longer wavelengths causing ratios to differ from their values in CHIANTI
- The plot shows the results after the correction.

References

- Airapetian, V. et al., 2021, ApJ, 916, 96
- Del Zanna, G. et al., 2021, ApJS, 909, 38
- Dere, K.P. et al., 1997, A&AS, 125, 149
- Landi, E. & Young, P.R., 2009, ApJ, 706, 1
- Snow, B. et al., 2018, ApJ, 863, 172
- Steffl, A. et al., 2004, *Icarus*, 172, 78
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