Contribution ID: **102** Contribution code: **CC02** Type: **Talk**

How to Fit All Emission Lines Simultaneously with Photoionisation Models

Wednesday, January 7, 2026 12:20 PM (15 minutes)

Optical strong-line ratio diagnostics are standard tools for diagnosing the physical conditions of ionised gas in star-forming galaxies. However, traditional 2D BPT diagrams are not optimal for visualising inconsistency between data and model in multi-D line ratio space due to poor projection angles. Ji & Yan 2020 showed that using reprojections of 3D line ratio space will help visualise the inconsistency. They found a photoionisation model that can simultaneously fit [NII]/Halpha, [SII]/Halpha, and [OIII]/Hbeta ratios. However, this model and all other models in the literature significantly over-predicts the relative strength of [SIII] 9530A line by a factor of 3, and also has a small systematics in predicting the [OII] 3727 doublet strength. Significant modifications on the input assumptions of the photoionization model is required to simultaneously fit 5 line ratios composed by these 7 emission lines. We explored the model assumption space by changing the abundance pattern between O, N, and S and shifting the correspondence between stellar ionising SED and the gas metallicity. With these different assumptions, grids of photoionisation models are generated using Cloudy spanning a range of ionisation parameters and metallicities, which are compared with the data in three sets of 3D line ratio space. We found a best-fitting model that can reduce the discrepancy in [SIII/[SII] by a factor of two while maintaining the good agreement in [NII]/Ha, [SII]/Ha, and [OIII]/Hb. Such a model that can fit more line ratios simultaneously is crucial for refining strong-line calibrations of metallicity and ionisation parameters.

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Session Classification: Contributed talks

Track Classification: CC02: ISM and Astrochemistry