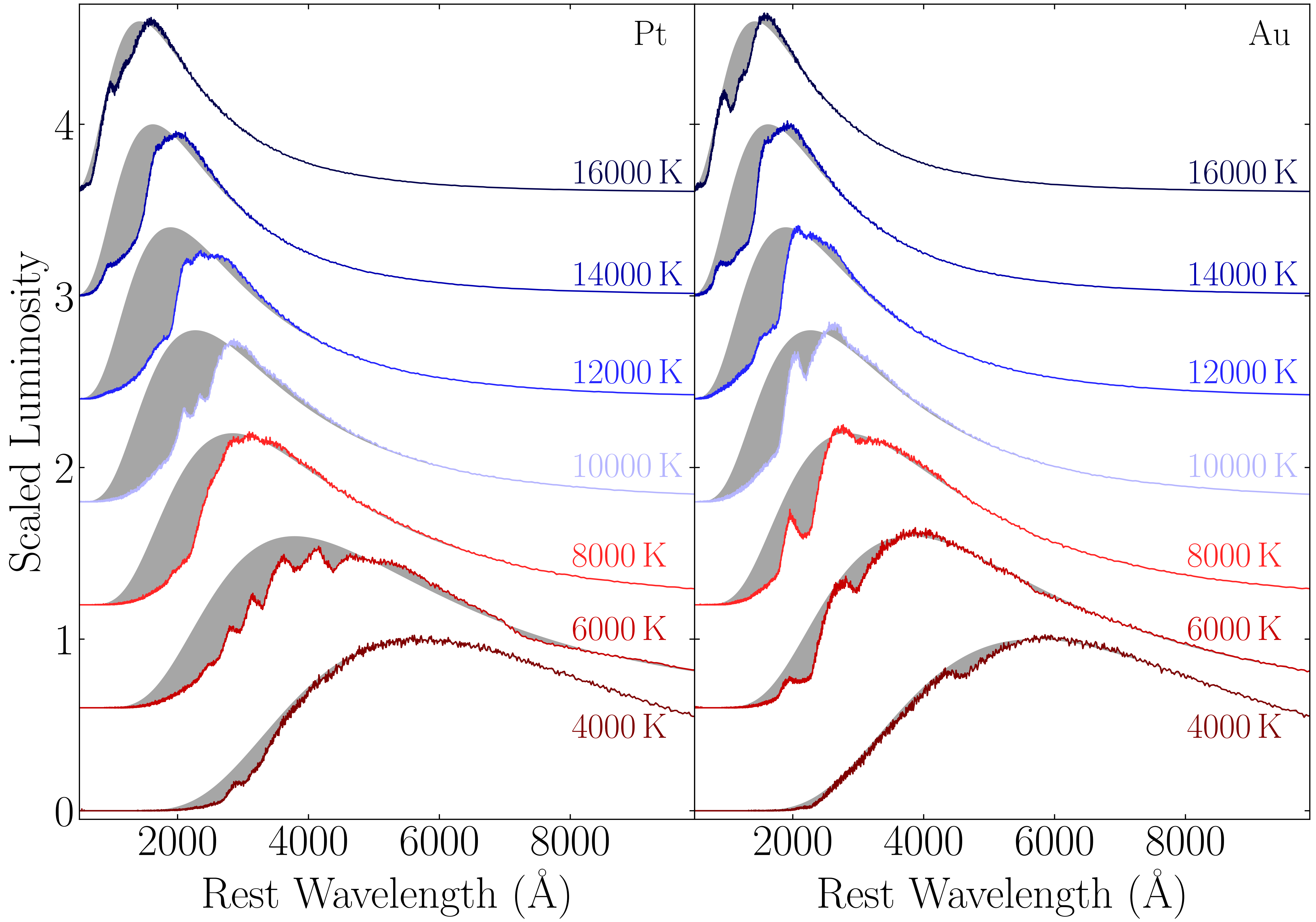
Spectroscopic modelling of the kilonova AT2017gfo

James Gillanders (Queen's University Belfast)

Pt and Au analysis paper accepted for publication in MNRAS (check out the preprint here)

Any comments/questions, feel free to come along and ask!

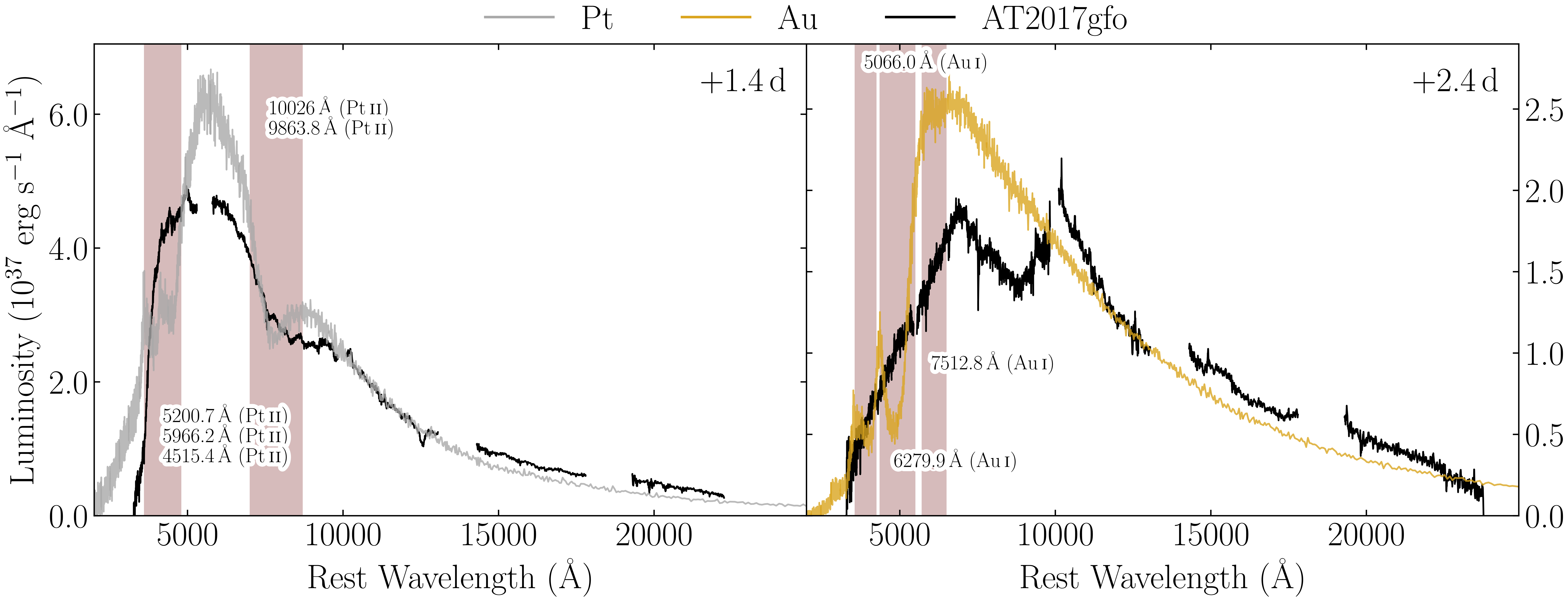
- Kilonovae are thought to produce some (or most) of the heavy *r*-process elements.
- When the first kilonova was discovered, in conjunction with the gravitational wave GW170817, there were claims it was rich in platinum and gold.
- To date, no-one has identified features of specific heavy elements.
- This is largely due to the lack of complete atomic data.
- We use new atomic data for neutral, singly- and doubly-ionised Pt and Au to demonstrate the usefulness of complete atomic data*.
- We produce photospheric and nebular phase model spectra, and compare to AT2017gfo.
- We find no strong evidence for Pt or Au features in the spectra of AT2017gfo, but highlight the usefulness of having access to a complete atomic data set for species of interest.



TARDIS models to illustrate the effect a realistic mass ($10^{-3}\,M_\odot$) of Pt & Au has on the SED at various ejecta temperatures.
There is line blanketing in UV, but no identifiable strong transitions in the optical or NIR.

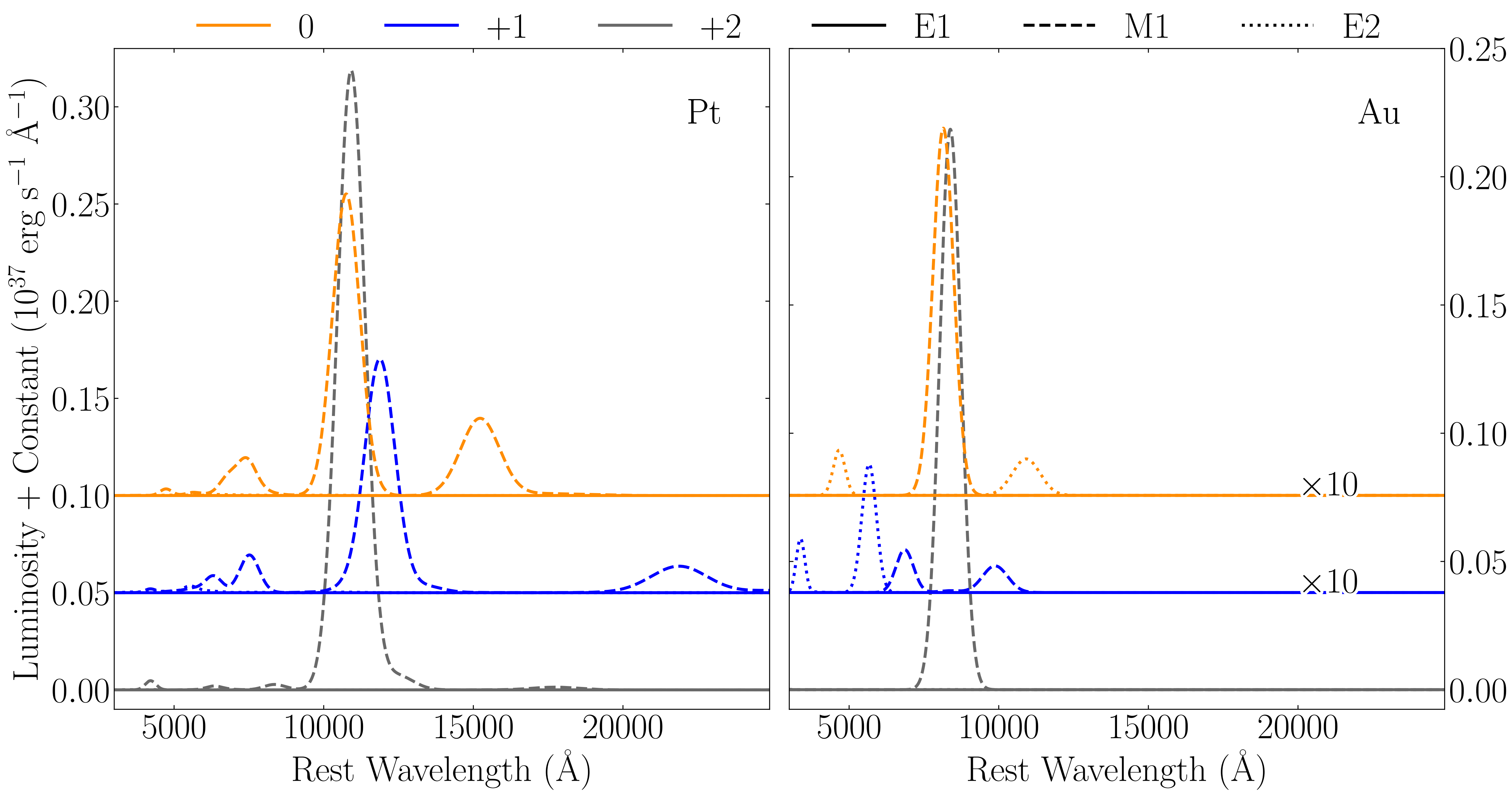
*Paper by Michael McCann (Queen's University Belfast), to be submitted to MNRAS.

Photospheric stage models with TARDIS

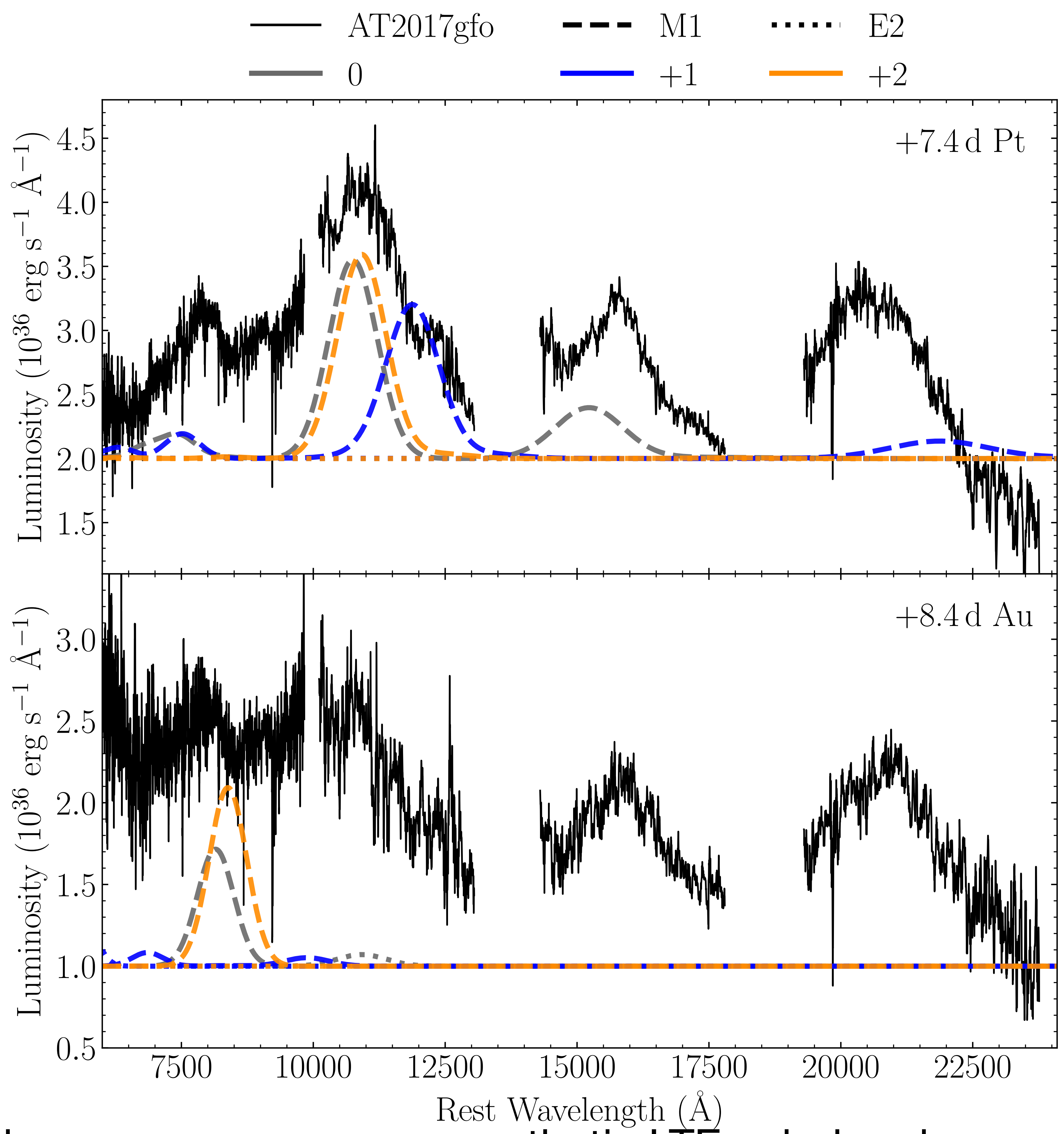


- High-mass pure Pt and Au TARDIS models to highlight the locations of the strongest potential features that would appear for these elements in an early phase spectrum.
- In both cases, the model spectra are compared with observed spectra of AT2017gfo to compare locations of the strongest features.
- The specific transitions that are most prominent are noted in the figure.
- We don't see good agreement between the strongest features of Pt/Au and the observed spectra.
- The Pt II absorption feature at $\sim 8500\,\text{Å}$ is coincident with an absorption feature in the observational data, but if this feature was the result of Pt II, then we should see the other features at bluer wavelengths.

Simple late stage nebular models



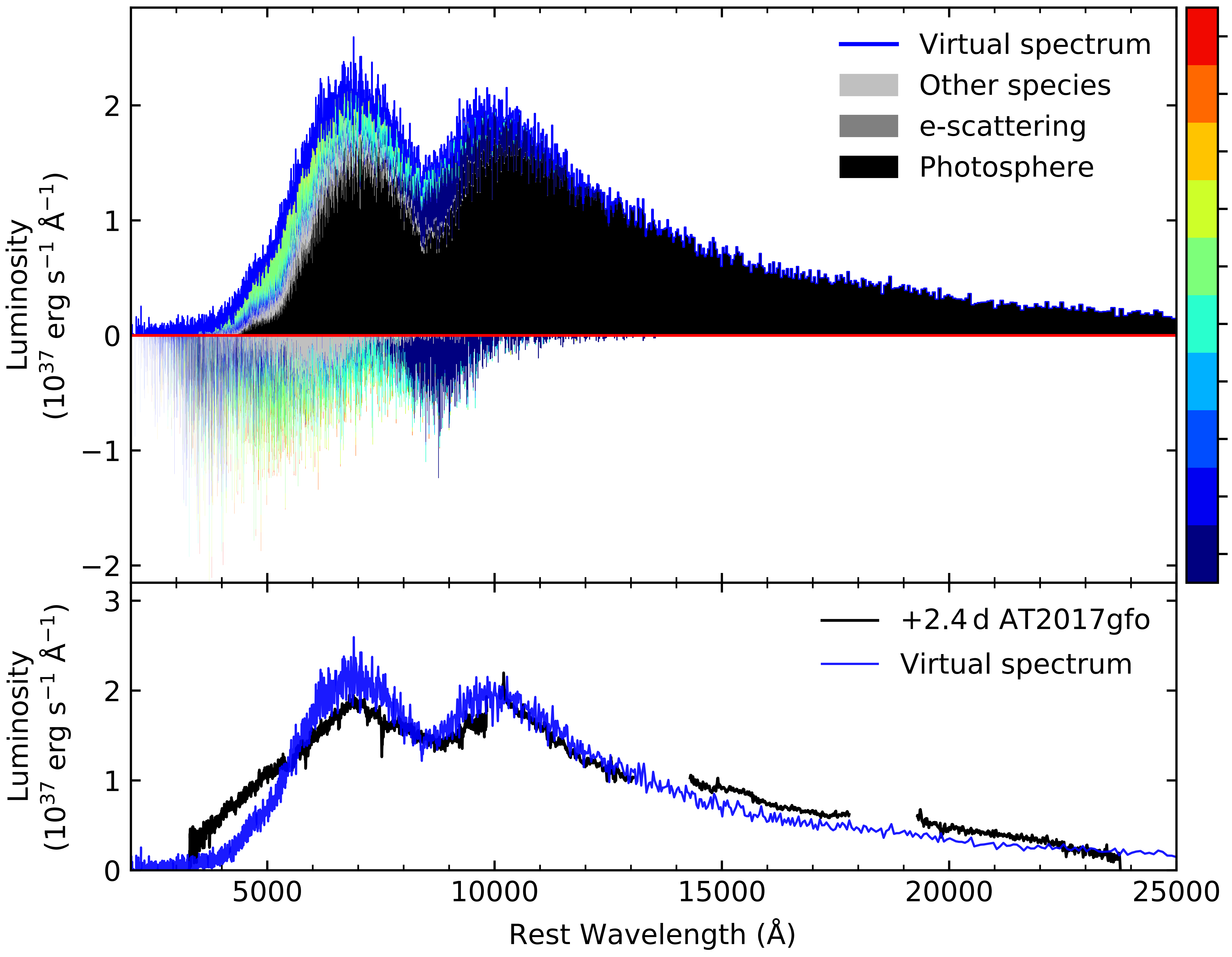
- Assuming a KN becomes optically thin, we can then predict the strongest emission features for Pt and Au, using the new atomic data set (McCann et al. in prep).
- Here we show a sequence of synthetic emission spectra for the individual ions of Pt and Au under investigation (left plot).
- Assuming LTE level populations, we were able to use the Einstein *A*-values for the transitions to calculate the strengths of features.
- From these, we can identify where these species would be expected to influence spectra.



- In the plot above, we compare our synthetic LTE nebular phase spectra for Pt I, II, III (top) and Au I, II, III (bottom) and two late-phase spectra of AT2017gfo.
- For our models there are features of comparable strength to those of AT2017gfo, for reasonable masses of Pt and Au (10^{-3}, 10^{-3} and $5 \times 10^{-4}\,M_{\odot}$ for Pt I, II and III, respectively, and 5×10^{-3}, 5×10^{-3} and $5 \times 10^{-4}\,M_{\odot}$ for Au I, II and III, respectively.)

Realistic composition models with TARDIS

- Previous works have attempted to identify specific features in the spectra of AT2017gfo (Smartt et al. 2017; Watson et al. 2019; Perego et al. 2020).
- These have focussed on fitting the data empirically.
- In this work, we are using realistic compositions that have been computed from BNS merger simulations and nucleosynthesis calculations (Bauswein et al. 2013; Goriely et al. 2013, 2015).
- Here we are taking these realistic compositions and attempting to forward model to match the observed sequence of spectra.
- Best-fitting TARDIS model for an early spectrum of AT2017gfo.
- Top panel: Model spectrum with the different contributions to the spectrum highlighted. There is significant contribution from photons that do not interact with the ejecta (black). We find Sr II produces strong absorption at $\sim 8000 - 10000$ Å, and that the spectrum is dominated by line blanketing from a multitude of heavy elements at shorter wavelengths.
- More to come!



References:
Bauswein A., Goriely S., Janka H. T., 2013, ApJ, 773, 78
Goriely S., Bauswein A., Janka H.-T., 2011, ApJ, 738, L32
Goriely S., et al., 2013, Phys. Rev. Lett., 111, 242502
Goriely S., et al., 2015, MNRAS, 452, 3894
Perego A., et al., 2020 (arXiv:2009.08988)
Smartt S. J., et al., 2017, Nature, 551, 75,
Watson D., et al., 2019, Nature, 574, 497