# *Even less gas around AU Mic*

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***Abstract***
We use high-resolution optical spectroscopy in order to improve the sensitivity to gas in the AU Mic disk by up to a factor ~1000 compared to previous attempts. No gas is found, implying that whatever gas-generating mechanism is operating in β Pic, it is absent in AU Mic.

***Background***
AU Microscopii is a nearby (10 pc) young (~12 Myr) star belonging to the β Pictoris moving group (Zuckerman & Song 2004, ARA&A 42:685) and harbouring an edge-on disk very similar to the one around β Pictoris itself. Because of its edge-on orientation, the disk is amenable to absorption spectroscopy, currently the most sensitive method to search for circumstellar gas (Lecavelier des Etangs et al. 2001, Nature 412:796; Roberge et al. 2005, ApJ 626:105; Redfield 2007, ApJ 656:97). A complication is that the star is a slow rotator ($v \sin i \sim 7$ km/s) of late type (M0V), resulting in many narrow absorption lines from the stellar atmosphere itself (in contrast to β Pic), and little flux in the bluer regions where most of the electronic transitions of atoms and ions are located. In addition, AU Mic is a very active star, meaning plenty of chromospheric emission lines, making the background continuum determination for absorption lines more challenging. The bright chromospheric emission lines have been used as an advantage in the FUV, where the photosphere otherwise is too dark to be detected. Using archival FUSE data, Roberge et al. (2005) have determined upper limits for $H_2$ ($N_{H_2} < 10^{19}$ cm$^{-2}$) around AU Mic using C II and O IV (at 1050 Å) emission lines as their background. Meanwhile, France et al. (2007, ApJ 668:117) find some tentative emission lines from hot $H_2$ (>800 K), at a column density of up to two orders of magnitude (depending on assumed temperature) below the Roberge et al. (2005) upper limit.

***This work***
Since we expect any gas orbiting AU Mic in the disk to be cold, thus their absorption lines to be narrow (< 2 km/s, as seen in β Pic), high spectral resolution up to R~150 000 is advantageous as it will resolve the chromospheric emission lines and simplify the estimate of the background to (unresolved) absorption lines. By observing metallic species in the blue/NUV (rather than $H_2$ in the FUV), we improve the sensitivity to gas by ~1000 (assuming cosmic abundance). This is due to the strong ground-state transitions available for e.g. Ca and Fe, compared to H. The metallic gas is also what has been observed around β Pic, while no convincing detection of hydrogen has been found yet (Thi et al. 2001, Nature 409:60; Lecavelier des Etangs et al. 2001; Chen et al. 2007, ApJ 666:466; Kamp et al. 2007, ApJ 660:469).

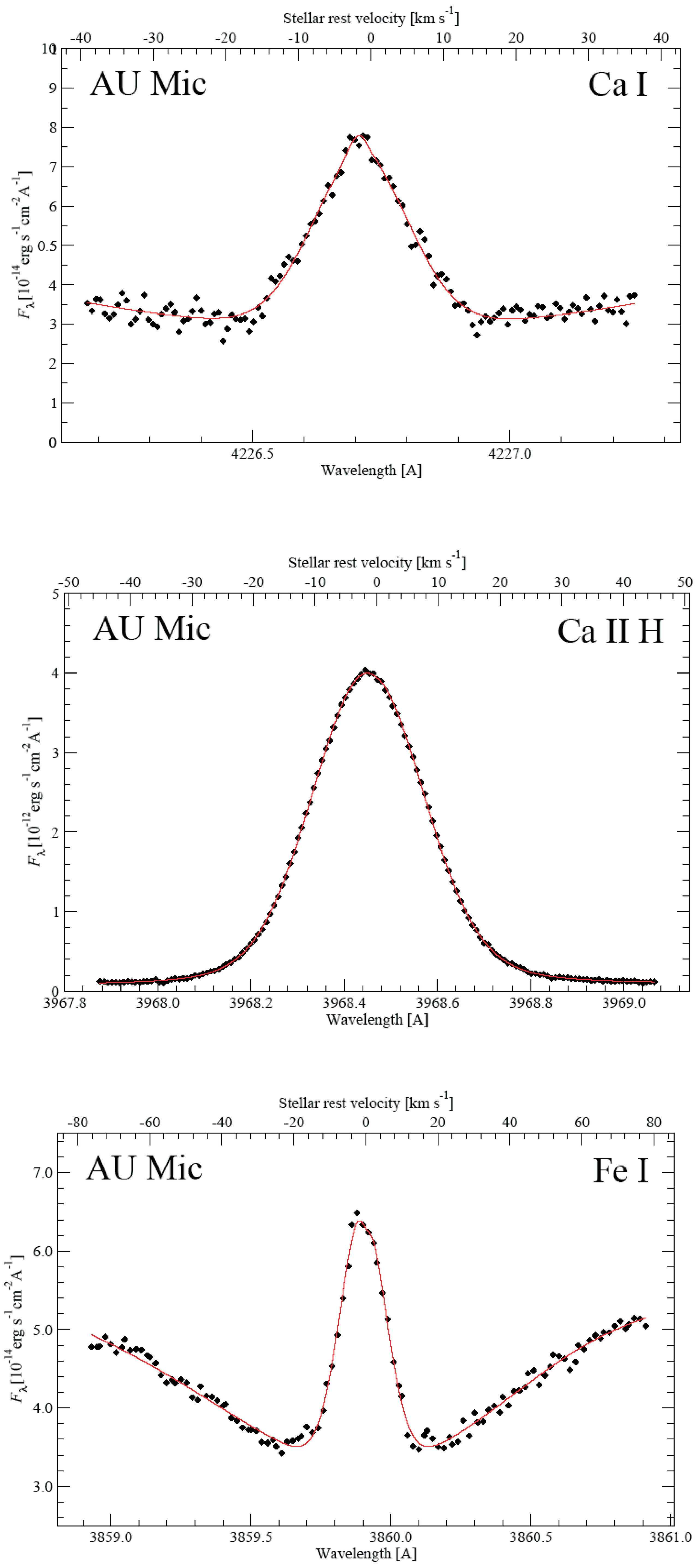
***Observations***
We used bHROS at Gemini South to simultaneously observe the Ca II H line (at 3968 Å) and the Ca I 4227 Å, thereby constraining the total Ca content, and also ionisation in case of detection. bHROS is a high-resolution ($R$~150 000) fiber echelle spectrograph, but with a limited simultaneous wavelength coverage. In a follow-up, we used the MIKE echelle spectrograph ($R$~83 000) at the Magellan/Clay 6.5m telescope, to observe Fe I at 3860 Å.

***Analysis***
The chromospheric emission lines are often well approximated by two superimposed Gaussians, one narrow and one broad, with the broader slightly redshifted (Redfield et al. 2003, ApJ 581:626). In addition, for the Ca I and Fe I lines there is a photospheric background in the form of a corresponding stellar absorption line, deeply pressure broadened. Consequently, we estimate the background continuum of any potential absorption line to be the superimposed sum of a Lorentzian profile (in absorption) and two Gaussian profiles (in emission), and fit for their parameters excluding the central 3 km/s region of the potential absorption line (so as to not bias the fit against absorption). With the background fit as a starting point, we then include an absorption line in the model, of width 2 km/s at the rest velocity of the star but at an unconstrained strength, and then fit the background simultaneously with the absorption line. In order to assess the statistical properties of the fit, we use $10^4$ monte carlo simulations per line, where random values normally distributed according to the estimated standard deviation per pixe are added, before a new fit is made.

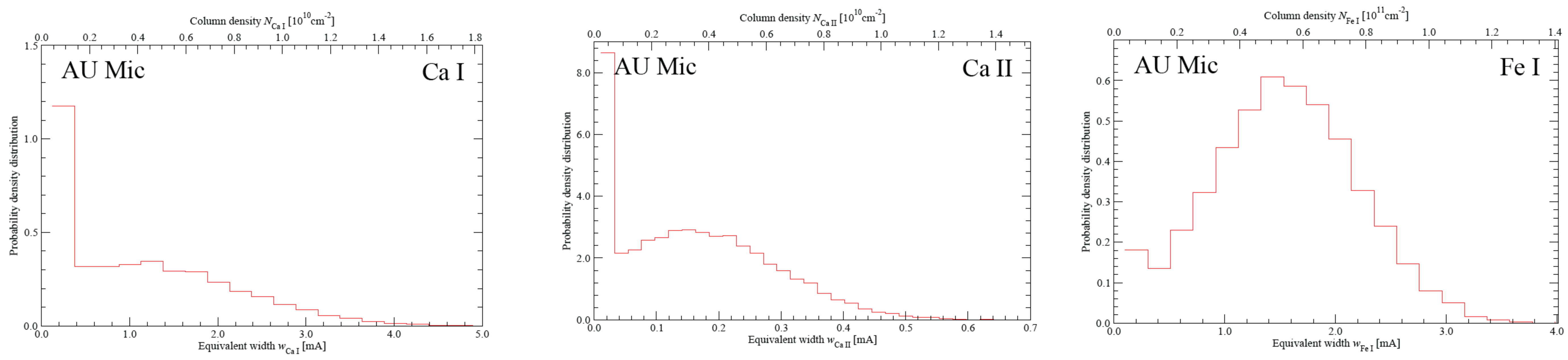
***Results***
We find no evidence for circumstellar Ca I, Ca II or Fe I gas around AU Mic. Our 3σ upper limits are $w_{\mathrm{Ca\,I}} < 1.4$ mÅ (corresponding to $N_{\mathrm{Ca\,I}} < 1.5\times10^{10}$ cm$^{-2}$), $w_{\mathrm{Ca\,II}} < 0.53$ mÅ ($N_{\mathrm{Ca\,II}} < 1.2\times10^{10}$ cm$^{-2}$), and $w_{\mathrm{Fe\,I}} < 3.3$ mÅ ($N_{\mathrm{Fe\,I}} < 1.2\times10^{12}$ cm$^{-2}$). The Fe I line is slightly asymmetrical, possibly indicating a small absorption at the 2σ level ($w_{\mathrm{Fe\,I}} = 1.4\pm0.7$ mÅ, $N_{\mathrm{Fe\,I}} = 4.9\pm2.5\times10^{11}$ cm$^{-2}$). The estimated probability distributions of the equivalent width / column density are presented below. Together, the column density of Ca is $N_{\mathrm{Ca}} < 2.7\times10^{10}$ cm$^{-2}$. For a gas of cosmic composition ($n_{\mathrm{Ca}}/n_{\mathrm{H}} \sim 2.29\times10^{-6}$), this implies $N_{\mathrm{H}} < 1.1\times10^{16}$ cm$^{-2}$, or $N_{H_2} < 6\times10^{15}$ cm$^{-2}$ (should all H be $H_2$).

***Discussion***
In the absence of a braking mechanism, the Ca gas would be removed by the radiation pressure from the chromospheric lines (not taken into account in Fernández et al. 2006, ApJ 643:509). The additional radiation pressure from chromospheric lines on Fe, however, is too small for Fe to be removed in the same way. Using the ionisation fraction determined by Fernández et al. (2006; $n_{\mathrm{Fe\,I}} \sim n_{\mathrm{Fe\,II}}$), we find the upper limit on Fe to be $N_{\mathrm{Fe}} < 2.4\times10^{12}$ cm$^{-2}$, corresponding to $N_{\mathrm{H}} < 7\times10^{16}$ cm$^{-2}$. Even if the tentative 2σ detection of Fe I is real and circumstellar (it could be interstellar), there is extremely little gas around AU Mic.

***Conclusion***
Whatever mechanism is producing gas in the β Pic disk, it is not present or is very inefficient in AU Mic.




*The black diamonds show the data, and the red line the fitted model.*




*Probability density distributions of the equivalent width and column density, as estimated from $10^4$ monte carlo simulations.*