Scientific context

Our team requests MPG 2.2m / FEROS observations of the DQ Tau system, which consists of an eccentric (e=0.568) spectroscopic binary embedded in a protoplanetary disk at 200\,pc [1]. The system is unique due to its periodic X-ray and sub-millimeter continuum flares and shows increased accretion signatures at periastron [2, 3, 4, 5]. These features are likely the result of complex interactions between the young stars' magnetic fields and the circumbinary disk. With an accepted ALMA proposal for the current Cycle (2021.1.01414.S, PI: S. van Terwisga) we will observe directly how the molecular layer of the protoplanetary disk responds to changing ionization conditions for the first time. In turn, these observations will be a powerful and direct tracer of the density structure and ionization degree of the molecular layer of the protoplanetary disk [6]. These are key parameters for models of their evolution and for the formation of planetary systems.

FEROS spectra of this system, taken (virtually) simultaneously with the sub-millimeter observations over the course of one orbital period of the binary, will provide a number of key observables. No other optical spectroscopy at such high resolution exist for DQ Tau at the moment.
First, these data will enable accretion rate measurements onto both stars, thanks to the high spectral resolution and large number of expected emission lines of H, as well as [OI] 3600\,$\AA$, CaII 8542\,$\AA$, and others [e.g. 7, 8]. We will use the known accretion rate to constrain the UV excess, a key component in our time-dependent disk chemistry models.
Second, FEROS spectroscopy during this epoch will allow us to refine or update the orbital parameters of the binary by Czekala et al. 2016. These observations will also shed new light on the interactions between the disk, the accretion streams, and the complex and interacting stellar magnetic fields of the central binary.

Additional data

We have currently already confirmed several independent optical/NIR broadband observations which will span the time immediately preceding and during the period of the ALMA and the proposed FEROS observations. The MASTER robotic telescope network, the Konkoly RC80 telescope, and TESS data at high cadence will observe DQ Tau throughout the epoch we target. We will therefore have up-to-date information on the brightness, color, and accretion state. These observations, and the high-resolution spectroscopic monitoring with FEROS we propose, will allow us to gain new insights into the DQ Tau system to be used for the ALMA observational campaign.

Technical

Our accepted ALMA program asks for observations to be scheduled on 2, 4, 6, 8, 10, 12, 16, and 20 December 2021. We expect the stellar and accretion activity to be strongest in a period of $\Delta\varphi = 0.4$ around periastron. This corresponds to the 6 days between 2 and 8 December 2021. The source (04h46m53.057s +17d00m00.135s) is easily observed at night during this period. The dates of these observations have dark sky conditions (moon illumination < 30% and large angular separation).

We aim for an S/N of 70 at 730 nm for each spectrum, which corresponds to about 36 minutes of on-source integration time (excluding overhead) per iteration. This was calculated using the FEROS observing time calculator, assuming mag_V = 13.7 (a conservative estimate for the magnitude in quiescence). It is expected that the source is brighter during (part of) the nights we request. In total, then, our observing time would come out to 3.5h, plus overheads. Although our team has some experienced observers, it should be mentioned I do not have any previous experience working with FEROS.

References

[1] **Czekala** et al. 2016, ApJ, 818, 156 [2] **Getman** et al. 2011, ApJ, 730, 6 [3] **Salter** et al. 2010, A&A, 521, A32 [4] **Tofflemire** et al. 2017, ApJ, 835, 8 [5] **Kóspál** et al. 2018, ApJ, 862, 44 [6] **Cleeves** et al. 2016, ApJ, 843, L3, [7] **Alcala** et al. 2017, A&A, 600, A20 [8] **Manara** et al. 2013, A&A, 558, A114