Leibniz-Institut für Astrophysik Potsdam

AIP

CV science with Athena: A case study of AM Herculis

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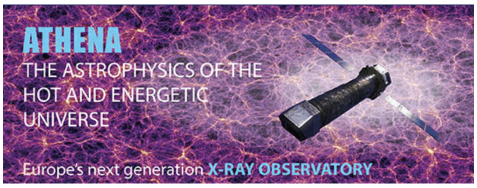


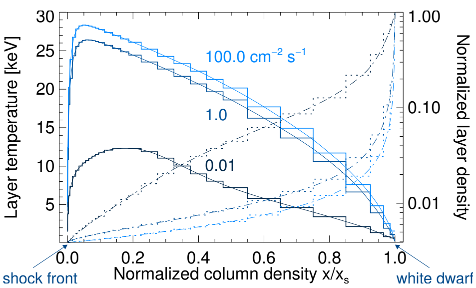
(http://www.the-athena-x-ray-observatory.eu/)

Motivation: CVs with Athena

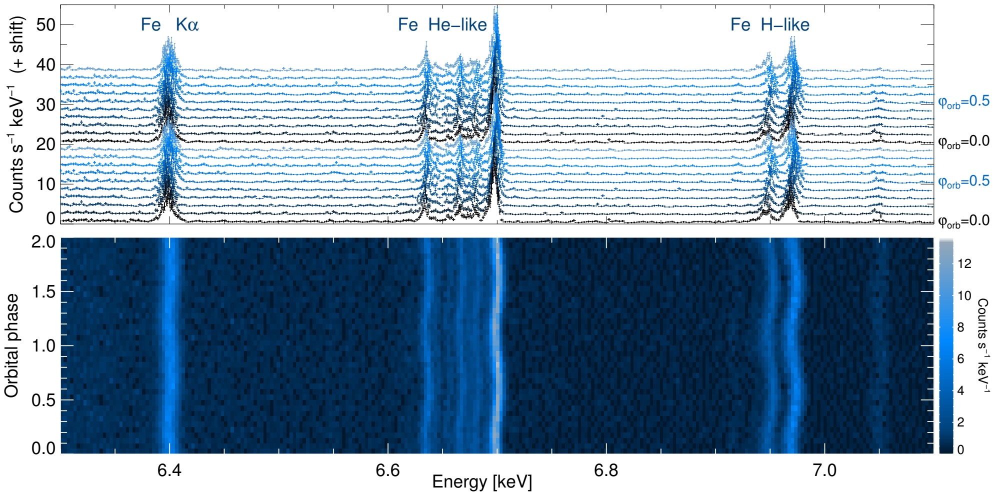
The science theme of the Advanced Telescope for High-Energy Astrophysics *Athena* was selected by ESA for its next Large Mission in November, with a proposed launch in 2028. Athena shall pursue topics of "The Hot and Energetic Universe" and be equipped with a Wide Field Imager and an X-ray calorimeter. With its high detection sensitivity and spectral resolution, it will allow a detailed view on the accretion on white dwarfs in (magnetic) cataclysmic variables, in particular the dynamics of the magnetically confined accretion flow. We investigate the capability of Athena with respect to spectral line analyses on the case of the prototype of magnetic CVs, AM Herculis.

X-ray accretion-column models

To simulate observations with the X-IFU calorimeter, we model the emission line spectrum of AM Her as a combination of multi-temperature plasma emission of the post-shock accretion column and of reflection (PEXMON, Nandra et al. 2007, MNRAS 382, 194). Our XSPEC column models are based on the radiation-hydrodynamic calculations of Fischer & Beuermann (2001, A&A 373, 211). We parameterize their density and temperature distributions for a stratified column of 30 layers. The models are sensitive to changes in the accretion rate, the white-dwarf mass, and the magnetic field strength. Binary accretion geometry and phase-dependent line shifts due to gas infall in the column, height-dependent gravitational redshift, and orbital velocity are taken into account. For different mass flow rates, we generate 10 phase-resolved X-ray spectra with a total integration time of 100 ks.



Structure of a model accretion column, parameterized for 30 strata: temperature (solid) and normalized density (dash-dotted) at three different mass flow rates $\dot{m}$. The x axis is given as dimensionless column density, which translates to geometrical height above the white dwarf.



A simulated 100 ks Athena/X-IFU observation of AM Her: The trailed spectrogram shows the velocity shifts of the iron emission lines during a binary orbit. Phase (time) increases along the y axis in this representation, energy along the x-axis. The colors in the lower panel code intensity, bright colors representing the bright emission lines.

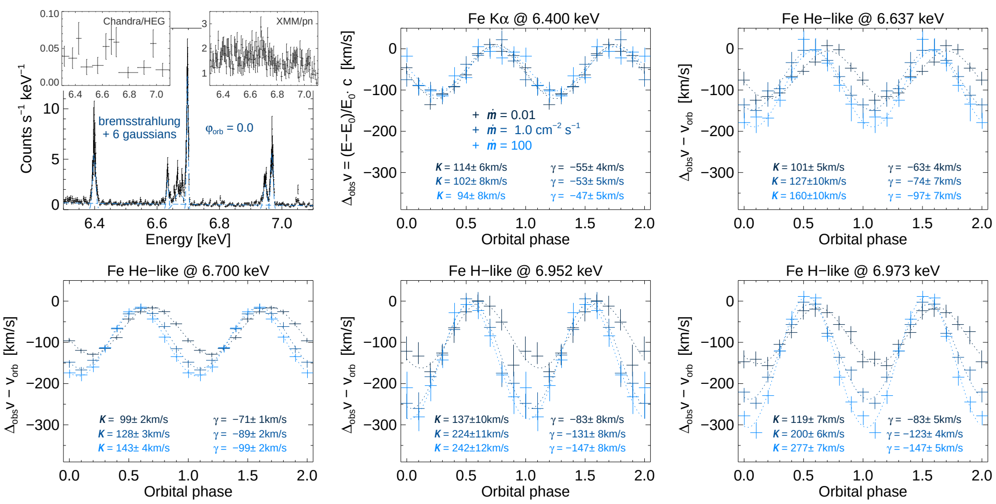
Emission line diagnostics: velocities

From the synthetic spectra, we determine the iron line energies by Gaussian fits, convert them to velocities, and fit them with sine curves. Orbital velocity and gravitational redshift of the white dwarf can be derived directly from the Fe Kα line. Input values of the simulation are $K_{K\alpha} = 100$ km/s, $\gamma_{K\alpha} = 50$ km/s. To fit the motion of the infalling gas in the flow, the orbital velocity is subtracted from the He-like and H-like Fe line components. The sine fits reveal their dependence on the mass flow rates. Sources of uncertainty are the fit accuracy (given in the figure below), the counting statistics in the data simulation, and the neglect of line broadening due to the orbital motion.

Our radial-velocity study recovers the velocity components in the H-like and He-like plasma lines and the neutral reflection line with 10 – 15% accuracy.

Prospects for CV research

The high spectral resolution of the Athena instruments will open new prospects of plasma diagnostics. Analyzing emission line shifts, we will gain a three-dimensional picture of the accretion column, locate the line emission regions, derive parameters of the accretion shock, and directly determine the white-dwarf masses from the gravitational redshift. Repeated observations allow for detailed variability studies of magnetosphere and plasma properties.



Phase-resolved sine fits to the radial velocities of the synthetic spectra. K denotes semi-amplitude, γ offset from 0. *Upper left panel:* XSPEC fit to the 10 ks simulation at $\varphi_{orb} = 0.0$. The small frames show the corresponding phase bins ($\Delta\varphi = 0.1$) of the Chandra and XMM-Newton observations of AM Her for comparison.