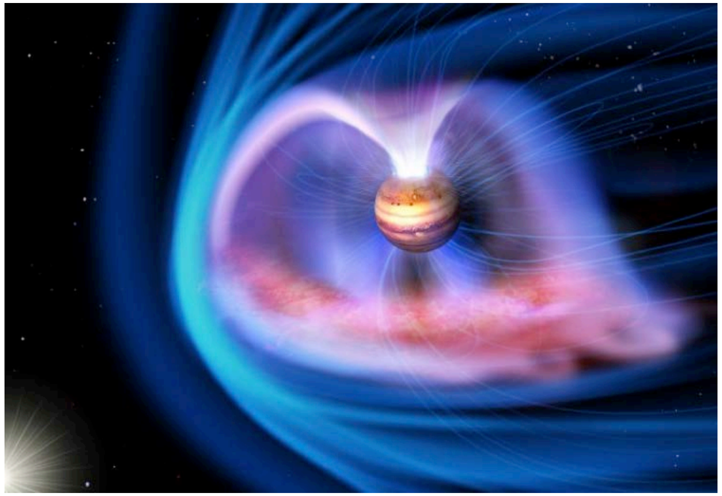
Athena and Jupiter's Dynamic Auroral Duo

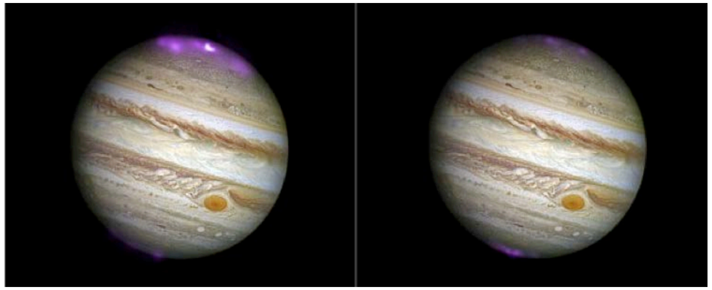
by Graziella Branduardi-Raymont, University College London/Mullard Space Science Laboratory - UK

Planets, moons and comets in our solar system are the astronomical bodies closest to Earth and provide us with a laboratory in which to observe physical processes and test theories applicable to much more distant cosmic scenarios. Unlikely as it may sound, planets, moons and comets shine in X-rays. Just as it happens with visible light, planets reflect solar X-rays, so their disks brighten and dim matching changes in solar X-ray output. Some of their moons produce X-rays by fluorescence following solar X-ray illumination or particle impacts on their surface. X-rays are also generated in the interaction of the solar wind (a plasma, i.e. a flow of charged particles and magnetic field continuously emanating from the Sun) with the upper atmospheres of planets like Venus, Mars, and Earth: the process involved, called 'charge exchange', excites the solar wind positive particles (ions) in their encounters with neutral atmospheric constituents; the ions then return to their normal state emitting X-rays. Charge exchange is most effective when the solar wind interacts with the extended neutral atmospheres (comae) of comets as they get close to the Sun, making them spectacular X-ray sources, in brightness and shapes.



Artist's impression of Jupiter's X-ray aurora and the magnetosphere. Credit: JAXA

The presence of a planetary magnetic field, such as at Jupiter, Saturn and Earth, leads to the formation of aurorae at the footprints of charged particles moving along the field (aurorae are also called 'Northern lights' in the Earth's North hemisphere). Jupiter has produced the biggest surprises since the early years of X-ray astronomy. The strong magnetic field of the planet, coupled with its fast rotation (a day on Jupiter lasts 10 Earth hours, and the planet's radius is more than 10 times that of Earth!) and the presence of the very active moon Io make the Jovian environment extreme and fascinating. Jupiter's duo of X-ray aurorae are bright and very variable in X-rays. Both ions and electrons contribute to the X-ray emission: the former by charge exchange and the latter by simply losing their energy slowing down in their travels. The data returned so far by X-ray observatories like XMM-Newton and Chandra have told us that probably both solar wind and Io are responsible for providing plasma to feed the charge exchange process in Jupiter's aurorae; however, their relative importance and the details of the mechanisms leading to X-ray emission after solar wind injection in the magnetosphere are not yet clear.



Images of Jupiter's X-ray aurora during varying solar wind conditions in 2011 [Dunn et al. 2016] overlaid on visible images of Jupiter from the Hubble Space Telescope. Left: The X-ray emission (increasing intensity from blue to white) is enhanced after the arrival of a coronal mass ejection from the Sun. Right: Dimmer auroral X-ray emission one day later. Credit: NASA: STScI/CXC

Athena will have a revolutionary role in the study of our solar system: its payload will examine in much greater detail, and on shorter timescales than possible so far, the energy distribution of the X-rays, providing information on the nature and motion of the ions and electrons involved; it will allow us to map accurately the emission from planetary atmospheres and comets, to search more deeply for auroral X-ray emission on Saturn and to try and detect X-rays from Uranus and Neptune.

In summary, astronomical bodies in our solar system are intimately related to what happens at the Sun. The kind of studies described here give us strong hints of what may be happening in other stellar systems hosting 'exoplanets' and of their physical conditions, including those that may be conducive to harbouring life.