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Gas in galactic halos

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Abstract. The interstellar medium in galactic halos is described as a consequence of feedback mechanisms from processes related to star-formation in the disk. The presence of gas in galactic halos is also expected due to accretion of gas from the circumgalactic environment. The observational evidence for gas in galactic halos - from the hot X-ray emitting coronal phase to cool molecular gas and dust - is reviewed and discussed in the context of current models of the ISM and the "infall vs. outflow" debate.

Keywords. galaxies: ISM, galaxies: evolution, galaxies: halo

1. Introduction

The presence of gas at significant height above the stellar disks in galaxies has been discussed in the past as part of the cycle of interstellar matter between the disk and the halo, e.g. in the framework of galactic fountain flows. This exchange of matter is expected from the feedback of energy and momentum caused by the young stellar populations through supernovae and stellar winds and is thus linked to the star formation rate in the disk. While evolutionary models of galaxies require infalling primordial gas to sustain the observed reservoir of gas and to explain the observed chemical abundances outflows seem to be required in galaxy evolution since galaxy formation models without feedback do not reproduce the properties of galaxies as observed in the local universe. In view of these concepts we are expecting both, gas in halos due to infall as well as due to outflows.

2. Observations of gas in galactic halos

More than half a century ago HI-21 cm observations of High Velocity Clouds (HVCs) in the Milky Way (MW) stimulated the discussion of gaseous galactic halos. The review by Putnam *et al.* (2012) describes the state of the art in this field and discusses consequences with regard to the infall vs. outflow discussion. For extragalactic objects NGC 891 is frequently considered the "typical" disk galaxy (and MW twin). The detection of a large HI halo (Oosterloo *et al.* 2007) led to the expectation that extended HI halos are typical for disk galaxies. However, the preliminary analysis (reported in this SpS) of HI data observed for a sample of disk galaxies in the HALOGAS project (Heald *et al.* 2012) rather leads to the conclusion that such HI halos are rare. This preliminary analysis also suggests that the mass of HI in the halo is correlated with the star formation in the disk. Similar relations have also been found for the presence of Warm or Diffuse Ionized Gas (WIM, DIG) in galactic halos (Rossa & Dettmar 2003; Miller & Veilleux 2003).

Cosmological simulations such as the GIMIC project (Crain *et al.* 2010) predict hot coronae as the consequence of infall from intergalactic filaments. The parameters of the model coronae are in general agreement with X-ray observations for galaxies over a wide range of masses. However, the X-ray observations for disk galaxies correlate equally well with the star formation rate in the disks if global parameters are considered (Tüllmann

et al. 2006; Li & Wang 2012). The spatial correlation of the observed X-ray halos with star formation regions in the disk is better explained in the outflow scenario.

The general presence of outflows is also suggested by observations of the cold ISM components in galactic halos: dust as well as molecular gas is present in the disk-halo interface of galaxies (Howk & Savage 2000; Veilleux *et al.* 2009). These observations are, however, currently limited to a handful of cases only.

All the above mentioned components of the ISM in galactic halos are typically accompanied by the presence of cosmic rays and magnetic field as shown by radio continuum observations (e.g., Dettmar & Soida 2006). This is again corroborating the case for galactic outflows being responsible for the presence of gas in galactic halos.

3. Conclusions

All constituents of the interstellar medium observed in the disks of spiral galaxies - from the cold molecular gas and the hot X-ray emitting plasma to magnetic fields and cosmic rays - are also observed in halos of galaxies. The presence of all these different gas phases seems to correlate with the starformation rate (per unit area) in the disk and is thus explained by outflows caused in an ISM driven by starformation activity. However, the observed samples of galaxies are not representative but rather biased to those with higher star formation rate. In addition, it has to be mentioned that for some gas phases such as the X-ray emitting HIM the observations are still limited by instrumental sensitivity.

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