30 Years of Photodissociation Regions:

A symposium to honor David Hollenbach's lifetime in science

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REVIEW TALK

Stars, Cars, and PDRs: The Physics of PDRs

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In this review I present the basic structure of a Photodissociation Region (PDR) and discuss the dominant heating and cooling processes. A PDR is gas in which far-ultraviolet (FUV) radiation plays a role in the heating and/or chemistry (Tielens & Hollenbach 1985). PDRs can be found where radiation escaping an HII region illuminates a nearby molecular cloud or in molecular cloud surfaces illuminated by the interstellar radiation field. The same physical processes and chemistry at work in the molecular cloud PDRs are also at work in diffuse interstellar clouds but with generally lower FUV fields and column densities.

In the outer regions of the cloud, the gas consists mainly of atomic H, He, O, and single ionization states of metals (e.g., $\mathrm{C^+}$, $\mathrm{Si^+}$, $\mathrm{S^+}$). At deeper layers, molecular $\mathrm{H_2}$ forms on grains and $\mathrm{C^+}$ recombines to atomic C. After $\mathrm{C^+}$ recombination, CO forms through a series of ion-neutral and neutral-neutral chemical reactions. Atomic and molecular freeze-out onto grains and grain surface reactions can additionally modify abundances and gas cooling in the cloud interior (Hollenbach et al. 2009) and may also be important for $\mathrm{H_2O}$ production in the diffuse ISM (Sonnentrucker et al. 2015).

Typically, grain photoelectric heating dominates in the outer layers while collisions with warm grains or cosmic-ray heating is of increasing importance in the deeper layers. However, for some conditions, more exotic processes such as vibrationally excited $\mathrm{H_2}$ (Sternberg & Dalgarno 1989) or $\mathrm{H_2}$ formation heating (Le Bourlot et al. 2012; Röllig et al. 2013) may become important. The main parameter which governs the heating rate and PDR structure is the ratio of incident FUV field strength, G_0, to gas density, n (Bakes & Tielens 1994; Weingartner & Draine 2001). For example, for high G_0/n, grain charging leads to a reduced heating efficiency and a drop in the line strengths of the PDR cooling lines (Malhotra et al. 2001). For low G_0/n, $\mathrm{H_2}$ and CO self-shielding draws the molecular gas to the cloud surface and reduces the atomic gas column density and line intensities (Wolfire et al. 1989, Burton et al. 1990). I will demonstrate how the PDR heating and structure changes with varying G_0/n.

The fine-structure lines of [OI] and [CII] dominate the cooling in the outer layers with CO dominating in the deeper layers although a host of cooling lines and emission diagnostics probe different depths and physical conditions (.e.g., Le Petit et al. 2006; Kaufman et al. 2006, Röllig et al. 2006). In addition to gas emission lines, PDRs also emit dust continuum emission and PAH features (Peeters et al. 2011). The production of these gas emission lines and dust features will also be discussed.

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