# A HI study of HII regions and dark clouds.

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Chapter one

# Introduction

**Summary.** The effects of dissociating radiation on molecular clouds are discussed. Isolated clouds in the interstellar radiation field are considered, as well as clouds exposed to the strong UV radiation field of nearby stars. Observational considerations for observing HI in photodissociation zones are outlined. An overview of previous observations of HI in dark clouds and HI near HII regions is presented.

## 1. HI and the effects of radiation on clouds

Since the detection of the 21 cm line of atomic hydrogen (HI) by Ewen and Purcell (1951) and Muller and Oort (1951) after the original prediction by Van de Hulst (1945), HI observations have been among the most important tools for the study of the interstellar medium (ISM) of our own galaxy as well of other galaxies. On the largest scale, the HI line has been used to determine the galactic rotation curve and the overall structure of the gaseous layer in the disk of the galaxy (cf., Burton, 1988 for a review). On smaller scales, 21 cm line studies of individual clouds have contributed greatly to our knowledge of structures in the interstellar medium. In addition, the 21 cm line has been of fundamental importance for our understanding of the phases of the ISM. One of the key observations in this respect has been the discovery of a warm and a cold phase in the ISM by combined HI emission-absorption observations with the Parkes interferometer by Radhakrishnan et al. (1972). The cold ($T{\sim}80$ K) component was observed in narrow absorption lines towards background continuum sources. The warm component, which is believed to have a temperature of about 8000 K, was observed in emission.

Since this discovery our knowledge of the ISM has increased substantially, and four phases of the ISM are now known: a hot ($\sim 10^6$ K) ionized medium (HIM) that occupies a large fraction of space and gives rise to a soft X-ray background, a warm ($\sim$ 8000 K) ionized medium (WIM) that is seen in diffuse H$\alpha$ radiation (Reynolds, 1984), a warm neutral medium (WNM) seen mainly in HI emission and a cold medium (CM). The most succesful model of the ISM so far has been proposed by McKee and Ostriker (1977). In this model the ISM is energetically regulated by supernova explosions, which create the HIM, regulate interstellar pressure and provide the energy for cloud motions. A review of our knowledge of the phases of the ISM and a description of some outstanding problems has recently been published by Kulkarni and Heiles (1988).

This thesis will concentrate exclusively on certain aspects of the CM. The CM is concentrated in clouds which are acted upon by radiation, cosmic rays, shock waves, gravity and the magnetic field. Although a wealth of observational material now exists concerning the CM, from HI and molecular line observations, and more recently from the IRAS survey, many questions are still unanswered. These questions concern cloud formation and evolution, the internal structure of clouds, cloud shapes, the physics of cloud boundaries, the heating agents of the CM and the role of the magnetic field. The principal aim of this thesis is to study the effects of radiation on clouds by means of HI observations, in two astrophysical contexts:

1) a molecular cloud in the interstellar radiation field (ISRF).
2) a molecular cloud exposed to dissociating radiation from nearby massive stars.

The underlying physical mechanism in these two situations is the same, i.e., photodissociation of molecular hydrogen. However, the energy density of the radiation field is in the second case much higher than in the first case. As a result different physical phenomena occur, and therefore the two cases are studied separately. In section 2 of this chapter the case of a molecular cloud in the ISRF will be discussed, and a brief review will be given of earlier observational work on this subject. Section 3 will describe the case of a molecular cloud exposed to the dissociating radiation of nearby massive stars. In this case the stars will ionize the gas in their immediate vicinity. Outside the resulting HII region a layer of HI will develop as a result of photodissociation of the molecular gas outside the ionization front. The role of this HI layer in the interaction of HII regions with their environments will be discussed in section 3 of this chapter, and a review of earlier studies of such photodissociation zones will be given.

## 2. HI and molecular clouds

### 2.1. HI in dark clouds and cloud complexes

The relative proportion of atomic and molecular hydrogen in an interstellar cloud is determined by the rates of formation and destruction of molecular hydrogen. The outer layers of such a cloud will be atomic, since these layers are exposed to the dissociating radiation of the ISRF. Due to the self-shielding properties of the hydrogen molecule (to be discussed in chapter two) the photodissociation rate in the cloud interior is reduced. Thus the cloud interior will in general contain a higher proportion of molecular hydrogen than the cloud envelope. This effect becomes even more pronounced in the denser regions of the cloud interior, since the $H_2$ formation rate is proportional to the square of the density. Thus molecular clouds can be viewed as the dense central regions of larger clouds, with predominantly atomic outer layers. Observational evidence for the correctness of this view



has been found by Wannie
21 cm line with the Arecib
Atomic envelopes associat
instance, Elmegreen and E
in the first galactic quadran
known dark clouds and gia
been found by Grabelsky et
Theoretical studies also in
clouds (e.g., Federman et al
may possess thin and dens
densest regions of much larg
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Atomic hydrogen is fou
regions. Since the cores of c
ISRF, the proportion of atom
Cosmic ray dissociation is the
Furthermore, an appreciable
HI to $H_2$ conversion. In this
as the conversion of hydrogen
this equilibrium between $H_2$ f
and Robinson, 1976; see also
to or longer than typical dyn
time). Observationally there
conversion. Shu (1973) and A
Knapp (1974), argue that cos
abundances in cloud cores. B
abundance as an age indicator
$10^7$ years. However, McCutch
that suggest much lower HI a
cloud cores. Cosmic ray disso
from an observational point of

### 2.2. Previous HI studies of

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history. For example, in 1955
HI column density was propor
year, it was however discovere
density could remain constant
al., 1955). Based on these an
dark clouds could be in molecu

The first HI survey of a l
who carried out constant-decl