Available online at www.sciencedirect.com
SCIENCE DIRECT®
New Astronomy 10 (2005) 385–391
New Astronomy
www.elsevier.com/locate/newast

Suggestions for an interstellar C_7H_2 search

Suresh Chandra [1], Pramod G. Musrif *, Ram M. Dharmkare

School of Physical Sciences, S.R.T.M. University, Nanded 431 606, Maharashtra, India

Received 9 November 2004; accepted 15 December 2004
Available online 17 March 2005
Communicated by F. Melchiorri

Abstract

Laboratory detection of the ring-chain molecule c-C_7H_2 has been reported by McCarthy et al. [McCarthy, M.C., Travers, M.J., Gottlieb, C.A., Thaddeus, P., 1997. A&A 483, L139]. Two ring-chain molecules c-C_3H_2 and c-C_5H_2 of this series have already been detected in the cosmic objects. We suggest that the c-C_7H_2 may be identified in cool cosmic objects through its transitions 4_{14}–5_{05}, 5_{15}–6_{06}, 6_{16}–7_{07} and 7_{17}–8_{08} at 23.241, 21.105, 18.953 and 16.787 GHz, respectively, in absorption against the CMB. Since, in absence of the availability of collisional rates, we have used scaled values for them, we have checked the sensitivity of the results on the collisional rates, by enhancing the rates for the transitions with $\Delta k_a = 0$ by a factor of 10. Though the transitions are not found sensitive to the collisional rates, our results still may be treated as qualitative in nature. These absorption lines may play an important role for identification of c-C_7H_2 in cool cosmic objects.

PACS: 33.20.Sn

Keywords: ISM; Molecules

1. Introduction

The 2_{20}–2_{11} transition of c-C_3H_2 at 21.587 GHz has been found in absorption against the CMB by Matthews et al. (1986) and Madden et al. (1989) in all the objects investigated, except the Planetary Nebula NGC 7027 where Cox et al. (1987) found this transition in emission. Two transitions 3_{13}–2_{12} and 3_{03}–2_{02} at 19.147 and 19.606 GHz, respectively, of c-C_5H_2 have been detected in TMC-1 by Dickens et al. (2001). Chandra and Shinde (2004) have proposed detection of 3_{13}–4_{04} transition at 4.314 GHz of c-C_5H_2 in absorption against the

* Corresponding author. Tel.: +91 9850401409.
E-mail addresses: sch@iucaa.ernet.in (S. Chandra), musrif_pramod@yahoo.com (P.G. Musrif).
[1] Visiting Associate, Inter-University Centre for Astronomy and Astrophysics, Pune 411 007, India.

1384-1076/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.newast.2004.12.005

cosmic microwave background (CMB). After detection of c-C_3H_2 and c-C_5H_2 in the cosmic objects, scientists are now interested in the identification of c-C_7H_2 in cosmic objects (Fig. 1). This ring-chain molecule c-C_7H_2 is an asymmetric top, planar molecule having a large electric dipole moment $\mu = 3.8$ Debye equally inclined with the axes of inertia so that its components along the a and b axes of inertia are $\mu_a = 2.69$ and $\mu_b = 2.69$ Debye. Thus, this isomer has both a-type and b-type radiative transitions, and therefore, the rotational energy levels cannot be separated into two different groups, as was the case for c-C_3H_2. Hence, the investigation of this molecule, likewise c-C_5H_2, is quite complicated. The molecular and distortional constants derived by McCarthy et al. (1997) for c-C_7H_2 are given in Table 1. Since the kinetic temperature in dark molecular clouds is rather low, only rotational transitions in the ground electronic and ground vibrational states take place.

Table 1
Molecular data

A (MHz)	34722.136
B (MHz)	1045.20523
C (MHz)	1014.25700
Δ_J (MHz)	17.2×10^{-6}
Δ_{JK} (MHz)	7.06×10^{-3}
μ_a (Debye)	2.69
μ_b (Debye)	2.69

We propose that c-C_7H_2 may be identified in the cool cosmic objects through its transitions 4_{14}–5_{05}, 5_{15}–6_{06}, 6_{16}–7_{07} and 7_{17}–8_{08} at 23.241, 21.105, 18.953 and 16.787 GHz, respectively, in absorption against the CMB.

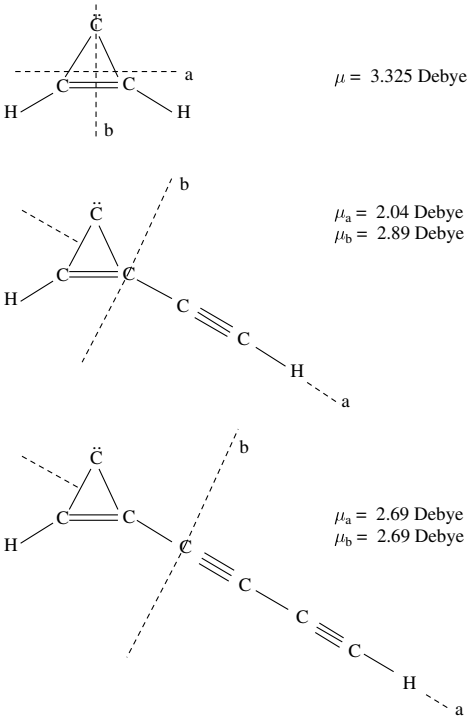

Fig. 1. The ring-chain molecules c-C_3H_2, c-C_5H_2 and c-C_7H_2 along with their inertial axes dipole moments (not to the scale). The c-C_3H_2 is a b-type asymmetric top molecule whereas c-C_5H_2 and c-C_7H_2 have both a- and b-type radiative transitions.

2. Basic formulation

The rotational energy levels of c-C_7H_2 accounted in the present investigation are given in Table 2. In our investigation, NLTE occupation numbers of the levels are calculated in an on-the-spot approximation by using the escape probability method (see, e.g., Rausch et al., 1996; Chandra and Shinde, 2004), where the external radiation field, impinging on a volume element generating the lines, is the CMB only. In the present investigation, a set of 53 linear equations coupled with 308 equations of radiative transfer is solved through the iterative procedure for given values of n_{H_2} and $\gamma \equiv n_{mol}/(dv_r/dr)$, where n_{mol} is density of the molecule and dv_r/dr the velocity gradient in the object. The input data required in the present investigation are the radiative transitions probabilities (Einstein A-coefficients) and the collisional rate coefficients.

2.1. Einstein A-coefficients

Rotational wave functions for an asymmetric top molecule can be described by linear combinations of symmetric top wave functions (Chandra et al., 1984a,b)