Molecular Gas toward Supernova Remnant Cassiopeia A

Ping Zhou[1,2] , J-T Li[3], Z-Y Zhang[4,5], J. Vink[1,6] , Y. Chen[2] , M. Arias[1], D. Patnaude[7] , and J. N. Bregman[3]

1. U. of Amsterdam, 2. Nanjing U., 3. U. of Michigan, 4. U. of Edinburgh, 5. ESO, 6. SRON, 7. SAO

Message 1. No evidence to support that Cas A is impacting the molecular clouds

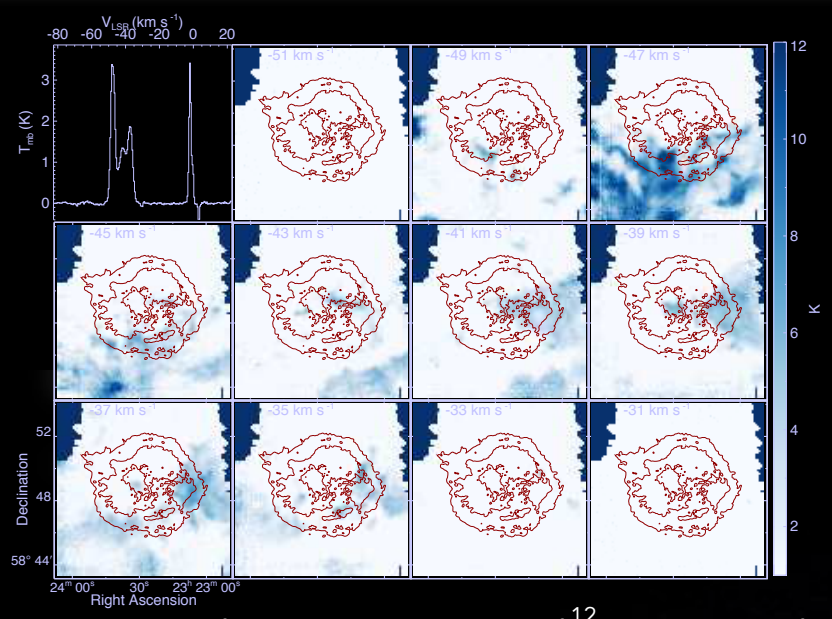


Fig. 1. Channel maps of the main-beam temperature of ^{12}CO 2–1.The top left panel shows the spectrum averaged over the FOV. Contours: Chandra X-ray

Molecular gas is **cold**:

- temperature T<~ 22 K
- the ^{12}CO 2-1/1-0 ratio is not specially enhanced in or at the boundary of the SNR

Molecular gas is **not shocked**:

- line width dV< 7 km/s
- CO line profiles are similar between the post-shock and background regions

Message 2. Molecular clouds are foreground

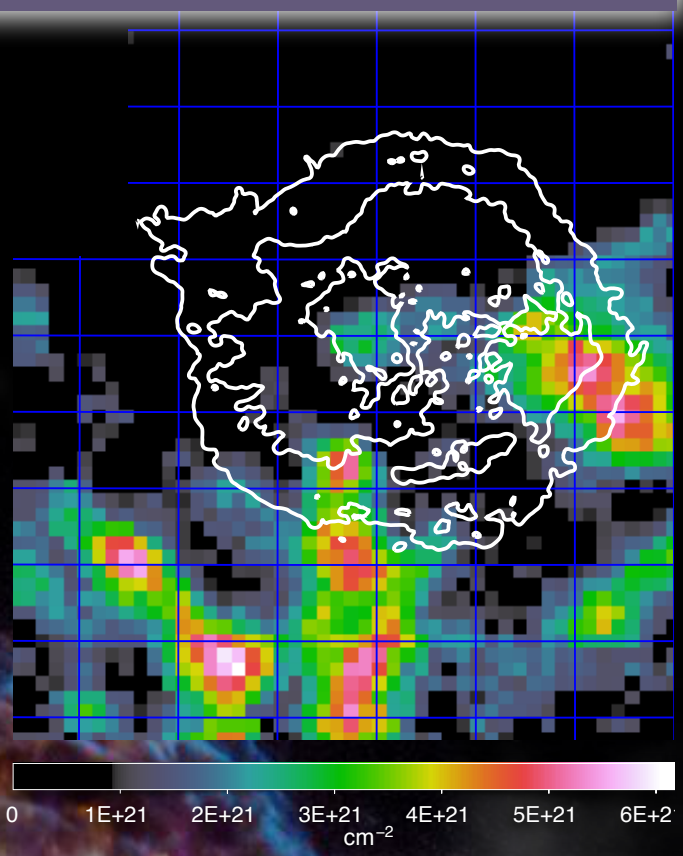


Fig. 2. Molecular column density N (H_2) distribution

Observations using the IRAM 30m telescope

~9'x9' maps of 12CO 1-0, 2-1 and 13CO 1-0
HCO+ 1-0 at the western radio peak
11"/22" resolution

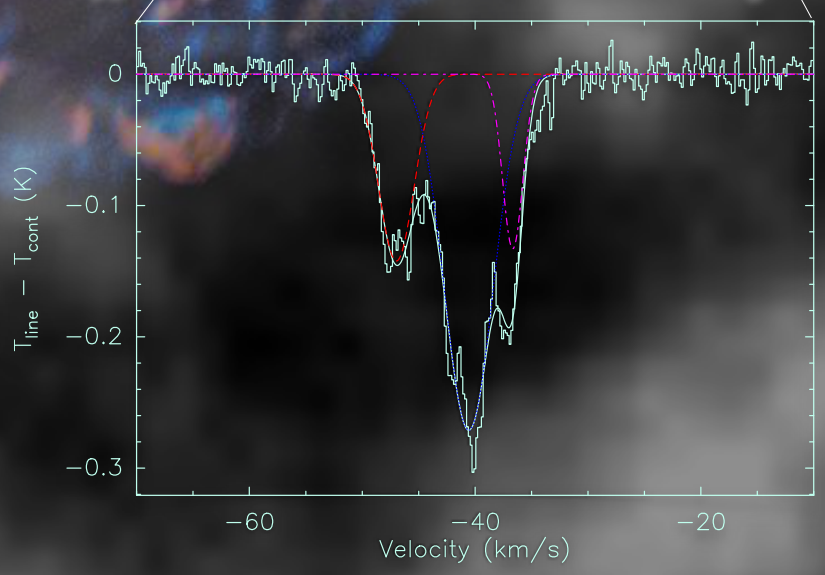
Message 3. The 20 K gas at V_{LSR}=-47 km/s is heated by background cosmic rays (CRs)

What is the heating source of the 20 K gas at ~-47 km/s (typical molecular gas has T~10 K)? We discussed 4 possibilities:

- SNR shock heating — excluded, because of no evidence of interaction
- SNR CRs — excluded, SNR CRs cannot heat gas 10 pc away or the CR energy is insufficient to heat the clouds
- SNR X-rays — excluded, X-ray energy is insufficient to heat the clouds
- **Background CRs** — Yes, as long as the CR ionization rate $\zeta(H_2)$ reaches the typical value of ~2x10^{-16} s^{-1}. The gas at -47 km/s is warmer because it is more quiescent

$$T_{\rm k} \sim 20[\frac{\zeta({\rm H_2})}{1.9\times10^{-16}\ {\rm s^{-1}}}]^{0.42}(\frac{dv/dr}{\rm km\ s^{-1}pc^{-1}})^{-0.42}\ {\rm K}$$

Fig .3. Absorption spectrum of HCO+ 1-0 near the radio peak, suggesting that all the molecular clouds are foreground



Background image:

Cas A behind molecular clouds

Grey: 12CO 2-1 (V_{LSR}=-55 to -30 km/s, IRAM 30m)
Color: X-ray (source:NASA/CXC/SAO)

Please check our paper
Zhou et al. 2018, ApJ, 865, 6 and references therein