CTB109: How a supernova remnant affects a giant molecular cloud

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Supernova remnants (SNRs) interact with the ISM through the physical act of shocking gas and radiatively through the production of high energy photons and cosmic rays [1]. CTB109 is an X-ray bright supernova remnant which is associated with a giant molecular cloud (GMC) to the west [2], making it a prime choice for studying how a SNR affects a GMC. We present molecular line observations using the IRAM 30m telescope, which we combine with X-ray, Radio and Infrared archival data and [CII] and [OI] observations from SOFIA. The molecular line data include the (J=1-0) and (J=2-1) lines of ^{12}CO, ^{13}CO, $C^{18}O$, the (J=1-0) lines of the dense gas tracers: HCN, HNC, HCO^+ and N_2H^+, and the (J=2-1) line of SiO. We map two different regions of the GMC, one in which we are confident the SNR has not reached and the other where we believe the SNR shock has hit the dense gas. This allows us the separate the effects of physical shocking and radiative interaction. Using all 6 CO lines and RADEX modeling we show that the cloud is externally heated, with dense CO-bright gas being heated above 100K. Using chemical modeling we show that only a high X-ray or cosmic-ray flux could heat the gas to such a high temperature without dissociating the CO molecules. The interior dense gas is relatively undisturbed suggesting a soft X-ray spectrum, consistent with the X-ray observations from Chandra. In the physically shocked region we see line-broadening in the CO lines, which our hydrodynamic simulations show can be indicative of a recent SNR shock hitting the gas. This is co-incident with a large, bright 24 micron feature in the Spitzer data and the edge of the SNR in X-ray and Radio observations, strengthening this interpretation. Our results show the importance of multi-line diagnostics in uncovering the underlying thermal and chemical effects a supernova has on a GMC.

[1] McKee and Ostriker 1977, ApJ, 218, 148

[2] Sasaki, M., Kothes, R., Plucinsky, P. P. and Gaetz T. J. 2006, ApJ, 642, 149