Stellar and interstellar content of the region interacting with cosmic rays in IC443

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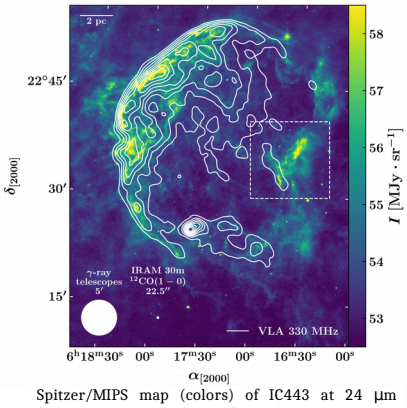
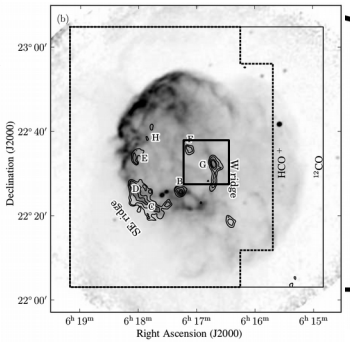
Abstract :

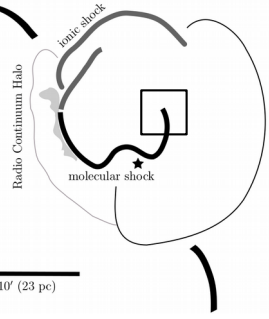
- Supernova Remnants (SNRs) represent a major feedback source of stars on galaxies : shock waves, energetic photons, cosmic rays (Crs).
- We study the properties of the gas and stars in IC443, an evolved shell type SNR at a distance of 1-1,5 kpc, with an estimated age of 30k years.
- We aim to fully characterize the stellar and interstellar content of the extended G region, which corresponds to the γ-ray peak detected by VERITAS and Fermi.
- We performed 10' × 10' mapped observations of CO(1-0), CO(2-1) and CO(3-2) transitions obtained with IRAM 30m and APEX telescopes.
- Our results show that a previously known shocked clump, a dense cloud and a mysterious ring-like structure are interacting with cosmic rays.

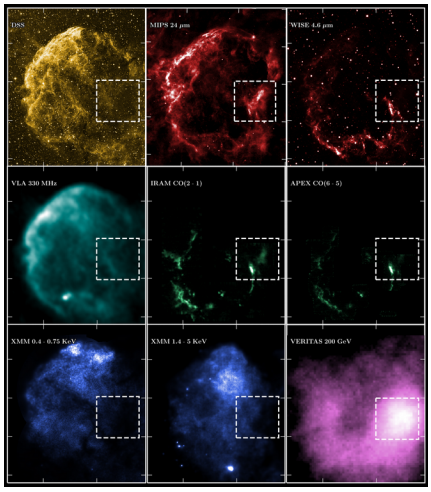


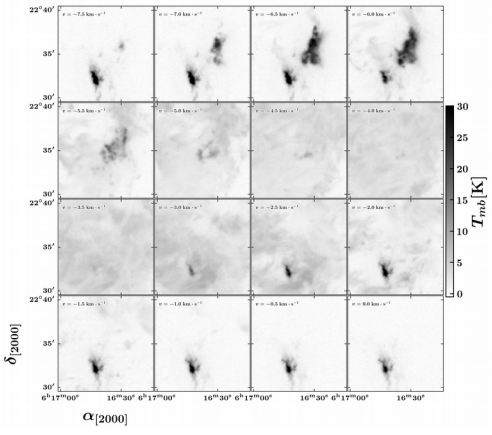
Spitzer/MIPS map (colors) of IC443 at 24 µm (Noriega-Crespo et al. 2009). In contours, the Very Large Array (VLA) emission map displays the morphology of the synchrotron emission at 330 MHz (Claussen et al. 1997). The white dashed box represents our 10' × 10' field of observations.

Introduction : IC443 is a shell type SNR located at the distance of 1-1.5 kpc. Its old age is well-suited to study the effects of the environment on star formation (around ≈30 kyr). IC443 has also been detected in the 10^{-1} – 10^{3} GeV energy range by Fermi, VERITAS, MAGIC and EGRET (Abdo et al. 2010, Humensky & VERITAS Collaboration 2015).









Channel map of the IRAM 30m ^{12}CO(2−1) observations. Each panel represent the emission integrated over an interval of 0.5km·s^{-1}, from v = −7.5km·s^{-1} to v = 0km·s^{-1} .

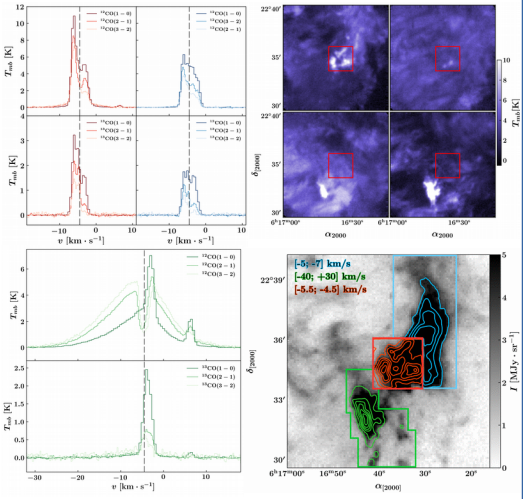
Observations: We carried out a 10' × 10' mosaic of the IC443G region with the APEX and the IRAM 30m telescopes toward the γ-ray peak detected by VERITAS and *Fermi*. We observed:

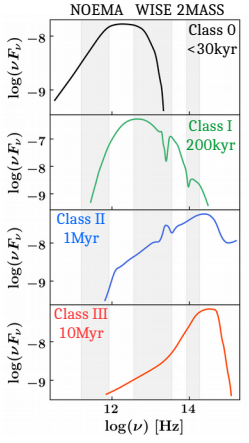
- ^{12}CO(1-0), (2-1), (3-2)
- ^{13}CO(1-0), (2-1), (3-2)
- C^{18}O (1-0), (2-1)

$$\log\left(\frac{N_{\rm up}}{g_{\rm up}}\right) = \log\left(\frac{N_{\rm tot}}{Q(T_{\rm ex})}\right) - \frac{E_{\rm up}}{kT_{\rm ex}}$$

region	$N_{\rm CO}$ [10^{17}cm^{-2}]	$M_{\rm sun}$
shock	[2.3-3.3]	[30-110]
dense cloud	[2.2-3.4]	[70-240]
ring-like structure	[3.9-5.8]	[50-170]
total field	[1.3-1.9]	[260-880]

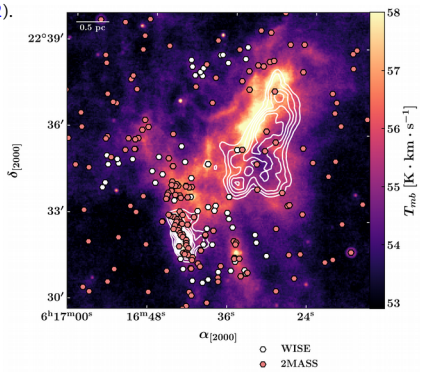
Measure of the mass: We use pixel-per-pixel, channel-per-channel optically corrected population diagrams (Goldsmith & Langer 1999) to determine the mass of CO and deduce the mass of the gas from the [H_2]/[^{12}CO] ratio (Frerking et al. 1982).





Spectral energy distribution of protostars at different evolutionary stages.

Stars: In order to characterize the local star formation over the extent of these molecular structures, we study the distribution of infrared and near infrared point sources in the field, using the 2MASS and WISE point source catalogues. We use empirical color criteria (Xu et al. 2011, Koenig & Leisawitz 2014), based on the idea that protostars have an infrared excess (Lada & Adams 1992).



Concluding remarks :

- **3 massive molecular structures are found.**
- **We cannot discard the quiescent gas (ring-like structure and dense cloud) to understand the γ-ray peak.**
- **Protostars might be injecting cosmic rays too. (Padovani et al. 2016)**
- **We detected a region that is likely very ionized, and that should be taken into account in the interpretation of the γ-ray peak.**
- ⚠ Estimation of the masses from the dust continuum might be much larger. We submitted a NOEMA proposal to observe it.
- ⚠ More generally, interferometry is needed to understand the nature of the whole region.

References :

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