At the rescue of elusive SNRs with XMM-Newton and Chandra

J. F. Albacete-Colombo[1], J. A. Combi[2,3], E. Sánchez-Ayaso[4], J. López-Santiago[5], G. E. Romero[2,3], J. Martí[4], P. Benaglia[2,3], P. L. Luque- Escamilla[4], A. J. Muñoz-Arjonilla[4], & J. R. Sánchez-Sutil[4]

1- Centro Universitario Regional Zona Atlántica (CURZA), Univ. Nacional del COMAHUE, Viedma (Negro), Argentina. [donfaca@gmail.com]

2- Instituto Argentino de Radio astronomia (CCT La Plata, CONICET), C.C.5, (1894) Villa Elisa, Buenos Aires, Argentina. [jcombi@fcaglp.unlp.edu.ar]

3- Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, La Plata, Argentina.

4- Escuela Politécnica Superior de Jaén (EPSJ), Universidad de Jaén (Spain). [esayaso@ujaen.es] , [jmarti@ujaen.es]

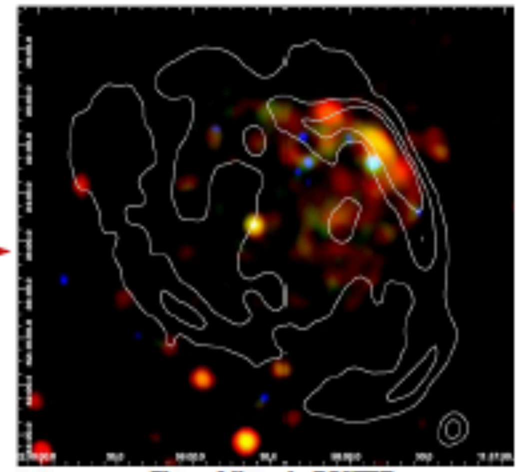
5- Departamento de Astrofísica y Ciencias de la Atmósfera, Universidad Complutense de Madrid, E-28040, Madrid, Spain. [jls@astrax.fis.ucm.es]

ABSTRACT:

We present the first results of a far-reaching Spaniard-Argentinian research program aimed at disclosing X-ray supernova remnants (SNRs). Here we report results on five remnants. Three of them belong to the mixed-morphology class. We have discovered a candidate for CCO in one of them. The other two objects are a PWN, and a very unusual source formed by a partial shell, internal X-ray emission and a possible compact object centered at the radio structure.

A multiwavelength study of the supernova remnant G296.8−0.3

The next one

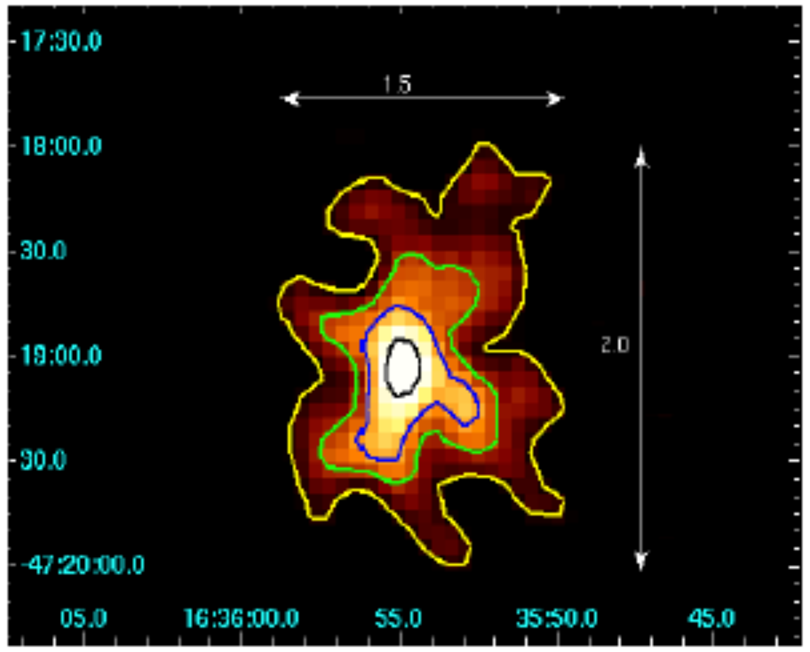


Please, follows the POSTER

Ref: Sanchez-Ayaso et al. In preparation

XMM-NEWTON detection of the supernova remnant G337.20.1

Ref: J.A. Combi, J.F. Albacete-Colombo, et al. 2007, AJ, 653: L41



G377.2+0.1: The figure shows the X-ray contours for the different emission levels in the 0.5–10.0 keV energies. The image does not reveal a typical rimbrightened outer SNR shell and the X-ray morphology shows centrally peaked emission, surrounded by a diffuse X-ray nebula. This could be the result of the absorption of the soft thermal emission from the forward shock by the very high absorbing column density.

The X-ray spectral analysis shows that central emission is well represented by a single power-law of index (Γ~0.98), being harder than the outer one (Γ~2.38). The most reasonable interpretation of observed emission from the central part of the SNR is synchrotron radiation from relativistic electrons accelerated in the vicinity of a central compact source in the SNR.

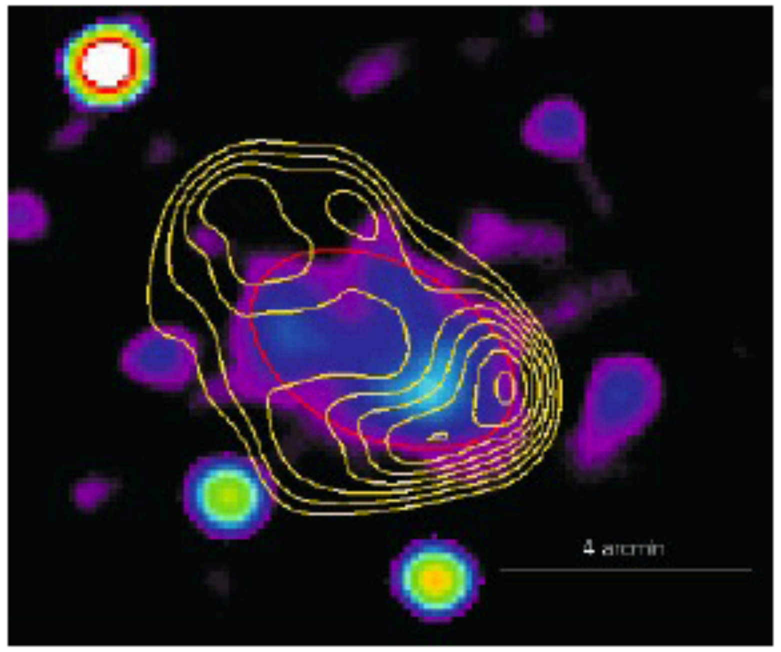
Possible reasons for the nondetection of a pulsar inside the SNR are a short rotation period (less than 400 ms) or unfavorable geometrical conditions. The presence of a pulsar is suggested by the central X-ray peak found inside G337.2+0.1. In this work (Combi et al. 2007), we explore the possibility that there exists a hidden pulsar powered component (plerion) within the SNR.

We use the 32.6 ks EPIC-PN observation to compare the time arrival distribution of source photons by means of the Kolmogorov-Smirnov test. We see no significant pulsed signal with a period greater than twice the readout time of the EPIC-PN camera in the FF mode, which corresponds to a Nyquist limit of 400 ms.

Complementary studies of the PWN scenario will involve high-resolution X-ray observations with the Chandra satellite, and radio observations with ATCA, to allow the comparison of the X-ray spectrum and morphology with those at the radio band. Gamma-Ray Large Area Space Telescope observations could reveal a GeV gamma-ray source if the proposed association with HESS J1634472 is correct.

Discovery of thermal X-ray emission in the supernova remnant G337.8−0.1 (Kes 41)

Ref: J.A. Combi, J.F. Albacete-Colombo, et al. 2008, 488, L25



G337.8-0.1 (Kes 41): The image shows the X-ray image of the SNR in the 0.5-10.0 keV energy band, with the radio contours at 843 MHz superposed. The image reveals diffuse Xray emission with an apparent filled-center structure and the absence of a compact source in its center. The X-ray peak is located at (RA=16:38'55.7", DEC= -46°58'32.4"), being the X-ray emission region less extended than the radio structure.

We find a high column density of N_H~6.9x10^{22} cm^{-2}, which supports a relatively distant location (d ≥ 7 kpc). The X-ray spectrum exhibits emission lines, indicating that the X-ray emission has a thin thermal plasma origin, and is well represented by a non-equilibrium ionization (NEI) plasma model.

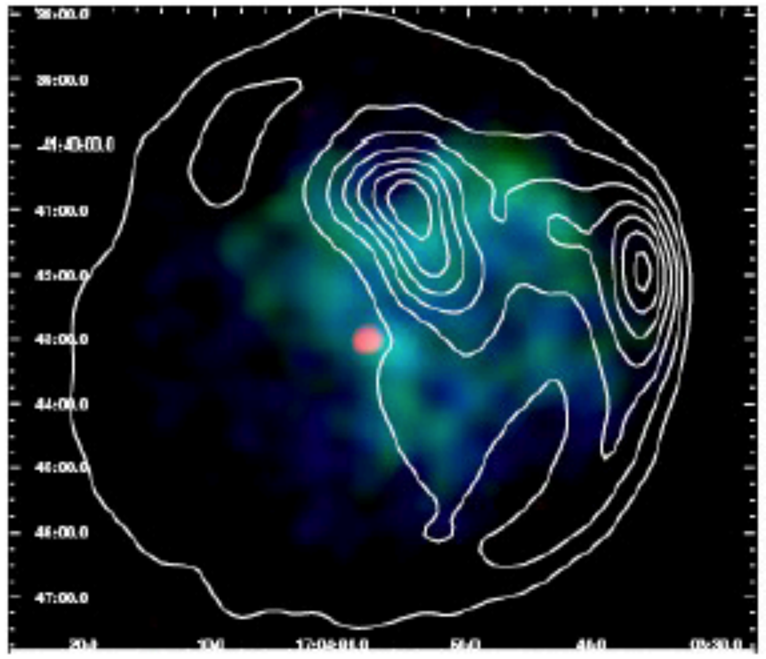
Several possible scenarios can explain thermal X-ray radiation inside radio shells of SNRs, i) cloudlet evaporation in the SNR interior ; ii) thermal conduction smoothing out the temperature gradient across the SNR and enhancing the central density ; iii) a radiatively cooled rim with a hot interior ; and iv) possible collisions with molecular clouds.

For a distance range from 7 to 12 kpc, we then obtained a volume of (2.8-14.8)x10^{58} cm^3. Based on the emission measure (EM) determined by the spectral fitting, we can estimate the electron density of the plasma, n_e, by n_e = sqrt(EM/V), which varies between 0.20 cm^{-3} and 0.26 cm^{-3}. The number density of the nucleons was simply assumed to be the same as that of electrons. The range of age t was then determined from the ionization timescale, τ, by $t = τ/n_e$. Therefore, the elapsed time after the plasma was heated is within (12.000-16.000) yr. The total mass of the plasma M(total) was estimated by n_e V m_H = (5–32) $M_⊙$, where m_H is the mass of a hydrogen atom. These results are consistent with the expected values for a middle-age SNR.

If the SNR is indeed propagating in a cloudy medium, the interaction of the shock-front with the adjacent molecular material could be responsible for the gamma-ray emission detected by the EGRET telescope.

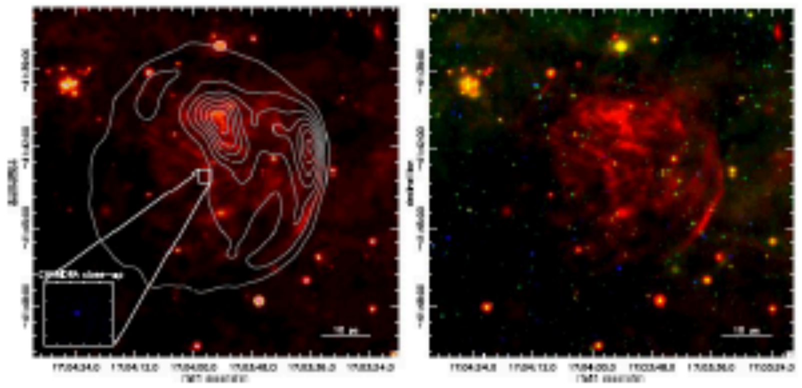
An X-ray study of the SNR G344.7-0.1 and the Central object CXOU J170357.8-414302

Ref: J.A. Combi, J.F. Albacete-Colombo, et al. 2010, 522, A50



G344.7-0.1: Chandra false color-coded X-ray image. Soft X-rays energies (0.5–1.2 keV) in red. Medium X-ray energies (1.2–2.5 keV) in green. Hard X-ray energies (2.5–8 keV) in blue. Smoothed image were convolved with a two-dimensional Gaussian function using the *aconvolve* CIAO task. Overlapping white contours are the 843 Mhz radio image taken from the MOST SNRs Catalog (Whiteoak & Green 1996). The position of the X-ray source CXOU J170357.8-414302, at the geometrical center of the SNR.

X-rays from most SNRs come from a hot thin plasma consisting of ejecta and swept-up interstellar medium. We adopt a pshock model that naturally reproduces the observed spectrum. The X-ray spectrum consist on a hot plasma of temperature (kT~1.17 keV), agrees with that expected from middle-aged SNR. We find a high column density of N_H~ 4.9x10^{22} cm^{-2}, probably due to an inhomogeneous foreground medium.

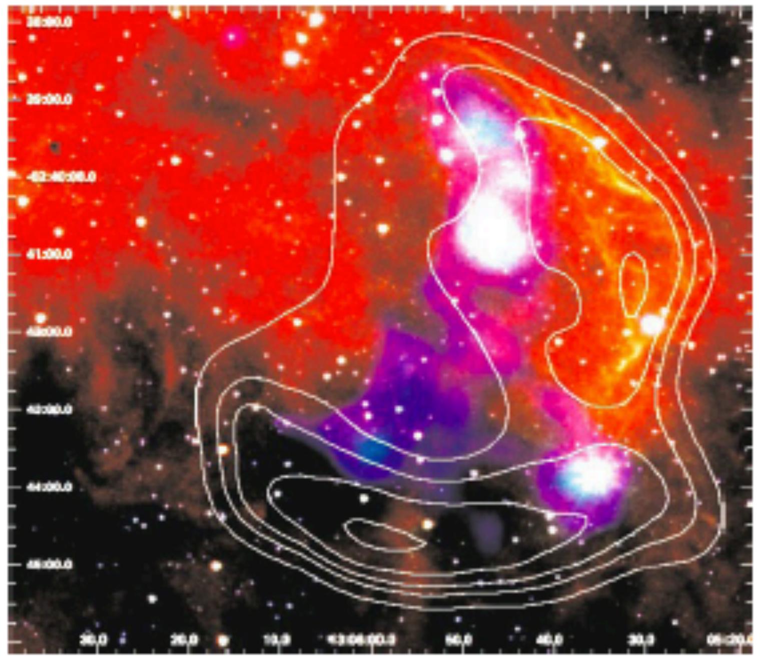


Left panel: MIPS 24 μm mosaic of G344.7-0.1. Radio contours are overplotted. The square marks the position of the punctual X-ray source observed with Chandra (small window in the left-bottom corner). Scale was determined assuming a distance of 14 kpc for the SNR. *Rigth panel*: three-color image of G344.7-0.1 (red is MIPS 24 μm, green is IRAC 8 μm, and blue is optical *R* band).

The point-like X-ray source located at the geometrical center of the SNR, exhibits steady X-ray flux emission that appears to exclude an accreting binary origin, soft thermal spectra that rules out a background active nucleus, lacks a radio counterpart, and contains no surrounding pulsar wind nebula. These characteristics are common with the so-called Central Compact Object (CCO), a new population of isolated neutron stars (NSs) with clear differences from isolated rotation-powered pulsars, and accretion-powered X-ray pulsars in close binary systems.

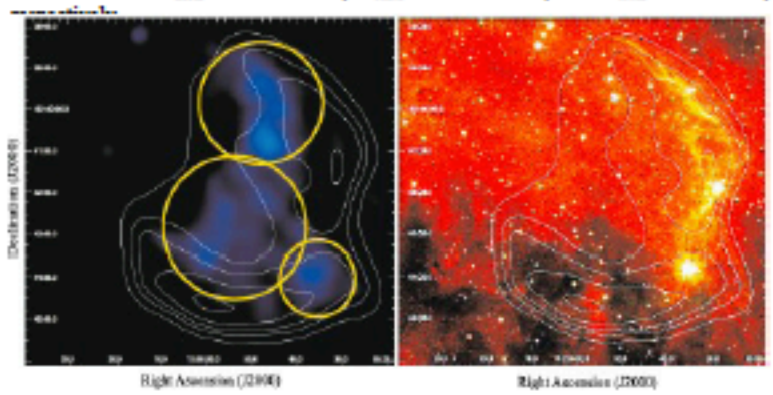
XMM-Newton detection of the supernova remnant G304.6+0.1 (Kes 17)

Ref: J.A. Combi, J.F. Albacete-Colombo, et al. 2010, A&A 523, A76



G304.6+0.1: composite color image of the radio, mid-infrared, and X-ray emissions. XMM-*Newton* blue image is in the 0.3–10 keV energy range. The radio contours (in white) at 843 MHz overlaid. red color are the IRAC three channels composed image of G304.6+0.1.

The X-ray spectrum was fitted by a combination of thermal and non-thermal models. The power-law model adequately fits high-energy photons (up to 5 keV) in which particle acceleration in shock-fronts could physically explain this X-ray emission. We compute physical parameters by using radio/mid-infrared and X-ray information, i.e. the volume *V* of the X-ray emitting plasma for the differents regions. The plasma fills regions like those observed in pannel. Assuming a distance of 9.7 kpc for the SNR, we obtain volumes V_{north} = 9.5x10^{57}cm^3, V_{centre}= 1.5 x10^{58}cm^3, and V_{south}=1.1x10^{57}cm^3, respectively.



Left panel: XMM-*Newton* color image of the X-ray emission in the 0.3–10 keV energy range (in blue) of G304.6+0.1 with the radio contours (in white) at 843 MHz overlaid. The extraction regions used for the spectral analysis are also indicated as yellow circles. *Right panel*: IRAC three-channels composed image of G304.6+0.1 with the radio contours (in white) at 843 MHz overlaid.

The emission measure (EM) is determined by the spectral fitting, the electron density of the plasma, n_e, by $\sqrt{EM/V}$, where n_e(north) ~ 0.99 cm^{-3}, n_e(centre) ~ 0.89 cm^{-3}, and n_e(south) ~ 2.26 cm^{-3}, respectively. The age *t* was then determined from the ionization timescale, τ, by $t = τ/n_e$. The elapsed time after the plasma was heated is in the range of (2.8-6.4)x10^4 yr. These results show that G304.6+0.1 is a mixed-morphology (MM) and middle-aged SNR.

The authors acknowledge support by DGI of the Spanish Ministerio de Educación y Ciencia under grants AYA2010-21782-C03-03, Plan Andaluz de Investigación Desarrollo e Innovación (PAIDI) as research group FQM-322 and the excellence fund FQM2009-5418 of Consejería de Innovación, Ciencia y Empresa of Junta de Andalucía, as well as FEDER funds. J.A.C. and J.F.A.C. are researchers of CONICET. J.F.A.C was supported by grant PICT 2007-02177 (SecyT, Argentina). J.A.C was supported by grant PICT 07-00848 BID 1728/OC-AR (ANPCyT, Argentina) and PIP 2010-0078 (CONICET, Argentina). J.L.S. acknowledges support by the Spanish Ministerio de Innovación y Tecnología under grant AYA2008-06423-C03-03.