THE X-RAY EMISSION OF A CLUMPY IRREGULAR GALAXY FROM THOUSANDS OF SUPERNOVA REMNANTS?

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1. OBSERVATIONS

Clumpy irregular galaxies contain 5-10 "clumps" which are hyperactive HII complexes each equivalent to 100 giant HII regions of the 30 Doradus type (Heidmann 1982). We observed one of them, Mkn 325 (= NGC 7673), with the Einstein IPC in Dec.1980 (seq.no 10201) for 3,200 s. The reduction was made kindly by D.E.Harris. The source was localized at

23h 25m 12.2s, + 23° 18' 25" (1950)

in agreement with the optical position, at a quite weak level (14 counts in the 1.4-2.9 kev range). Thus we could not get valuable spectral information, only that the spectrum is rather not soft. Correction for galactic absorption $N_H = 5\times10^{20}$ at.cm^{-2} (Heyles 1975) is applied. Fits of power law spectra happen to all go through the point with flux density 4.5×10^{-5} mJy at 3.0×10^{17} Hz (1.24 kev) and they yield a flux $(1.1 \pm 0.3)\times10^{-13}$ erg cm^{-2} s^{-1} inside 1-3 kev and an X-luminosity $(2.2 \pm 0.3)\times10^{41}$ erg s^{-1} inside 0.5-4.5 kev, for a distance 49 Mpc.

2. OVERALL SPECTRUM

Combining this X-ray result to published or unpublished data in other spectral domains we obtain the overall global spectrum given in the Table and Figure. Tokunaga's IR measurements refer to a 10" aperture and, being partial, give only a spectral index: $\alpha = 0.53$. Huchra's UBV are also partial and give $\alpha = -1.56$ (a galactic absorption $A_B = 0.31$ correction was applied). The UV fluxes falling inside the IUE large slit were converted to global values using the photometry of the clumps by Coupinot et al. (1982); galactic absorption was also corrected for.

3. DISCUSSION

We first recall that these same UV results show that Mkn 325 may contain 4.2×10^4 O8V + 1.10×10^5 B8I stars (even more if there is internal absorption) and that at 155 nm it radiates 1.2×10^{28} erg s^{-1} Hz^{-1}, i.e.

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frequency (Hz)	flux density (mJy)	reference
1.415×10^{9}	39 ± 4	Bieging et al.1977
2.700×10^{9}	26 ± 4	Bieging et al.1977
5.000×10^{9}	≲ 18	Biermann et al.1980
1.070×10^{10}	10.3 ± 0.7	Heidmann et al.1982
8.333×10^{13}	7.2 ± 0.65	Heidmann and Tokunaga private com.
1.364×10^{14}	9.6 ± 0.15	Heidmann and Tokunaga private com.
1.364×10^{14}	30	Heidmann and Shaya private com.
2.400×10^{14}	12.5 ± 0.25	Heidmann and Tokunaga private com.
5.425×10^{14}	20.7	Huchra 1977
6.818×10^{14}	16.2	Huchra 1977
6.818×10^{14}	32	de Vaucouleurs et al.1976
8.197×10^{14}	10.8	Huchra 1977
1.176×10^{15}	5.8	Benvenuti et al.1982b
1.935×10^{15}	4.2	Benvenuti et al.1982a
3.000×10^{17}	4.5×10^{-5}	this paper

Table. Global emission of Mkn 325 versus frequency

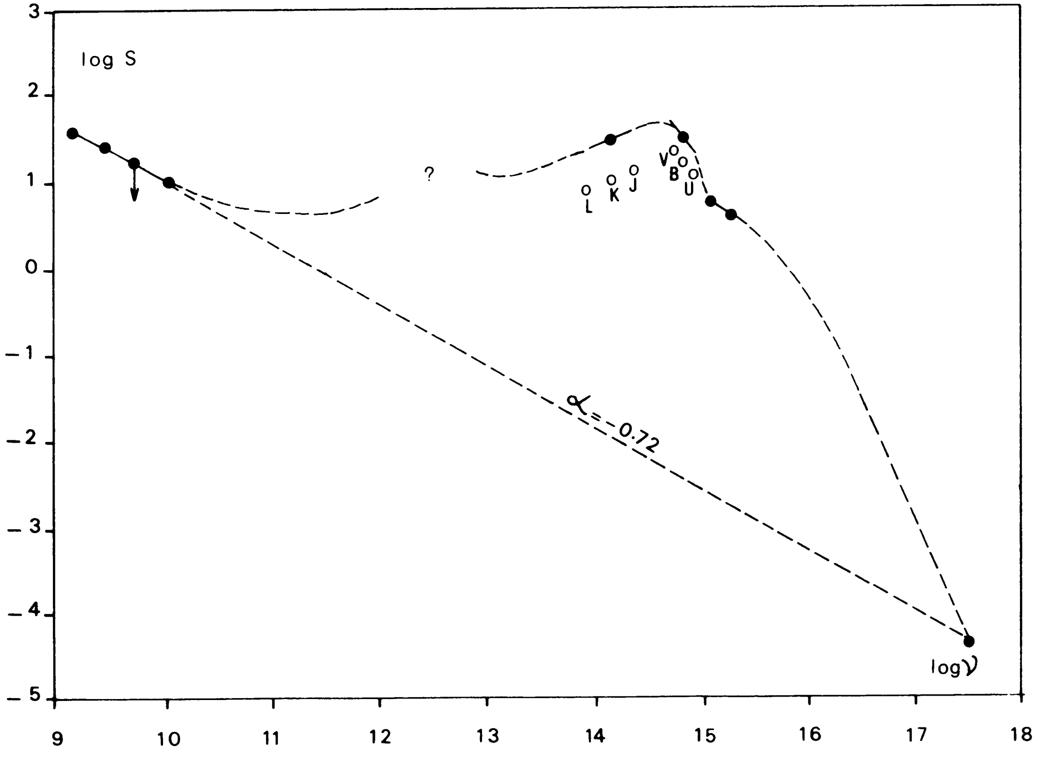

Figure. Overall spectrum of Mkn 325 in mJy vs Hz

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670 times more than the giant HII region 30 Dor. It is with these yardsticks of extreme star formation activity that we have to appraise the X-luminosity of Mkn 325.

O and B stars, class I-V, have X-luminosities (always in the same kev range) $10^{30}-10^{34}$ erg s^{-1} (Vaiana et al.1981); then they fall short. Supernova remnants reach easily 10^{37} erg s^{-1} (Van Speybroeck et al.1979, Agraval and Riegler 1980, Dopita et al.1981, Long et al.1981). Then about 10^4 such SNRs could account for the Mkn 325 X-emission. This is a tremendous number and corresponds to one SNR for 10 early OB stars. X-ray binary stars are more powerful,reaching above 10^{38} erg s^{-1} (Long et al.1981, Seward and Mitchell 1981) so that 1,000 X-binaries could also account for the emission, i.e. one for 100 OB stars.

We note an interesting fact: the strongest X-source in the LMC, the binary LMC X-1, may be physically associated with the giant HII region 30 Dor. If we scale up its X-luminosity $2x10^{38}$ erg s^{-1} with the factor 670 derived above from UV data we get $1.4x10^{41}$ erg s^{-1}, which is practically the Mkn 325 observed value. Thus, as well in X-rays as in the UV, this galaxy can be considered as a collection of $\sim$700 giant HII regions.

The overall spectrum shows that the X-flux density is in line with the extrapolated radio spectrum: spectral index from radio to X $\alpha = -0.72$, radio index $\alpha = -0.66 \pm 0.01$ (Heidmann et al.1982). The same fact was also observed by Fabbiano et al.(1982) for peculiar galaxies.

Physically these relationships between radio, UV and X emissions may be understood through the initial mass functions of the gigantic bursts which link SNRs and/or young supernovae of the SN1979c type (radio), OB stars (UV) and X-binaries (X).

4. TRIGGERING OF THE BURSTS OF STAR FORMATION

We did not detect X-emission from the nearby paired galaxy Mkn 326 (= NGC 7677). This sharpens most interestingly the problem of the triggering of the huge bursts of star formation in Mkn 325. First we note that with the radial velocity difference 157 km s^{-1} and the separation 95 kpc found by Bottinelli et al.(1975), an eventual tidal interaction in the pair occured $\sim 6x10^8$ years ago, which is an order of magnitude larger than the presumed age of the bursts. Second, Mkn 326 is comparable to Mkn 325 in luminosity (1.8 times less from Huchra, 1977), in neutral hydrogen mass (3 times more), in total mass (4 times more from Bottinelli et al.,1975) and in diameter (equal from de Vaucouleurs et al.,1976). Third, in spite of this similarity, CFH 3.6m telescope plates (Coupinot et al.1983) show that Mkn 326 is a spiral with no morphological disturbance; further it has normal B-V (0.71) and U-B (0.06) colors while Mkn 325 is much bluer (0.35 and -0.43, Huchra, 1977). All this, combined with the fact that we did not detect X-emission from Mkn 326, is against a tidal triggering of the bursts of Mkn 325 as proposed by Duflot and Alloin (1981).

The fact that, on the other hand, the velocity field in Mkn 325 does not show signs of a merging process (Duflot and Alloin 1981) leaves quite open the interesting question of the origin of the extreme star bursting activity in clumpy irregular galaxies which was recently discussed by Boesgaard et al.(1982).

The incompleteness of this Einstein observation, made at the end of its career (3,500 s out of 40,000 allocated),reduced its potentiality to get X-spectral slope and maping, informations which would be first-hand for the investigation of the high-mass part of the initial mass function of the bursts and of the exact nature of the end-products of short-lived stars in the clumps, especially through comparison with high resolution Space Telescope optical and VLA radio imageries.

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DISCUSSION

FABIAN: We have recently published X-ray observations of a similar burst of star formation, in a small galaxy 2 magnitudes intrinsically fainter than the SMC (Stewart et al.M.N.R.A.S.Aug.82). This galaxy, NGC 5408, radiates $\sim 10^{40}$ erg s^{-1} in X-rays. We conclude that massive binaries produce the X-rays and not SNRs.

HEIDMANN: Yes. But I should stress again that clumpy galaxies are 100 times more luminous intrinsically and this could lead to different physical conditions; see e.g. our failure to detect the CO mm line (Gordon et al. 1982, P.A.S.P. 94, 415).

DENNEFELD: What does the visible spectrum of Mkn 325 look like? From what you said one should expect either spectral features typical of SNRs (like [SII] for example) or Wolf-Rayet characteristics of hot stars as seen in giant HII regions, or both.

HEIDMANN: We obtained optical spectra of clumpy galaxies at Mauna Kea (see Ap.J. 252, 487): in addition to typical HII features there is indeed enhancement of the [SII] lines which indicates presence of SNRs. With A. Pitault we are looking for WR stars features, which at first sight are not prominent.

BLAIR: With regards to whether X-ray binaries or SNRs are mainly responsible for the X-ray emission you see: with a burst of star formation, one would expect many massive stars to form, and the remnants of these massive stars seem to be prodigious X-ray emitters (cf.the NGC 4489 SNR with $L_X \sim 10^{39}$ erg s^{-1} and 41.9 + 58 in M82 with the same luminosity, as discussed in the previous talk by Kronberg). Even though their lifetimes are quite short, there may be enough of these objects after a burst of star formation to dominate the X-ray emission.

HEIDMANN: Yes. In fact we hope to get information from a combination of X-ray and of radio VLA observations. We may also think about new types of X-ray emitters in our hyperactive bursts. Indeed Heeschen, Yin and I, in a VLA study of clumpy galaxies, just discovered the first known case of a strong, compact, variable radiosource which is not nuclear. Such a feature should be investigated for its X-ray properties with future instruments.