Wolf-Rayet Phenomena in Massive Stars and Starburst Galaxies
Proceedings IAU Symposium No. 193, ©*1999 IAU*
K.A. van der Hucht, G. Koenigsberger & P.R.J. Eenens, eds.

ASCA observation of Henize 2-10

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Abstract. We present results of X-ray spectroscopy of the prototypical Wolf-Rayet galaxy Henize 2-10 with *ASCA*. We find that the X-ray spectrum is best described by a model with soft ($kT \simeq 0.7$ keV) and hard ($kT \simeq 3.9$ keV) components. The soft component is attributed to the hot gas associated with the superwind, and the hard component with a collection of the young sources (young SNRs and HMXBs) associated with the starburst.

1. Introduction

Henize 2-10 is the prototypical Wolf-Rayet starburst galaxy (Conti 1991; Sugai & Taniguchi 1992) at a distance of 8.7 Mpc (Stevens & Strickland 1998). The soft X-ray (0.2–2 keV) properties have been observed with *ROSAT* (Dickcow *et al.* 1996; Stevens & Strickland 1998). With *ASCA*, we can study the hard X-ray properties of this prototypical WR galaxy for the first time.

2. Results and discussion

The X-ray emission from He2-10 is detected both at soft (0.5–2.0 keV) and hard (2.0–10 keV) energy bands. The source is not resolved with *ASCA*, but fortunately *ROSAT*-HRI has resolved the source (Dickow *et al.* 1996). We find an emission excess at > 2.0 keV, suggesting the presence of a hard component in addition to a soft component (Dickow *et al.* 1996; Stevens & Strickland 1998). Thus, we fit the spectra with a two-component Raymond-Smith model. In addition to the Galactic absorbing column ($N_{\rm H} = 9.69 \times 10^{20}$ cm^{-2}), we assume an intrinsic absorbing column for the hard component, which corresponds to the molecular-gas concentration at the nucleus (Kobulnicky *et al.* 1995). However, because its peak position is slightly offset from the nuclear star-forming region containing numerous WR stars, we assume that a half of the gas is effective for the absorption ($N_{\rm H} = 3.0 \times 10^{22}$ cm^{-2}). We find from spectral fitting that the soft component dose not suffer from absorption in excess of the Galactic column. Results are shown in Table 1.

Some important properties of the soft component are: extended morphology (Dickow *et al.* 1996), temperature ($\sim 10^7$ K), lower metallicity, and little absorption. All these suggest that the soft X-ray emission comes from the hot gas associated with the superwind (*e.g.*, Della Ceca *et al.* 1997). Possible agents of the hard component are Low Mass X-ray Binaries (LMXBs), High Mass X-ray Binaries (HMXBs), and young SNRs. The contribution of LMXBs would not be

Table 1. Results of the spectral fits

model	kT_{soft}[a] (keV)	abundance[a] ($Z_\odot$)	$norm_{soft}$[a] (10^{-5})	kT_{hard}[a] (keV)	$norm_{hard}$[a] (10^{-5})	χ^2_ν
$RS_{soft}+RS_{hard}$	$0.73^{0.86}_{0.54}$	$0.047^{0.13}_{0.010}$	$49.0^{90.3}_{29.8}$	$3.94^{54.6}_{1.41}$	$17.2^{57.4}_{6.9}$	0.90

f_X(0.5-2.0 keV)[b]	f_X(2.0-10.0 keV)[b]	L_X(0.5-2.0 keV)[c]	L_X(2.0-10.0 keV)[c]
2.80	1.27	2.54	1.15

[a]Allowed ranges of the parameters are 90% confidence intervals.
[b]Absorption corrected flux in units of 10^{-13} ergs cm^{-2} s^{-1}.
[c]Absorption corrected luminosity in units of 10^{39} ergs s^{-1}.

significant because the time-scale for formation of LMXBs is much larger than the age of the starburst (Esteban & Peimbert 1995). Typical temperatures are >15 keV and ~ 2–3 keV for HMXBs and young SNRs, respectively. The derived temperature for He2-10, $kT \simeq 3.9$ keV, favors young SNRs, but we cannot reject the possibility of HMXBs because of the large allowed range of the temperature. The observed X-ray luminosity can be explained if there are approximately 100 young SNRs or 10 HMXBs because their X-ray luminosities are $\sim 10^{37}$ erg s^{-1} and $\sim 10^{38}$ erg s^{-1} for a young SNR and a HMXB, respectively. However, because the current number of WR stars is only ~ 300 (Vacca & Conti 1992), and the lifetime of the young SNRs ($\sim 10^4$ yr) is shorter than that of WR stars ($\sim 10^5$ yr), the expected number of young SNRs would be less than 100, suggesting that only young SNRs are not enough to explain the observed luminosity. Thus we conclude that the origin of the hard component is a collection of the young sources (young SNRs and HMXBs) associated with the starburst.

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Discussion

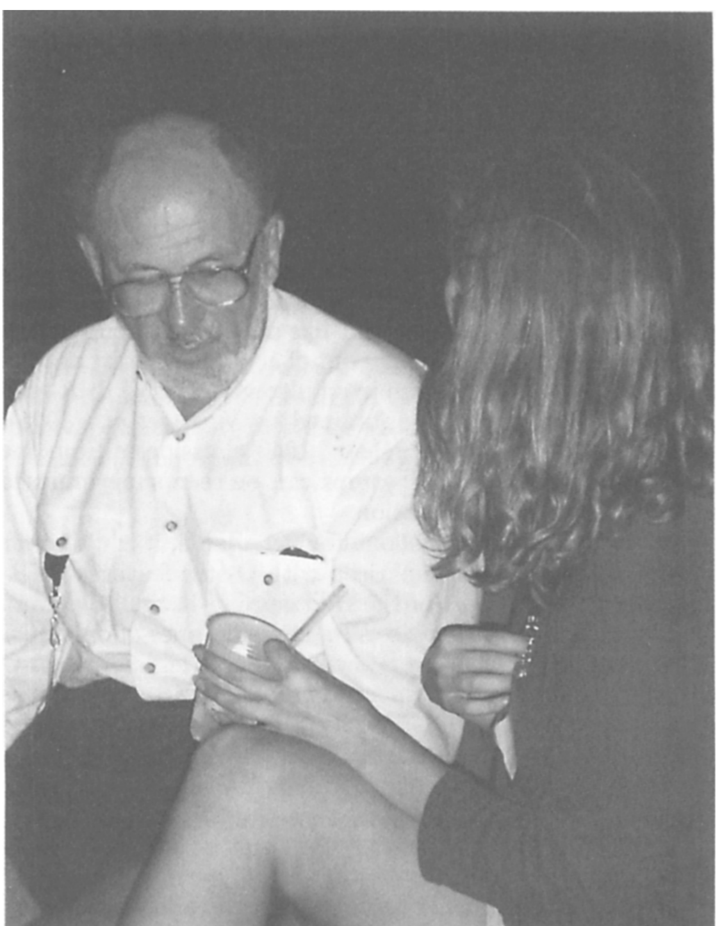
Koenigsberger: Could you comment on the contribution you would expect to the X-ray luminosity from the interaction of the stellar winds and SNR's?

Ohyama: The expected X-ray luminosity from the stellar wind is only $\sim 10^{-3}$ of the observed X-ray luminosity. Thus, although the temperature increases as a result of the interaction, the luminosity is still not enough to explain the observed value.

Beck: When you calculate the SNR contribution to the X-ray, remember that at least $5\times$ as many O and WR stars as you see are hiding behind the extinction; they will give you at least a factor of 5 or even 10.

Esteban: How many young SNRs do you need to explain all the X-ray luminosity?

Ohyama: Young SNRs would contribute only to the hard X-ray emission and the required number is about 100. The soft component comes from the hot gas associated with the superwind, or superbubble, caused by the collective effect on *all* SNRs (including evolved SNRs). The total number of all SNRs is 600–2300 (Esteban & Peimbert 1995, A&A 300, 18), which is enough to explain the thermal energy of the bubble.



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