LWS OBSERVATIONS OF A STATISTICAL SAMPLE OF LATE-TYPE GALAXIES FROM THE VIRGO CLUSTER

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ABSTRACT

The ISO Guaranteed Time program VIRGO is an ISOPHOT 40 - 220 μm study of a complete volume-limited, unbiased sample of spiral, irregular and BCD galaxies from the VIRGO cluster, selected from the Virgo Cluster Catalogue (VCC) of Binggeli *et al.* 1985, as described in Boselli *et al.* 1997. From these galaxies a sample of 19 cluster spiral galaxies was selected for study with LWS around the [C II] 157.68 μm fine structure line.

The subsample of 19 galaxies comes from both the cluster core (within 2 degrees of M87) and the cluster periphery (more than 4 degrees from the position of maximum galaxy surface density), enabling us to probe any difference between the conditions in the core and periphery.

We observed the subsample with the Long Wavelength Spectrometer around the [C II] 157.68 μm cooling line. This line probes not only photodissociation regions (e.g. Stacey *et al.* 1991) associated with massive star formation, but also, potentially, the quiescent diffuse HI component of the interstellar medium.

Here we present a preliminary reduction and analysis of the LWS spectra. Future work will combine the [C II] line fluxes and the FIR continuum fluxes with optical, radio (synchrotron), UV and X-ray measurements to provide detailed information on the structure and energy balance of the ISM in disks of galaxies, as well as their current and past star-formation activity.

Key words: ISO; Virgo

1. OBSERVATIONS AND DATA REDUCTION

VCC Galaxies observed by LWS, together with background reference positions (denoted VBACK) to check for foreground [C II] emission from the Milky Way, are given in table 1. All objects were observed between 30th June and 15th July 1996. No problems were reported with any observation.

Table 1. Observing log.

TARGET	RA (J2000)	DEC (J2000)	Observed
VCC 66	12h 12m 46.9s	10d 52' 07.0"	12 Jul
VBACK01	12h 13m 30.9s	15d 30' 47.2"	9 Jul
VCC 92	12h 13m 48.4s	14d 54' 07.2"	9 Jul
VBACK03	12h 13m 52.4s	8d 29' 12.2"	12 Jul
VCC 460	12h 21m 13.2s	18d 23' 03.6"	8 Jul
VBACK04	12h 25m 05.9s	17d 43' 52.1"	8 Jul
VCC 857	12h 25m 56.0s	18d 12' 47.6"	8 Jul
VCC 873	12h 26m 06.8s	13d 06' 47.6"	4 Jul
VBACK14	12h 26m 06.8s	13d 06' 47.6"	4 Jul
VCC 1003	12h 27m 26.2s	11d 06' 30.3"	5 Jul
VCC 1043	12h 27m 45.7s	13d 00' 30.4"	5 Jul
VCC 1110	12h 28m 29.5s	17d 05' 06.8"	8 Jul
VCC 1158	12h 29m 03.0s	13d 11' 07.1"	4 Jul
VCC 1253	12h 30m 02.9s	13d 38' 07.7"	4 Jul
VCC 1326	12h 30m 57.2s	11d 29' 02.1"	5 Jul
VCC 1412	12h 32m 05.5s	11d 10' 38.8"	5 Jul
VCC 1690	12h 36m 49.9s	13d 09' 53.8"	5 Jul
VCC 1727	12h 37m 43.5s	11d 49' 06.4"	15 Jul
VCC 1813	12h 39m 56.3s	10d 10' 38.0"	15 Jul
VCC 1869	12h 41m 13.6s	10d 09' 14.9"	15 Jul
VBACK12	12h 43m 08.5s	9d 47' 34.4"	15 Jul
VCC 1972	12h 43m 32.4s	11d 34' 46.7"	15 Jul
VCC 1987	12h 43m 57.2s	13d 07' 35.1"	30 Jun
VBACK13	12h 48m 14.5s	12d 58' 38.7"	30 Jun
VCC 2070	12h 48m 23.2s	8d 29' 14.9"	15 Jul

The Auto Analysis Results from OLP version 6 were further processed using the ISO Spectral Analysis Package (ISAP) by: reading data in; discarding bad LWS data points; averaging scans for detector 8 (the one that covers the 158 μm region); rebinning; and finally fitting gaussians to any lines seen in the data to obtain flux and central wavelength.

2. RESULTS AND DISCUSSION

Of the 19 galaxies in the sample, 15 were detected. An example galaxy, VCC 66, is shown in figure 1. Of the six background positions used, five had no detectable emission and one was mistakenly pointed at one of the galaxies in the sample (confirming the flux and wavelength for that galaxy). We therefore conclude that the instrumental setup used was insufficient to detect any foreground [C II] emission from our own galaxy and therefore none of the galaxy detections are contaminated by galactic [C II].

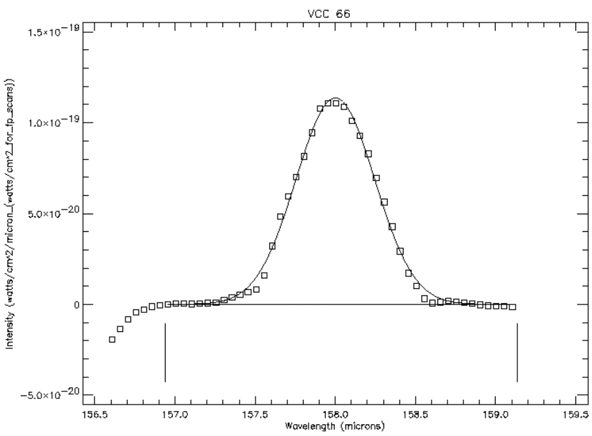

Figure 1. LWS spectrum of VCC 66 around [C II]. The vertical lines are limits used by the line fitting program, and the negative flux values below 157 μm are a processing artefact.

Figure 2 shows the relation between dust continuum and [C II] emission for 13 galaxies also observed in the broad band C160 filter (centered at 175 μm) by Völk et al. (in preparation). As the pixel areas are similar (99” circular for LWS, 89 × 89” for ISOPHOT-C200), the plot denotes the relation between the [C II] and dust emission from the projected inner 7 kpc of each galaxy (for a 15Mpc cluster distance). Upper limits are 3 sigma. As the FIR continuum brightness from dust typically has a pronounced spectral maximum in the C160 filter range, the plot can be interpreted in terms of ratios between line and dust continuum luminosity. The dotted line in Fig. 2 is not a fit but denotes a linear relation between FIR brightness and [C II] brightness such that the ratio of line to continuum luminosity integrated over the C160 filter, after correcting for the different aperture sizes, is 0.5 percent. The one galaxy not detected by either LWS or ISOPHOT is VCC 1158, a B_T 12.1 mag. Sa from the cluster core region.

Although statistics are poor and there are large intrinsic line/continuum ratio variations between galaxies, the data show an overall linear correlation between [C II] and dust continuum luminosity. They are broadly consistent with the LWS [C II] measurements in 5 Sc or later Virgo spirals by Smith *et al.* 1997. Galaxies which have higher continuum and line brightnesses tend to have later Hubble types. This is qualitatively consistent with an interpretation in which the [C II] emission from the central regions is proportional to the surface density of photodissociation regions, and the dust is substantially heated by the non-ionising UV radiation field. The tendency for the correlation to flatten off with increasing brightness, as observed by Stacey *et al.* 1991 for a sample embracing starburst and ultraluminous galaxies, is not apparent for the relatively quiescent Virgo sample. There is no apparent relation between the [C II] line/dust continuum ratio and position in the cluster or HI mass surface density in the galaxian disks. Therefore, any relation of the [C II] emission to the diffuse HI component of the ISM is not obvious, at least for the central regions of the disks observed.

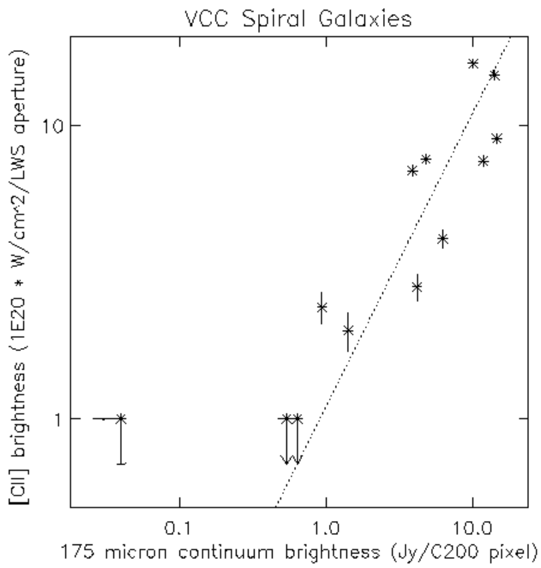

Figure 2. Correlation between [C II] brightness observed towards the nucleus of 13 galaxies also observed with the broad band ISOPHOT-C C160 filter. The error bars for the ISOPHOT measurements are smaller than the symbol size, represent random uncertainties only and do not contain the systematic uncertainty in the calibration.

REFERENCES

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Boselli *et al.* 1997, AA Supp 121, 507

Smith *et al.* AJ 1997 114, 138

Stacey *et al.* 1991, ApJ 373, 423

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