**SPITZER-IRS HIGH-RESOLUTION SPECTROSCOPY OF THE 12 μm SEYFERT GALAXIES. II. RESULTS FOR THE COMPLETE DATA SET**

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**ABSTRACT**

We present our Spitzer-Infrared Spectrometer (IRS) spectroscopic survey from 10 μm to 37 μm of the Seyfert galaxies of the 12 μm Galaxy Sample, collected in a high-resolution mode (R ~ 600). The new spectra of 61 galaxies, together with the data we already published, give us a total of 91 12 μm Seyfert galaxies observed, out of 112. We discuss the mid-IR emission lines and features of the Seyfert galaxies, using an improved active galactic nucleus (AGN) classification scheme: instead of adopting the usual classes of Seyfert 1’s and Seyfert 2’s, we use the spectropolarimetric data from the literature to divide the objects into categories “AGN 1” and “AGN 2,” where AGN 1’s include all broad-line objects, including the Seyfert 2’s showing hidden broad lines in polarized light. The remaining category, AGN 2’s, contains only Seyferts with no detectable broad lines in either direct or polarized spectroscopy. We present various mid-IR observables, such as ionization-sensitive and density-sensitive line ratios, the polycyclic aromatic hydrocarbon (PAH) 11.25 μm feature and the H2 S(1) rotational line equivalent widths (EWs), the (60–25 μm) spectral index, and the source extendedness at 19 μm, to characterize similarities and differences in the AGN populations, in terms of AGN dominance versus star formation dominance. We find that the mid-IR emission properties characterize all the AGN 1’s objects as a single family, with strongly AGN-dominated spectra. In contrast, the AGN 2’s can be divided into two groups, the first one with properties similar to the AGN 1’s except without detected broad lines, and the second with properties similar to the non-Seyfert galaxies, such as LINERs or starburst galaxies. We computed a semianalytical model to estimate the AGN and the starburst contributions to the mid-IR galaxy emission at 19 μm. For 59 galaxies with appropriate data, we can separate the 19 μm emission into AGN and starburst components using the measured mid-IR spectral features. We use these to quantify the brightness thresholds that an AGN must meet to satisfy our classifications: AGN 1’s have an AGN contribution ≥73% and AGN 2 ≥ 45% of their total emission at 19 μm. The detection of [Ne v] lines turns out to be an almost perfect signature of energy production by an AGN. Only four (~7.5%) of 55 AGN 1’s and two (10%) out of 20 AGN 2’s do not have [Ne v] 14.3 μm down to a flux limit of ~4 × 10^{-15} erg s^{-1} cm^{-2}. We present mean spectra of the various AGN categories. Passing from AGN-dominated to starburst-dominated objects, the continuum steepens, especially at wavelengths shorter than 20 μm, while the PAH feature increases in its EW and the high ionization lines decrease. We estimate H2 mass and excitation temperature through the measurement of the S(1) rotational line of this molecule. Finally, we derive the first local luminosity functions for the brightest mid-IR lines and the PAH feature at 11.25 μm. No statistical difference is apparent in the space densities for Seyfert 1’s and 2’s of a given line luminosity, or for the new classes of AGN 1’s and 2’s. We use the correlation between [Ne v] line and nonstellar IR continuum luminosity to derive the global output of accretion-powered galactic nuclei in the local universe.

**Key words:** galaxies: active – galaxies: starburst – infrared: galaxies

**Online-only material:** color figures, extended figure, figure set, machine-readable tables

1. INTRODUCTION

This paper contains the final results of the Spitzer high-resolution IRS spectroscopic survey of the sample of Seyfert galaxies (hereafter 12MSG) included in the Infrared Astronomical Satellite (IRAS) 12 μm galaxy sample (Rush et al. 1993, hereafter RMS). In Tommasin et al. (2008, hereafter Paper I), we have presented and analyzed the first 30 high-resolution spectra of 29 Seyfert galaxies of this sample (one IRAS galaxy, Mrk 1034, was coincident with a pair, for which we obtained two spectra). The first spectroscopic observations of active galaxies with the Infrared Spectrometer (IRS; Houck et al. 2004) onboard the Spitzer Space Telescope (Werner et al. 2004) have been collected on classical active galactic nuclei (AGNs; Weedman et al. 2005) and ULIRGs (Armus et al. 2007). After the work presented in Paper I and the referenced works therein, a few more studies have discussed the Spitzer mid-IR spectra of Seyfert galaxies, among these Deo et al. (2007), Meléndez et al. (2008a), and Wu et al. (2009). As expected, the mid-IR spectra of Seyfert galaxies show forbidden lines originating in the narrow-line regions (NLRs), excited by the AGN ionizing flux. This power is thought to be produced by black hole accretion, i.e., ultimately from the conversion of gravitational into radiative energy. The fine structure lines of [Ne v] at 14.32 μm and 24.31 μm originate exclusively in the highly ionized gas (with an ionization potential of 97 eV) illuminated by the AGN.5 As discussed in Paper I, the [O iv] line at 25.88 μm (ionization...
potential of 55 eV) is most probably excited from the AGN. In fact, Meléndez et al. (2008b) consider this line as an accurate and truly isotropic indicator of AGN activity, even if it could also originate from high-excitation starburst emission or in shocks in low-metallicity starbursts (Lutz et al. 1998).

The $[\text{Ne} \text{II}]15.55\mu$m line ($\text{Ne}+ \text{ and Ne}++$ have ionization potentials of 14 eV less than $\text{O}++ \text{ and O}+++$, respectively) can be excited both from AGN activity (Gorjian et al. 2007) and from starbursts (Thornley et al. 2000). Superimposed on the AGN spectra, the lines of $[\text{Ne} \text{II}]12.81\mu$m, $[\text{S} \text{II}]18.71\mu$m and 33.48$\mu$m, and $[\text{Si} \text{II}]34.82\mu$m originate in gas with moderate ionization and most of their emission is generated by young newly formed stars, even if some contribution from the AGN is also expected (Spinoglio & Malkan 1992). The relationship between the $[\text{O} \text{IV}]25.88\mu$m, $[\text{Ne} \text{II}]15.55\mu$m, and $[\text{Ne} \text{II}]12.81\mu$m lines in an heterogeneous sample of Seyfert galaxies has been studied by Meléndez et al. (2008a), who found that Seyfert 1’s and Seyfert 2’s have different AGN and star formation contributions to the total emission.

The interstellar medium produces the pure rotational lines of molecular hydrogen, as already shown by the early results of Infrared Space Observatory (ISO) spectroscopy in Genzel et al. (1998) and Rigopoulou et al. (2002), respectively. Wu et al. (2009) analyzed the IRS low-resolution spectra of 103 Seyfert galaxies from the 12MSG and measured the polycyclic aromatic hydrocarbon (PAH) emission features and the silicate absorption strength. The PAHs have been proposed as star formation tracers by Puget & Leger (1989), while the silicate absorption is sensitive to heavy dust obscuration of the nucleus.

According to the simplest Unified Model for AGN, the Accreting Torus Model (ATM; Malkan et al. 1998), Seyfert 1 and 2 galaxies are the same kind of objects, only viewed from different angles. The strongest demonstration of this is detection via optical spectropolarimetry of the broad-line region (BLR) emission—the defining characteristic of Seyfert 1— in a significant minority of Seyfert 2 galaxies (Antonucci & Miller 1985; Antonucci 1993). A different scenario postulates an evolutionary difference: that Seyfert 2 are the early stages of the transition of H II/starburst galaxies into Seyfert 1’s. Two suggested evolutionary progressions are H II $\rightarrow$ Seyfert 2 (Kauffmann et al. 2003; Storchi-Bergmann et al. 2001), or a fuller scenario of H II $\rightarrow$ Seyfert 2 $\rightarrow$ Seyfert 1 (Hunt & Malkan 1999; Krongold et al. 2002; Levenson et al. 2001). Because the radiation due to the star formation processes is roughly isotropic, the ATM predicts no observational difference in the star formation tracers between Seyfert 1’s and 2’s. If, on the other hand, star formation is stronger in Seyfert 2’s, as suggested in Buchanan et al. (2006), then some evolution from Seyfert 2’s to Seyfert 1’s could be invoked. If general interstellar extinction toward the center of the galaxy is extremely high, optical data alone might not always provide the correct (intrinsic) classification.

Our sample is described in Section 2; the observations and the data reduction are briefly reported in Section 3; the direct results of our observations, the estimates of the H$_2$ masses and temperatures, and the measure of the continuum extendedness are presented in Section 4; the diagnostic diagrams and the semi-analytical models to interpret them are presented and discussed in Section 5. In Section 6 the $[\text{Ne} \text{V}]$ is quantified as an unambiguous AGN activity indicator, in Section 7 we show that the mid-IR diagnostics differentiate AGN 1’s from the other populations, and we derive the average spectra for each class of objects that can be used as templates also for predictions and comparisons with high-redshift populations. Finally, in Section 8, we present the line luminosity functions for our sample, and calculate the total accretion power generated in the local universe. The conclusions are summarized in Section 9.

2. THE SEYFERT GALAXIES OF THE 12 $\mu$m GALAXY SAMPLE

From the original Seyfert galaxies list of the RMS, we present 91 IRS high-resolution spectra, including one-third of them which were published in Paper I. Our final sample is over 80% complete, large enough to give reasonable statistical results, with 41 Seyfert 1’s, 47 Seyfert 2’s, and three galaxies which have been reclassified as optical starburst galaxies, according to NED.6

Another improvement of this work is the classification that we adopt: we reclassify the Seyfert 1’s and 2’s into more general “AGN 1’s” and “AGN 2’s.” We consider AGN 1’s to be all those with BLRs, including those Seyfert 2’s with hidden broad-line regions (hereafter HBLR), observed in polarized light. The remaining Seyfert 2’s lacking any broad permitted lines, even in polarized light, are classified as AGN 2’s. Our classification scheme is an attempt to identify a “clean” category of intrinsically broad-line AGN. We follow Tran (2001) and Tran (2003), who made a spectropolarimetric survey of the 12MSG. Out of the original 47 Seyfert 2’s, they found HBLR in 19, 20 lacking an HBLR and they reclassify 11 objects as LINER, H II or starburst galaxies.7 We classify as non-Sy for all these latter objects and similar ones (in the diagrams, LINER and H II or starburst galaxies will be distinguished). Exceptions are NGC1097 and MRK897 that we reclassify as being an AGN 1 and an AGN 2, respectively. We refer to Appendix A for the details on the classification of each one of these objects. Tran (2003) also adopt a somewhat arbitrary distinction between “bona fide” and “non-bona fide” Seyfert 1’s, based on the NED classification of Seyfert 1.8, Seyfert 1.9 types, and on radio loudness. For the remaining 13 objects not considered as “bona fide” Seyfert 1 in Tran (2003), we prefer instead to carefully classify them on the basis of detection or not of optical broad lines, either in direct or polarized spectra. We present the details on the classification of these 13 galaxies in Appendix A. We summarize here that we classify as AGN 1 seven Sy 1 of the original RMS list (NGC2526, NGC1097, NGC1365, NGC2639, NGC7316, ES0545-G13, and ES0362-G18), we classify NGC5347 as an HBLR (Moran 2007), and we reclassify as AGN 2 one galaxy (NGC5506). We consider as non-BLR four objects for which there is no evidence of broad lines, but they lack polarization observations (NGC1194, NGC4602, MRK1034, and MRK897). Finally we reclassify as non-Sy two galaxies (NGC3511 and MRK1034) and NGC897. Although Tran (2003) distinguishes the radio-loud 3C galaxies, we actually classify NGC1371 and NGC1097 independently of their radio characteristics, because of the presence of broad-line emission.

We note that seven Seyfert 1’s have Balmer lines with relatively small FWHM, under 2000 km s$^{-1}$ but which are nonetheless produced in a BLR (Zhang & Wang 2006), these are usually classified as “narrow-line Seyfert 1’s,” but our sample

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6 NASA Extragalactic Database, IPAC, Caltech Pasadena, http://nedwww.ipac.caltech.edu/  
7 Among these 11 objects, three (Mrk897, NGC7496, and NGC7590) were presented in Paper I and the other eight are NGC1056, NGC1097, NGC4922, NGC5505, NGC6810, NGC7130, MCG+0-29-23, and CGCG838-051, whose IRS spectra are presented in this paper.
contains too few to define another category. It will turn out that their IR spectra do not appear different from those of normal Seyfert 1’s (see Section 4).

In summary, our observed sample of “original” Seyfert galaxies contains 55 objects showing some evidence of broad lines, either in direct (34 Sy 1) or polarized light (21 HBLR) that we classify as AGN 1, 20 classified as AGN 2 (non-HBLR), and four non-BLR not included in the AGN 2 class. We will also consider in the following the 13 non-Sy galaxies; however, these latter will not be used for any statistical derivation.

Following the results of Wu et al. (2009), who have defined as “20 μm peakers” the Seyfert galaxies having a flux ratio $F_{20 \mu m} / F_{30 \mu m} > 0.95$, we have also identified these in our sample$^8$ to search for any difference with our classes of galaxies. We refer to Appendix B for the results on these objects.

3. OBSERVATIONAL AND DATA REDUCTION

Most of the sample galaxies—the 29 galaxies presented in Paper I and the 23 galaxies in this paper—have been observed within the Spitzer Guaranteed Time Project 30291 (PI: Fazio). IRS high-resolution observations of another 37 objects, belonging to the 12MSG, were extracted from the Spitzer Science Center (SSC) archive. For 25 of the latter objects, the observing mode was similar to the one of P30291, namely the off-source observations have been collected to allow accurate background subtraction. For the remaining 12 sources from the archive (see Table 1), no off-source observation was taken. For these objects, we give the line intensities, as for the other galaxies, but not the equivalent widths (EWs) of the emission features and lines. Nor do we present the for the other galaxies, but not the equivalent widths (EWs) of the emission features and lines. Nor do we present the for the other galaxies, but not the equivalent widths (EWs) of the emission features and lines. Nor do we present the for the other galaxies, but not the equivalent widths (EWs) of the emission features and lines. Nor do we present the for the other galaxies, but not the equivalent widths (EWs) of the emission features and lines. Nor do we present the

The spectra of the new 61 galaxies are shown in Figure 1. For all galaxies for which the off-source spectra have been subtracted, both the SH (Short High resolution spectrometer module, see Paper I) and the LH (Long High resolution spectrometer module, see Paper I) spectra are presented. For the galaxies for which no off-source observation was available, we show in the figure the on-source SH spectrum only. This latter is only marginally affected by the lack of background subtraction, because the theoretical background, as measured using the background estimator provided by the SSC, is less than 10% of the total measured SH emission. For these galaxies, we show only the detected lines in the LH range; we do not present the whole spectrum, because it is affected by a higher level of background (estimated to be about 20%–30% of the total measured emission). The spectra of MRK335, F05563-G018, NGC5135, IC4329A, NGC5347, and NGC5506 show only the LH detected lines, because after background subtraction, the LH orders are not well inter-calibrated and thus the continuum cannot be defined properly.

Table 2 reports the fluxes of the fine structure lines, measured with a Gaussian fit, for both the SH and LH spectra. Table 3 gives the fluxes of the molecular H$_2$ rotational lines S(0), S(1), S(2), and S(3) and the PAH 11.25 μm integrated flux, measured with a moment fit, and its EW. We consider as detections the resulting PAH integrated flux by the continuum flux density and remove the correct continuum from the galaxy. By dividing the PAH fluxes by removing from the spectra the continuum under a baseline traced from the continuum shortwards of the PAH feature to the continuum longwards of the [Ne ii] line. Such a large interval has been chosen because, in addition to the feature at 11.25 μm, two other PAH features are present (approximately at 12.0 μm and at 12.5 μm) and they increase the level of the apparent continuum under the 11.25 μm feature. The integration range of the PAH emission depends on the feature’s intensity, for the brightest sources it can be as wide as 0.5 μm (11.15–11.65 μm). Choosing this large baseline allowed us to avoid the other PAH contributions and remove the correct continuum from the galaxy. By dividing the resulting PAH integrated flux by the continuum flux density at the midpoint wavelength of the baseline, we can obtain the EW of the feature.

4. OBSERVATIONAL RESULTS

The journal of the observations of the 61 galaxies presented here is shown in Table 1, giving for each galaxy: the equatorial coordinates at the 2000 equinox; the redshift; the original RMS Seyfert class and the new classification; the IRAS fluxes at 12 and 25 μm; the observing date and the number of cycles and integration times per cycle.

Table 1: Journal of Spitzer IRS Observations

| Name | R.A. (2000.0) | Decl. (2000.0) | Type | New Class. | z | $F_{12 \mu m}$ (Jy) | $F_{25 \mu m}$ (Jy) | Obs. Date | SH Int. Time (s) | LH Int. Time (s) | Notes |
|------|--------------|---------------|------|------------|---|-------------------|-------------------|----------|-----------------|-----------------|-------|
| MRK335 | 00:06:19.5 | +20:12:10 | Sy 1 | 0.025785 | 0.27 | 0.45 | 2009 Jan 12 | 4 × 30 | 2 × 60 | 3 |
| MRK938 | 00:11:06.5 | −12:06:26 | Sy 2 | 0.019617 | 0.40 | 2.37 | 2006 Dec 20 | 2 × 30 | 4 × 14 | |
| MRK348 | 00:48:47.1 | +31:57:25 | Sy 2 | 0.015034 | 0.49 | 1.02 | 2007 Sep 1 | 2 × 30 | 4 × 14 | |
| NGC0526A | 01:23:54.4 | −35:00:56 | Sy 1 | 0.019097 | 0.23 | 0.48 | 2007 Aug 1 | 6 × 7 | 4 × 14 | 2,4 |
| IRAS01475−0740 | 01:50:02.7 | −07:25:48 | Sy 2 | 0.017666 | 0.31 | 0.96 | 2007 Apr 4 | 3 × 20 | 6 × 60 | |

Notes. (1) Data without off-source measurements; (2) data from Spitzer Archive; (3) data from PS0253 to be released; (4) see Appendix A for the source classification.

(This table is available in its entirety in a machine-readable form in the online journal. A portion is shown here for guidance regarding its form and content.)

8 The “20 μm peakers” in our sample are MRK335, MRK348, NGC424, NGC526A, MCG-2-8-39, F03450+0055, ESO033-G002, MRK0006, MRK704, MRK1239, 3C254, MCG-6-30-15, IC4329A, NGC6860, and NGC7213.

9 SMART is available on the SSC Web site and developed by the Infrared Spectrograph (IRS) Instrument Team at Cornell University (Higdon et al. 2004).
Figure 1. *Spitzer*–IRS SH and LH spectra of the observed Seyfert galaxies. Wavelengths have been shifted to the galaxies rest frames. For the objects with no off-source observation the SH spectrum is shown, because slightly affected from the background emission ($\approx 10\%$), together with the $>3\sigma$ detected lines in separated boxes. (A color version and the complete figure set (61 images) are available in the online journal.)
For the two Seyfert galaxies in common with Rigopoulou et al. (2002), NGC526A and NGC7582, our results are in complete agreement, even though they used ISO spectra, for which the H$_2$ S(1) data were obtained through an aperture of 14′′ × 27′′, that is seven times larger than the aperture of SH. This implies that the H$_2$ emission is concentrated in the inner ∼50 arcsec$^2$ of these two large (several arcminutes in diameter) galaxies.

In Figures 3(a) and (b), we present the H$_2$ flux versus PAH flux and the H$_2$ luminosity versus PAH luminosity. We confirm the results of Paper I with our new classification: there are no differing trends which could discriminate between AGN 1 and AGN 2.

### 4.2. Source Extendedness

The SH and LH spectra overlap in the range 17–19 μm, allowing us to form an estimate of the extendedness of the sources called $R$, the ratio of the flux measured in LH to the flux measured in SH in an adjacent spectral interval. This parameter can be defined only for sources after an appropriate background subtraction. We refer to Paper I for the details.

In Table 4 presents the derived temperatures $T$ in Seyfert and starburst galaxies and by Higdon et al. (2006) in ULIRGs, ranging from $10^7$ to $10^9 M_{\odot}$. The average mass (in units of $10^9 M_{\odot}$) for the AGN 1 class is 1.8 ± 1.3, for AGN 2 is 0.65 ± 0.47, excluding from the average the outlier NGC1142 because it has a mass an order of magnitude larger than the others. For non-Sy galaxies is not possible compile a sensible average, because their masses spread over a wide range of values; MRK1034 NED1 has a mass of 5.36, CGCG381-051 3.8, NCG3511 0.15, and NCG7590 0.12. For the two Seyfert galaxies in common with Rigopoulou et al. (2002), NGC1365 and NGC7583, our results are in complete agreement, even though they used ISO spectra, for which the H$_2$ S(1) data were obtained through an aperture of 14′′ × 27′′, that is seven times larger than the aperture of SH. This implies that the H$_2$ emission is concentrated in the inner ∼50 arcsec$^2$ of these two large (several arcminutes in diameter) galaxies.

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### Table 2

Fine Structure Lines in our Sample

| Name    | Line Fluxes (10$^{-14}$ erg s$^{-1}$ cm$^{-2}$) in SH | Line Fluxes (10$^{-14}$ erg s$^{-1}$ cm$^{-2}$) in LH |
|---------|-----------------------------------------------|---------------------------------------------------|
|         | [S iv] (10.51 μm) | [Ne ii] (12.81 μm) | [Ne v] (14.32 μm) | [Ne v] (15.56 μm) | [S iv] (18.71 μm) | [N v] (12.71 μm) | [O iv] (25.89 μm) | [S iv] (33.48 μm) | [S iv] (34.82 μm) |
| MRK335  | 0.43 ± 0.03    | 0.25 ± 0.05    | 0.38 ± 0.04    | 0.61 ± 0.04    | ...               | <0.62               | 1.97 ± 0.18    | 7.24 ± 0.19    | <1.21               | <1.45               |
| MRK938  | <1.46    | 52.1 ± 1.45    | <2.19    | 6.37 ± 0.55    | 7.56 ± 0.64    | ...               | <0.37               | <0.66               | <10.7               | 40.5 ± 4.21               |
| MRK438  | 7.16 ± 0.43    | 16.4 ± 0.35    | 5.82 ± 0.35    | 20.4 ± 0.38    | 7.00 ± 0.55    | ...               | 4.95 ± 0.36    | 17.6 ± 0.42    | 12.2 ± 1.12    | 9.8 ± 1.21               |
| NGC526A | 5.32 ± 0.58    | 5.77 ± 0.52    | 6.35 ± 0.45    | 10.4 ± 0.71    | <2.50    | ...               | 5.92 ± 0.29    | 19.3 ± 0.44    | 5.91 ± 1.05    | 8.58 ± 1.19               |
| IRAS01475−0740 | 2.14 ± 0.32    | 13.7 ± 0.30    | 6.38 ± 0.32    | 9.95 ± 0.34    | <4.55               | ...               | 1.87 ± 0.29    | 6.49 ± 0.31    | 3.12 ± 0.83    | <6.13               |

(This table is available in its entirety in a machine-readable form in the online journal. A portion is shown here for guidance regarding its form and content.)

### Table 3

Molecular Hydrogen Lines and PAH Emission Feature at 11.25 μm

| Name    | Line Fluxes (10$^{-14}$ erg s$^{-1}$ cm$^{-2}$) |
|---------|-----------------------------------------------|
|         | H$_2$ S(3) (9.67 μm) | H$_2$ S(2) (12.28 μm) | H$_2$ S(1) (17.04 μm) | H$_2$ S(0) (28.22 μm) | PAH (11.25 μm) | EQ.W. (μm) |
|         | (1)               | (2)               | (3)               | (4)               | (5)               | (6)               |
| MRK335  | ...               | <0.16    | 0.39 ± 0.05    | <0.72               | ...               | ...               |
| MRK938  | 2.72 ± 0.38    | ...               | 7.06 ± 0.65    | <1.02               | 292               | <0.687               |
| MRK438  | ...               | <1.05    | 1.77 ± 0.48    | <1.14               | ...               | ...               |
| NGC526A | ...               | <1.65    | 2.40 ± 0.77    | <1.41               | ...               | ...               |
| IRAS01475−0740 | ...               | <1.20    | 2.75 ± 0.30    | <2.18               | 30.3               | −0.071               |

Notes. Columns 1–4 give the line fluxes of the H$_2$ rotational lines in units of 10$^{-14}$ erg s$^{-1}$ cm$^{-2}$. Columns 5 and 6 give the flux and the EW of the PAH 11.25 μm emission feature, respectively.

(This table is available in its entirety in a machine-readable form in the online journal. A portion is shown here for guidance regarding its form and content.)
Figure 2. $H_2$ excitation diagrams. For each measured line, the natural logarithm of the level population normalized to its statistical weight is plotted against the upper level energy (in temperature units). For each pair of adjacent transitions the connecting line is shown, whose inverse value represents the gas temperature: the dashed line connects the S(0) and S(1) detections, the dotted line the S(1) and S(2), and the solid line the S(2) and S(3). Upper limits have been used to obtain limiting slopes and hence limiting temperatures and masses (see the text).

(A color version and an extended version of this figure are available in the online journal.)

because the aperture corrections to photometry of extended sources are not well defined for IRAC and MIPS. We find that, using both IRAC at 8 μm and MIPS at 24 μm, the extendedness classes we have defined are reproduced for our sources, although there are some differences in individual values. This implies a broad agreement among the IRS, IRAC at 8 μm, and MIPS at 24 μm measurements of the extendedness. A paper with the analysis of the IRAC four channels and MIPS at 24 μm images of the Seyfert galaxies of our sample is in preparation.

5. AGN DIAGNOSTIC DIAGRAMS: DATA AND MODELS

One of our aims is to develop a method to disentangle the contributions of the AGN and the starburst to the total IR emission of the Seyfert galaxies of our sample using mid-IR spectral features. In this section we use the diagnostic diagrams, together with semi-analytic models, to estimate the AGN contribution in each of the following observed quantities: the extendedness of the source, the EWs of the PAH at 11.25 μm, and of the [Ne II] line at 12.81 μm, the line ratios [Ne V]/[Ne II]12.81 μm and [O IV]/[Ne II]12.81 μm and the spectral index $\alpha$ at (60–25) μm. We constructed analytic models for these quantities, because they provide the best separation of emission from AGN and non-AGN, and therefore the best estimates of the AGN percentage contribution to the total mid-IR emission at 19 μm. The simple equations for each of the models are given in Appendix C. In the following plots of those quantities, we compare the observations with the semi-analytic models, which are plotted with solid lines.

5.1. Line Ratios Versus PAH Equivalent Widths

In Figure 4(a), the line ratio [Ne V]/[Ne II]14.32 μm is shown as a function of the EW of the PAH feature at 11.25 μm. This ratio is the best AGN tracer in the IRS wavelength range, because [Ne V] can be excited only by the AGN ionizing continuum. Its ratio to [Ne II]12.82 μm is not directly affected by abundances. Seventy-six percent of the AGN 1’s have an absolute value of the EW of the PAH at 11.25 μm and of the [Ne II] line at 12.81 μm, the line ratios [Ne V]/[Ne II]14.32 μm and [O IV]/[Ne II]12.81 μm and [O IV]/[Ne II]12.81 μm and the spectral index $\alpha$ at (60–25) μm. AGN 2’s (i.e., non-HBLR) show a wide range of both the EW of the PAH and of the neon line ratio. Figure 4(b) shows a similar diagram with the PAH EW versus [O IV]/[Ne II] line ratio. This diagram presents the

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10 For IRAC, see http://ssc.spitzer.caltech.edu/irac/calib/extcal/index.html.
same characteristics of the former, but with fewer upper limits, confirming its results. There is an Sy 1, NGC7213, that has not been detected in the $[O\text{ iv}]$ line and has been reported to be at an intermediate stage between LINER and Seyfert (Starling et al. 2005).

Both the diagrams of Figure 4 show semianalytic models which reproduce the empirical data and estimate the percentage of the AGN and the starburst contributions to the total IR emission at 19 $\mu$m. If we define as an Seyfert-dominated galaxy any of the sources with an AGN contribution equal or more than 50% (see the dashed lines in the diagrams), this corresponds to a

the line ratios $[Ne\text{ v}]/[Ne\text{ ii}] > 0.054$ and $[O\text{ iv}]/[Ne\text{ ii}] > 0.28$. Using this simple argument, we confirm that all the AGN 2’s (non-HBLR’s) are Seyfert-dominated, even if they span a wide range of AGN percentage in the diagnostic diagrams. We report in the Table 6 the average PAH EW and $[Ne\text{ v}]/[Ne\text{ ii}]$ ratio for each class of galaxies.

Also the diagrams PAH EW versus $[Ne\text{ v}]14.32\mu m/[Si\text{ ii}]$ 34.8 $\mu m$ and PAH EW versus $[Ne\text{ ii}]15.55\mu m/[Ne\text{ ii}]$ 12.82 $\mu m$, presented in Figures 5(a) and (b), show similar characteristics as the previous two: the line ratio increases when the PAH EW decreases. All these diagrams (Figures 4 and 5) show the general inverse relation between the AGN dominance, as measured from the ionization sensitive line ratios, and the star formation dominance, estimated from the PAH EW.

5.2. Line Ratios as Density Indicators

In the IRS high-resolution spectral range, there are two fine structure line doublers, from which the electron density can be derived. These are $[Ne\text{ v}]$ at 14.32 $\mu m$ and 24.31 $\mu m$ and $[Si\text{ ii}]$ at 18.71 $\mu m$ and 33.48 $\mu m$. Following Dudik et al. (2007), as already reported in Paper I, we present the diagram of the neon doublet ratio versus the sulfur doublet ratio in Figure 6. In the diagram are shown the low-density limits for both line ratios and the estimated electron density as calculated by Dudik et al. (2007) assuming a temperature $T = 10^4$ K. The sulfur doublet ratio has been computed correcting the flux of the $[Si\text{ ii}]$18.71 $\mu m$ taken through the smaller aperture SH, multiplying it by its extendedness factor (see Table 5) to be compared with the larger aperture LH. If the ratio of two lines of the same species is below the low-density limit, either there is extinction that preferentially reduces the flux of the shorter wavelength transition, and/or the assumed temperature is wrong, and these doublet ratios could not be used to measure the electron density.

We find that 34% of the AGN 1’s lie under the neon ratio low-density limit and 15% under the sulfur low-density limit, and that 30% of the AGN 2’s lie under the sulfur limit and 30% under the neon’s. Our current sample is much larger than that of Paper I, making these results statistically significant.

Taken at face value, these diagrams indicate low electron densities ($10^{3-4} \text{ cm}^{-3}$) in the $[Ne\text{ v}]$ emitting region. For a typical ionizing luminosity of $10^{43} \text{ erg} \text{ s}^{-1}$ and an ionization parameter of $10^{-2}$, this implies a characteristic radius of about 100 pc. Since the recombination time is long, for densities of $10^{3-4} \text{ cm}^{-3}$ it ranges from 10 to 100 years, $^{11}$ “fossil” NLR emission will continue to be detectable in AGN 2 which could have “shut down” production of ionizing photons for the last 300 years. We suspect this may be the explanation of many of the “pure Seyfert 2” members of our AGN 2 class.

Thus, a significant percentage of each of the Seyfert types falls under the low-density limit for either one or the other doubllet, therefore, at least for the galaxies whose line ratio(s) are below the limit, we cannot estimate correctly the electron densities. However, all the objects are below the low-density limit only in one line ratio and not in the other line ratio. If extinction were responsible, both ratios would show this effect. We do not have any explanation for this unexpected behavior and the possibility that some currently adopted atomic parameters for these lines (transition probabilities and/or collision strengths) might be inaccurate must be considered.

$^{11}$ A typical recombination time is $\tau_r \sim 10^5/n_e$ years (Osterbrock & Ferland 2006, p. 22).
In Figure 7(a), we show the [S\textsc{iii}] doublet ratio as a function of the [S\textsc{iv}]10.51 µm/[Si\textsc{ii}]34.8 µm ratio, with the [S\textsc{iii}]18.71 µm flux corrected for the extendedness factor (compared to Section 4.2). These lines are produced either in the NLRs of the active nuclei or in the H\textsc{ii} regions. In Figure 7(b), the [Ne\textsc{v}] doublet ratio as function of the [Ne\textsc{v}]14.32 µm/[Ne\textsc{ii}]12.82 µm line ratio is given. Figures 7(a) and (b) show no differences in the density-sensitive line ratios between the different Seyfert populations.

5.3. Ionization Diagrams

[Ne\textsc{v}]14.32 µm and [O\textsc{iv}]25.89 µm are the best AGN tracers in the high-resolution IRS spectra. We normalized them both to the [Ne\textsc{ii}]12.81 µm, that is mainly produced in the H\textsc{ii}/star-forming regions, to produce two ionization-sensitive ratios (in Figure 8(a)). All the sources lie along the same sequence. As expected, the AGN 1’s occupy the highest ionization region of the diagram as in the other diagrams. Most AGN 2’s lie in the same region of the AGN 1’s. This diagram can be used to estimate the ionizing power in the NLR, both in AGN 1 and AGN 2 objects. As mentioned above, we computed a semianalytic model to reproduce the data in this diagram. We choose as the threshold to consider a source as an Seyfert-dominated AGN again a 50% AGN contribution to the 19 µm continuum, and this includes all the AGN 1’s and all the detected AGN 2’s. A clear implication is that using optical spectroscopy to identify Seyfert nuclei, as we have done in the 12MGS, will systematically miss out a significant population of non-HBLR Seyfert 2’s (weak AGN 2’s) which have less than 50% AGN contributions to their IR emission at 19 µm.

Veilleux et al. (2009) present the same diagram for their sample of ULIRGs belonging to the QUEST survey, and compute a model to estimate the AGN and starburst contributions to the total emission. Their values of the line ratios are in the same range as ours. However, the percentage of AGN contribution they estimate is on average lower than the percentage we compute. This difference is likely due to the different populations of the samples. In fact, ULIRGs have a stronger starburst component than Seyfert’s and/or more heavily obscured AGN emission, even in the mid-IR.

5.4. Line Equivalent Width Diagnostics

The line EWs can also be used to estimate the contributions of the AGN and the starburst to the total galaxy emission. Since the original IRAS studies of Seyfert galaxies (Spinoglio & Malkan 1989; Rush et al. 1993; Spinoglio et al. 1995, 2002), we have known that the mid-IR continuum can be dominated by the AGN continuum (e.g., from 12 µm to 25 µm), while at longer wavelengths the continuum due to the galactic disk and reprocessed thermal emission from dust around the young stellar populations increases, and it dominates the total emission at wavelengths of 60–100 µm. Therefore, the EWs of emission lines in the mid-IR are differently affected by the underlying continuum, as a function of the wavelength: around 12 µm the EW will be more depressed by the strong AGN continuum, than they would be around 25 µm. The lines originating in the galactic disk and its star-forming regions, such as [Ne\textsc{ii}]12.8 µm and the H2 S(1) at 17.02 µm, will have a smaller EW in objects with a stronger AGN continuum, while the lines tracing the AGN, like [Ne\textsc{v}]14.32 µm and the [O\textsc{iv}]25.89 µm will not suffer this depression because they are enhanced in proportion to the strength itself of the AGN, keeping their EWs more constant.

In our analysis of the EWs, we consider only objects for which an accurate measurement of the continuum was possible through background subtraction and with detected lines, neglecting the ones with upper limits. The EW of the [Ne\textsc{ii}]12.81 µm, the [Ne\textsc{v}]14.32 µm, the [Ne\textsc{iii}]15.55 µm, the [O\textsc{iv}]25.89 µm, and H2 17.02 µm are reported in the Table 7.

We present in Figure 8(b) the PAH EW as a function of the [Ne\textsc{ii}]12.82 µm EW. This diagram is able to disentangle Seyfert-dominated AGN from starbursts. Comparing it with
Table 5
Photometric Fluxes and Extendedness Factors

| Name            | $F_{19.9\mu m}$ (SH) (Jy) | $F_{19.9\mu m}$ (LH) (Jy) | $R$  | Class |
|-----------------|--------------------------|--------------------------|------|-------|
| MRK938          | 0.742 ± 0.006            | 0.885 ± 0.009            | 1.19 | II    |
| NGC234          | 0.589 ± 0.007            | 0.647 ± 0.003            | 1.10 | I     |
| NGC526A         | 0.363 ± 0.017            | 0.361 ± 0.013            | 0.993|       |
| IRAS01475–0740  | 0.462 ± 0.003            | 0.507 ± 0.004            | 1.1  | I     |
| NGC1056         | 0.130 ± 0.006            | 0.209 ± 0.001            | 1.61 | I     |
| NGC1142         | 0.096 ± 0.001            | 0.184 ± 0.015            | 1.92 | III   |
| MCG-2.8-39      | 0.356 ± 0.005            | 0.379 ± 0.003            | 1.06 | I     |
| NGC1494         | 0.336 ± 0.007            | 0.427 ± 0.004            | 1.27 | II    |
| NGC1241         | 0.100 ± 0.004            | 0.144 ± 0.002            | 1.44 | II    |
| NGC1320         | 0.698 ± 0.005            | 0.743 ± 0.005            | 1.06 | I     |
| NGC1386         | 0.793 ± 0.015            | 0.990 ± 0.006            | 1.23 | II    |
| IRAS03450+0055  | 0.473 ± 0.006            | 0.463 ± 0.003            | 0.98 | I     |
| 3C210           | 0.579 ± 0.024            | 0.577 ± 0.006            | 0.996|       |
| MRK618          | 0.568 ± 0.012            | 0.577 ± 0.002            | 1.02 | I     |
| F04385-0828     | 0.910 ± 0.007            | 1.008 ± 0.006            | 1.1  | I     |
| NGC1667A        | 0.053 ± 0.004            | 0.154 ± 0.009            | 2.91 | II    |
| ESO366-G018     | 0.339 ± 0.005            | 0.361 ± 0.002            | 1.06 | I     |
| ESO253-G3       | 0.565 ± 0.003            | 0.667 ± 0.002            | 1.18 | II    |
| MK1239          | 0.944 ± 0.001            | 0.971 ± 0.002            | 1.07 | I     |
| 3C234           | 0.237 ± 0.005            | 0.258 ± 0.005            | 1.09 | I     |
| NGC3982         | 0.116 ± 0.003            | 0.172 ± 0.003            | 1.48 | II    |
| MK766           | 0.873 ± 0.002            | 0.999 ± 0.003            | 1.18 | II    |
| NGC4388         | 1.225 ± 0.011            | 1.445 ± 0.008            | 1.18 | II    |
| NGC4941         | 0.209 ± 0.020            | 0.247 ± 0.006            | 1.18 | II    |
| NCG5005         | 0.139 ± 0.015            | 0.240 ± 0.005            | 1.7  | III   |
| MCG-3-39-64     | 1.990 ± 0.011            | 1.992 ± 0.005            | 1.00 | I     |
| MCG-6-30-15     | 0.681 ± 0.019            | 0.679 ± 0.010            | 0.996|       |
| NGC5548         | 0.425 ± 0.006            | 0.502 ± 0.005            | 1.17 | II    |
| MCG-2.40-4      | 0.576 ± 0.006            | 0.690 ± 0.005            | 1.2  | II    |
| FSC15480–0344   | 0.455 ± 0.006            | 0.496 ± 0.002            | 1.09 | I     |
| NGC6810         | 1.514 ± 0.005            | 1.910 ± 0.004            | 1.26 | II    |
| NGC6860         | 0.280 ± 0.003            | 0.317 ± 0.004            | 1.13 | I     |
| MRK509          | 0.557 ± 0.007            | 0.631 ± 0.004            | 1.13 | I     |
| IC5063          | 2.344 ± 0.008            | 2.480 ± 0.011            | 1.06 | I     |
| NGC7130         | 0.814 ± 0.009            | 1.094 ± 0.004            | 1.34 | II    |
| NGC7172         | 0.256 ± 0.014            | 0.338 ± 0.003            | 1.32 | II    |
| NGC7213         | 0.425 ± 0.020            | 0.541 ± 0.003            | 1.27 | II    |
| NGC7134         | 0.233 ± 0.008            | 0.248 ± 0.004            | 1.07 | I     |
| MCG-3-58-7      | 0.661 ± 0.005            | 0.677 ± 0.005            | 1.04 | I     |
| NGC7582         | 2.337 ± 0.042            | 3.290 ± 0.015            | 1.40 | II    |
| CGCG381-051     | 0.336 ± 0.008            | 0.343 ± 0.011            | 1.02 | II    |

Table 6
Classification Table

| Property          | Sy 1  | HBLR | AGN 1 | AGN 2 | Non-Sy | “20\mu m Peakers” |
|-------------------|-------|------|-------|-------|--------|-------------------|
| Extendedness      | 1.17 ± 0.29 | 1.17 ± 0.22 | 1.17 ± 0.26 | 1.39 ± 0.45 | 1.54 ± 0.58 | 1.08 ± 0.08 |
| EW [Ne ii] 11.25 \mu m | -0.15 ± 0.20 | -0.16 ± 0.19 | -0.15 ± 0.19 | -0.35 ± 0.27 | -0.81 ± 0.42 | -0.04 ± 0.04 |
| EW [Ne ii] 12.81 \mu m | -0.28 ± 0.027 | -0.28 ± 0.026 | -0.28 ± 0.026 | -0.81 ± 0.057 | -0.116 ± 0.029 | -0.014 ± 0.015 |
| EW [Ne ii] 17.07 \mu m | -0.09 ± 0.008 | -0.09 ± 0.008 | -0.09 ± 0.008 | -0.84 ± 0.069 | -0.058 ± 0.062 | -0.008 ± 0.003 |
| %AGN at 19 \mu m | 92% ± 6% | 92% ± 8% | 92% ± 7% | 79% ± 16% | 69% ± 16% | 98.8% ± 1.5% |
| $\alpha_{(60-25)\mu m}$ | -0.84 ± 0.62 | -0.86 ± 0.81 | -0.86 ± 0.74 | -1.65 ± 0.93 | -2.19 ± 0.65 | -0.44 ± 0.65 |

Note: The mean values have been computed without considering the upper limits for all quantities and the zero values for the PAH EW.
extendedness $\leq 1.3$. But 2/3 of the non-Sy have extendedness $\geq 1.3$. AGN 2 splits almost equally in the two regions: eight of 18 lie in the AGN 1 region and 10 in the other.

Comparing the diagrams of the extendedness versus EW PAH and versus EW [Ne ii] with our semianalytic model, we find that these diagrams do separate the Seyfert-dominated AGN from starburst-dominated ones: a modeled AGN contribution greater than 75% corresponds to $|\text{EW PAH}| \leq 0.4$ $\mu$m and $|\text{EW [Ne ii]}| \leq 0.08$ $\mu$m.

The diagram of [Ne iii] EWs versus the 19 $\mu$m source extendedness (Figure 9) shows a similar trend of the figure with [Ne ii], but with a much higher scatter. In contrast, the diagrams of the [Ne v] and [O iv] EWs versus the 19 $\mu$m source extendedness (that we do not show) do not show any clear trend. This confirms that the high-ionization lines are almost totally produced in the active nuclei with no significant contribution from extended regions. [Ne iii] is an intermediate case, with contributions from both the Seyfert nucleus and also the extended star-forming regions.

The IRAS 12 $\mu$m luminosity and the [Ne v]14.32 $\mu$m/[Ne ii]12.82 $\mu$m line ratio are not correlated for any Seyfert type (see Figure 11), confirming the finding of Paper I. We
Figure 6. [Ne v]14.3 μm/[Ne ii]24.3 μm line ratio vs. the [S iii]18.7 μm/[S iii]33.5 μm line ratio. Symbols as in the previous figures, except for the open crossed symbols indicating the ratio of objects with small aperture [S iii]18.71 μm measures and the filled symbols directly above them showing the aperture corrected [S iii] line ratio. The dashed lines show the low-density limits (see the text). The solid lines at the top and at the right give the corresponding electron densities.

(A color version of this figure is available in the online journal.)

Notice that high-luminosity objects, e.g., those with $L_{12μm} > 10^{44}$ erg s$^{-1}$, have the ratio [Ne v]14.32 μm/[Ne ii]12.82 μm > 0.2, i.e., are AGN dominated. Figures 12(a) and (b) show the diagrams of [Ne v]14.32 μm/[Ne ii]12.82 μm and [Ne iii]15.55 μm/[Ne ii]12.82 μm versus (60–25) μm spectral index. In both diagrams, AGN 1’s lie in the upper right region, with [Ne v]/[Ne ii] > 0.05 and [Ne iii]/[Ne ii] > 0.1, and the spectral index $α_{60–25} > −2.2$. The non-Sy’s cluster in a region [Ne v]/[Ne ii] < 0.2 and [Ne iii]/[Ne ii] < 0.5, with a steeper spectral index, $α_{60–25} < −1.2$. AGN 2 lie across both the regions. The average spectral indices are given in Table 6.

5.5. The AGN and Starburst Contribution to the 19 μm Flux

By inverting the semianalytic models, i.e., solving the analytical expressions with the true values of the observed quantities, we obtained a value of $R_l$, defined as starburst to AGN continuum ratio at 19 μm (see Appendix C) for each of the five observed quantities of every source. We then computed the mean value of $R_l$ to estimate the relative percentage of AGN and starburst emissions. From the value of $R_l$ we computed in Table 8 the percentages of the starburst and of the AGN emission. When, for a particular source, the scatter is greater than half of the mean and is due to a single $R_l$ value of one of the models, which does not describe that source because of a noisy detection, we removed that discrepant value of $R_l$ and recomputed the mean. The sample of sources to which we apply this analysis is reduced from the observed sample of 89 because the models depend on the extendedness and the PAH EW, which are not always detected (for the PAH) or measurable (for the extendedness). We found that the model can disentangle the AGN and the starburst emission for 31 AGN 1 (17 bona fide Sy 1’s and 14 HBLR), three non-BLR, 15 AGN 2’s, and nine objects reclassified as non-Seyferts. As can be seen from the histogram in Figure 13, Sy 1’s have a mean AGN contribution at 19 μm of 92% ± 6%; HBLR’s 92% ± 8%; AGN’s 79% ± 16%, non-Sy’s 69% ± 16%, and non-BLR’s 62% ± 7%. These average percentages are also given in Table 6. It is perhaps an uncomfortable surprise that up to half of the 19 μm continuum in the IRS slit can come...
from a normal AGN, but still not be strong enough to make it unambiguously classified as an AGN from spectroscopy. As discussed below, this has lead to substantial confusion in the literature when Seyfert “AGN” are discussed and compared, using different selection observations.

The differences that we find between the AGN 1 and the AGN 2 (even if the latter cannot be considered from our data as an homogeneous population), i.e., the lower ionization ratios, the increased PAH and [Ne II] EQW, the extendedness of the 19 μm emission, can all be related to a weaker strength of the AGN component with respect to the starburst component. As a matter of fact, all our AGN 2’s have evidence of an AGN both in the optical (as seen in their optical line ratios in the BPT diagrams (Baldwin et al. 1981), where we have used the optical spectral observations of D. Rodriguez et al. 2010, in preparation) and also in the hard X-rays, at 2–10 keV (Shu et al. 2007; Malizia et al. 2007; Bianchi et al. 2005), 2–8 keV (Cardamone et al. 2007), 15–136 keV (Deluit 2004), or 40–100 keV (Bird et al. 2007).

5.6. Line Equivalent Widths for the Different AGN Types

The average EW of the fine structure lines in the various AGN classes will change depending on whether the line emission, and also the underlying continuum, is dominated by the nonstellar nucleus or the hot stars. Thus, the EW of [Ne v]14.32 μm is the same for AGN 1’s: 0.020 ± 0.021 and AGN 2’s: 0.025 ± 0.010 μm, because both the line and the underlying continuum emission are proportional to the luminosity of the AGN component. The EW drops in non-Seyfert galaxies because of the complete cutoff of [Ne v] emission—it is detected in two non-Seyfert galaxies which are classified as LINER (see Appendix A), but measured only in NGC7130, for which we have an off-source measurement.

The [O iv] EW decreases somewhat because the underlying continuum has a larger starburst contribution passing from AGN 1 to non-Sy, in fact the [O iv] EW of the AGN 1 is 0.116 ± 0.134 μm, of the AGN 2 is 0.093 ± 0.054 μm and of the non-Seyfert galaxies: 0.033 ± 0.035 μm. In contrast, the [Ne v] and the H2 EWs increase for the same sequence of objects, that is [Ne v] EW for the AGN 1 is 0.028 ± 0.026 μm, for the AGN 2 it is 0.081 ± 0.057 μm, for the non-Seyfert galaxies it is 0.116 ± 0.029 μm and the average EQW H2 is a factor of 10 greater in the non-HBLR’s and the normal galaxies than in Sy 1’s and HBLR’s (AGN 1: 0.009 ± 0.008 μm; AGN 2: 0.046 ± 0.069 μm; normal galaxies: 0.058 ± 0.062 μm). These trends are summarized in the “classification table” given in Table 6.

6. [Ne v] AS AN INDICATOR OF AGN ACTIVITY

Because of the very high ionization potential of Ne v, we consider it as the best emission feature to distinguish active galaxies from starburst galaxies. Strong starburst activity could possibly excite some high-ionization lines such as [O iv]25.89 μm (Lutz et al. 1998), but the ionizing spectrum of O and B stars is not hard enough to produce much Ne++. Shocks would need to have exceptionally high velocities. Among the 91 sources we analyzed and in Paper I classified as Seyfert galaxies, 16 objects have no [Ne v] emission. As mentioned in Section 2, 10 (NGC1056, MCG+00-23-029, NGC5005, NGC6810, CGCG381-051, MCG-03-34-063, NGC7496, NGC7590, NGC3511, and MRK1034 NED01) of these 16 galaxies have already been reclassified as LINER, H II, or starburst galaxies by Tran (2001, 2003). Four are Sy 1’s: NGC1097 and NGC2639 lie in the H II region area of the BPT diagram based on [N ii]6584 Å/Hα versus [O iii]5007 Å/Hβ (Baldwin et al. 1981); NGC7213, which also lacks the [O iv] line detection and has been classified as intermediate between LINER and Seyfert (Starling et al. 2005). The other undetected sources are the AGN 2 NGC4501 and MRK938, which also lack a detectable [O iv] line.

In contrast, two of the non-Sy’s show [Ne v]14.32 μm emission: NGC4922 and NGC7130 are LINERs, whose active nu-
Table 7
Equivalent Widths of Key Lines

| Name      | [Ne ii]12.81 μm (μm) | [Ne v]14.32 μm (μm) | [Ne iii]15.56 μm (μm) | H2 17.02 μm (μm) | [O iv]25.89 μm (μm) |
|-----------|----------------------|---------------------|-----------------------|------------------|---------------------|
| MRK335    | −0.002               | −0.005              | −0.010                | −0.005           | ...                 |
| MRK938    | −0.106               | ...                 | −0.025                | −0.025           | ...                 |
| MRK348    | −0.030               | −0.008              | −0.037                | −0.004           | −0.063              |
| NGC526A   | −0.017               | −0.022              | −0.040                | −0.013           | −0.165              |
| IRAS01475−0740 | −0.028         | −0.006              | −0.023                | −0.008           | −0.023              |
| NGC1056   | −0.103               | ...                 | −0.093                | −0.025           | −0.007              |
| NGC1142   | −0.141               | −0.016              | −0.063                | −0.056           | −0.032              |
| MCG-2-8-39 | −0.011              | −0.022              | −0.030                | −0.006           | −0.103              |
| NGC1194   | −0.007               | −0.009              | −0.018                | −0.005           | −0.060              |
| NGC1241   | −0.113               | −0.015              | −0.076                | −0.045           | −0.066              |
| NGC1320   | −0.013               | −0.019              | −0.022                | −0.006           | −0.066              |
| NGC1386   | −0.019               | −0.040              | −0.045                | −0.007           | −0.154              |
| IRAS03450+0055 | −0.001        | ...                 | −0.008                | ...              | −0.010              |
| 3C120     | −0.017               | −0.038              | −0.065                | ...              | −0.461              |
| MRK618    | −0.028               | −0.007              | −0.009                | −0.004           | −0.031              |
| F0338-0828 | −0.015            | −0.001              | −0.009                | −0.004           | −0.013              |
| NGC1667   | −0.183               | −0.023              | −0.195                | −0.078           | −0.065              |
| ESO362-G018 | −0.043            | −0.012              | −0.026                | −0.007           | −0.044              |
| ESO253-G3  | −0.028               | −0.014              | −0.040                | −0.004           | −0.058              |
| F05563-3820 | −0.005            | −0.004              | −0.009                | ...              | ...                 |
| MRK1239   | −0.007               | −0.002              | −0.010                | ...              | −0.037              |
| 3C234     | ...                 | −0.010              | −0.017                | ...              | −0.099              |
| NGC3982   | −0.100               | −0.039              | −0.073                | −0.028           | −0.050              |
| MK766     | −0.032               | −0.028              | −0.031                | −0.002           | −0.071              |
| NGC3488   | −0.088               | −0.054              | −0.116                | −0.014           | −0.296              |
| NGC4941   | −0.075               | −0.050              | −0.143                | −0.028           | −0.225              |
| NGC5005   | −0.136               | ...                 | −0.091                | 0.178            | −0.044              |
| MCG-3-39-64 | −0.034           | −0.039              | −0.070                | −0.004           | 0.1088              |
| MCG-6-30-15 | −0.010            | −0.007              | −0.009                | −0.007           | −0.076              |
| NCG5135   | −0.176               | −0.032              | −0.087                | −0.021           | ...                 |
| IC4329A   | −0.014               | −0.014              | −0.031                | ...              | ...                 |
| NGC5347   | −0.006               | −0.004              | −0.008                | ...              | ...                 |
| NGC5506   | −0.034               | −0.029              | −0.072                | −0.007           | ...                 |
| NCG5548   | −0.020               | −0.013              | −0.017                | ...              | −0.076              |
| MCG-2-40-4 | −0.022             | −0.010              | −0.015                | −0.013           | −0.030              |
| FSC15480−0344 | −0.017         | −0.018              | −0.028                | −0.002           | −0.120              |
| NGC6810   | −0.086               | ...                 | −0.014                | −0.013           | −0.005              |
| NGC6860   | −0.015               | −0.010              | −0.023                | −0.010           | −0.087              |
| MRK509    | −0.027               | −0.006              | −0.032                | ...              | −0.096              |
| IC5063    | −0.012               | −0.015              | −0.033                | −0.005           | −0.075              |
| NGC7130   | −0.146               | −0.016              | −0.052                | −0.012           | −0.020              |
| NGC7172   | −0.092               | −0.026              | −0.046                | −0.019           | −0.163              |
| NCG7213   | −0.053               | ...                 | −0.031                | −0.007           | ...                 |
| NGC7314   | −0.039               | −0.082              | −0.106                | −0.007           | −0.467              |
| MCG-3-58-7 | −0.013             | −0.013              | −0.017                | −0.005           | −0.024              |
| NGC7582   | −0.126               | −0.022              | −0.060                | −0.016           | −0.088              |
| CGCG381−051 | −0.087             | ...                 | −0.006                | ...              | ...                 |

Note. MRK335, F05563-3820, NGC5135, IC4329A, NGC5347, and NGC5506 do not have calculated [O iv] EW, because even if they have background-subtracted spectra, the continuum in the (19−35) μm range results not well calibrated.

cle can produce highly photoionized gas emission (Dudik et al. 2009). There are also four sources with detections of [Ne v] at 14.32 μm but not 24.31 μm. Nevertheless, we consider them as [Ne v] emitters, even if not detected at 24.31 μm, because the noise of LH is greater than the noise of SH.

In conclusion, we can consider the [Ne v] emission lines as a strong indicator for a galaxy to be classified as an AGN. In fact, it is detected in 88% of the AGN 1’s, 90% of the AGN 2’s, only the 17% of the non-Sy’s. This means that deep spectroscopic searches, e.g., for [Ne v]14 μm, can discover relatively weaker AGN with lower luminosities, which only produce less than 45% of the total 19 μm emission observed.

Thus, our IR classification of galactic nuclei turns out to be in very close agreement to the classifications of them originally made from optical spectroscopy. The 12MGS AGN sample, which is originally defined based on optical spectra, does not contain very heavily obscured (“buried”) Seyfert nuclei, more or less by definition. Deep searches for [Ne v]14 μm emission in the remaining “non-Seyfert” members of 12MGS would be required to find out how common buried Seyferts are. A first step
Figure 9. (a) PAH 11.25 μm EWs vs. extendedness parameter. The black line shows the behavior of the analytical model for this diagram. (b) [Ne ii]12.8 μm EWs vs. extendedness parameter. The black line shows the behavior of the analytical model for this diagram.

(A color version of this figure is available in the online journal.)

Figure 10. [Ne iii]15.5 μm line EW vs. extendedness parameter. (A color version of this figure is available in the online journal.)

Figure 11. [Ne v]14.3 μm/[Ne ii]12.8μm line ratio vs. 12 μm luminosity. (A color version of this figure is available in the online journal.)

7. AGN 1 STATISTICS

We give in Table 9 the probabilities $P$ that the two AGN 1 subpopulations, the Sy 1’s and the HBLR Sy 2’s, do not differ significantly from one another, for each of the observed quantities. To derive those probabilities, we used a Kolmogorov–Smirnov test, which calculates the probability of two sets of data values arising from the same intrinsic distribution. The higher the probability, the closer are the two sets of data. We have grouped similar diagrams together to derive an average probability $⟨P⟩$, with its standard deviation. For the first group of the relations combining fine structure line ratios with PAH equivalent width (EW PAH versus [Ne v]/[Ne ii], versus [Ne iii]/[Ne ii], versus [O iv]/[Ne ii], versus [Ne v]/[Si ii]), we obtain $⟨P⟩ = 73\% \pm 31\%$ that the AGN 1 populations—Sy 1’s and HBLR Sy 2’s—belong in the same class. For the second group, relations of the extendedness versus the EW of the

This has recently been taken by Goulding & Alexander (2009), who uncovered a significant fraction of [Ne v]-emitting luminous IR galaxies whose Seyfert nuclei had been missed by previous optical spectroscopy, due to the lack of sensitivity and heavy dust reddening.
the relations between the H$_2$S(1) line and the PAH flux and $\text{[Ne\ ii]}$. We define as spectral index $\alpha$ the logarithm of the flux at 27 $\mu$m divided by the flux at 25 $\mu$m. All the normalized average spectra are presented together in Figure 14, and are available electronically. They are compared to the average spectrum of a sample of starburst galaxies from the IRS high-resolution data by Bernard-Salas et al. (2009).

The slopes of the continua of the average spectra are steepest in starburst and non-Seyfert’s and in AGN 2, with spectral indices$^{12}$ (10–35) $\mu$m of $-2.88$, $-2.25$, and $-1.65$, respectively. We cannot fit the continuum of the bona fide Sy 1’s and the HBLR with a single power law. Instead we must distinguish the (10–18) $\mu$m and the (18–35) $\mu$m continuum slopes. The shorter wavelength range in the bona fide Sy 1’s has a spectral index of the averaged spectra of $-1.21$ and for the HBLR of $-1.95$, while the longer wavelength range has continuum spectral indexes of $-0.65$ and $-0.90$, respectively.

Wu et al. (2009) find an average spectral index of the Seyfert 1’s to be $-0.85 \pm 0.61$ and of the Seyfert 2’s to be $-1.53 \pm 0.84$, quite similar to the original findings based on IRAS data of Edelson & Malkan (1986).

Figure 14 shows a clear sequence. The highly ionized lines, such as [S iv], [Ne v], and [O iv], are intense in the mean spectra of the Seyfert 1’s, HBLR Sy 2’s, and AGN 2’s. The PAH feature is stronger in starburst galaxies, non-Seyfert’s, and AGN 2, and is weaker in AGN 1. Thus, going from Seyfert-dominated to starburst-dominated objects, the continua steepen from AGN 1 to AGN 2 to non-Seyfert’s and starbursts, the higher ionization lines decrease not only in their flux, but also in their EWs (see Section 5.6), while the PAH feature remains almost constant to AGN activity (see Section 5.6). The presence of a BLR is closely correlated with strong thermal continuum from hot dust grains which emit around 10 $\mu$m.

7.2. Line Luminosity Functions

From our statistically complete sample of galaxies, we are able to compute the first IR line luminosity functions for Seyfert 1’s and Seyfert 2’s. The 12MGS includes 53 Seyfert 1’s and 63 Seyfert 2’s, but only 42 Seyfert 1’s and 50 Seyfert 2’s have been observed by IRS, therefore we have to correct the luminosity function for completeness. Table 10 gives

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**Figure 12.** (a) $\text{[Ne\ v]}$14.3 $\mu$m/$\text{[Ne\ ii]}$12.8 $\mu$m line ratio vs. the 60–25 $\mu$m spectral index. The black line shows the behavior of the analytical model for this diagram. (b) $\text{[Ne\ iii]}$15.5 $\mu$m/$\text{[Ne\ ii]}$12.8 $\mu$m line ratio vs. the 60–25 $\mu$m spectral index. (A color version of this figure is available in the online journal.)

[12] We define as spectral index $\alpha = \frac{\log(F_\lambda)}{\log(\lambda)}$. The presence of a BLR is closely correlated with strong thermal continuum from hot dust grains which emit around 10 $\mu$m.
Table 8
AGN and Starburst Contribution at 19 \( \mu \)m

| Name               | AGN (%) | Starburst (%) | Error |
|--------------------|---------|---------------|-------|
| **Seyfert 1**      |         |               |       |
| ESO012-G021        | 85.4    | 14.6          | 4.5   |
| ESO545-G013        | 78.4    | 21.6          | 13.5  |
| NGC0931            | 97.7    | 2.3           | 0.7   |
| MRK618             | 95.6    | 4.4           | 3.4   |
| ESO362-G018        | 85.9    | 14.1          | 4.3   |
| MRK0006            | 98.2    | 1.8           | 0.9   |
| MRK0009            | 97.6    | 2.4           | 0.7   |
| MRK79              | 98      | 2             | 1.1   |
| MKN1239            | 97.7    | 2.3           | 1.6   |
| NGC4602            | 95.6    | 4.4           | 1.1   |
| NGC4748            | 92.8    | 7.2           | 3.9   |
| MRK0817            | 92.1    | 7.9           | 5.0   |
| IRAS15091−2107     | 92.5    | 7.5           | 3.4   |
| ESO141-G055        | 97      | 3             | 1.7   |
| NGC6860            | 93.9    | 6.1           | 3.4   |
| MKN509             | 90.9    | 9.1           | 4.6   |
| **HBLR**           |         |               |       |
| ESO541-IG012       | 95.9    | 4.1           | 1.9   |
| NGC0424            | 96.9    | 3.1           | 2.2   |
| NGC0513            | 72.5    | 27.5          | 3.2   |
| IRAS01475−0740     | 93.8    | 6.2           | 2.9   |
| NGC1125            | 79.1    | 20.9          | 5     |
| MCG-2-8-39         | 97      | 3             | 0.5   |
| F04385-0828        | 95.8    | 4.2           | 2.3   |
| NCG4388            | 91      | 9             | 3.1   |
| NCG5347            | 92.9    | 7.1           | 4.1   |
| TOLOLO1238−364     | 84.4    | 15.6          | 3.7   |
| MCG-3-39-64        | 96.9    | 3.1           | 2.0   |
| MCG-2-40-4         | 94.6    | 5.4           | 0.8   |
| FSC15480−0344      | 94.5    | 5.5           | 0.5   |
| IRAS20210+0319     | 95.6    | 4.4           | 1.3   |
| MCG-3-58-7         | 95.7    | 4.3           | 1.7   |
| **AGN 2**          |         |               |       |
| MRK938             | 52.9    | 47.1          | 12.6  |
| IRAS00198−7926     | 96.8    | 3.2           | 0.8   |
| NGC1142            | 44.8    | 55.2          | 6.2   |
| NGC1241            | 69      | 31            | 7.9   |
| NGC1320            | 95.4    | 4.6           | 1.4   |
| NGC1667            | 71.7    | 28.3          | 11.9  |
| ESO033-6002        | 96.8    | 3.2           | 1.9   |
| ESO253-63          | 89.6    | 10.4          | 2     |
| NGC3660            | 75.5    | 24.5          | 7.3   |
| NGC3982            | 80.6    | 19.4          | 7.7   |
| NGC4501            | 70.2    | 29.8          | 7.6   |
| NGC4968            | 90.1    | 9.9           | 2     |
| NGC6890            | 89.5    | 10.5          | 1.3   |
| NGC7582            | 68.8    | 31.2          | 11.3  |
| NCC7172            | 85.3    | 14.7          | 3.5   |
| **Non-BLR**        |         |               |       |
| MRK1034 NED02      | 63.8    | 36.2          | 17.5  |
| NGC4602            | 68      | 32            | 11.9  |
| **Non-Sy**         |         |               |       |
| MRK1034 NED01      | 67.0    | 33.0          | 21.0  |
| NGC1056            | 68      | 32            | 12.1  |
| NGC5005            | 43.1    | 56.9          | 8.5   |
| MCG-3-34-63        | 41.6    | 58.4          | 17.7  |
| NGC6810            | 80.5    | 19.5          | 8.8   |
| MRK0897            | 53.8    | 46.2          | 16.1  |
| NGC7130            | 77.2    | 22.8          | 9.8   |
| NGC7496            | 81.2    | 18.8          | 9.3   |
| NGC7590            | 75.6    | 24.4          | 10.3  |
| CGCG381-051        | 87.5    | 12.5          | 14    |

Figure 13. Histogram shows the percentage of AGN contribution.
(A color version of this figure is available in the online journal.)

We do not find any significant difference in the line LFs of Seyfert 1’s and Seyfert 2’s, which are indistinguishable at the 2\( \sigma \) level. We also computed the line luminosity functions separately for the AGN 1’s and the AGN 2’s, using our new classification, and find no differences, probably because the shift of the 20 HBLR from the Seyfert 2’s class into the new AGN 1 class has not a noticeable (statistical) effect on the new AGN 1 luminosity functions, while it increases the uncertainties in the AGN 2 luminosity function. We do not present the luminosity functions with the new classification, because the AGN 1 sample size is 53 but the AGN 2 sample is only 21, making the statistics of these latter quite poor.

Our sample includes all the galaxies selected at 12 \( \mu \)m that show evidence of Seyfert activity through optical spectroscopy. We are aware that some AGN activity can be detected in the mid-IR in optically unidentified AGN. Goulding & Alexander (2009), using a volume limited sample to \( D \) < 15 Mpc, find that \(~50\%\) of the AGNs they detect are not identified using optical spectroscopy. However, these objects are typically starburst-dominated systems hosting modest AGN activity and have low luminosities. The luminosity of the [Ne \( v \)]14.32 \( \mu \)m emission line measured in these galaxies is about \( 10^{37}–10^{39} \) erg \( s^{-1} \), which is too low to affect our luminosity function (see Figure 16(a)).

8. THE ACCRETION POWER IN THE LOCAL UNIVERSE

Because the [Ne \( v \)]14.3 \( \mu \)m line is uniquely generated by the accretion process through the ionizing continuum of the
The accretion power in the local universe at 19 μm and the 19 μm luminosity determine the correlation between the luminosity in this line and the accretion power in the local universe. The first step is to measure the central engine, its luminosity function can be used to measure the AGN component. We can use this relation to convert the luminosity function, their inclusion or exclusion should not affect the luminosity integral substantially. The derived accretion power with the power which originates in the starburst component of our Seyfert galaxies. We follow a similar procedure by using the [Ne v]14.32 μm versus starburst luminosity relation, as taken from the starburst percentage of the sample galaxies from Table 8:

$$\log L_{19\mu m}^{AGN} = 0.9667 \times \log L([Ne\,v]14.32\mu m) + 4.3263$$

and is shown in Figure 21(a), for each of the galaxies detected in the [Ne v]14.32 μm line and for which we have a measure of the AGN component. We can use this relation to convert the [Ne v]14.32 μm line luminosity function, of the whole set of galaxies measured in this line, into a 19 μm AGN luminosity function. We present this latter in Figure 21(b). The integration over all luminosities and over the volume defined by the average redshift of the 12MSG of $z = 0.030$ (RMS) gives a measure of the accretion power in the local universe at 19 μm of $2.1 \times 10^{46}$ erg s$^{-1}$.

If we want to convert this monochromatic power at 19 μm into the bolometric power due to accretion, we simply use the relations between the bolometric luminosity and the IR luminosities published in Spinoglio et al. (1995). Taking the typical spectral index for Seyfert galaxies $\alpha(12\text{–}19\mu m) = -1$ and the 12 μm versus bolometric luminosity correlation, we find a bolometric power of accretion of $8.0 \times 10^{46}$ erg s$^{-1}$, over the local volume out to $z = 0.03$. We are well aware that the relation between 12 μm and bolometric luminosity has been derived from large-beam (few arcminutes square) IRAS data, however both quantities are affected by possible extended emission in an analogous way. Moreover, all the Seyferts are dominated by AGN emission, which is almost pointlike. In any case, a better estimate of the bolometric correction will be done using the nuclear fluxes of the 12MSG that we are planning to measure through the Spitzer IRAC and MIPS images (L. Spinoglio et al. 2010, in preparation).

A more serious concern is that not all of the AGN 2’s now emitting [Ne v] are generating accretion power right now, i.e., in this decade, even though they evidently did in some previous centuries. This is offset to some degree by the missing population of “weak” AGN 2’s which are not optically classified as Seyferts because their AGN component produces less than 50% of their IR emission currently (which we call “non-Seyfert-dominated”). The existence of these AGN 2’s continues to complicate many discussions about “AGN,” since they can leave and enter this category depending on details of the detection observations. But since the 14.32 μm luminosities of all these AGN 2’s are well below the characteristic “knee” in the luminosity function, their inclusion or exclusion should not alter the luminosity integral substantially.

We compare the derived accretion power with the power which originates in the starburst component of our Seyfert galaxies. We follow a similar procedure by using the [Ne ii]12.81 μm versus starburst luminosity relation, as taken from the starburst percentage of the sample galaxies from Table 8:

$$\log L_{19\mu m}^{SB} = 0.9897 \times \log L([Ne\,ii]12.81\mu m) + 2.0198.$$
### Table 10

Line Luminosity Functions of Seyfert 1 and Seyfert 2

| Luminosity | Luminosity Function (10\(^{-6}\) Mpc\(^{-3}\) mag\(^{-1}\)) |
|------------|-------------------------------------------------|
| \(L_{\text{[S\textsc{iv}]}(10.51\,\mu\text{m})}\) | \(\text{[S\textsc{iv}]}(10.51\,\mu\text{m})\) |
| \(L_{\text{[Ne\textsc{ii}]}(12.81\,\mu\text{m})}\) | \(\text{[Ne\textsc{ii}]}(12.81\,\mu\text{m})\) |
| \(L_{\text{[Ne\textsc{v}]}(14.32\,\mu\text{m})}\) | \(\text{[Ne\textsc{v}]}(14.32\,\mu\text{m})\) |
| \(L_{\text{[Ne\textsc{iii}]}(15.56\,\mu\text{m})}\) | \(\text{[Ne\textsc{iii}]}(15.56\,\mu\text{m})\) |
| \(L_{\text{[S\textsc{iii}]}(18.71\,\mu\text{m})}\) | \(\text{[S\textsc{iii}]}(18.71\,\mu\text{m})\) |
| \(L_{\text{[Fe\textsc{iv}]}(24.32\,\mu\text{m})}\) | \(\text{[Fe\textsc{iv}]}(24.32\,\mu\text{m})\) |
| \(L_{\text{[S\textsc{ii}]}(25.89\,\mu\text{m})}\) | \(\text{[S\textsc{ii}]}(25.89\,\mu\text{m})\) |
| \(L_{\text{[S\textsc{ii}]}(33.48\,\mu\text{m})}\) | \(\text{[S\textsc{ii}]}(33.48\,\mu\text{m})\) |
| \(L_{\text{H}\alpha(1)}\) | \(\text{H}\alpha(1)\) |
| \(\text{PAH}\) | \(\text{PAH}\) |

#### Seyfert 1

| \(L_{\text{[S\textsc{iv}]}(10.51\,\mu\text{m})}\) | \(\text{[S\textsc{iv}]}(10.51\,\mu\text{m})\) |
| \(L_{\text{[Ne\textsc{ii}]}(12.81\,\mu\text{m})}\) | \(\text{[Ne\textsc{ii}]}(12.81\,\mu\text{m})\) |
| \(L_{\text{[Ne\textsc{v}]}(14.32\,\mu\text{m})}\) | \(\text{[Ne\textsc{v}]}(14.32\,\mu\text{m})\) |
| \(L_{\text{[Ne\textsc{iii}]}(15.56\,\mu\text{m})}\) | \(\text{[Ne\textsc{iii}]}(15.56\,\mu\text{m})\) |
| \(L_{\text{[S\textsc{iii}]}(18.71\,\mu\text{m})}\) | \(\text{[S\textsc{iii}]}(18.71\,\mu\text{m})\) |
| \(L_{\text{[Fe\textsc{iv}]}(24.32\,\mu\text{m})}\) | \(\text{[Fe\textsc{iv}]}(24.32\,\mu\text{m})\) |
| \(L_{\text{[S\textsc{ii}]}(25.89\,\mu\text{m})}\) | \(\text{[S\textsc{ii}]}(25.89\,\mu\text{m})\) |
| \(L_{\text{[S\textsc{ii}]}(33.48\,\mu\text{m})}\) | \(\text{[S\textsc{ii}]}(33.48\,\mu\text{m})\) |
| \(L_{\text{H}\alpha(1)}\) | \(\text{H}\alpha(1)\) |
| \(\text{PAH}\) | \(\text{PAH}\) |

#### Seyfert 2

| \(L_{\text{[S\textsc{iv}]}(10.51\,\mu\text{m})}\) | \(\text{[S\textsc{iv}]}(10.51\,\mu\text{m})\) |
| \(L_{\text{[Ne\textsc{ii}]}(12.81\,\mu\text{m})}\) | \(\text{[Ne\textsc{ii}]}(12.81\,\mu\text{m})\) |
| \(L_{\text{[Ne\textsc{v}]}(14.32\,\mu\text{m})}\) | \(\text{[Ne\textsc{v}]}(14.32\,\mu\text{m})\) |
| \(L_{\text{[Ne\textsc{iii}]}(15.56\,\mu\text{m})}\) | \(\text{[Ne\textsc{iii}]}(15.56\,\mu\text{m})\) |
| \(L_{\text{[S\textsc{iii}]}(18.71\,\mu\text{m})}\) | \(\text{[S\textsc{iii}]}(18.71\,\mu\text{m})\) |
| \(L_{\text{[Fe\textsc{iv}]}(24.32\,\mu\text{m})}\) | \(\text{[Fe\textsc{iv}]}(24.32\,\mu\text{m})\) |
| \(L_{\text{[S\textsc{ii}]}(25.89\,\mu\text{m})}\) | \(\text{[S\textsc{ii}]}(25.89\,\mu\text{m})\) |
| \(L_{\text{[S\textsc{ii}]}(33.48\,\mu\text{m})}\) | \(\text{[S\textsc{ii}]}(33.48\,\mu\text{m})\) |
| \(L_{\text{H}\alpha(1)}\) | \(\text{H}\alpha(1)\) |
| \(\text{PAH}\) | \(\text{PAH}\) |

Note: The values are given in units of erg s\(^{-1}\).
9. DISCUSSION AND CONCLUSIONS

Our large sample of Seyfert galaxies, and the accompanying spectropolarimetric classifications have improved and extended the analysis of Paper I. In the IR diagnostic diagrams presented, we find that AGN 1—defined as having broad-line emission of some kind—have high values of ionization-sensitive line ratios, relative to the strength of star formation tracers. In contrast, those galaxies we reclassify as non-Seyfert's have low ionization-sensitive line ratios and high PAH EWs, and lie in the opposite regions of the diagnostic diagrams from AGN. The class of AGN 2's—those without broad lines—spread across both regions of the diagrams.

The simplest and strongest version of the AGN Unified Model requires that any differences between Seyfert 1's and Seyfert 2's should be due to the inclination angle of an obscuring structure (e.g., of a torus) with the line of sight to the observer, the Seyfert 2's being covered by the thick dust in the equator.
However, in order to salvage this unification model from the results presented here, one has to explain why AGN 2’s show a wider range of mid-IR properties, with similarities both to AGN 1 and the non-Seyfert’s. Perhaps this could derive from the particular geometry of the “torus-BLR-scattering region”: the torus in fact can absorb the radiation not only from the BLR but also from the scattering region where the polarized emission could be produced, depending, for example, from the precise inclination angle, or the intrinsic clumpiness of the torus.

That is the basic suggestion of Heisler et al. (1997). However, to suppress high-ionization emission lines we observe in the IR—which are assumed to be isotropic—the absorbing structure would also need to block out a significant fraction of the ionizing photons that would otherwise illuminate the NLR, even though this does not seem to happen in Seyferts with any detectable BLR. But once additional intrinsic differences other than just the viewing angle are admitted, the attractive simplicity of ATM unification is lost.
In contrast, however, there may be “genuine” Type 2 Seyfert nuclei. These would be the half of our AGN 2 category which have smaller proportions of AGN emission, and do not have analogs among the Seyfert 1s. As we discussed, the remaining NLR emission we detect in the optical and IR spectra of these true Sy 2s may be the “fossil” remnants of a 10–100 pc extent of gas that had been ionized by an AGN which was active in previous millennia, but has been effectively “turned off” for the last several hundred years. Given their strong variability over all timescales, AGN which recently “turned off” must exist. Depending on the duty cycles of power generation through black hole accretion, they could account for up to half of our AGN 2. This would then imply the existence of a comparable population of “recently turned on” AGN. These could stand out as having unusually strong broad-line and near-IR continuum emission, relatively to their NLR strength. The most likely candidates for these “young” or more accurately, “rejuvenated” AGN 1’s are those Seyfert 1’s having relatively strong Fe II emission and low values of NLR/BLR ratios such as [OIII]5007/Hβ ( Boroson & Green 1992). Thus, it could well turn out that long-term variability is at least as important as viewing angle in unifying the various observed classes of AGN.

The main results of this paper are as follows.

1. We present the Spitzer–IRS high-resolution spectra of almost 80% of the Seyfert galaxies of the 12 μm galaxy sample, a total of 91 galaxies.

2. We adopted a spectropolarimetric classification, with the “AGN 1” class broadly defined to include both the Seyfert 1’s and the “HBLR” Seyfert 2’s, as detected through optical spectropolarimetry. All of our IR diagnostics are consistent with Sy 1’s and HBLR Sy 2’s belonging to the same single class. The AGN 2 class contains the remaining Seyfert 2 galaxies without polarized broad lines are likely a mixture of weaker AGN 1, in which the BLR exists but has not yet been detected, and “true” AGN 2, galaxies that may not have been producing much hard ionizing radiation for the last several hundred years. Our AGN 1/2 distinction, based solely on reddening-independent IR data, is supported by more of the data than the usual traditional classification scheme that divides the Seyfert 1’s and 2’s based strictly on the detectability of BLR emission in direct optical spectroscopy. It appears that the mid-IR observed properties characterize the AGN 1 as an homogeneous class...
Figure 21. (a) [Ne v]14.3 μm vs. AGN 19 μm luminosity, symbols are as in the previous figure. (b) AGN 19 μm luminosity function.

(A color version of this figure is available in the online journal.)

Table 11
New Classification, PAH Flux, and EQ.W. and H$_2$ Masses for Sources in Paper I

| Name               | Old Class. | New Class.    | PAH at 11.25 μm | EQ.W. (10$^8$ M$_\odot$) |
|--------------------|------------|---------------|-----------------|--------------------------|
| IRAS00198−7926     | Sy 2       | Non-HBLR      | 31.2            | -0.066                   | < 19.36 |
| ESO012-G021        | Sy 1       | HBLR          | 88.9            | -0.417                   | < 1.91  |
| IRAS00521−7054     | Sy 2       | HBLR          | 12.5            | -0.031                   | < 27.80 |
| ESO541-IG012       | Sy 2       | HBLR          | 19.2            | -0.001                   | < 0.42  |
| NGC0424            | Sy 2       | HBLR          | 74.7            | -0.588                   | 3.69    |
| MRK1034 NED01a     | Sy 1       | Non-Sy        | 87.1            | -1.105                   | 5.36    |
| MRK1034 NED02a     | Sy 1       | Non-BLR       | 187             | -1.051                   | < 11.86 |
| ESO545-G013a       | Sy 1       |               | 21.9            | -0.262                   | 2.37    |
| NGC0931            | Sy 1       |               | 39.5            | -0.043                   | ...     |
| NGC1125            | Sy 2       | HBLR          | 64.2            | -0.465                   | < 0.33  |
| ESO0033-G002       | Sy 2       | Non-HBLR      | 10.8            | -0.024                   | 0.66    |
| MRK0006            | Sy 1       |               | 20.0            | -0.041                   | < 30.29 |
| MRK0009            | Sy 1       |               | 15.2            | -0.039                   | < 2.20  |
| NGC3516            | Sy 1       |               | 25.8            | -0.037                   | < 0.22  |
| NGC3660            | Sy 2       | Non-HBLR      | 32.4            | -0.584                   | 0.94    |
| NGC4501            | Sy 2       | Non-HBLR      | 36.1            | -0.652                   | 0.41    |
| NGC4602a           | Sy 1       | Non-BLR       | 28.2            | -0.689                   | 0.38    |
| TOLOLO1238-364     | Sy 2       | HBLR          | 111             | -0.131                   | < 0.44  |
| NGC4748            | Sy 1       |               | 20.7            | -0.300                   | 0.38    |
| NGC4968            | Sy 2       | Non-HBLR      | 88.1            | -0.133                   | < 0.30  |
| MCG-3-34-63        | Sy 1       | Non-Sy        | 16.7            | -1.176                   | < 1.24  |
| MRK0817            | Sy 1       |               | 24.5            | -0.043                   | < 2.73  |
| IRASF115091−2107   | Sy 1       |               | 25.7            | -0.081                   | < 9.36  |
| ESO141-G055        | Sy 1       |               | 19.2            | -0.056                   | ...     |
| NGC6890            | Sy 2       | Non-HBLR      | 48.8            | -0.155                   | 0.20    |
| MRK0897            | Sy 2       | Non-Sy        | 117             | -1.194                   | 1.66    |
| IRASF22017+0319    | Sy 2       | HBLR          | 9.56            | -0.021                   | < 6.75  |
| NGC7496            | Sy 1       | Non-Sy        | 153             | -0.419                   | < 0.12  |
| NGC7590            | Sy 1       | Non-Sy        | 56.1            | -1.166                   | 0.12    |

Note. a See Appendix A for the source classification.
of objects. The mid-IR behavior of AGN 2’s, instead, shows objects similar to AGN 1’s and others more similar to non-Seyfert galaxies.

3. Semianalytic models based on the observed mid-IR spectra are effective in separating the AGN and starburst components in Seyfert galaxies. We find that for 31 AGN 1 the average AGN percentage contribution to the 19 μm luminosity is 92.2% ± 6.6%, while for 16 AGN 2 this percentage decreases to 79.3% ± 15.7% and for nine non-Seyfert’s is 67.6% ± 17.2%. Although with large scatter, there is a clear trend of decreasing AGN strength from AGN 1 to AGN 2 to non-Seyfert’s. Ionization-sensitive line ratios can discriminate AGN 1’s from AGN 2’s and non-Seyferts. The diagnostic diagram of [Ne v]/[Ne ii] versus [O iv]/[Ne ii] provides a measure of the AGN strength in both AGN 1’s and AGN 2’s. The AGN 2 do not appear to be a homogeneous population with respect to starburst tracers, such as the EW PAH and the EW of [Ne ii]. Moreover, some AGN 2 nuclei could either contain more ongoing star formation and/or be covered by more dust than any of the AGN 1’s.

4. The 0-0 S(1) H2 rotational transition can be used to estimate the mass of the emitting regions. The average mass value is of the order of 10^8 M⊙, which is in agreement with other estimates for Seyfert and starburst galaxies.

5. The density-sensitive line ratios (the [Ne v] and [S iii] doublet ratios), in about 40% of the objects imply electron densities below the low-density limit. Therefore, they cannot be used reliably to estimate the electron density of these regions. The simple interpretation that the line emission from the NLR and the H ii regions can be heavily absorbed by dust even in these mid-IR lines (Dudik et al. 2007) is not confirmed from our data because the galaxies of our sample do not show both line ratios affected at the same time in the same objects. In addition, the abnormally low ratios occur with the same frequency in all different types of emission line galaxies. The other possibility is that some assumed atomic physics parameters need revision for both of these line ratios.

6. We derived for the first time the line luminosity functions for either classical Seyfert 1’s and 2’s and also for AGN 1 and AGN 2. We do not find significant differences between the various populations, in either the shape or the normalization of their line LFs.

7. The mid-IR [Ne v] lines are unambiguous tracers of the AGN NLR. We therefore use the [Ne v] line luminosity function of all Seyfert galaxies to estimate the accretion power in the local universe within a volume out to z = 0.03. We find that the power originating from accretion at 19 μm is ~2 \times 10^{36} erg s⁻¹, about four times less than the bolometric power. For comparison, the power related to star formation and stellar evolution in the Seyfert galaxies population at 19 μm is one-tenth of that one from accretion.

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APPENDIX A

CLASSIFICATION: NOTES ON INDIVIDUAL OBJECTS

For the sources already presented in Paper I, we refer to Table 11 for the adopted classification and for the PAH 11.25 μm integrated flux and equivalent width as well as the H2 masses derived from the H2 rotational lines observations. We have repeated the measurements of fluxes and equivalent widths of the PAH 11.25 μm to be consistent with the method adopted here, and also because we found that some of the equivalent widths given in Paper I were affected by non-traceable errors. The derivation of the masses presented in Paper I was affected by some errors, therefore we recomputed their values.

1. NGC526A: no detected broad lines, according to new data from Bennert et al. (2006), however broad Hα wings were observed more than 20 years ago (A. Lawrence 2009, private communication). Because of the possible changes in BLR characteristics over timescales of the order of years, we conservatively classify this object as an AGN 1.

2. MRK1034 NED1 = Akn80: does not have a Seyfert-like optical spectrum (Osterbrock & Phillips 1977). We classify it as a non-Sy (IRS spectrum in Paper I).

3. MRK1034 NED2 = Akn81: only narrow lines, slightly wider than the instrumental resolution (Osterbrock & Phillips 1977). We classify it as a non-BLR as no polarimetric observations are available (IRS spectrum in Paper I).

4. ES0545-G13 = MCG-3-7-11 = MBG 02223-1922: detected broad Hα and Hβ ~ 2000 km s⁻¹ (Coziol et al. 1993). We classify this object as an AGN 1 (IRS spectrum in Paper I).

5. NGC1056: classified as an H ii region galaxy through optical spectroscopy by Veilleux et al. (1995).

6. NGC1097: detected broad Hα ~ 10000 km s⁻¹ FWHM (Storchi-Bergmann et al. 1993). On the basis of this BLR evidence, we classify this object into the AGN 1 class.

7. NGC1194: only narrow lines were detected: Hα ~ 230 km s⁻¹ FWHM and [O iii]~5007 Å ~ 400 km s⁻¹ FWHM (Kirhakos & Steiner 1990). Because no polarization data are available, we classify it as a non-BLR object, but we are unable to include it in either AGN 1 or AGN 2 classes.

8. NGC1365: detected broad Hβ of 1896 km s⁻¹ FWHM (Schulz et al. 1999). On the basis of the BLR evidence, we classify this object into the AGN 1 class. Note that [Ne v] is detected.

9. ES0362-G018 = MCG-05-13-017: Hβ has a width of 5240 ± 500 km s⁻¹ FWHM, therefore is a genuine AGN 1 (Bennert et al. 2006).

10. NGC2639: detected broad Hα of 3879 km s⁻¹ FWHZ (Keel 1983). On the basis of the BLR evidence, we classify this object into the AGN 1 class.

11. NGC3511: only narrow lines were detected: Hα ~ 135 km s⁻¹ FWHM, this galaxy is classified as H ii region galaxy (Kirhakos & Steiner 1990). We classify this object as a non-Sy.
12. MCG+00-29-23: classified as an H\textsc{ii} region galaxy through optical spectroscopy by Veilleux et al. (1995).

13. NGC4602: detected only marginal evidence for an H\textalpha broad component with FWZI \(\sim 10,000\) km s\(^{-1}\) (Kollatschny & Fricke 1985). We classify it as a non-BLR, as no polarimetric observations are available (IRS spectrum in Paper I).

14. NGC4922: classified as intermediate between a LINER and an H\textsc{ii} region galaxy through optical spectroscopy by Veilleux et al. (1995).

15. NGC5005: classified as a LINER galaxy (Goodrich & Keel 1986; Terashima et al. 2000).

16. NGC5506: observed in spectropolarization: no broad H\textalpha component was detected at a level of \(1 \times 10^{-15}\) cgs (Lumsden et al. 2004). We classify this object as a non-HBLR, and thus AGN 2.

17. NGC6810: classified as a transition object between an H\textsc{ii} region galaxy and an AGN, having an [O \textsc{iii}]/\Hbeta width of 304 km s\(^{-1}\) FWHM and an H\textalpha width of 263 km s\(^{-1}\) FWHM and the following line ratios: [N \textsc{ii}]/H\alpha = 0.62, [O \textsc{iii}]/H\beta = 0.6, [S \textsc{ii}]/H\alpha = 0.3 (Kirhakos & Steiner 1990). We conservatively classify it as a non-Sy.

18. MRK897: D. Rodriguez et al. (2010, in preparation) confirm the classification of this galaxy as a Seyfert 2 of Durret (1994). Because of the lack of polarization data, we classify it as a non-BLR (IRS spectrum in Paper I).

19. NGC7130 = IC5135: classified as a LINER (Veilleux et al. 1995).

20. NGC7314: detected in spectropolarization at H\textalpha: F6563(broad) = \(5.6 \times 10^{-15}\) cgs (Lumsden et al. 2004). We classify this object as an HBLR, and thus AGN 1.

21. NGC7496: the relative strength of the emission lines in the nucleus of this object is typical of normal photoionization (Veilleux et al. 1995). We classify this object as an HBLR, and thus AGN 2.

22. NGC7590: the relative strength of the emission lines in the nucleus of this object is typical of normal photoionization found in H\textsc{ii} regions (Storchi-Bergmann et al. 1995; IRS spectrum in Paper I).

23. CGCG381-051: classified as an H\textsc{ii} region galaxy through optical spectroscopy by de Grijp et al. (1992).

**APPENDIX B**

**PECULIARITIES OF THE “20 \(\mu\)m PEAKERS”**

We have considered the “20 \(\mu\)m peakers” identified by Wu et al. (2009) in Section 2 and computed the average values of the discussed quantities in the classification Table 6. We find in our sample 15 “20 \(\mu\)m peakers”: 11 Sy 1’s, three HBLR’s, and one AGN 2. The major peculiarities of this group of objects are that they are almost all compact at 19 \(\mu\)m, they have very faint PAH 11.25 \(\mu\)m emission, a flat average spectral index (60–25) \(\mu\)m, and low EWs of the lines (see Table 6).

In particular, among them 11 are compact sources (belonging to the extendedness class I), one belongs to class II, three do not have background subtracted spectra and therefore no extendedness measurement. Seven of them do not show any PAH feature at 11.25 \(\mu\)m and the mean PAH EW 11.25 \(\mu\)m among the other eight objects is \(-0.04 \pm 0.04\) \(\mu\)m. The mean EW of the lines and the feature in Table 6 are consistent with the lowest values for the AGN 1. On the other hand, the AGN contribution is among the highest values in the AGN 1’s, as can be seen from the mean [Ne \textsc{v}]14.32 \(\mu\)m/[Ne \textsc{ii}]12.81 \(\mu\)m ratio, the mean spectral index, and the average modeled AGN contribution.

**APPENDIX C**

**MATHEMATICAL TREATMENT OF THE MODELS**

We present here the details of the semianalytic models. To model the observed IR quantities, we have found an analytical expression for each of them as a function of \(\mu\), which is defined as the ratio of the starburst dust continuum at 19 \(\mu\)m to the AGN flux at the same wavelength. \(\mu\) varies from zero-emission totally from the AGN—to infinity—emission totally from the starburst:

\[
\mu = \frac{F_{19\mu m}^{AGN}}{F_{19\mu m}^{gal}}.
\]  

The extendedness is defined as the ratio between the flux measured at 19.5 \(\mu\)m from the LH slit to that measured at 19 \(\mu\)m by the SH slit. If we define \(F_{19\mu m}^{gal}\) and \(F_{19\mu m}^{AGN}\) as the fluxes of galaxy and AGN, respectively, through the SH slit, then the maximum the LH slit can intercept four times the \(F_{19\mu m}^{AGN}\) and that \(F_{19\mu m}^{AGN}\) does not depend on the slit aperture, can be approximated to a pointlike source, then Flux(LH) = \(F_{19\mu m}^{AGN} + 4 \cdot F_{19\mu m}^{gal}\), Flux(SH) = \(F_{19\mu m}^{AGN} + F_{19\mu m}^{gal}\).

\[
ex = \frac{F_{19\mu m}^{AGN} + 4 \cdot F_{19\mu m}^{gal}}{F_{19\mu m}^{AGN} + F_{19\mu m}^{gal}} = \frac{1 + 4 \cdot \frac{F_{19\mu m}^{gal}}{F_{19\mu m}^{AGN}}}{1 + \frac{F_{19\mu m}^{gal}}{F_{19\mu m}^{AGN}}} = 1 + 4 \cdot \frac{\mu}{1 + \mu}.
\]  

We know that the PAH emission feature at 11.25 \(\mu\)m originates in the host galaxy only, while its underlying continuum derives from both galaxy and AGN. Therefore, we can predict its EW as

\[
\text{EW PAH} = \frac{A_1 \cdot F_{11.25\mu m}^{gal}}{F_{11.25\mu m}^{gal} + F_{11.25\mu m}^{AGN}},
\]  

where \(A_1\) is a constant depending on the measured features flux and we adopt \(A_1 = 1.8\) for the PAH at 11.25 \(\mu\)m. From the assumption that we can model the continua with a power law

\[
v^{-\alpha} F_v = k,
\]  

where \(v\) is the spectral index and \(k\) is a constant. We adopt \(\alpha = -1.4\) for the AGN component and \(\alpha = -2\) for the galaxy, these values are in agreement with the values commonly used as spectral index for AGN and starburst and available in the literature (compared to Edelson & Malkan 1986). We derive the \(F_{11.25\mu m}^{gal}\) and the \(F_{11.25\mu m}^{AGN}\) as functions of \(F_{19\mu m}^{gal}\) and \(F_{19\mu m}^{AGN}\), respectively, and consequently as functions of the free parameter \(\mu\). From Equations (C3) and (C4), the PAH EW becomes

\[
\text{EW PAH} = \frac{1.8 \cdot \left( k/19\mu m \right) \left( 12.81\mu m/11.25\mu m \right) \left( -2+1.4 \right) \cdot \mu}{k/19\mu m \left( 12.81\mu m/11.25\mu m \right) \left( -2+1.4 \right) + 1}.
\]  

The [Ne \textsc{ii}] EW has contributions both from the galaxy and from the AGN:

\[
\text{EW[Ne \textsc{ii}]} = \frac{A_2 \cdot F_{12.81\mu m}^{gal} + B_2 \cdot F_{12.81\mu m}^{AGN}}{F_{12.81\mu m}^{gal} + F_{12.81\mu m}^{AGN}}.
\]
Because the galaxy component is stronger than the AGN’s in the [Ne ii] emission, we chose the constant $A_2 = 0.25$ and $B_2 = 0.001$.

The procedure for modeling the line ratios is similar. We modeled the emission of each single line and then we simply took their ratio:

$$\frac{[\text{Ne} \text{v}]}{[\text{Ne} \text{ii}]} = \frac{A_3 \cdot F_{14.32 \mu m}^{\text{gal}} + B_3 \cdot F_{14.32 \mu m}^{\text{AGN}}}{A_2 \cdot F_{12.81 \mu m}^{\text{gal}} + B_2 \cdot F_{12.81 \mu m}^{\text{AGN}}} \quad \text{(C7)}$$

$$\frac{[\text{O} \text{iv}]}{[\text{Ne} \text{ii}]} = \frac{A_4 \cdot F_{25.89 \mu m}^{\text{gal}} + B_4 \cdot F_{25.89 \mu m}^{\text{AGN}}}{A_2 \cdot F_{12.81 \mu m}^{\text{gal}} + B_2 \cdot F_{12.81 \mu m}^{\text{AGN}}} \quad \text{(C8)}$$

with $A_1 = 0$ and $B_1 = 0.01$ and $A_4 = 0$ and $B_4 = 0.01$, because we consider the [Ne v]14.32 $\mu m$ and [O iv]25.89 $\mu m$ lines to be produced exclusively by the AGN.

To model the $\alpha_{(60-25)\mu m}$ spectral index, we use its definition as

$$\alpha_{(60-25)\mu m} = \frac{\log \left( F_{60 \mu m} / F_{25 \mu m} \right)}{10 \log \left( \lambda_{60 \mu m} / \lambda_{25 \mu m} \right)} \quad \text{(C9)}$$

writing $F_{60}(60 \mu m)$ and $F_{25}(25 \mu m)$ in terms of $F_{\text{gal}}$ and $F_{\text{AGN}}$, considering that $F_{\nu}(60 \mu m)$ is due mainly to the galaxy emission, it becomes

$$\alpha_{(60-25)\mu m} = \frac{\log \left( F_{60 \mu m}^{\text{gal}} + 0.001 F_{60 \mu m}^{\text{AGN}} \right)}{\log \left( F_{25 \mu m}^{\text{gal}} + F_{25 \mu m}^{\text{AGN}} \right)} \quad \text{(C10)}$$

The treatment of the previous equations is the same of the EW PAH model’s. All the factors $A_i$ and $B_i$ have been found by fitting the data with the models and they depend on the instrument (spectrograph properties, slits areas, spectral extraction methods). These same models can be suitable for other observables and instruments, by scaling those factors.

APPENDIX D

PAH 11.25 $\mu m$ EW: LOW-VERSUS-HIGH-RESOLUTION COMPARISON

We plot in Figures 22(a) and (b) the PAH 11.25 $\mu m$ EW measured by Wu et al. (2009) versus that measured by us, to compare the results on the objects in common. In Figure 22(a), we present the ratio of the values found by us to the values of Wu et al. (2009) to better show the scatter of the two sets of data. In Figure 22(b), we plot the PAH 11.25 $\mu m$ EW by Wu et al. (2009) versus ours and we computed their least-square fits, calculated the mean slopes and their confidence intervals by using the bootstrap method (by 1000 resampling). The two sets of data are consistent with each other, as is shown by the slope of the lines reproducing the least-square fits of the data: considering all the galaxy types, the slope of the fitting line is $1.14 \pm 0.17$; if we consider only the AGN 1 and AGN 2, the slope is $0.97 \pm 0.18$. These two results agree within the errors. However, the fitting line slope becomes steeper when we add the non-Sy’s data, because for these we used a different method to measure the PAH emission feature at 11.25 $\mu m$. Wu et al. (2009) remove the continuum underlying the range 10.80–11.80 $\mu m$ and integrate the PAH feature flux inside this window, in each of the sources. On the other hand, we measure the flux in the range 11.15–11.65 $\mu m$ for all the sources, but we subtract the continuum underlying the whole range 11.2–13.0 $\mu m$ for those sources having in this range a broad multicomponent feature. This results in a lower continuum baseline measure and therefore in a higher PAH feature EW.

APPENDIX E

ADDITIONAL OBSERVATIONAL MEASUREMENTS

E.1. Weak Ionic Fine Structure Lines

Besides the ionic lines we presented in Section 4, the spectra of seven sources showed other fine structure...
E.2. Full Width Half-maximum of the Spectral Lines

The lines FWHM are due to the velocity field of the gaseous regions where they are produced. The velocity dispersion $\sigma$ of the [O III] at 5007 Å, originated in the NLRs, is related to the black hole mass (Nelson 2000; Greene & Ho 2005). It is interesting to extend the same relation to the mid-IR lines of [Ne V] at 14.32 μm, [Ne V] at 24.31 μm, and the [O IV] at 25.89 μm, because they suffer less obscuration than the optical lines and are mostly originated by the AGN activity, though the [O IV] can be contaminated by strong starburst emission.

Dasyra et al. (2008) claim to have measured resolved spectral widths of the IRS lines. The IRS resolving power for the high-resolution modules is on average (500 ± 50) km s$^{-1}$ along the whole spectrum. We find the FWHM of all the lines to be, within the errors, of the same value of the resolving element and to have a scatter of about 15% of the mean value (the mean value and the standard deviation of the FWHM of all the fine structure lines are reported in Table 13). We cannot conclude that the lines are resolved, because we consider a line to be resolved if its FWHM is significantly larger than the resolution element. While Dasyra et al. (2008) consider the instrumental velocity dispersion (the one corresponding to the resolving power of the instrument) as the ratio between resolution element and 2.55, we compare the measured FWHM with the resolution element itself, to be more conservative.

Moreover, both the typical AGN lines and those originated by starburst emission have nearly the same mean FWHM (see Table 13), which does not change with the Seyfert or galaxy type. The AGN lines, originated from the NLR, should suffer from more broadening than the lines emitted by the galactic regions. We conclude that the broadening of the lines is not intrinsic to the gas motion, but most probably is due to instrumental effects, otherwise we would measure different widths from lines originated from the different regions.

In conclusion, we consider that the FWHM of the lines measured in the IRS spectra do not measure the dispersion velocity field in the NLR, and higher spectral resolution data would be necessary.

### Table 12

| Name         | [Ar v] (13.10 μm) | [Fe ii] (22.93 μm) | [Fe ii] (24.52 μm) | [Fe ii] (25.99 μm) | [Fe ii] (33.04 μm) |
|--------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| NGC1056      | ...               | ...               | ...               | 2.83 ± 0.04       | ...               |
| NGC1142      | ...               | ...               | ...               | 2.51 ± 0.03       | ...               |
| NGC1194      | ...               | 0.85 ± 0.01       | ...               | 2.41 ± 0.01       | ...               |
| NGC1241      | 0.02786           | ...               | ...               | 6.80 ± 0.61       | ...               |
| ESO253-4G    | ...               | 11.12 ± 0.05      | ...               | 9.69 ± 0.12       | 1.23 ± 0.08       |
| NGC5135      | ...               | ...               | ...               | 11.81 ± 0.10      | ...               |
| NGC6810      | ...               | ...               | ...               | ...               | ...               |
| NGC7130      | ...               | ...               | ...               | ...               | ...               |

### Table 13

| Emission Line | Dispersion Velocity (km s$^{-1}$) | FWHM | St. Dev. |
|---------------|----------------------------------|------|---------|
| [S iv]10.51 μm | 685                              | 122  |
| [Ne v]12.81 μm | 604                              | 151  |
| [Ne v]14.32 μm | 625                              | 123  |
| [Ne v]15.56 μm | 638                              | 119  |
| [S iii]17.11 μm | 673                              | 185  |
| [Ne v]23.32 μm | 601                              | 163  |
| [O iv]25.89 μm | 552                              | 89   |
| [S iii]33.48 μm | 580                              | 119  |
| [Si iv]34.82 μm | 708                              | 215  |
| H2 S(1) 17.04 μm | 587                              | 149  |

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