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A New-infrared Diagnostic for AGNs using 2MASS and New 10μm Data

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Abstract

To study dust in Seyfert (Sy) Galaxies, we have combined new high resolution N band photometry for 87 Sy's with 2MASS J and K_s band photometry to obtain color-magnitude and color-color relations for the central $1''$ of Active Galactic Nuclei (AGN) from the IRAS 12μm Sample.

The J-K_s vs. absolute N band color-magnitude diagram shows a trend of increasing absolute N band luminosity with redder J-K_s colors. This result is consistent with a simple first order picture in which an AGN with more emission at N, also has more emission at K_s, which dominates the flux from the bulge stars and leads to a redder J-K_s color.

The J-K_s vs K_s-N color-color diagram also shows an interesting relation. Most of the Sy's occupy a limited area of the color-color diagram, but there are many outliers which we believe represent two different dust distributions at work. Those galaxies with very red J-K_s seem to be those that have dust in their host galaxy reddening their nuclear light. On the other hand, those with very red K_s-N colors but with bulge-like J-K_s colors may, through a combination of torus geometry and dust content, lead us to observe along a line of sight of very heavy extinction, absorbing even J and K_s light but allowing N band light to penetrate leading to a redder K_s-N color.

1.1 Sample and Observations

To conduct our survey we chose the Sy's identified in the Extended 12μm Sample compiled by Rush et al. (1993) which contained 118 Sy's, 95 of which were accessible at the latitude of Palomar Observatory. The 12μm Sample contains a large number of Sy's spanning a wide range in luminosity.

We used the JPL mid-infrared camera (MIRLIN) (Ressler et al. 1994) on the Palomar 200" telescope to image the Sy's. At 10μm the beam size of the 200" is $0.''5$ (FWHM) while the plate scale of MIRLIN is $0.''15$ per pixel giving us an oversampled image over a field of view of $19''$.

We observed 87 AGN and detected 62. 31 were Sy 1's and 31 were Sy 2's. All detected sources had a point source down to $1''$. Four objects had bright extended emission. Arp 220, NGC 1068 and 7469 are already known to have bright extended emission at 10μm (Becklin et al. 1973 and Keto et al. 1992). One new object, Mrk 1239 showed a $1''$ extension to the NW at very low signal to noise. (Figure 1.1) Four Sy 1's and 6 Sy 2's showed very faint extended residuals.

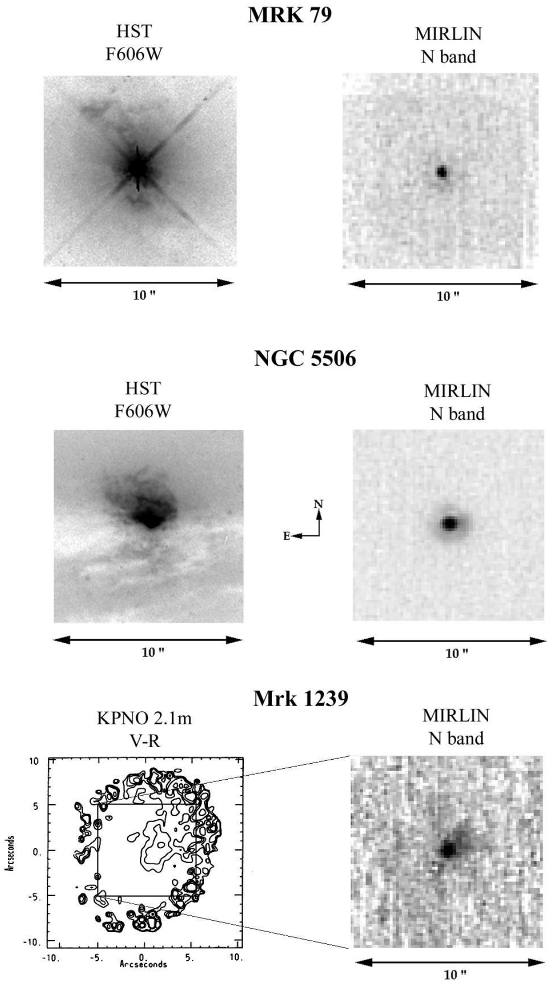

Fig. 1.1. Figures from Malkan et al. (1998) (Top and Middle left) and Mulchaey et al. (1996) (bottom left with V-R=1.35 [DV-R= -0.16 (outer contour),-0.23,-0.3,-0.37) compared to MIRLIN images (Top, Middle, Bottom right). The top image is Mrk 79 showing a point source in the optical and mid-IR. The middle image of NGC 5506 shows no point source in the optical, but a very bright one at N band. Note the Airy ring around the 10μm image showing that we are diffraction limited. The bottom left image of Mrk 1239 shows a NW extension in the optical and the inner box shows the region imaged in the mid-IR.

1.2 Comparison With 2MASS

The Two Micron All Sky Survey (2MASS) provided a good near-IR dataset to compare to our mid-IR results. Both the near and mid IR provide good dust penetration capabilties. The 2MASS peak pixel flux, which has a diameter of $1''$ for the center of each galaxy was similar to our $1.''5$ diameter photometry aperture.

In comparing the J-K_s vs absolute N band magnitude there is a trend with redder J-K_s colors corresponding to greater N band luminosity. (Figure 1.2) Since there is little contribution at J from the AGN (Alonso Herrero et al. 2001), this means that the N band flux is correlated with the K_s band flux. As the N flux increases, so does the K_s flux, which dominates the flux from the bulge stars and leads to a redder J-K_s color.

In the J-K_s vs K_s-N color-color diagram (Figure 1.3) the Sy's fall into three main regions. Region I seems to hold most of the Sy's. Region II seems to be comprised of objects which are reddened by host galaxy dust, many are disturbed/interacting galaxies or edge-on galaxies: e.g. NGC 5506 (see Figure 1.1). In Region III the J-K_s colors are bulge-like (J-K_s<1.5) likely indicating that there is little to no AGN contribution at NIR wavelengths, thus leading to a very steep K_s-N color. The absence of NIR light may be due to an edge-on view of the dusty torus absorbing most of the J and K_s flux. Another possible explanation may come from optical spectra of these objects. Two Region III members are identified as LINER's (Low Ionization Nuclear Emission-Line Region galaxies (Ho, Filippenko, & Sargent (1996)) which lack the total power output of Sy's. It is a tantalizing connection which requires a larger follow-up to see if LINER activity contributes to the difference in color.

1.3 Summary and Conclusions

We have observed 87 galaxies at N band from the Extended 12μm sample and we detected 62 of them, 31 Sy 1's and 31 Sy 2's. All detected galaxies showed point sources down to a resolution of $1''$. Four had bright extended emission, while 10 others showed very faint extended residuals.

In a comparison of J-K_s color with absolute N magnitude there is a trend for the redder colors to correspond to more luminous N magnitudes. This result is consistent with a simple first order picture in which an AGN with more emission at N, also has more emission at K_s, which dominates the flux from the bulge stars and leads to a redder J-K_s color.

In the J-K_s vs K_s-N color-color diagram, in the regions where the bulge does not dominate (J-K_s>1.5), Sy 1's and Sy 2's separate based on color with Sy 1's clustering more than Sy 2's. Redder J-K_s outliers correspond to AGN's reddened by host galaxy dust. The reddest K_s-N colors are likely caused by complete absorption of nuclear K_s light or the colors are possibly related to LINER activity.

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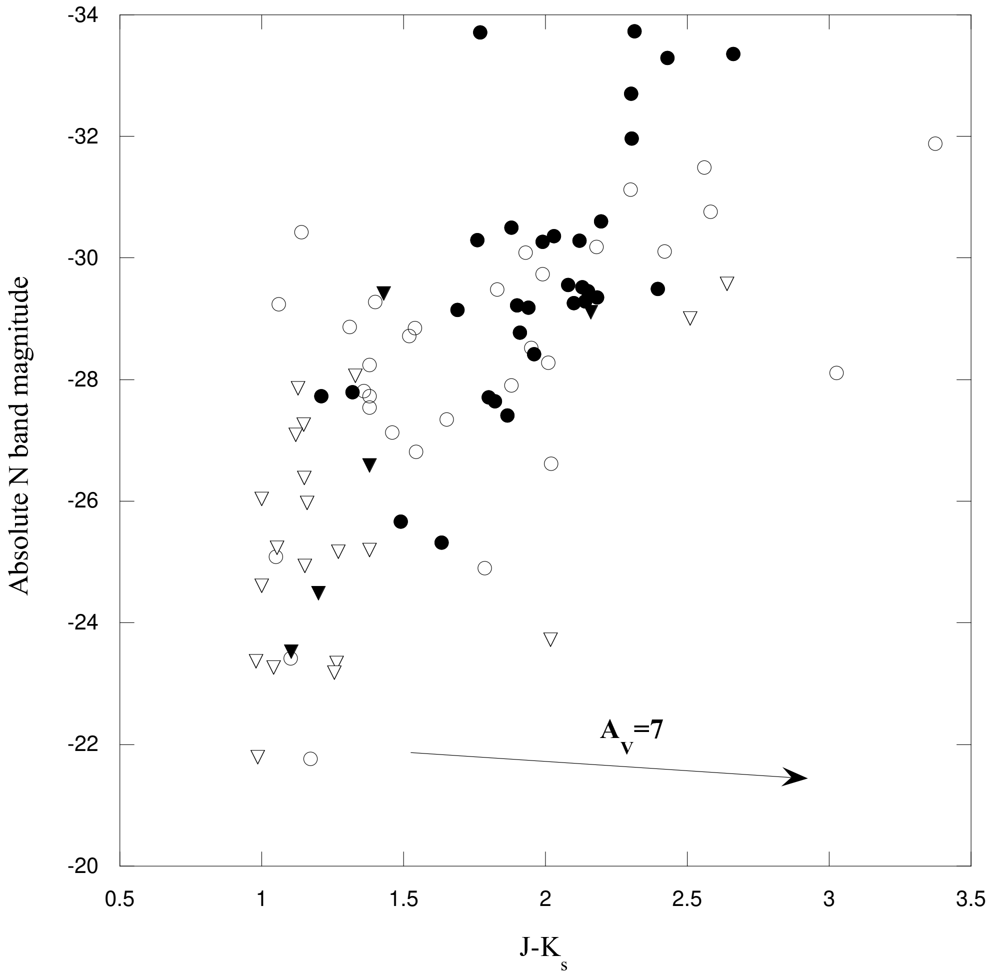

Fig. 1.2. J-K$_s$ vs absolute N band magnitude for 2MASS peak pixel flux. Filled circles are Sy 1's and unfilled circles are Sy 2's. Filled triangles are Sy 1 upper limits and unfilled triangles are Sy 2 upper limits. Note the trend of redder J-K$_s$ colors corresponding to greater N band luminosity.

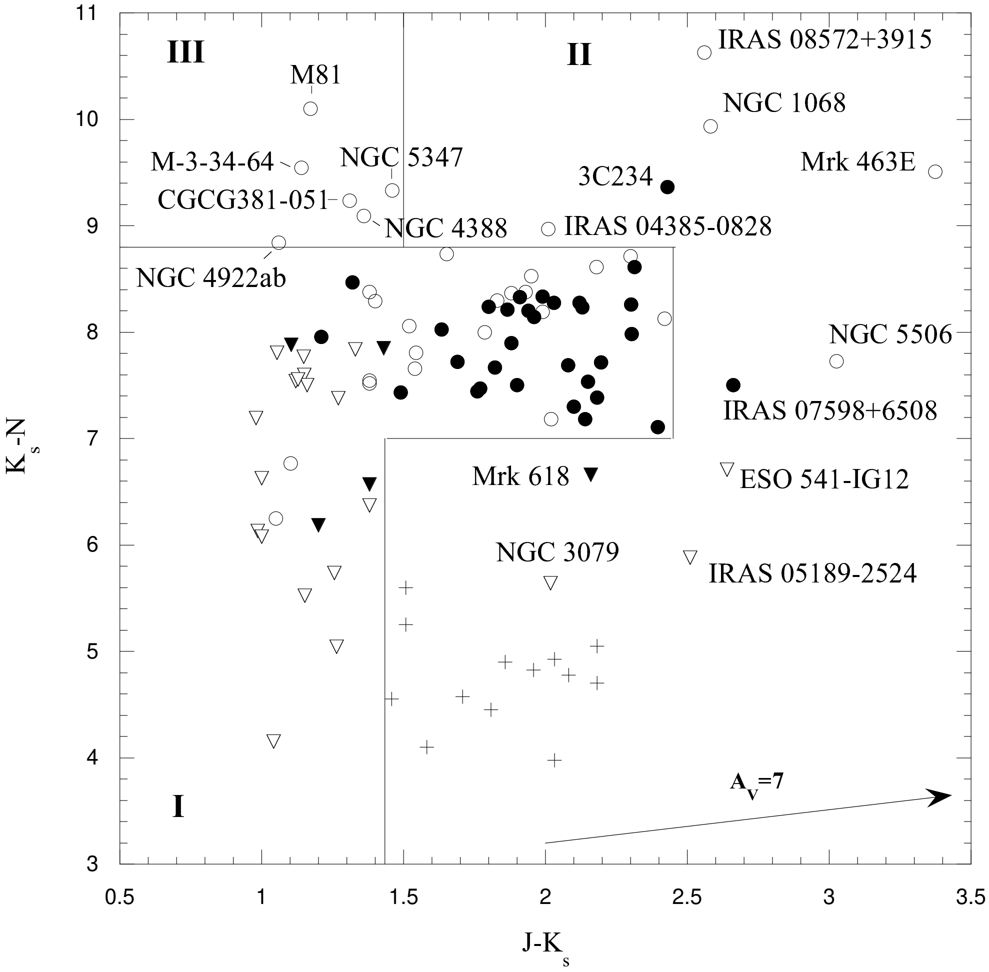

Fig. 1.3. J-K_s vs K_s-N. Filled circles are Sy 1's and unfilled circles are Sy 2's. Filled triangles are Sy 1 upper limits and unfilled triangles are Sy 2 upper limits. Crosses are from the Palomar Bright Quasar survey by Neugebauer et al. (1987). The Sy's congregate predominantly in Region I. Region II contains outliers which are likely due to reddening by the host galaxy. Region III probably has the nuclear AGN emission completely blocked thus leaving bulge-like J-K_s colors, but very steep K_s-N colors.