THE STELLAR CONTENT OF THE BULGES OF SPIRAL GALAXIES: WHAT DO WE KNOW AND HOW DO WE KNOW IT?

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ABSTRACT. For a true picture of the stellar content of the bulges of spiral galaxies it is necessary to combine spectroscopic and photometric observations from the ultraviolet to the infrared. In early-type spirals one generally finds a metal-rich, old population with no excess of low mass stars. In later type systems there is an increasing contribution from young stars. The population in the Galactic bulge is representative and does not contain a significant number of stars with large IR excesses.

1. Introduction

There is a poem which I am sure most of us have read as children about three blind men and an elephant. It tells the story three sightless people trying to describe an elephant based on what they can feel. Unfortunately, the poet allowed each of the three people to feel only one part of the elephant. So, we have the first person describing the elephant as snake-like as he could only feel the trunk. The second person thought that elephants must be like trees since he was feeling one of the elephant's legs. The third person concluded that elephants are hairy beasts – he was feeling the tail.

A not too dissimilar situation exists when it comes to describing spiral galaxies: conclusions about their stellar content by observers who concentrate primarily on one region of the electromagnetic spectrum will, not unexpectedly, be focused on those stars that are the main contributors to the region of the spectrum under observation. Ultraviolet observers will emphasize stars that may be metal poor or young, or a combination of the two. K and M dwarfs will make their presence felt most strongly in the red spectral region. Observations in the thermal infrared will be unduly influenced by the presence of IR/OH stars and other objects with significant amounts of mass loss. Although each of these galaxy observers will, like the elephant investigators, be partially correct, all of them will be completely wrong in trying to generalize their limited findings. An elephant certainly has all of the traits attributed to it by its three examiners but altogether can be characterized by none of them. The same is true for a spiral galaxy: it will contain some of each of the types of stars deduced by its examiners, but none of these types can be said to give an overall picture.

When multi-wavelength observations of spiral galaxies are combined, it becomes obvious that the stellar populations of these galaxies are highly composite. There are late-type dwarfs and giants, metal poor and metal rich stars, old and young ones, and a smattering of stars with infrared excess emission. The relative numbers of each of these types of stars varies in a more or

B. Barbuy and A. Renzini (eds.), The Stellar Populations of Galaxies, 245–254.

less systematic way along the Hubble sequence. In fact, the delineation of this variation and its interpretation is of fundamental importance in understanding the evolution of spiral galaxies. In this brief review I will examine the compositeness of the stellar population of spiral galaxies and bring to your attention a number of interesting recent pieces of research. These represent some, but certainly not all of the important findings on the topic that have appeared since the thorough review by O'Connell (1983).

2. Issues of Technique and Input for Stellar Synthesis Models

Let me first call your attention to a recently completed Ph.D. thesis by David Silva from the University of Michigan, now a post-doctoral fellow at Kitt Peak. He is the latest of several researchers in the field to emphasize the need for improved accuracy of the observations that go into synthesis models rather than achieving a yet finer grid to cover the phase space of the models. A number of well chosen examples serve as clear illustrations of his point. One of these is a comparison of the stellar libraries of Pickels and Jacoby and their collaborators. Particularly below 4500 Å there are major differences in the spectrophotometry of stars of ostensibly the same spectral type drawn from the two libraries. Whether one set of spectra or the other is used in models has a major effect on the conclusions drawn concerning the presence of a young stellar population. Presumedly, these differences in the spectrophotometry arise from calibration differences in the original observations.

Silva also points out that in linear evolutionary population synthesis, if the entire energy distribution is used, the continuum information will dominate over the line information. This can lead to significant degeneracy in the solutions and underscores the need to get the correct luminosity function. Two examples that he gives are the high degree of correlation between the energy distributions of K2V and K2III stars (r=0.998) and between the energy distributions of weak and strong line K giants (r=0.997). The result is that in evolutionary population synthesis, degenerate relations will often be selected rather than physically correct ones. The implication is that one should not just rely on a single goodness of fit parameter; careful examination of the residuals between model and observations is required. Silva also emphasizes the importance of broad band colors from the ultraviolet to the infrared. As I have emphasized elsewhere (Frogel 1985, 1988), a comparison of observed and predicted colors provides a simple but key first test of a model and can set parameter space boundary conditions for luminosity functions.

Next, I went to mention the work of E. Bica, D. Alloin, and their collaborators. At meetings on topics similar to the theme of this one, we have often been admonished by A. Renzini that we are neglecting one of the best tools for population synthesis, namely clusters. Although there have been limited attempts to use clusters as building blocks, Bica and Alloin are the first to make a major effort in this direction. Their data base for population synthesis consists of integrated colors and spectra of star clusters in the Magellanic Clouds and the Milky Way from 3700 to 8000 Å region at 11 Å resolution. They use absorption features and the overall shape of the continuous energy distribution to match clusters to galaxies. Their cluster data define two sequences: changing [Fe/H] at constant age (Galactic globulars); nearly constant [Fe/H] with variable age (Magellanic Clouds). Many of their most important results are discussed in other papers presented at this conference. For spiral bulges, their results are in general agreement with the earlier work of Turnrose (1976). For the late-type spirals, they agree with my own, considerably less detailed, analysis of UBVJHK colors (Frogel 1985) of the nuclei of the spirals, also based on integrated cluster photometry.

A potential shortcoming in the work of Bica and his collaborators is an incomplete sampling of the necessary parameter space of temperature, metallicity, and age for the stars that go into synthesis models of galaxies. This should not be confused with Silva's claim, mentioned above, that better sampling of parameter space is not necessarily needed. He was referring to the fineness of the grid. Here we are talking about undefined boundaries. The problem is the following. Whitford and Rich (1983) and Rich (1988) have shown that the K giants in Baade's Window in the bulge of the Milky Way, have a mean [Fe/H] of twice solar. The cluster data base use by Bica *et al.* has no high [Fe/H] globular clusters nor does it have high metallicity analogues of the intermediate age clusters in the LMC.

While some of the oldest open clusters in the Galaxy have the potential to remedy the latter shortcoming, none of these open clusters comes even close to the richness needed in insure proper sampling of the relatively short-lived but major contributors to the bolometric luminosity of such stellar assemblages, namely luminous late-type stars on the asymptotic giant branch (cf. Houdashelt *et al.* 1991). On the other hand, it may be possible to alleviate the problem of missing old, high [Fe/H] stars. As reported at this conference, Ortolani, Bica, and their collaborators are obtaining new optical data for several bulge globular clusters in the Milky Way. These are the most metal rich clusters known in the Galaxy (Armandroff and Zinn 1988). An effort is also underway to obtain infrared photometry for these objects (Frogel, Terndrup, and Armandroff, in preparation). Infrared data is crucial for a determination of bolometric luminosity and temperature of the giant stars. In addition new data on metal rich globular clusters in M31 (Jablonka, private communication) confirms the extrapolations used by Bica *et al.* to compensate for a somewhat incomplete data base. Finally, one could treat the stellar population of the Galactic bugle as a cluster, albeit one of a unique type, and include it in parallel with the other clusters in a library. We (Terndrup and myself) are pursuing such an approach.

To conclude this section, I would like to remind you of something obvious but that is often overlooked: the problem of radial gradients. Even at the relatively close distance of the Virgo Cluster, spectrophotometric observations with a slit size as small as 2" still corresponds to ~45" in M31 or 1.3° in the bulge of our own galaxy. We know that there are strong metallicity gradients in the Galactic bulge on this scale. Therefore, in interpreting observations with even relatively high spatial resolution in extragalactic systems, we must always bear in mind that not only will there be a range in age and metallicity (not to mention velocity dispersion and possibly IMF), that characterizes the stars at every position in a galaxy, but the observed distribution functions will be affected by strong spatial gradients.

3. The Composite Population of Spiral Bulges

3.1. DWARFS VERSUS GIANTS

The Na I doublet near 8200 Å is an often used spectral feature in attempts to determine the relative contribution of dwarf and giant stars in a stellar population since it is quite strong in dwarfs but weak in giants. Unfortunately, contamination by Telluric features has made interpretation of observations of Na I difficult and controversial. In addition, it now appears that these observations are affected by other stellar absorption features (Alloin and Bica 1989; Xu, Veron-Cetty, and Veron 1989). Blended with the Na I absorption are metallic lines in K giants and TiO absorption at 8198.5 and 8205 Å in late-type giants. Xu *et al.* conclude that in luminous galaxies the observed Na I feature is actually a blend of all three components, each contributing about equally. Alloin and Bica find that in the center of M31 the enhanced absorption in the 8200 Å region is due to the 8205 Å TiO feature rather than Na I. They also demonstrate that in giant stars Na I is weakly correlated with [Fe/H] because of the blends with other stellar features. The correlation is in the sense that Na I absorption gets stronger in cooler stars. Thus it would appear that claims based on Na I feature for a dwarf enriched population in the integrated light of many galaxies are exaggerated.

In a recent preprint, Delisle and Hardy present a study of the spatial variation in the nuclei of early-type spirals and E galaxies of the Ca II triplet, TiO bands, and the Na I doublet. Their conclusions as to the contamination of the Na I absorption by other stellar absorption features is in agreement with those of Alloin and Bica and of Xu *et al.* They also find that Na I correlates more strongly with global parameters likes M_V and the Mg_2 lines rather than with details of the initial mass function deduced from models. This finding, too, is consistent with the importance of the contaminating features rather than just a simple dwarf - giant effect on the observed Na I strength.

There is a well defined decrease in the strength of the Na I blend with increasing central distance in half of the galaxies in the Delisle and Hardy sample. Since the lines that blend with the Na I feature are expected to be metallicity sensitive, the observed radial dependence, as well as the global correlation mention above, probably reflects an overall correlation with metallicity. The CaII triplet shows similar but less well defined dependencies. An interesting finding of Delisle and Hardy is that one TiO band increases with increasing radial distance. Could this be related to the fact that in a metal rich population the brightest stars in M_{bol}, which also happen to be the reddest, are relatively quite faint in the I band (see the contribution by Ortolani, Barbuy, and Bica elsewhere in the volume)? If a declining value of [Fe/H] is associated with increasing radial distance, than as the distance increases, so would the relative contribution to the I band of the reddest stars thus causing an apparent increase in the strength of some TiO bands. The behavior of TiO bands may also be complicated if one encounters a significant population of luminous AGB stars in regions that have experienced star formation in the past few billion years.

The Wing-Ford band of FeH can provide another important constraint on the relative numbers of M giants and dwarfs as it is very sensitive to the presence of dwarfs later than M4 (Whitford 1977). Unfortunately, it is in an even more difficult part of the spectrum to observe than the Na I doublet. Hardy and Couture (1988) reported the first clear-cut detection of this band in several E galaxies. They showed that measurements of the FeH band are probably affected, and may even be dominated by the (2-3) band of the δ system of TiO. Hardy and Couture's results "very likely exclude dwarf-enriched models" for the E galaxies they observed. Whitford (1977) was unable to detect the band in any of the galaxies he observed.

To sum up, recent observations of spectral features that are most sensitive to the presence of late type dwarfs in the integrated light of galaxies give no convincing evidence for the presence of an excess number of such stars in the systems studied to data. A luminosity function similar to the Salpeter one is adequate, in most cases, to understand the spectral features and continuous energy distributions of these galaxies.

3.2. OLD VERSUS YOUNG STARS

What observational criteria can be used to distinguish between age differences and metallicity differences? The fact that observations of galaxies are averages over volumes that probably encompass significant radial variations in these two physical parameters greatly complicates the problem. This issue is particularly critical when very distant galaxies are observed. It is also significant when observing spiral bulges as, except for edge-on systems, there will always be a contribution from the part of the disk that lies along the line of sight to the bulge.

If young stars are present in a galaxy they will be obvious at blue wavelengths and have little or no effect in the red. Therefore, the detection and analysis of a young stellar component can best be done by the measurement of spectral features and colors in the blue. Determination of the main sequence turnoff is particularly important. Examples of how a young stellar component can be detected and distinguished from a blue but old and metal poor component are given by Frogel (1985) and Bica and Alloin (1987).

In contrast to the blue, the red and near-infrared spectral regions are dominated by cool giants from a relatively old stellar population. Colors and spectral features in the red and near-ir will be sensitive primarily to abundance variations and secondarily to details of the AGB and to the ratio of dwarf to giant stars. The presence of supergiants can introduce some complications, but these are easy to sort out. If used in combination, the blue and red spectral region together can set strong constraints on the age and metallicity of a stellar population. An example of the use of just broad band colors to constrain isochrone synthesis models is provided by Charlot and Bruzual's (1991) recent work.

In another example Bica and Alloin (1987) compare blue and red spectral features in the same set of galaxies. In late type spirals the blue features, e.g. Ca II H&K lines and CN absorption, are considerably weakened compared with the red features. If blue features alone had been observed, one might draw the conclusion that the late-type spirals are metal weak. But Bica and Alloin argue convincingly that the weakness of the blue features is due almost exclusively to *dilution* by the continuum light of young, hot stars. Central to their reasoning is the fact that the red spectral features in the same galaxies show a much smaller change with galaxy type. Bica and Alloin's conclusions for the nuclei of late-type spirals are in accord with the earlier work of O'Connell (1982) and Frogel (1985) who based their analysis on lower resolution spectral data or just broad-band colors. In the latter work, Frogel showed that the UBV colors are decoupled from the JHK ones in a sample of about 20 late-type spirals. This suggests that the current level of star forming activity varies considerably from one galaxy to the next, even at the same Hubble type. An obvious cause of this would be if periods of particularly active star formation were discrete and took place on a time scale significantly less than the age of the galaxy.

3.3. OBSERVED TRENDS WITH HUBBLE TYPE

In the previous two subsections I have reported that recent studies of the stellar content of spiral bulges lean heavily towards three conclusions. In varying degrees, these conclusions require that observations be made over a wide enough baseline in order to sort out the effects of age from metallicity. In the 1990s, it has finally become clear that "wide enough baseline" means at least from the blue cutoff of the atmosphere to the near infrared. These three general conclusions concerning the stellar content of spiral bulges are:

1) they can be highly composite;
2) the initial mass function of the stars appears normal, i.e. there is no evidence for an enhancement in the numbers of late-type dwarfs;
3) the available observations of spiral bulges point to the presence of a young population in some of them and a metal poor population in (almost) none of them.

How do these conclusion vary with Hubble type? An answer may be found in a recent, comprehensive survey of stellar populations in the bulges of spiral galaxies by Bica and Alloin (1987) and Bica (1988). I will briefly summarize their findings relevant to the question.

Earlier and more luminous spirals are generally very similar to E and S0 galaxies. Bica and Alloin find little or no evidence for blue HB stars in these systems, implying that there is no significant metal poor population in the bulges of early-type spirals. Later type spirals and the less luminous ones of a given type have more prominent contributions from young stars, but the change in the mean [Fe/H] is small. Their findings for the three main classes of spirals are:

> Sa: Spirals of this class are very homogeneous. They are characterized by a red continuum and strong absorption features. There could be a small contribution from a 5 Gyr old population.
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> Sb: The higher luminosity Sbs are red and strong lined, similar to ellipticals and Sas. Lower luminosity Sbs are also red, but the absorption spectrum is not as strong lined. Occasionally one finds an Sb with a blue nucleus, e.g. N4569, probably due to a recent period of particularly active star formation.
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> Sc: As a group Scs are much less homogeneous than Sbs or Sas. The lower luminosity ones have blue to very blue energy distributions implying a significant population of young stars. In the bluest group, a component of the stellar population with an age of ≤ 3×10^8 yrs contributes nearly 90% of light at 4000 Å and nearly 60% at 9000 Å.

4. How Similar are Spiral Bulges and Elliptical Galaxies?

It has been known for a long time that the colors and spectral absorption features of elliptical galaxies and the bulges of early type spirals are quite similar. Morgan's (1956) qualitative spectroscopy of the integrated light from Baade's Window in the bulge of the Milky Way and Whitford's (1978) seminal study of the same field raised the possibility that delineation of the properties of the stars in Baade's Window would be valuable in furthering our understanding of the stellar content not just of spiral bulges, but of elliptical galaxies as well (Frogel and Whitford 1987; Frogel 1985)

Recent studies already mentioned provide further evidence for a strong similarity in the stellar content of E galaxies and the bulges of *early-type* spirals. For example Delisle and Hardy (1991) find that to within the observational uncertainties, the mean strengths of red stellar absorption features in early-type spiral bulges and E galaxies are indistinguishable. Bica, Arimoto, and Alloin (1988) combine evolutionary models, e.g. those described by Arimoto and Yoshii (1987) and cluster synthesis technique of Bica and Alloin (1987) to show that spiral nuclei and elliptical nuclei of comparable total mass have had very similar star forming histories and, consequentially, similar present day stellar populations.

What about late-type spirals? In so far as their old stars are concerned, they appear to be quite similar to E type galaxies (e.g. Frogel 1985), although it is difficult to distinguish between populations that are 5 to 10 Gyr old and those that are 10 to 15 Gyr old. Overall, though, there are significant differences between the bulges of late-type spirals and typical E galaxies (Alloin 1973; Turnrose 1976; O'Connell 1976 and 1982; Frogel 1985; the papers of Bica and collaborators referred to earlier). These differences may best be summarized by saying the late-type spirals have energy distributions that are significantly bluer than those of the early type spirals and E galaxies. This blue energy distribution arises from a population of young stars

https://doi.org/10.1017/S0074180900120340 Published online by Cambridge University Press

mixed with the old population. The relative proportion of young and old stars varies strongly from galaxy to galaxy. In fact, it is misleading to speak of an "old" and a "young" population in these galaxies since star formation has probably never really stopped in many of them.

There are some striking differences between spiral bulges and E galaxies. The nuclei of many spirals have strong emission line spectra indicative of H II regions as well as non-thermal emission. While as many as half of E and S0 galaxies have detectable [N II] 6584 emission (Phillips *et al.* 1986), this emission tends to be quite weak and difficult to detect in contrast to that found in the spiral nuclei. The emission in spirals may more properly be associated with the inner part of a disk rather than the bulge. Gas flowing inwards through the disk or along a bar could fuel the star formation and non-thermal activity observed in spiral nuclei. Perhaps the most fundamental difference between spiral bulges and ellipticals, and the whose origin is the least understood, is the fact that spiral bulges are rotationally supported whereas E's are, for the most part, pressure supported.

5. Evolutionary Synthesis Models

Stellar synthesis models tell us primarily about spiral bulges as they are today, not their evolutionary history. We need to account for the observed distributions of metallicity and age of the stars as well as their kinematics, Sandage's (1986) "three dominant parameters in the population concept". The recent work of Arimoto and his collaborators (e.g. Arimoto and Yoshii 1987; Koppen and Arimoto 1990) has done much to help us understand the evolution of stellar properties. Their underlying premise is that rapid star formation drives chemical enrichment of the interstellar medium in spiral bulges until a supernova driven wind expels the remaining gas. The effects of such a wind are discussed in detail by Vader (1987).

Koppen and Arimoto (1990) use the above scheme to explain a number of the global characteristics of spiral galaxies that vary systematically along the Hubble sequence. They consider a simple 3 component model: 1) a bulge with relatively low angular momentum that collapses in a free-fall time (~0.1 Gyr); a SN driven wind turns on after ~1 Gyr to terminate star formation; 2) a disk with high angular momentum, a long collapse time scale, and slow star formation rate (SFR) time scale; 3) a halo in which there is no star formation. The halo gas is enriched by material blown out of bulge by SN, and subsequently falls back into disk and enriches it in turn.

For a metallicity distribution, N(Z), they use data on the Galactic bulge from Rich (1988) and published data on G dwarfs to fix parameters for one galaxy - the Milky Way. The peak of N(Z) gives the yield, y, within the bulge almost independent of other parameters. The width of N(Z) gives the gas depletion rate times the age. The metallicity distribution for G dwarfs sets an upper limit on the time scale for a SN driven wind from the bulge. They can then explain the correlation with Hubble type of the mean metallicity of spiral disks and the gas content of the disks for Sa through Sc spirals.

Koppen and Arimoto construct a model sequence in which the bulge to disk ratio, B/D, and the SFR in the disk vary monotonically with Hubble type. The B/D variation in terms of relative integrated luminosity, is consistent with observations. From Sa through Scd Koppen and Arimoto's model sequence has the following properties: The SFR per unit mass in the disk declines by only factor of 3 from the early to the late type spirals. At the same time, the mean metallicity of the bulge relative to that of the disk increases from unity to a factor of 4 while the ratio of bulge mass to disk mass declines from 2.5 to less than 0.1. As Koppen and Arimoto point out, the higher SFR in the disks of early type spirals means that the enrichment rate is higher than in the disks of later type spirals. This results in the smaller contrast in mean metallicity between bulge and disk for earlier type systems than later type ones. In the bulge component of their models the initial accretion of gas and the SFR are independent of the B/D ratio. The result of this is that the mean metallicity of the bulge does not change much over the spiral sequence. On the other hand, pollution of the disk by bulge gas is greatest in early type spirals because the mass of the bulge is greatest so the largest amount of matter is lost. They also require that the yield for the bulge be 4 times greater than that for the disk in order to account for differences in N(Z) between the two components distribution, similar to Pagel's (1987) result. This difference in yield can be accounted for by an increase in the slope of the IMF in the disk by only 20%, 1.3 to 1.55. Such a small difference in slope between disk and bulge is not surprising as the time scales for the SFR in the disk and bulge are probably driven by different processes, e.g. spiral density waves in the disk, and cloud-cloud collisions in the bulge.

There are two obvious properties of spiral galaxies that have not been taken into account in the above model. First of all, spirals show a big range in properties even at the same Hubble type. Secondly, the range in metallicity within a given spiral disk is greater even than the range from one galaxy to another. Nevertheless, this model provides a simple but enlightening approach to understanding the global properties of the stellar content of spiral bulges.

6. Are the Bulges of the Galaxy or of M31 Representative?

Whitford's (1978) study of the integrated light in Baade's Window provided quantitative evidence that the stellar content of the Galactic Bulge is similar to that of early-type galaxies, both ellipticals and spirals. Use of Galactic bulge M giants in stellar synthesis models has resulted in significantly improved fits in the red and near-infrared to the integrated light of E galaxies (Frogel and Whitford 1987; Frogel 1988; Terndrup *et al.* 1990). In brief, evidence in favor of the stellar content of the Galactic bulge being typical of other early type systems is accumulating. Nothing has yet been found that seriously challenges this result.

M31 is the nearest large spiral to the Milky Way. Individual stars in its bulge and disk can be studied without recourse to observations from space. Thus it is important to determine as quantitatively as possible whether or not the stellar population of its bulge is similar to that of our own Galaxy. In resolving this issue we are also addressing the representative nature of the Galactic bulge. All recent studies conclude that M31's bulge in integrated light is typical of other early-type systems. Delisle and Hardy (1991) find absorption features in the bulge of M31 to be indistinguishable from other early type spiral bulges or from E galaxies. In central 4" of M31, Alloin and Bica (1989) find that the enhanced absorption near the 8200 NaI doublet is due to a feature at 8205, probably TiO. Thus there is no evidence for dwarf enhancement, consistent with observations of other most other galaxies. Bica, Alloin, and Schmidt (1990) find that both the bulge and the semi-stellar nucleus of M31 are dominated by the old, metal-rich stellar component. They estimate that at most 10-20% of the flux can come from an intermediate age component. Again, these are limits characteristic of E galaxies and early-type spirals.

Recent remarkable advances in the technology of infrared arrays has finally allowed us to image the bulge of M31 at 2.2 μm and compare the physical characteristics of M31's luminous M giants with those in the Galactic bulge (Rich *et al.* 1989). Results from two programs have recently been published (Rich and Mould 1991; Davies *et al.* 1991), and the conclusions and not nearly as clear cut as in the case of the integrated light of the two bulges. Bolometric luminosity functions for two fields in M31 are similar to the luminosity function for Baade's Window except that for M31 the brightest stars are 0.5 to 1.0 magnitude brighter than those in Baade's Window. Although this result could be taken as evidence for a component to the stellar population with an age several Gyr younger than that of the Galactic bulge, Davies *et al.* argue that these bright stars are from M31's disk that lies along our line of sight but behind its bulge. Observations of M32 reported at this conference by W. Freedman show a population of luminous stars in that galaxy as well. They cannot be explained away by a disk. Some resolution of the problems raised by these observations of M31 and M32 is expected by the time these conference proceedings appear in press.

The Galactic Bulge and IR/OH Sources

From balloon and other data, emission at ~2.2 μm from the Galaxy shows a well defined disk and bulge structure, typical of other spiral galaxies. For example, Melnick *et al.* (1987) find for $15° \leq l \leq 60°$ the FWHM of 2.4 μm emission is ~5°. For the central 10°, on the other hand, the FWHM is nearly twice this amount. Emission at 2.4 μm is primarily from photospheres of K and M giants (Frogel 1988).

IRAS has detected numerous stellar sources in the bulge, many of which are classified as OH/IR stars on the basis of their colors and luminosities (Whitelock, *et al.* 1991; van der Veen and Habing 1990). Are there sufficient numbers of these sources to constitute an important component of the population and make a significant contribution to the integrated light of the bulge at 12μm? Stellar emission at this wavelength will be dominated by circumstellar dust. Rowan-Robinson and Chester (1987) make corrections for the severe extinction for the IRAS sources, particularly at low latitudes, calculate the effects of sources with low optical depths in their dust shells, and predict $L = 1.7 \times 10^8\ L_{sun}$ for the total luminosity. They also predict what would be seen in the central 4' of M31 and find consistency with Soifer *et al.*'s (1986) value - 4.9Jy at 12μm. This is about 2 times greater than expected from purely photospheric emission but in close agreement with the excess predicted by Frogel and Whitford for Baade's Window from ordinary M giants alone. So the stars contributing to excess in both galaxies are probably similar.

There is a more direct and less model dependent way to investigate the influence of OH/IR stars on the integrated light from the bulge. That is to map out the spatially integrated 12 μm flux measured by IRAS. This values are derived from the total flux detected by IRAS, thus removing limitations associated with source confusion and the detection limit for faint sources. For example, the untreated IRAS data revealed a FWHM of ≤1° within 6° of the Galactic center (Gautier *et al.* 1984). I have completed an analysis of the preliminary, prerelease version of the "Super Sky Flux" maps from IRAS. These represent the best attempt to date to give maps of the sky at all IRAS wavelengths with all known instrumental effects plus the zodiacal light contribution removed. Within the statistical uncertainties I find that the integrated 12 μm flux between $b = \pm 2$ to $\pm 12°$ is no greater than that predicted from models based on optically identified M giants alone (Blanco *et al.* 1984; Frogel and Whitford 1987; Frogel *et al.* 1990). The conclusion, then, is that the OH/IR stars are not a significant component of the bulge population, even at 12μm.

My own research has been supported in part by NASA grant NAG 5-1367 through their ADP program.

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