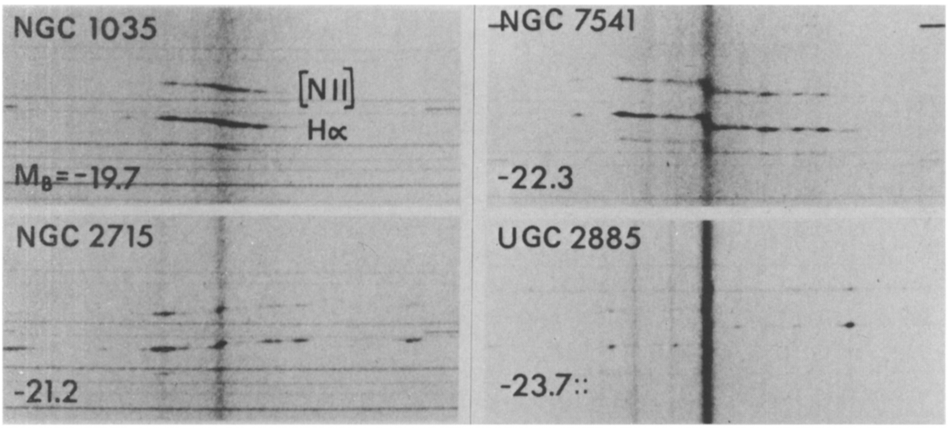
OPEN DISCUSSION; SESSION II (Chairman John A. Graham)

GRAHAM: We now come to the discussion and we'll start with a short, two-minute contribution from Vera Rubin. Vera has a few slides to show us of spectra of nuclei of Sc galaxies.

RUBIN: Disk spiral galaxies form a two-dimensional sequence. Galaxies vary systematically not only with Hubble type, but also with luminosity within a single Hubble type. I would like to show you spectra of four



Sc galaxies showing how their red spectral properties vary as a function of luminosity. All are normal Sc galaxies. The first slide shows a galaxy of absolute magnitude -19. You cannot see the nucleus well and that's just the point. The nuclear continuum is extremely weak in the red. You're looking at Hα, the emission line that's strongest, and [NII] and [SII]. This is the lowest luminosity galaxy I'll show. This is very much like an HII region: strong Hα, weaker [NII], almost no red stellar continuum. The next slide, with increasing luminosity to about -21, the red stellar continuum gets stronger, the NII lines get stronger relative to Hα. The [SII] lines, which are not shown here, get weaker; [SII] lines are strongest in low luminosity spirals. Next slide please. This is about -23. The continuum is getting still stronger. [NII] is getting stronger with respect to Hα. What I'm calling the

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nucleus is about 300-500 pcs on the galaxy. The final slide shows the highest luminosity Sc of ~ -23.7. The continuum has gotten so strong that you probably can not see Hα and [NII]. Perhaps you can tell that [NII], which is at the upper part of the diagram, is stronger than Hα. I would urge observers not to make composite Sc spectra unless they're dealing with Sc galaxies of the same type. I would also suggest that when you look at galaxies like M33, which is an Sc but also of lowish luminosity, you're seeing the kind of HII spectrum which I showed on the first or second slide. Thank you.

GRAHAM: Thank you Vera. We thought that what we would do for the discussion was, first, to discuss the first two papers by Bob O'Connell and Dave Crampton on spiral galaxies and also any comments about Vera Rubin's contribution; and then, later on, we'll go and talk about elliptical galaxies and Sandy Faber's contribution. So, does anybody have any comments on the spiral galaxy papers?

SERRANO: Yes, I only have a general comment on the first two talks. One must be very careful about concluding anything from a relation between luminosity and metallicity, because even though it's very exciting that it's similar to elliptical galaxies one must remember that even irregular galaxies and blue compact galaxies have the same mass-metallicity relation (Lequeux, Peimbert, Rayo, Serrano, Torres-Peimbert 1979: Astron. Astrophys. 80, 155). We do not understand that relation between mass and metallicity, and I don't think one can jump to any conclusion if such a relation exists for the bulges.

GRAHAM: Would you like to comment on that, Sandy?

FABER: I would like to direct a question to both speakers, but, I guess, particularly to Dave Crampton, because now I'm in the position of being an observer who has, I think, a considerable amount of data that bear on this question. I know for sure from these data that it's not simply a metallicity sequence, because the Hβ variations, the absorption line variations, are too large for it simply to be a metallicity sequence. On the other hand, Dave has admitted as much, so now the position of people like myself is to ask: what is your quantitative view? As long as people took totally polarized views it was easy to agree with one or the other. But now that the situation isn't quite so clear I would appreciate, as somebody who might conceivably write a paper on this subject, a more quantitative statement about what effect is important here.

CRAMPTON: For our Sc galaxies to match real galaxies we had to include about 75 % of the light from metal-poor globular clusters. To answer what is important is somewhat difficult. In the red part of the spectrum we have to add ordinary solar abundance globular clusters to match Mg b and the other features in the red. But it is in the blue where we find big differences, and particularly at H9, 3835 Å - I would have shown it to you if the slide had been more easily visible. The hydrogen line there gets blended with metal lines as you go down to increasing

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spectral type, say from A5 to F5, there's a very large number of metal lines which come in. If you compare the ratio of the the hydrogen lines in Sc galaxies to the K line, you'll find that, when you have a young population, H9 gets very strong due to the metal lines coming in. They come in earlier than metal lines in other parts of the spectrum. But for metal-poor stars that's not true. If you take a globular cluster like M15 or M92, that line is not enhanced. That is one of the criteria we use most of all to distinguish between metal-poorness and age difference.

GRAHAM: Any more questions on the spiral galaxy nuclei? I guess I had one question which is probably a very much more elementary one. It is my understanding, it is not correct, Bob, that when one is talking about the bulge, when one is talking about a globular cluster, when one is talking about the nuclear region of the galaxy, one is really dealing with stellar densities that are very, very different? It seems to me that one ought to be careful in making a straight comparison, say, between the integrated properties of a globular cluster and a nucleus of a galaxy when one is dealing with very big differences in stellar density. Am I right in that? Do you have some rough figures?

O'CONNELL: I don't have figures, but that is correct and there is a fundamental problem of definition here. Operationally when we talk about the nucleus of a galaxy, we're really talking about the inner 10 arcsec or so because that's what you can observe with standard techniques. That region is going to be, in a late-type spiral, a composite of: the spheroid; a true semi-stellar nucleus, if one exists, as in M33; the inner disc and then there may be special structures like these hot spots, for example. But other things may be possible that only exist in the nuclear regions as a result of interactions between these other components. So you have to be very careful and admit that you're dealing with a very complex physical region. Something that Dave touched on is really a key issue in all of this. I claim that the nuclear regions of late-type spirals appear to have a lower mean age. The real question you want to answer there is whether the bulge of a late-type spiral has a lower mean age, or whether the component you're seeing, containing the younger stars, is not really a part of the bulge population. That's a very critical question and I don't think it can be answered with current techniques.

GRAHAM: I'll just add a very quick comment on that, myself. Using the 4-m telescope in Chile on spectroscopy of the relatively nearby galaxies, I've always been very, very impressed with how the spectrum will change when you just move the slit of the spectrograph one second of arc one way or the other. I think that it is very important that one understands exactly what is going through the slit of the spectrograph.

CARRASCO: I just have a very short comment to Dave Crampton's statement on the similarity in the kinematics of bulges of spirals to elliptical galaxies. I entirely disagree with the statement that the kinematics of bulges of spiral galaxies and that of elliptical ones is very similar.

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The available data today indicate that bulges are rotationally flattened systems, while the flattening of ellipticals is most likely due to their triaxial character.

GRAHAM: Do we have any more comments?

BECKLIN: I'd just like to point out that due to extinction by dust there is a tremendous selection effect in deducing the star formation rate of nuclei of galaxies from optical and UV data. This has been demonstrated by a recent observation that Scoville, Young, Capps and I made on the IRTF, where we looked at the 60 brightest Virgo spiral galaxies at 10 μm. We found, to our surprise, that we detected over half of them. If you interpret these observations in terms of star formation, which is very reasonable, then the mean luminosity in the central 500 pcs of these Virgo spirals is 10^9 $L_\odot$ in O and B stars.

GRAHAM: Do we have any more contributions on spiral galaxies? Do we have any comments about Sandy Faber's paper on nuclei of elliptical galaxies?

RENZINI: Canonical stellar evolution theory predicts that, say, of the order of one percent of the integrated luminosity coming from an old stellar population ($\sim 15 \times 10^9$ yr) is produced by stars hotter than 30 000 K in the phase when they are crossing the region of planetary nebulae nuclei (Renzini: 1981, Annales de Physique 6, 87). This hot component must be taken into account when one is dealing with an old stellar population because stars are dying, after all, and not stopping their evolution at the tip of the red giant branch or at the end of the horizontal branch; instead they continue until the white dwarf stage. Moreover there is another possible component which should be kept in mind. These are accreting white dwarfs in binary systems, which are probably the precursors of Type I supernovae. If the current view about the progenitors of Type I supernovae is correct, putting two and two together, you can easily find that another one percent of the integrated light of an elliptical galaxy should come from accreting white dwarfs of temperatures of $\gtrsim$ 30 000 K. Extreme temperatures of such objects is $\sim 10^6$ K, so they will also contribute to the soft X-rays.
I have a question to observers: is the observed UV flux shortward of 2000 Å consistent with an upper limit of, say, a few percent - 2 or 3 % - of the integrated light produced by old stars?

FABER: Some years ago when Charlie Wu and Beatrice Tinsley and myself and several other authors wrote a paper on the ultraviolet flux of M31 we did consider this question for the planetaries. We decided that simply the known number of planetaries would contribute half of the amount of the ultraviolet flux with some uncertainty. So if Alvio comes along and says he's going to give us another magic factor of two, that would create rather good agreement. I have not, myself, looked at this correspondence for the IUE data; if anyone else has and cares to comment, I'd be very glad to hear it.

INAGAKI: The kinematics of giant and smaller ellipticals are quite different, so I'd like to know whether there will be systematic differences in the nature of the individual stars between them?

FABER: Well, right now we're working on the hypothesis that the only difference is a difference in overall metal abundance. That's really what I was devoting my talk to. We don't have the final results yet. Maybe another year or so.

GRAHAM: We have another comment from Dr Carrasco and then one from Dr Peimbert.

CARRASCO: I would like to argue a little bit more in favor of the ultraviolet light of elliptical galaxies coming from Population II objects. There is evidence that amongst the field OB stars in our Galaxy there is a kinematic subgroup that shares the kinematics of the old disk population (Carrasco, Bisiacchi, Cruz-Gonzáles, Firmani, Costero: 1980, Astron. Astrophys. 92, 253). Spectroscopically they are quite indistinguishable from the true extreme Population I objects. There is also a very interesting correlation between their kinematical properties and their spin rotational properties. Wouldn't you expect to find such stars in ellipticals and that they are more likely to be the source of the ultraviolet flux?

PEIMBERT: Gustavo Bruzual, Sylvia Torres-Peimbert and I have made an integrated model for the light of the nucleus of M81 using IUE data. We can fit all the features comprising the 1200 to 8000 Å region, without the need of O and B stars. We need only a single burst of star formation 10 billion years ago and some horizontal branch light. Just a few old HB stars added to the model would affect the emission lines as well as the 1200 to 1500 Å region in a way that would be incompatible with the observations.

VAN DEN BERGH: This is a question addressed to Sandy Faber. It has sometimes been suggested that the supernovae of Type I that are seen in elliptical galaxies are associated with a young, or at least moderately young, population component. In view of your new results, do you consider this interpretation less likely?

FABER: I suppose so. I think it's the only really good piece of evidence that still exists in favor of the young stars. In face of the more or less overwhelming amount of evidence that now seems to be on the opposite side, I guess I'd have to say I give it lower weight.

SCHWEIZER: A quick question for Sandy Faber. What fraction of your ellipticals are field ellipticals, and what fraction are in clusters? It may have something to do with how many young stars you see in them.

FABER: That's a very interesting question, François. I don't think it matters though, actually. Probably for the sample it's about half and half, but the interesting thing is that by looking at the Hβ absorption-

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line properties you could get an idea of whether or not the strength of Hβ is out of step with the strengths of the other metal lines. If it is enhanced, you might conclude that, aha, you're seeing a burst of young stars in the nucleus of this galaxy. Out of a sample of 225 galaxies there is one elliptical galaxy with a spectrum like M32 or stronger-lined that possibly falls into this category. On the statistics of one object you can't make any conclusions about their being in clusters or outside of clusters. My feeling at the moment is that if it's an elliptical galaxy it doesn't have any young stars in its nucleus, no matter where it is.

GRAHAM: To put François Schweizer's question more specifically: do you think that the infall of intergalactic material plays any part at all in star formation and in the evolution of galactic nuclei? (Laughter)

FABER: Yes, I think it does, and those are, perhaps, the galaxies we're systematically getting rid of by classifying them as peculiar. (Laughter) I do have galaxies that seem to show bursts of stars in the nucleus, but they're in general not classified as ellipticals. They're ones with dust, hot spots, and other peculiarities.

GRAHAM: Yes, that's a good answer. I think many of us gravitate towards peculiar galaxies. Any more questions?

TAYLOR: I wish to make a general statement of uncertainty. We do not understand star formation which is important in any discussion of the evolution of stellar populations. We know that there are widely varying mechanisms which trigger star formation; the initial burst of star formation in an elliptical galaxy is certainly very different from the star formation in spiral arms. What we do not know is the extent to which, once star formation starts, the final result depends on the origin. Is the initial mass function determined by the large scale process of star formation so that there are wide variations in it, or is it determined more by microscopic physical conditions when it might not be so variable? Until we do understand better what determines the initial mass function there must be serious uncertainties in a discussion of galactic evolution.

GRAHAM: Any other comments? I was wondering if there are words of wisdom from Dr Geoffrey Burbidge, who might be able to tell us which way we should be going? Geoff, anything to say?

BURBIDGE: No, no, no.

GRAHAM: Nothing to say? (Laughter)

BURBIDGE: I'd have to go back so far that ... (Laughter)

GRAHAM: Well, if there are no other questions or comments I'll thank all the speakers today.