Probing the Stellar Contents of Nearby Galaxies with WIRCAM

T. J. Davidge

November 6, 2004

NRC · CNRC

Scientific Questions

- How did nearby spiral galaxies form?
  - Halos can tell us about galaxy evolution from the initial interaction between protogalactic fragments to the present day. Did all halos form from early monolithic collapse episodes, or are some halos the result of disk disruption (e.g. Dalconton studies)?
  - The disk can tell us about the evolution of spiral galaxies since the last major merger episode. Disks experience evolution due to viscosity, infall, tidal interactions etc. How do theoretical predictions about these processes compare with observations?
- Are some nearby dwarf galaxies experiencing morphological evolution?
  - Some nearby galaxy groups (e.g. M81, Centaurus) are in a more active evolutionary state than the Local Group, and some dwarf systems may be evolving from rotationally supported to pressure supported systems.
- What can we learn about the advanced stages of stellar evolution from studies of nearby galaxies?
  - A detailed census of the stellar contents of large portions of galaxies are required to gain insight into rapid phases of stellar evolution (e.g. upper AGB, massive RSGs near the RSG cutoff).

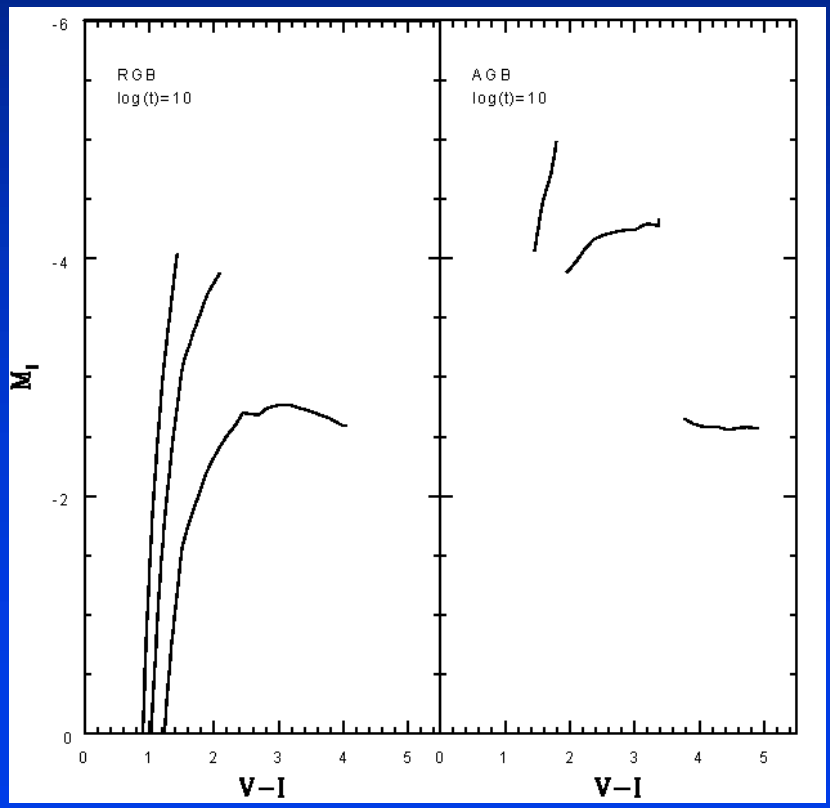
The current talk will focus on stars in nearby galaxies, but there is also much information that could be obtained from studies of the ISMs of nearby galaxies (e.g. H_2 and HI distrubutions etc)

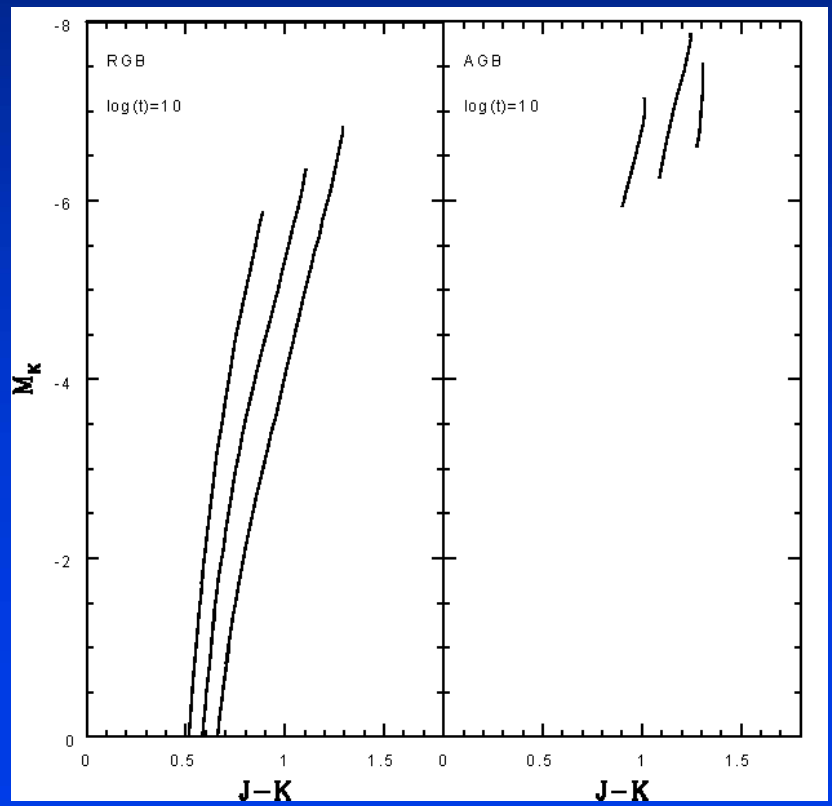
Have not included M31 and M33, since another talk was going to deal with these targets

NRC · CNRC

Why IR Observations of Stars in Nearby Galaxies are Important

- Line blanketing is less of a factor in the IR than in the visible, making it easier to detect cool stars, such as very metal-rich RGB and AGB stars.





Why IR Observations are Important (Con't)

- Certain types of objects, such as C stars, can readily be identified based on their broad-band near-infrared photometric properties.

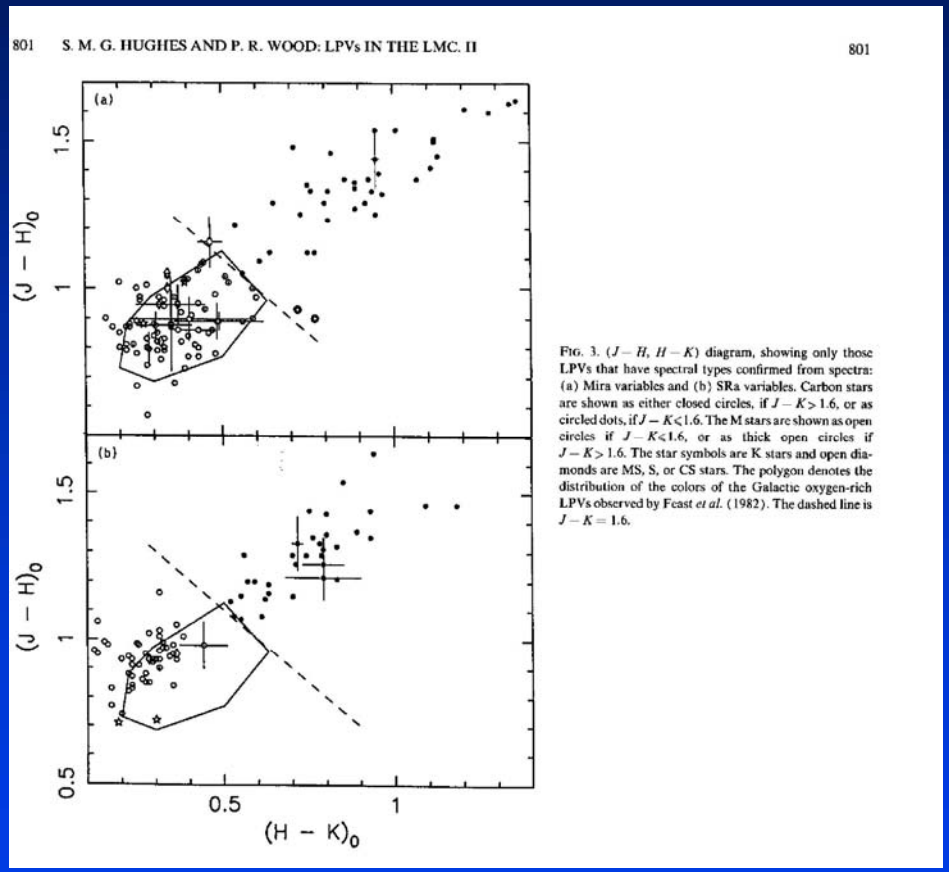


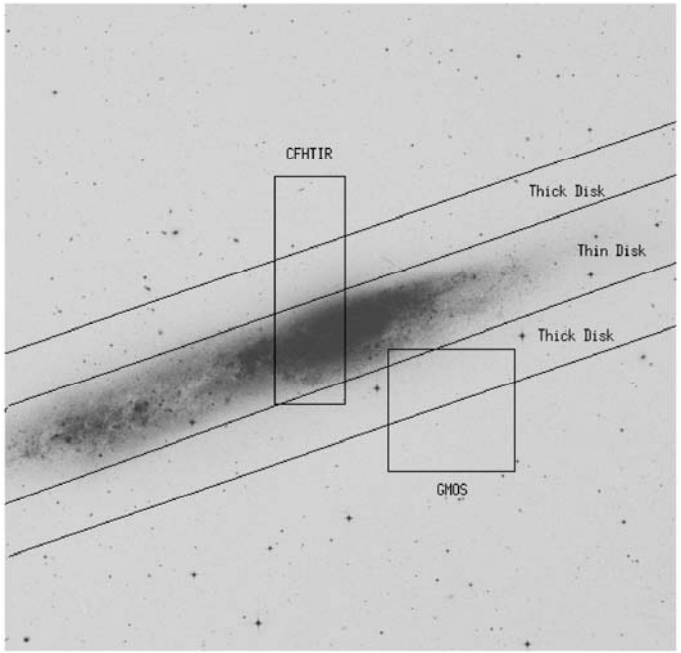
FIG. 3. $(J-H, H-K)$ diagram, showing only those LPVs that have spectral types confirmed from spectra: (a) Mira variables and (b) SRa variables. Carbon stars are shown as either closed circles, if $J-K>1.6$, or as circled dots, if $J-K<1.6$. The M stars are shown as open circles if $J-K<1.6$, or as thick open circles if $J-K>1.6$. The star symbols are K stars and open diamonds are MS, S, or CS stars. The polygon denotes the distribution of the colors of the Galactic oxygen-rich LPVs observed by Feast *et al.* (1982). The dashed line is $J-K=1.6$.

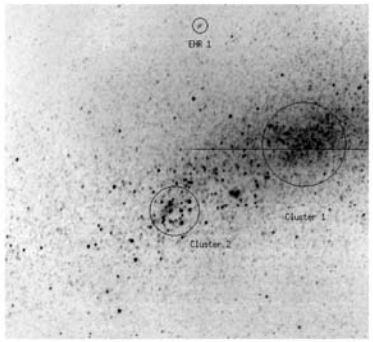
NRC · CNRC

Why IR Observations are Important (Con't)

- The contrast between red and blue stars is higher in the IR than in the visible, making it easier to resolve RGB and AGB stars.
- IR colours are sensitive to log(g), making it easier to distinguish between foreground dwarfs, and bright evolved stars in the target galaxy.
- The near-infrared contains strong absorption features, such as the first-overtone CO bands, that can be studied with narrow-band filters.
- V-K colors are an extremely good T_{eff} probe.

NGC 55: An Example

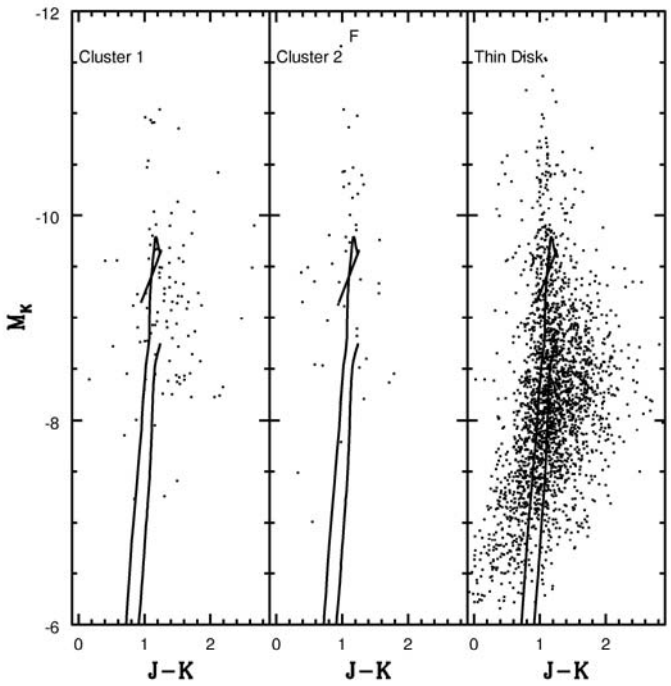




- Data obtained with the CFHTIR during November 2002
- JHK' images of three adjacent fields, with 12 minutes per filter.
- μ = 27.0
- Davidge (2004), submitted to ApJ

NRC · CNRC

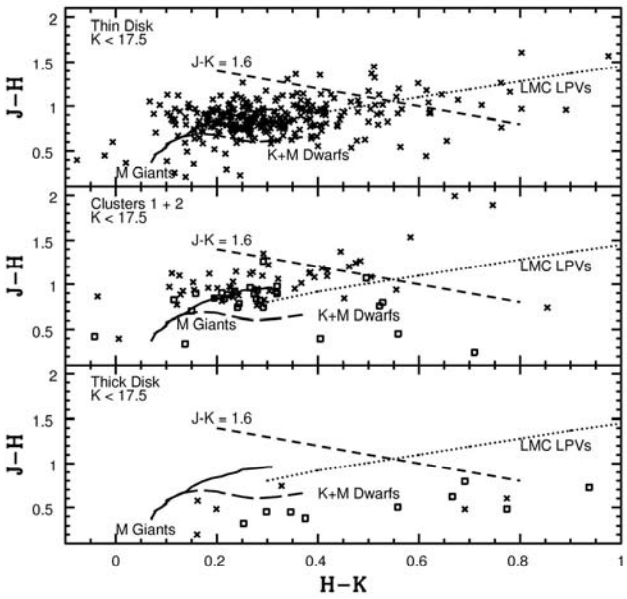
NGC 55: An Example (Con't)



- The K, J-K CMDs show a prominent vertical sequence. The brightest stars on this sequence (M_K < -10) are RSGs, with ages log(t) = 7.0
- The bright end of the AGB sequence can be matched with log(t) = 8.1 isochrones, indicating that stars at the AGB turn-on are present.
- Fainter AGB stars have ages log(t) >= 9.0.
- Star formation has been on-going in this part of NGC 55 for a number of Gyr.
- The integrated photometric properties of this part of NGC 55 are consistent with the central regions of other Sc galaxies.

NRC · CNRC

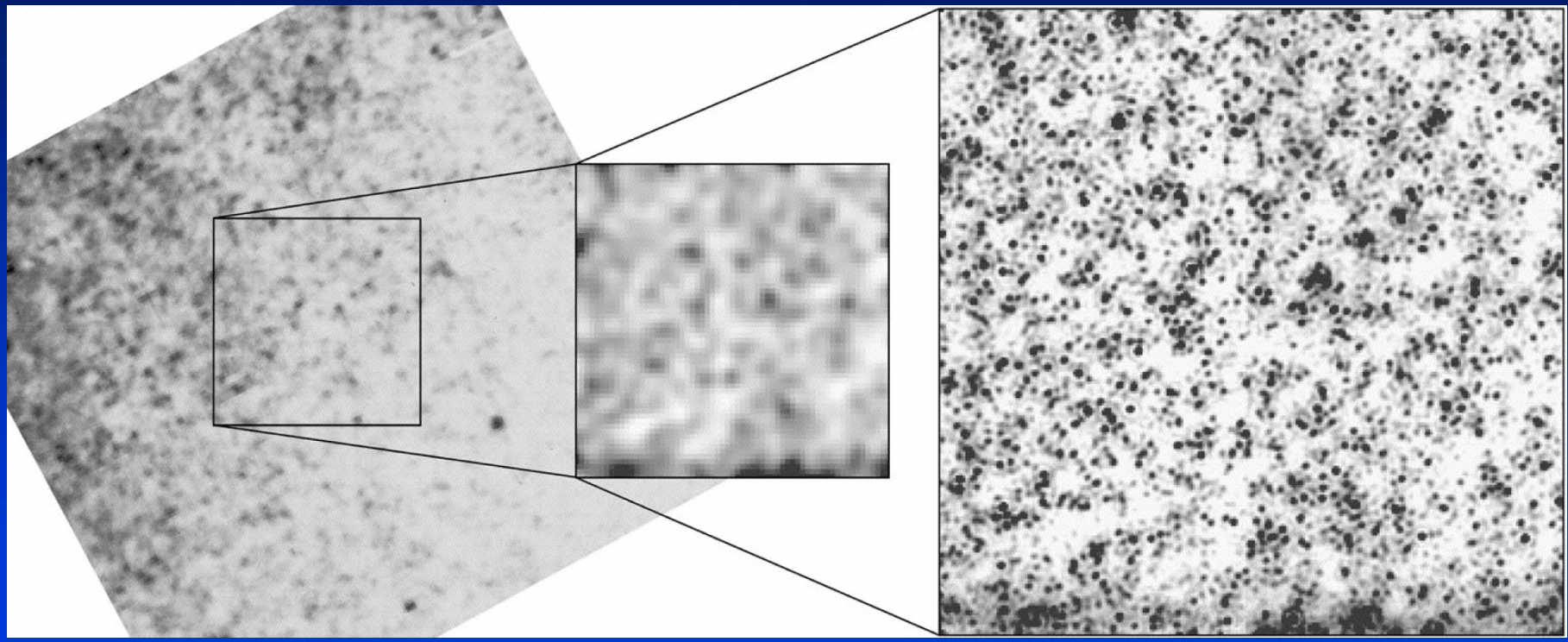
NGC 55: An Example (Con't)



- The majority of stars in the disk of NGC 55 have near-infrared spectral-energy distributions consistent with them being bright giants. Some objects have colours indicating that they are C stars.
- At large offsets from the disk the bright stellar content is dominated by stars with SEDs indicative of dwarfs.

NRC · CNRC

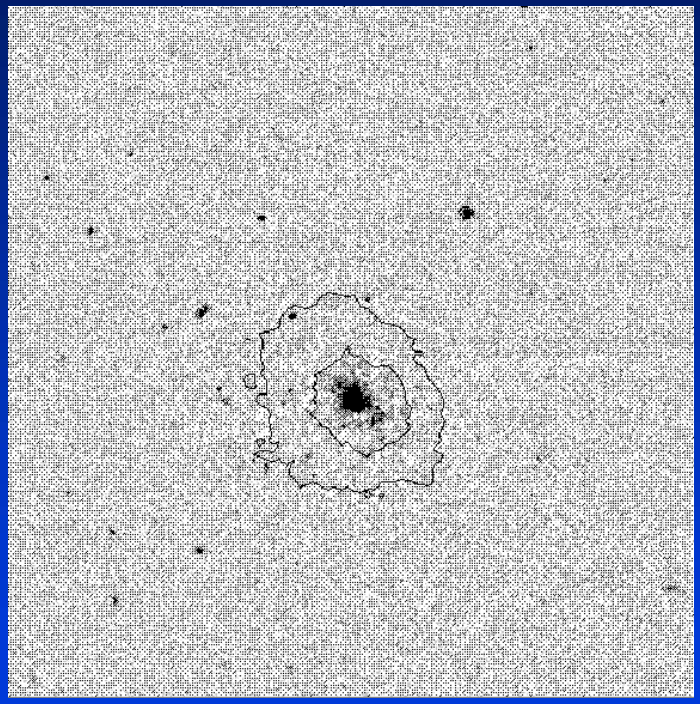
Crowding Can be a Problem when Studying Dense Stellar Environments



From Stephens et al. 2003, AJ, 125, 2473

NRC · CNRC

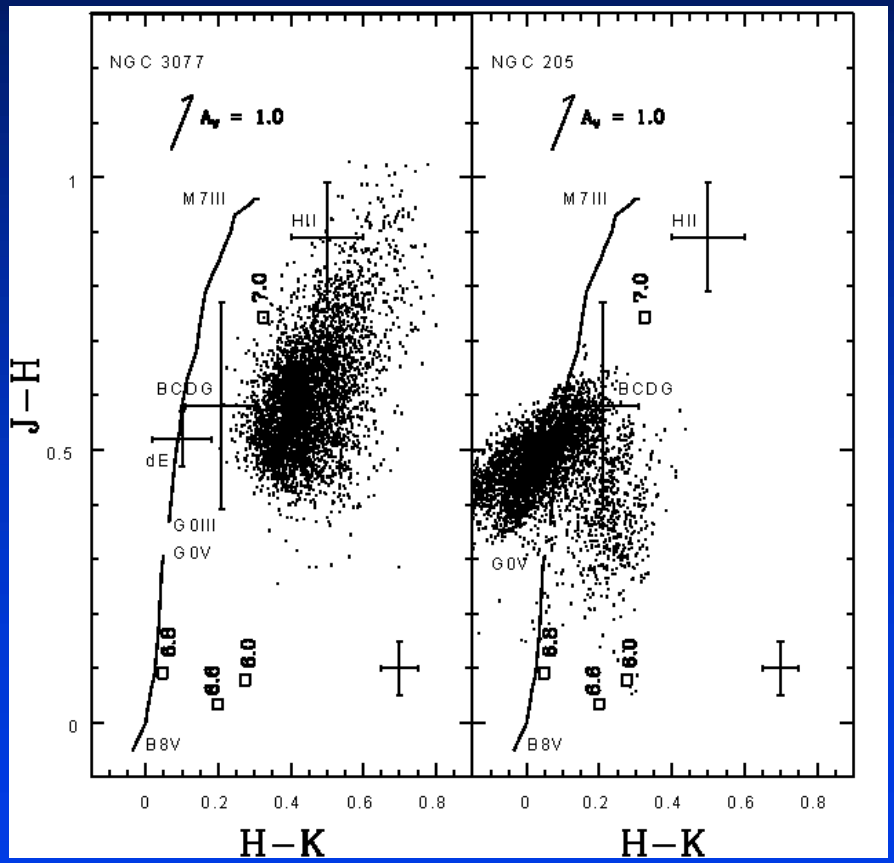
NGC 3077: What can be Done When Stars are not Resolved.



- Observed with CFHTIR during June 2001.
- JHK’ observations with 360 sec per filter
- FWHM = 0.7 arcsec
- The bright sources in the image are a mixture of globular clusters and young compact clusters.
- Davidge 2004, AJ, 127, 1460

NRC · CNRC

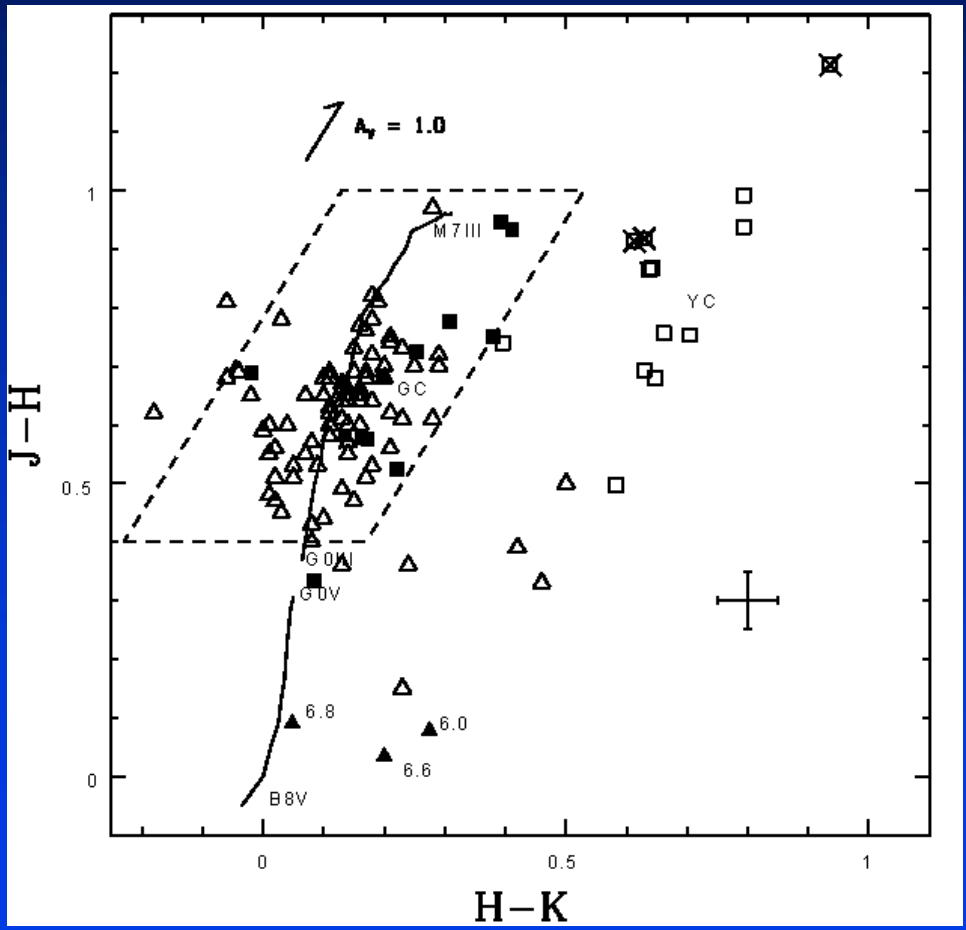
NGC 3077 (Con't)



- The integrated light from the central regions of NGC 3077 has a near-infrared SED that is consistent with a heavily reddened young population ($\log(t) < 7$, $A_V = 3 – 4$).
- A population like that near the center of NGC 205 can not contribute a large fraction of the light in K.

NRC · CNRC

NGC 3077 (Con't)

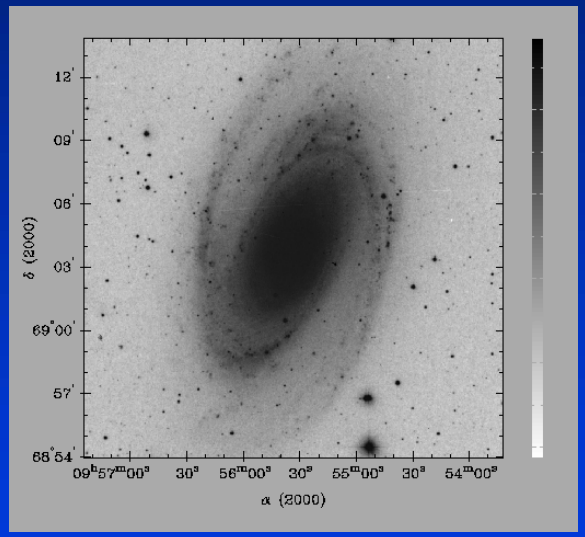


- The majority of bright point sources within a few arcmin of the center of NGC 3077 have near-infrared SEDs that are consistent with them being classical globular clusters or bright, compact young star clusters.
- S_N ~ 2.5. This is consistent with what is seen in nearby dEs, such as NGC 205.
- Based on the young clusters, the SFR during the past few million years has likely been 0.25 – 0.50 M_0 year $^{-1}$.

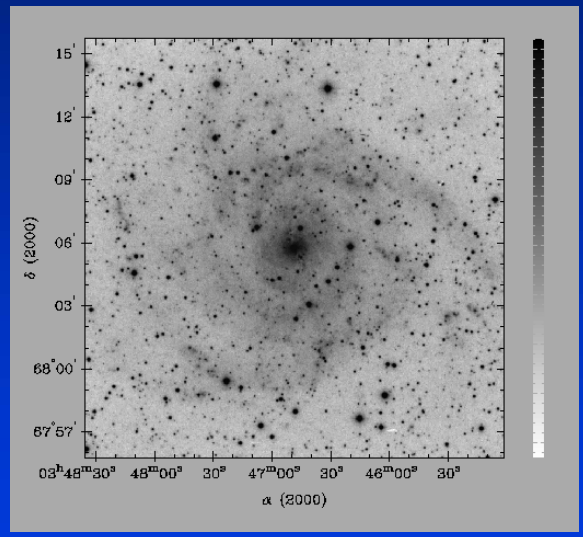
NRC · CNRC

WIRCAM and Surveys of Nearby Galaxies

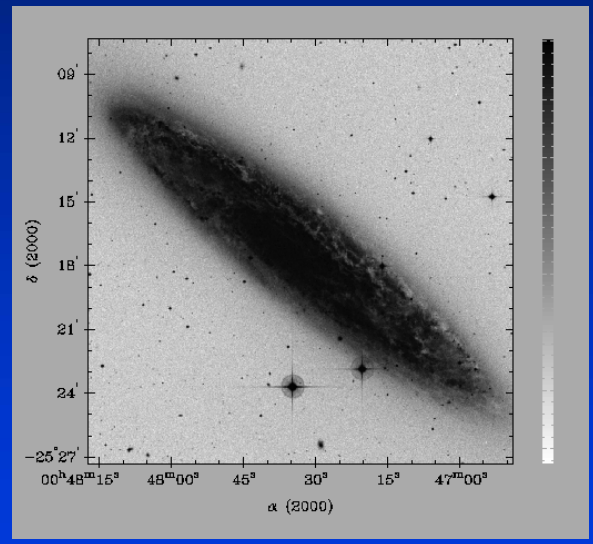
- The 20 x 20 arcmin field of view of WIRCAM is well-suited to studies of nearby galaxies.



M81



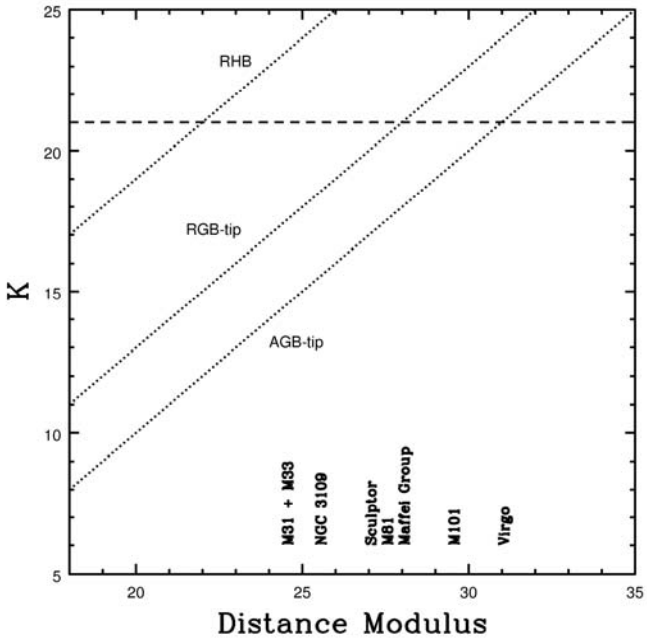
IC 342



NGC 253

NRC · CNRC

WIRCAM and Surveys of Nearby Galaxies (Con't)



- AGB stars can be detected out to distances of a few Mpc with 1 hour exposures in K during median seeing conditions.
- Would require comparable exposure times in J and H, so 3 hours per galaxy per pointing.
- Would investigate the photometric properties of pixels to probe the stellar contents of crowded environments.

NRC · CNRC

WIRCAM Survey of the Resolved Stellar Contents of Nearby Galaxies

- M81 Group + Maffei 1 Group: Can not be done with UKIRT and IRTF because have declinations greater than 60 degrees.
  - M81 group has a mass comparable to that of the Local Group, but is in a different evolutionary stage, where tidal interactions are important.
  - Maffei 1 group is slightly more distant than M81, and is affected by considerable line of sight extinction and foreground star contamination.
  - Would likely do 10 – 20 pointings per group, including some fields in the peripheral regions of the brightest galaxies.
- Northern extension of Sculptor Group (NGC 247 + NGC 253)
- NGC 3109 + Sex A/B
- M31, M33 and other Local Group members are also obvious targets – can resolve RGB-tip stars with ease in these systems.

NRC · CNRC

WIRCAM Survey of the Resolved Stellar Contents of Nearby Galaxies (Con't)

- Could also consider an extension to more distant systems where individual stars may not be resolved, but where the integrated photometric properties of disks, spheroids, and the brightest globular clusters can be investigated.
  - M101 group
  - Leo (NGC 3379 et al.)
  - Virgo
  - Coma?

Nearby Galaxies + WIRCAM = Excellent Science

- Time request would likely be for 100 – 150 hours on source during median seeing conditions.
- Two advantages over UKIRT:
  - Pixel scale (0.3 versus 0.4 arcesc)
  - Sky coverage (UKIRT can't observe North of 60 degrees declination).
- The main goal of studies of nearby galaxies is to place them in the context of more distant systems (or place more distant systems in the context of nearby galaxies). At present most surveys focus on particular topics (e.g. measuring merger rates at high redshift etc). Perhaps we should we consider more comprehensive surveys, such as `The Evolution of Disks' or `The Evolution of Angular Momentum' that covers galaxy evolution from high to low redshifts.