Recent Accomplishments

BRAGGING LIST

14 First Author refereed journal articles (#15 submitted soon) with 291 citations
37 Total refereed papers with 852 citations

Gave talks at 10 institutions over the past year

Lead first extra-galactic Keck LGS AO science paper (2005)
Lead first high-z supernova study with AO (2007)
Author on 10% (10 of 100) of all LGSAO papers from Keck
First Author on 7 of 100 LGSAO papers from Keck

Developed the first extra-galactic AO observations data base
Developed Photometry techniques for faint point source photometry with AO
Developed PSF characterization techniques for AO photometry

SCIENCE in past year

1) FOUR FIRST AUTHOR PAPERS

a) "**The Asymptotic Giant Branch and the Tip of the Red Giant Branch as Probes of Star Formation History: The Nearby Dwarf Irregular Galaxy KKH 98**".

In this paper we showed that we could use Keck AO to resolve individual stars in galaxies outside the local group. We studied a nearby (distance = 2.5 Mpc) dwarf irregular galaxy and found that we could recover its star formation history from NIR color-magnitude diagrams. This technique worked well for the SFH over the bulk of cosmic time, except for the period from roughly 0.3-1 Gyrs, precisely the time when TP-AGB stars are most luminous in the NIR. We found that current stellar evolution models prefer larger numbers and higher luminosities for these stars than the data support. With corrections for these effects, we should be able to use these techniques to trace the star formation histories of galaxies at even farther distances with Keck and TMT.

b) "**The Black Hole Masses and Star Formation Rates of z >1 Dust Obscured Galaxies (DOGs): Results from Keck OSIRIS Integral Field Spectroscopy**."

We use the unique capabilities of the integral field spectrograph OSIRIS behind Keck AO to spatially resolve H-alpha in a sample of four z=2 ultra-luminous infrared galaxies selected to be very faint at optical wavelengths. We resolve both a broad-line AGN component and a narrow-line component that might be from either the AGN or star formation. There is no evidence for significant spatially extended star formation in these systems. We find that the

black hole masses of these galaxies are low given their host luminosity suggesting that they are experiencing a period of rapid black-hole growth. Their star formation rates also appear to be low compared to other ULIRGs and sub-mm galaxies at these redshifts, suggesting that star formation has already begun to shut down in these systems.

c) **"The Contribution of TP-AGB and RHeB Stars to the Near-IR Luminosity of Local Galaxies: Implications for Stellar Mass Measurements of High Redshift Galaxies**."

This is a fundamental paper. For the first time we can test the contribution of AGB and RHeB stars to the NIR luminosities of galaxies across a large sample (23 galaxies) with very well determined star formation histories. We find that both AGB and RHeBs contribute significant fractions of the NIR flux even though these galaxies have well developed red giant branches. This means that at high redshift, when the RGB has not had time to develop these stars could contribute huge fractions of the NIR flux, we estimate up to 70%. We show that stellar population synthesis (SPS) models of these galaxies, do not reproduce the correct numbers and luminosities of these two types of stars. The models tend to over-predict the contribution of AGB stars by roughly a factor of 2 and under-predict the contribution from RHeBs. The upshot is that while NIR M/L ratios may be correct in current SPS codes, the optical/NIR light ratios are likely to be wrong. This is a phenomenon that has been observed in post-starburst galaxies.

d) **Herschel SEDs of DOGs (about to be submitted)**

This is also a fundamental paper. In Melbourne et al. 2005 we showed that LIRGs at z~1 appear to be normal star forming galaxies (with large stellar disks), rather than major mergers as they typically are in the local universe. Now it is becoming increasingly clear that at z=2, typical ULIRGs lie on the main sequence of star forming galaxies and behave more like scaled up versions of local star forming galaxies rather than like local ULIRGs which have merger driven star formation. In this paper, we turn this idea on its head. Our sample of z=2 ULIRGs are extremely red in optical-to-MIR color, and are termed dust obscured galaxies or DOGs. DOGs are a sub-class of ULIRGs at z=2. However, unlike the typical main sequence ULIRGs, the DOGs behave exactly like merger driven ULIRGs in the local universe. Their mid-to-FIR SEDs suggest that they are either dust obscured AGN with little ongoing star formation, or they are forming stars at very high rates, likely in very compact gas rich regions that result from mergers.

2) THREE NEW PROJECTS

a) **What causes gas to fall onto a central black hole?**

While mergers and secular processes such as bar formation can drive gas towards the centers of galaxies, it is not clear how the gas looses enough angular momentum to drop below 10 pc of the galactic centers. One possibility is that stellar evolution plays a role. Gas brought close to the galaxy center is likely to form stars. These stars will eventually evolve and affect their environment. Massive AGB stars in particular drive stellar winds with the proper kinetics to cause a drag on the ambient gas, causing it to loose angular momentum and feed the central black hole. Spectral signatures of massive AGB stars have been seen within the central 150 pc of several nearby AGN. Using Keck OSIRIS, I have started a program to test if these AGB stars exist on the much smaller spatial scale required to fuel AGN.

b) **AGB stars at longer wavelengths**.

While it is clear that AGB stars contribute significant fraction of the NIR light of galaxies, it is less clear what contribution they provide at longer wavelengths. The are likely to be a major contributor at 3.6 and 4.5 um, where the stellar contribution is typically dropping and the dust contribution has not become large. But they also will contribute some fraction to 8 and 24 micron fluxes of galaxies. If they are a relatively larger contributor at these wavelengths then this will affect MIR derived SFR estimates
of galaxies. We are exploring this possibility in M31 and other nearby galaxies with resolved stellar populations.

c) **Metallicities of galaxies with FIR Spectroscopy**

Gas phase metallicities have been studied extensively in the optical, and several galaxy scaling relations have been discovered, including a metallicity-luminosity and metallicity-mass relation. However, optically measured gas phase metallicities of local ULIRGs tend to fall significantly below the local relations. At high redshift the ULIRGs are even further off of the local relations even though they have already formed a significant fraction of their stars. One issue may be that optically derived metallicities do no work for very dusty galaxies, because they will tend to trace the outer regions of these galaxies rather than the inner dusty regions where most of the star formation is happening. This will bias optically derived metallicities low. We have proposed to measure MIR metallicity diagnostics from Herschel spectroscopy for local ULIRGs to determine if the metallicities of the dust obscured gas are higher than the metallicities of the dust free gas.

TEACHING in Past Year

1) POMONA PHYSICS
   a) year long intro to physics lab course
   b) e&m, electronics, light
      i. modified a circuit lab to include aspects of vision science
      ii. created a new lenses lab, presenting concepts of light gather power, magnification, and image inversion.
   b) mechanics, fluids, gasses
      i. helped design a writing exercise that mimics a conference proceeding
      ii. focused our lab design sessions on developing specific content and process goals

2) CREATED "THINK LIKE AN ASTRONOMER"
   a) Inquiry based 5 lesson astronomy course for high-school and college
   b) covers, planets, light and color, stars, galaxies, and telescopes
   b) ran it at Glendale Community College

INSTRUMENTATION in Past Year

1) NIRES
   a) NIR spectrograph for Keck
   b) JHK in on shot
   c) worked to diagnose the quality of the imager and spectrograph detector
   d) was instrumental in the decision to seek a new detector for the spectrograph