NC SPACE GRANT GRADUATE RESEARCH FELLOWSHIP PROGRAM
EXEMPLARY APPLICATION EXAMPLES (PHD AND MASTERS)

PhD level application: Awarded FY2009:

Research Project:

The goal of this research initiative is to continue ongoing work on a new technique for measuring the ages of stellar populations based on near-infrared spectroscopic studies of nearby galaxies. This technique can then be applied to the high redshift (early) universe by future missions such as the James Webb Space Telescope (JWST) to characterize the earliest generations of star formation in galaxies.

In general, the star formation history of galaxies is very complex, and is not easy to measure with certainty. To sort out the various stellar contributions to the integrated light of a stellar population requires the use of population synthesis modeling. Briefly put, a model population of a specific age and chemical composition is synthesized by combining the light of stars in various evolutionary stages, weighted according to the numbersand luminosities of the stages. In principle, by comparing the observed spectra of star clusters and galaxies with the model spectra, one can determine the mean age and chemical composition of the observed system.

Recent advances have been made in stellar population modeling, especially in the treatment of the advanced stages of stellar evolution. In particular, the models of Maraston (2005) take into account recent studies of stars on the asymptotic giant branch (AGB), which is a stellar evolutionary stage characterized by an inert C-O core, hydrogen and helium shell burning, and an extended, cool, very luminous outer envelope. When the helium-burning shell becomes thermally unstable and undergoes periodic flashes, the star is said to be on the thermally pulsing AGB (TP-AGB). The addition of TP-AGB stars in stellar population models is especially important when modeling young and intermediate age (~100Myr and ~2Gyr old) populations, because at those ages there will be an appreciable number of massive TP-AGB stars, enough that they provide unique color and spectroscopic features in the near-infrared, indicating their presence. In fact, the models show two discontinuous phase transitions in the IR features of a stellar population: one corresponding to the first appearance of the TP-AGB at about 100 Myr, and another after the lower mass RGB stars begin to dominate the IR output at around 2 Gyr. These transitions provide an exciting new chronometer which is specifically applicable to the types of stellar populations found in the high redshift galaxies (which are only a few Gyr old and may still have young stellar populations) to be observed with JWST. We plan to test the predictions of the IR chronometer on nearby, well-known galaxies in order to calibrate the technique. We are in the unique position of being able to obtain high quality IR and optical spectroscopy with the SOAR telescope, as well as having an accurate age-dating technique developed by my advisor Dr. James Rose (e.g. Rose 1985, 1994) which we will use as a calibrator for the IR features. Thus, we can use nearby galaxies as test cases to calibrate the IR chronometer, which will then be applied to high redshift objects.

We have already amassed a small spectroscopic sample of galaxies with the infrared OSIRIS spectrograph and the optical Goodman Spectrograph on the 4.1m SOAR Telescope at Cerro Pachon, Chile. We have also examined the Maraston (2005) models and defined appropriate spectroscopic indices which can act as tracers of age or composition. The N.C. Space Grant would allow me to continue to work on this new age-dating technique, and travel to meetings and conferences to present my results to the astronomical community. I will also be applying for observing time on the

NASA Infrared Telescope Facility, and the Grant would allow me to travel to Hawaii if I am awarded the time.

Beginning in the Summer of 2009, I will exploit UNCs access to the SOAR telescope and gather more data. I am scheduled for at least two nights every month through August on OSIRIS, and several half-nights for optical follow-up with Goodman. If awarded time on IRTF, I will travel to Hawaii in the fall, and during the fall will begin the process of comparing predictions of the stellar models with our galaxy spectra in order to calibrate IR features with the optical age measurements. During the winter of 2009-2010 I will begin writing a paper describing our results and travel to meetings to present the technique, and prepare for the completion of my PhD thesis dissertation.

References

Maraston, C. 2005, MNRAS, 362, 799
Rose, J. A. 1985, AJ, 90, 1927
Rose, J. A. 1994, AJ, 107, 206

Relevance to NASA Mission Directorates:

One of the fundamental objectives of the NASA Origins program, and the Universe division of the Science Mission Directorate, is to understand how galaxies first assembled in the early universe and how they subsequently evolved through generations of stars to produce the diversity of galaxies observed in today's universe. In order to meet this objective, we must be able to date the ages of the earliest galaxies that formed at high redshift. The goal of this research proposal is to develop a new technique for determining the ages of such galaxies using optical and near-infrared observations. This technique should eventually be utilized by the James Webb Space Telescope (JWST) to probe the earliest generations of stars in galaxies at high redshift.

Specifically, we will use the contributions of stars on the thermally-pulsing asymptotic giant branch (TP-AGB), which is a short lived but very luminous stage of stellar evolution, to construct a chronometer well suited for stellar populations with ages on the order of 1 Gyr. Most importantly, we will test and calibrate our new technique using optical and near-infrared observations of nearby galaxies.

Research and Career Interests:

I have always found the diversity and complexity of galaxies and their evolution over cosmic time to be one of the most fascinating topics in astronomy. I hope to continue studying galaxies, and to be a involved in the next generation of instruments which will help solve the most fundamental questions about the formation of structures, and trace the history of star formation to the present era. The most exciting prospect I could imagine at the present time would be to eventually become a part of the JWST science team, and help guide the scientific projects that will be executed on the next world-class space observatory. My goal is to use the research outlined in this proposal to begin a career working on galaxy evolution research, and the instruments necessary to perform the needed observations.

I hope to complete my PhD in 2010, and will look to do post-doctoral research in extragalactic astronomy. The age-dating technique I will be developing for my thesis should allow me to have some flexibility in the research I do, as it will have many applications in galaxy studies: star formation histories of early galaxies, star formation properties of interacting galaxies, etc.

Masters level application; Awarded FY2009:

Research Project:

The design of the thermal protection system (TPS) for planetary entry of large vehicles, such as the Crew Exploration Vehicle (CEV), depends on the accurate estimate of the heating environment of the vehicle. At maximum heating, it is expected that radiative heating is as important as the convective heating. Moreover, the flow is transitional and/or turbulent, which means higher rates of heat transfer to the vehicle. This will result in higher ablation rates which, in turn, can have a significant role in estimating the heating environment of the vehicle.

It has long been recognized1 that there is significant difference in temperature between pyrolysis gases and the char layer and that mass deposition is significant in the char layer. In spite of that, current ablation calculations are dominated by equilibrium assumptions and codes like CMA2 and FIAT3 are used almost exclusively. Such codes may be satisfactory for estimating ablation in a laminar flow environment which has always been assumed for planetary entry. However, current trend is to use larger vehicles such as The Mars Science Lab (MSL) and CEV. Design of such vehicles is based on turbulent heating which results in higher heat flux to the ablating surface. It is anticipated that, for such flows, nonequilibrium conditions between the pyrolysis gases and the char layer cannot be ignored.

Current approaches for mass injection into the boundary layer are constrained to the elemental composition of the pyrolysis gases and equilibrium assumption. Recent experiments using mass spectroscopy4 have established the existence of decomposition products in PICA whose masses ranged from 12 to 108 amu. This suggests that current approaches used in describing the nature of gases injected into the boundary layer may not be accurate.

Ablation products can have a significant effect on radiative heating. A recent study of radiation during Stardust entry5 which focused on the N and O lines showed good prediction of the radiation emission from the N lines but poor prediction of the radiation from the O lines. Since nitrogen is essentially inert, this study illustrates the importance of accounting for the chemical reactions that involve oxygen.

The influence of ablation products is not limited to radiative heating; it has a significant influence on convective heating. Thus, accurate accounting of the role of ablation products is crucial for the optimum design of TPS.

When the pyrolysis gases are formed, a carbonaceous residue remains and this adds to the thickness of the char layer. On the other hand, char is removed at the outer surface as a result of thermal, chemical or mechanical processes which may be attributed to sublimation, aerodynamic shear, spalling or oxidation. As a result, the thickness of the char layer may increase or decrease.

The research will provide a code which will complement FIAT. It is to be used when it is deemed that nonequilibrium ablation may play an important role when designing a TPS. This is expected when high rates of heat transfer are predicted. Analysis will be applied to an existing ablating material such as PICA and the results will be compared with FIAT. Since radiation calculations were carried out for Stardust, the results will be applied to Stardust and compared with available radiation data.

The research will be conducted at NASA Ames Research Center during a 10 week internship between June and August under the direction of Dr. Nagi Mansour and Dr. Hassan A. Hassan. NASA Ames is an ideal location for this research because they have an active program devoted to studying thermal protection systems for entry vehicles.

References

1. 1. Clark, R. K., Simulation of Pyrolysis-Gas Flow through a Char Layer During Ablation, NASA TN D-5464, October 1969.

2. 2. Moyer, C. B., and Rindal, R. A,. An Analysis of the Coupled Chemically Reacting Boundary Layer and Charring Ablation, Part II, Finite Difference Solution for the In-Depth Response of Charring Materials Considering Surface Chemical and Energy Balances, NASA CR-1061, June 1968.

3. 3. Chen, Y K., and Milos, F. S., Ablation and Thermal Response Program for Spacecraft Heatshield Analysis, *Journal of Space Craft and Rockets,*Vol.36, No. 3, 1999, pp.475-483.

4. 4. Marschall, J., and Oser, H., Simultaneous Characterization of Mass Loss & Pyrolysis Gas Species during Ablator Themal Decomposition. SRI International Final Report MP 08-023, May, 2008.

5. 5. Lin, Y., Prabhu. D., Trumbel, K. A., Saunders, D., and Jenniskens, P., Radiation Modeling For the Reentry of the Sardust Sample Return Capsul, AIAA Paper 2008-1213, January 2008

Relevance to NASA Mission Directorates:
This research will support the Aeronautics Research Mission Directorate by providing a high fidelity computational model for studying the thermal protection systems of reentry vehicles.

Research and Career Interests:
I am becoming more and more interested in computational fluid dynamics (CFD) and I plan on pursuing research opportunities in this field as my career advances. I believe that CFD is a very important and useful tool in our quest for space exploration and it makes possible the study of phenomena that are otherwise impossible to produce in a safe, cost effective way.

CFD however, is not my only interest. I have been very interested in autonomous systems such as unmanned aerial systems (UAS) and advanced control systems that propel exploration to where man cannot currently go. I believe that as these technologies advance, a balance will emerge between manned and unmanned systems that work together in a symbiotic relationship. As an avid programmer and aviation enthusiast, I am very interested in how this new world of exploration will progress and I hope to have a part in its development.

I enjoy problem solving, programming, and learning specifically towards aerospace systems and I hope that no matter what career path I eventually take, it will be full of these things. As a graduate student I will work hard to incorporate this into my research. I then plan to continue my education and earn a PhD. It is difficult to know what will happen after I earn a PhD, but I hope to find an organization that not only allows me to fulfill the objectives I have mentioned here, but encourages them.