Annual Report for Period:09/2007 - 08/2008 **Submitted on:** 07/16/2008
Principal Investigator: Jogee, Shardha . **Award ID:** 0607748
Organization: U of Texas Austin
Submitted By:
Jogee, Shardha - Principal Investigator
Title:
Bars and their Impact on Galaxy Evolution over the Last Eight Billion Years
Project Participants
Senior Personnel
Name: Jogee, Shardha
Worked for more than 160 Hours: Yes
Contribution to Project:
Dr. Jogee is the PI of the NSF grant that funded the science project and education and public Outreach (EPO) program. She is
responsible for the overall direction and management of the project. She is involved in the scientific analyses and in advising
graduate students Irina Marinova and postdoctoral fellow Fabio Barazza. On the EPO front, Dr Jogee has been responsible for the
scientific input and development of the Galaxy & Cosmic Explorer Tool (GCET), working closely with graduate students Achal
Augustine and Aaron Smith.
Name: Hemenway, Mary Kay
Worked for more than 160 Hours: No
Contribution to Project: ***9/1/06-8/31/08***
Dr. Hemenway leads the education team and guides the development of the education activities for K-12 students. Dr. Hemenway
is supported by this grant and a NASA grant.
Name: Lester, Daniel
Worked for more than 160 Hours: No
Contribution to Project: ***9/1/06-8/31/07***
Dr Lester helped in the preparation of the K-12 activities. In collaboration with the PI , he prepared a proposal to UT for
developing an instructional tool for activities on galaxy evolution. Dr. Lester_$-1?`s time is funded by McDonald Observatory.
Name: Preston, Sandra
Worked for more than 160 Hours: No
Contribution to Project: *9/1/06-8/31/08*
Ms. Preston supervises the Education and Outreach staff, prepares reports and sets up the team meetings. She is supported by the
McDonald Observatory
Post-doc
Name: Barazza, Fabio
Worked for more than 160 Hours: No
Contribution to Project:
Dr Barazza is a postdoctoral fellow working on disk galaxies in SDSS and GEMS. He is supported by a NASA grant.
Graduate Student
Name: Marinova, Irina
Worked for more than 160 Hours: Yes
Contribution to Project:
Ms Marinova is a graduate student funded by the NSF project. The proposed program will constitute a major part of her masters
and Ph.DD. thesis.

Name: Worhatch, Randi

Worked for more than 160 Hours: No
Contribution to Project: ***6/1/07-8/31/07***
Ms. Worhatch, an astronomy graduate student, worked on the formative evaluation to determine what activities would be of most interest to students. She also assisted in the creation of an activity and helped to field test it. Ms. Worhatch was supported by this grant and a NASA grant.
Name: Weinzirl, Tim
Worked for more than 160 Hours: Yes
Contribution to Project:
Worked on bulge-bar-disk decomposition to constrain the origin of bulges in hierarchical models of galaxy evolution. Supported by this grant and several other NASA and startup grants
Name: Heiderman, Amanda
Worked for more than 160 Hours: Yes
Contribution to Project:
Helped to classify bars in the STAGES survey and characterize gslaxy interactions. Supported by this grant and several other NASA and startup grants.
Undergraduate Student
Technician, Programmer
Name: Worked for more than 160 Hours: Contribution to Project:
Other Participant
Name: Fricke, Kyle
Worked for more than 160 Hours: Yes
Contribution to Project: ***9/1/06-8/31/08***
Mr. Fricke prepares the educational activities, field tests them with teachers, and has assisted with the creation of the GCET tool.
Mr. Fricke is supported by this grant and a NASA grant.
Research Experience for Undergraduates
Organizational Partners
NASA Virtual Design Center
Other Collaborators or Contacts
I) RESEARCH PROGRAM
Collaborators who are not funded by the NSF grant include Dr Fabio Barazza, Dr Isaac Shlosman, Dr Hans-Walter Rix, Dr Chris Conselice, Dr Chien Peng, Dr Andreas Burkert, Dr Sadegh Khochfar.

II) EPO PROGRAM
Collaborators who are not funded by the NSF grant include the Faculty And Student Teams for Technology (FAST Tex) at the University of Texas Division of Instructional Innovation and Assessment (DIIA), as well as Texas high school teachers Chris Cotter, Christy Budynkiewicz, and Karen Green, who have helped test ideas ad the activities in their classrooms. This grant has provided stipends to Cotter and Budynkiewicz.

Activities and Findings
Research and Education Activities:
1. Dr Jogee and her research group at UT Austin have led papers in the areas below.

A) Bars as a function of environment

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Deleted: Mr. Fricke prepares the educational activities, field tests them with teachers, and has assisted with the creation of the GCET tool.
Mr. Fricke is supported by this grant and a NASA grant.

B) The origin of bulges and the problem of bulgeless galaxies

C) History of Galaxy Interactions and their Impact on SF over the Last 7 Gyr

D) Properties and Impact of Interacting Galaxies in the A901/02 Supercluster from STAGES

2. Furthermore, in collaboration with other co-team members from the GEMS, Coma, STAGES collaboration, Dr. Jogee has worked on and co-authored papers that address the evolution of galaxies as a function of redshift and environment

- `GEMS Survey Data and Catalog'
- `An Explanation for the Observed Weak Size Evolution of Disk Galaxies
- `The HST/ACS Coma Cluster Survey: I - Survey Objectives and Design'
- `The dark matter environment of the Abell 901/902 supercluster: a weak lensing analysis of the HST STAGES survey'

II) EPO PROGRAM

Year 1

We kicked off this project at a meeting of the team on September 22, 2007. Team members include Dr. Shardha Jogee, the PI; Dr. Mary Kay Hemenway; Sandra Preston; Kyle Fricke; Randi Worhatch (graduate student); and Chris Cotter, a local high school science teacher. Dr. Dan Lester was also present.
Just prior to the kickoff meeting, we were introduced to the NASA Virtual Design Center (VDC), a service of the Mid-Atlantic Region Space Science Broker, at the Astronomical Society of the Pacific meeting in September 16-18, 2006. Using the VDC design template, our team began by conducting a survey of high school students to determine their current level of astronomical knowledge and to identify the areas of astronomy that interest them most.
Shortly after the survey was conducted, on October 9, we contacted Dr. Laurie Ruberg at the VDC to formally request facilitation. The education team met with Dr. Ruberg and her staff by telecom on October 13, December 13, and May 8, and by videoconference on November 17. In addition, Dr. Hemenway met with Dr. Ruberg for two hours in Seattle on January 6, 2007 when both were attending the AAS/AAPT national meeting.
In addition to the meetings, the VDC has provided written assessment of our product. Their suggestions have been of great value in developing our product, including both implementation and assessment. It is our intention to continue using their design process as we continue with the other activities that complete the package for this project.
Also at the kickoff meeting, we identified an opportunity to submit a proposal to UT's FAST Tex Program. FAST Tex is a grant program whereby faculty are awarded time by tech-savvy students to build instructional technologies for use in UT Austin courses. The PI , with the help of Dr. Lester, submitted a proposal to build a tool called the Galaxy & Cosmic Evolution Explorer Tool. The tool will allow undergraduate and graduate

students to explore the GEMS (Galaxy Evolution from Morphology) and related data sets. Once the tool is developed, it can be used with the high school activities for this EPO project. The proposal was successful. Up to 300 hours of graduate student time is available to build this tool. As of early May, 2007, the tool is almost complete and planning for its use at various levels (introductory college students, college science majors, and high school) is underway.

Progress On Educational Activities

Using the VDC information, a plan was implemented to create five activities that could be used in a high school classroom over a one-week period . Each activity will build upon the knowledge gained in the previous activity. Advanced classes can enter into the fivestep program at whatever knowledge level is appropriate.

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The project team met on January 19 and April 20, 2007 to review the progress of the activities.

The first of five activities focuses on the differences in galactic structures and how galaxies are classified. The second activity covers multiwavelength astronomy, Wien's Law, resolution, and the different galactic features that can be viewed in various wavelengths. The third activity will cover stellar evolution. The last two activities will utilize the Galaxy & Cosmic Evolution Explorer Tool to connect to ideas about galactic evolution, look-back time, and redshift.

The five activities are all in different stages of completion. The first activity ("Galactic Inquiry") is complete. The NASA/MU-Bozeman CERES Project created it. The second activity ("Galaxies in a Different Light") was created by our team and is in the last stage of development, having already been pilot-tested in two different high-school classrooms with positive results and also having incorporated extensive feedback from the Virtual Design Center. The third activity is also in the later stages of development. It will be based on one of our pre-existing stellar evolution activities, but will be enhanced to be relevant to the Galaxy & Cosmic Evolution Explorer Tool. The last two activities are now in the preliminary planning stages and their final design will depend on the outcome of the Galaxy & Cosmic Evolution Explorer Tool.

The PI is working with the FAST Tex team through the end of May 2007 to build the Galaxy & Cosmic Evolution Explorer Tool.

Progress on Galaxy and Cosmic Explorer Tool

Schedule

Description Dates Responsibility

Kick off meeting September 22, 2006 at 4 pm Team

FAST TEX proposal awarded November 1, 2007 Shardha/Dan

NASA EPO progress report due January 14, 2007 Sandi/Shardja

NASA anniversary date and midterm reporting March 17 2007 Sandi

Activities tested January 18, 2007 Kyle, Randi

Team progress meeting January 19, 2007 at 4 pm Team

Team progress meeting February 16, 2007 at 4 pm Team

Activities developed and tested Ongoing

Mary Kay, Kyle,

Randi, Kyle

Complete Galaxy & Cosmic Evolution Explorer
Tool May 31, 2007 Shardha
CAST 2007 proposals due April 1 2007 MKH, Kyle
Team progress meeting April 20, 2007 Entire Team
NSF progress report due June 1, 2007 Sandi/Shardha
Present paper on GCET at "Cosmos in the
Classroom" meeting in CA August 3-5, 2007 MKH
Do NEEIS reporting September 1, 2007 Sandi
Present paper on Multiwavelength Galaxy at ASP
meeting in Chicago
September 5-7,2007 MKH, Kyle
Present 3 hr short-course at CAST meeting in Nov 15-17, 2007 MKH, Kyle, Chris
3
Austin
Present paper on GCET at AAS meeting in Austin January, 2008 Shardha Jogee
NASA EPO progress report due Jan 14 2008 Sandi/Shardja
NASA research grant anniversary date Jan 14 2008
NASA anniversary date and midterm reporting March 17, 2008 Sandi
CAST 2008 proposals due April 1, 2008 MKH, Kyle
NSF anniversary date July 31 2008
Do NEEIS report September 1, 2008 Sandi
Present activities at CAST meeting in Fort Worth Nov 6-8, 2008 MKH, Kyle, Chris
NASA research grant expires January, 14 2009
NSF grant expires July 31, 2009
Do NEEIS reporting September 1, 2009 Sandi
NASA EPO progress report due January 14, 2010 Sandi/Shardja

Year 2

A Galaxies and Cosmos Explorer Tool (GCET; http://www.as.utexas.edu/gcet/) has been created using the recent large galaxy surveys conducted with NASA's Hubble Space Telescope Advanced Camerafor Surveys (ACS). The GCET is an online web-based tool that allows the general public and students to actively participate in quantitative analyses of HST images from the Galaxy Evolution from Morphology and SEDs (GEMS) survey, one of the widest-area galaxy surveys conducted in two filters with ACS to date. The tool allows users to surf the vast cosmos and access ACS images of over 8,000 galaxies over the last eight billion years. For galaxies of interest, users can measure the size, determinethe lookback time for concordance cosmology, perform morphological classification on images at two rest-frame wavelengths, and gauge the different stellar populations present. Users can record their measurements, as well as reference information, such as coordinates and redshift, of each galaxy into Excel spreadsheets for further analysis. The celestial coordinates can be used to extract further multiwavelength data from existing archives and upcoming virtual observatories. For undergraduate classes, more advanced IDL or C-based analyses that employ the full samples, can be combined with the visualization capabilities of GCET in order to explore the nature of interesting objects, such as the most massive galaxies, starbursting systems, as well as interacting and merging galaxies. GCET provides a powerful tool for discovery learning in undergraduate introductory science classes as well as high schools.

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Deleted: The activities for this project include producing a set of educational products, including activities for high school students that are closely linked to the PI's research on galaxy evolution using GEMS data, presenting teacher professional development workshops at the Conference for the Advancement of Science Teaching to train teachers to use these activities, and conducting videoconferences with the classrooms of teachers who attend the professional development workshops. A plan was implemented to create five activities that could be used in a high school classroom over a one-week period. Each activity builds upon the knowledge gained in the previous activity. Advanced classes can enter into the five-step program at whatever knowledge level is appropriate.

The first of five activities focuses on the differences in galactic structures and how galaxies are classified. The second activity covers multiwavelength astronomy, Wien's Law, resolution, and the different galactic features that can be viewed in various wavelengths. The third activity covers stellar evolution, focusing on colors and masses of different stars. The last two activities will utilize the Galaxy & Cosmos Explorer Tool (GCET), described below, in order to connect to ideas about galaxy evolution, stellar populations traced at different wavelengths, bandpass shifting, look-back time, and redshift.

After the original planning meeting, Dr. Lester and the PI submitted a successful proposal to the Faculty And Student Teams for Technology (FAST Tex) program at the University of Texas Division of Instructional Innovation and Assessment (DIIA). FAST Tex is a program whereby faculty are awarded time by tech-savvy students to build instructional technologies for use in UT Austin courses. The PI was awarded 300 student hours to create the Galaxies and Cosmos Explorer Tool (GCET) for undergraduates and K-12 students.

The testing phases of the tool took place from July to Nov 2007 and a pilot version *was* released for testing in classrooms in Feb 2008. Final improvements based on feedback *were* made in summer 2008 for the final version to be released in Sep 2008.

The third activity (æLives of StarsÆ) was created by our team. It was pilot-tested with a group of high-school teachers and in a high-school classroom with students. *The first* three activities were presented to teachers in a 3-hour short course at the Conference for the Advancement of Science Teaching in November, 2007.

The last two activities are in the early stages of development. A six-page student guide for using GCET has been created and field-tested withhigh-school teachers with positive results. The guide is the fundamental piece in both activities and is currently being further developed and improved upon.

We are working with folks from Google to make GCET available at Google Sky.

Findings:

I) RESEARCH PROGRAM

I provide below, under (A) to (D) a summary of the results of my research group, which included over 2007-2008 three beginning graduate
students (A. Heiderman, T. Weinzirl, I. Marinova), two undergraduate Dean scholars (S. Miller and K. Penner), and postdoctoral fellow F.
Barazza.

A) Bars as a function of environment
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- Barazza, F.~D., Jablonca, P., Desai, V., Jogee, S. & the EDisCS collaboration 2008
- Marinova, I., Jogee, S., & the STAGES collaboration 2008a
- Marinova, I., Jogee, S., & the STAGES collaboration 2008b
- Weinzirl, T., Jogee, S. & the Coma collaboration, in prep

While bars in the field have been widely studied, comparatively little is known about the frequency, properties, and impact of bars in rich
clusters. Not only do clusters provide an interesting laboratory to test bar formation models, but bars can also be used to test the mode of
cluster growth. Using the bar analysis package and quantitative approach established in Jogee et al (2004), we are currently exploring bars in
clusters through two studies: a study of 800 bright galaxies in the STAGES A901/902 supercluster survey at a redshift z~0.17. (Marinova,
Jogee, & the STAGES collaboration 2008b), as well as a study of 500 galaxies in the ACS treasury survey of the rich Coma cluster at z~0.025
(Weinzirl, Jogee, & the Coma collaboration, in prep.). Dr Jogee is also collaborating on a related study of 2256 disk galaxies in the EDisCS
survey of clusters at z~0.4 to 1.0 (Barazza, Jablonka, Desai, Jogee & the EDisCS collaboration 2008b).

Our early results from the STAGES survey suggest that the optical bar fraction in the rich A901 and A902 clusters is similar to that of the
field, and shows no significant trend with any local environment tracer, such as the projected mass density kappa, Sigma_{10}, ICM density
from X-ray emission, and the projected distance to the nearest cluster center (Marinova, Jogee, & the STAGES collaboration 2008). Similarly,
no significant difference is found between the optical bar fraction of field and clusters over z~0.4 to 1.0 in

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Deleted: GCET is an online web-based tool that allows students to actively engage in the exciting adventure of exploring the evolution of galaxies over a large fraction of the age of
the Universe, through quantitative measurements of galaxy sizes, morphological classifications, and exercises relating redshift to lookback time
in the framework of current concordance cosmology. The PI has been working with two graduate students (Achal Augustine in computer
science and Aaron Smith in DIAA) to develop GCET.

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The second activity ('Galaxies in a Different Light') was created by our team. It was pilot-tested in two different high-school classrooms with
positive results and also has incorporated extensive feedback from the Virtual Design Center.

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Annual Report: 0607748
Page 4 of 11

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the EDisCS survey (Barazza et al
2008b). The latter study also finds no evidence for any strong decline in the optical bar fraction with redshift. Taken together, our results
increasingly suggest that the processes controlling the frequency and properties of bars are not a strong function of environment.

B) The origin of bulges and the problem of bulgeless galaxies
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- Weinzirl, T. Jogee, S., & Barazza, F. 2008
- Weinzirl, T., Jogee, S. Khochfar, S., Burkert, A., & Kormendy, J. 2008 (WJKBK08)

In Lambda CDM models of galaxy evolution, there are in principle three main mechanisms to build bulges of spiral galaxies: major mergers,
minor mergers, and secular processes (see WJKBK08 for details). The major merger of two spiral galaxies destroys the disk component and
leaves behind a classical bulge, around which a stellar disk forms when hot gas in the halo subsequently cools, settles into a disk, and forms
stars. Minor mergers can also grow bulges in several ways. A tidally induced bar and/or direct tidal torques from the companion can drive
gas into the inner kpc (e.g., Quinn et al. 1993; Hernquist & Mihos 1995; Jogee 2006 and references therein), where subsequent SF forms a
compact high v/sigma stellar component, or disky pseudobulge.In addition, the stellar core of the satellite can sink to the central region via
dynamical friction. Finally, bulges can also have a secular origin: here, a stellar bar or globally oval structure in a **non-interacting** galaxy
drives gas inflow into the inner kpc, where subsequent SF forms a disky pseudobulge (e.g., Kormendy 1993; Jogee 1999; Kormendy &
Kennicutt 2004; Jogee, Scoville, & Kenney 2005).

These different mechanisms to form bulges have been postulated for a long time. However, what is still missing is {\it a quantitative
assessment of the relative importance of different bulge formation pathways} in high and low mass spirals. For instance, although bulges are
an integral part of massive present-day spiral galaxies, we still cannot answer the following basic question: do most bulges in massive spirals
form via major mergers, minor mergers, or secular processes?

In WJKBK08, we attempt one of the first quantitative comparisons of the properties of bulges in a fairly complete sample of high mass
(M*>= 1e10 Mo) spirals to predictions from Lambda CDM-based simulations of galaxy evolution. We derive the bulge-to-total mass ratio
(B/T) and bulge Sersic index n by performing 2D bulge-disk-bar decomposition on H-band images of 146 bright, high mass, moderately
inclined spirals.

1) Interestingly, we find that as many as ~56% of high mass spirals have low n<=2 bulges: such bulges

exist in barred and unbarred galaxies
across all Hubble types. Furthermore a striking ~66% of high mass spirals have B/T<=0.2

2) We compare the observed distribution of bulge B/T in high mass spirals to predictions from Lambda-CDM-based semi-analytical models.
In the models, a bulge with B/T<=0.2 can exist in a galaxy with a past major merger, only if the last major merger occurred at z>2 (lookback >
10 Gyr). The predicted fraction of high mass spirals with a past major merger and a bulge with a present-day B/T<=0.2 is {\it a factor of over
fifteen smaller} than the observed fraction (~66%) of high mass spirals with B/T<= 0.2. The comparisons {\it rule out major mergers as the
main formation pathway for bulges in high mass spirals}. Contrary to common perception, {\it bulges built via major mergers seriously fail to
account for the bulges present in ~66% of high mass spirals}. !

3) In the models, the majority of low $B/T \le$~0.2 bulges exist in systems that have experienced {\it only minor mergers, and no major
mergers}. These bulges can be built via minor mergers and secular processes. So far, we explored one realization of the model focusing on
bulges built via satellite stars in minor mergers and find good agreement with the observations. Future models will explore more realistic minor
merger scenarios and secular processes in paper~II.

C) History of Galaxy Interactions and their Impact on SF over the Last 7 Gyr
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- Jogee, S, et al. & the GEMS collaboration, 2008a
- Jogee, S, et al. & the GEMS collaboration, 2008b
- Miller, S., Jogee S, & the GEMS collaboration 2008

The merger history of galaxies impacts the mass assembly, star formation history, AGN activity, and structural evolution of galaxies. The
merger rate/fraction at z>1 remains highly uncertain, owing to relatively modest volumes and bandpass shifting effects, but with a general trend
towards higher merger fractions at higher redshifts. Even the merger rate at z<1~has proved hard to robustly measure for a variety of reasons,
ranging from small samples in early studies, to different methods on large samples in later studies.

In Jogee et al. (2008a,b), we have performed a complementary and comprehensive observational estimate of the frequency of interacting
galaxies over z~0.24--0.80 (lookback times of 3--7 Gyr), and the impact of interactions on the SF of galaxies over this interval. Our study is
based on HST ACS, COMBO-17, and Spitzer 24 mum data from the GEMS survey. We use a large sample of ~3600 (M>=1e9 Mo) galaxies
and ~790 high mass (M>=2.5e10 Mo) galaxies for robust number statistics. Two independent methods are used to identify strongly interacting
galaxies: a tailored visual classification system complemented with spectrophotometric redshifts and stellar masses, as well as the CAS merger
criterion (A >0.35 and A>S; Conselice 2003). This allows one of the most extensive comparisons to date between CAS-based and visual

classification results. While many earlier studies focused only on major mergers, we try to constrain the frequency of minor mergers as well,
since they dominate the merger rates in Lambda-CDM models. Some of our results are outlined below.

1) Among ~790 high mass galaxies, {\it the fraction of visually-classified interacting systems over lookback times of 3--7 Gyr ranges from
9% +- 5\% at z~0.24--0.34, to 8%+-2% at z~0.60--0.80, as averaged over every Gyr bin. These systems appear to be in merging or
post-merger phases, and are candidates for a recent merger of mass ratio M1/M2>~1/10. The lower limit on the major (M1/M2> 1/4) merger
fraction ranges from 1.1% to 3.5% over z~0.24--0.80. The corresponding lower limit on the minor (1/10<=M1/M2< 1/4) merger fraction

ranges from 3.6% to 7.5%. This is the first, albeit approximate, empirical estimate of the frequency of minor mergers over the last 7 Gyr.

For an assumed value of ~0.5 Gyr for the visibility timescale, it follows that {\it each massive (M>=2.5e10 Mo) galaxy has undergone ~0.7
mergers of mass ratio>1/10 over the redshift interval z~0.24--0.80. Of these, we estimate that 1/4 are major mergers, 2/3 are minor mergers,
and the rest are ambiguous cases of major or minor mergers. The corresponding merger rate R is a few times 1e-4} galaxies Gyr-1 Mpc-3.
Among ~2840 blue cloud galaxies of mass M>e1e9 M0, similar results hold.

2) We compare our empirical merger rate R for high mass galaxies to predictions from different Lambda CDM-based simulations of galaxy
evolution, including the halo occupation distribution (HOD) models of Hopkins et al (2007); semi-analytic models (SAMs) of Somerville et al.
(2008), Bower et al. (2006), and Khochfar & Silk (2006); and smoothed particle hydrodynamics (SPH) cosmological simulations from Maller
et al. (2006). To our knowledge, such extensive comparisons have not been attempted to date, and are long overdue.{\it We find qualitative
agreement between the observations and models, with the (major+minor) merger rate from different models bracketing the observed rate, and
showing a factor of five dispersion.} One can now anticipate that in the near future, improvements in both the observational estimates and
model predictions will start to rule out certain merger scenarios and refine our understanding of the merger history of galaxies.

3) The idea that galaxy interactions generally enhance the SFR of galaxies is well established from observations (e.g., Joseph & Wright 1985;
Kennicutt et al. 1987), and simulations (e.g., Hernquist 1989; Mihos & Hernquist 1994, 1996; Springel, Di Matteo & Hernquist 2005b).
However, simulations cannot uniquely predict the factor by which interaction enhance the SF activity of galaxies over the last 7 Gyr, since
both the SFR and properties of the remnants in simulations are highly sensitive to the stellar feedback model, the bulge-to-disk (B/D) ratio, the
gas mass fractions, and orbital geometry (e.g., Cox et al 2006; di Matteo et al. 2007). Thus, empirical constraints are needed. Among ~3600
M>=1e9 Mo galaxies, we find that {\it the average SFR of visibly interacting galaxies is only modestly enhanced compared to non-interacting

galaxies over z~0.24--0.80. This result is found for SFRs based on UV, UV+IR, and UV+stacked-IR data. This modest enhancement is
consistent with the results of di Matteo et al. (2007) based on numerical simulations of several hundred galaxy collisions.

4) The SF properties of interacting and non-interacting galaxies since z< 1 are of great astrophysical interest, given that the cosmic SFR
density is claimed to decline by a factor of 4 to 10 since z~1 (e.g., Lilly et al. 1996; Ellis et al 1996; Hopkins 2004; P{\'e}rez-Gonz{\'a}lez et
al. 2005; Le Floc'h et al. 2005).We therefore set quantitative limits on the contribution of obviously interacting systems to the UV-based and
UV+IR-based SFR density over z~0.24--0.80.Among ~3600 M>=1e9 Mo galaxies, we find that visibly interacting systems only account for a
small fraction (< 30%) of the cosmic SFR density over lookback times of ~3--7 Gyr (z~0.24--0.80). In effect, our result suggests that {\it the
behavior of the cosmic SFR density over the last 7 Gyr is predominantly shaped by non-interacting galaxies, rather than strongly interacting
galaxies}. This suggests that the observed decline in the cosmic SFR density since z~0.80 is largely the result of a shutdown in the SF of
non-interacting galaxies.

D) Properties and Impact of Interacting Galaxies in the A901/02 Supercluster from STAGES
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- Heiderman, A., Jogee, S., & the STAGES collaboration 2008a
- Heiderman, A., Jogee, S., & the STAGES collaboration 2008b

In project (C), we looked at the history and impact of galaxy interaction in the *field* over the last 7 Gyr. In project (D), we extend this work
from field to three rich galaxy clusters within the Abell 901/902 supercluster at z~0.165. We present a study of interacting galaxies and the
influence of environment in the A901/02 supercluster, based on 774 bright, intermediate mass (M_V<=-18; M>1e9 Mo) galaxies. We use HST
ACS F606W data from the STAGES survey, COMBO-17, Spitzer 24 micron, and XMM-Newton X-ray data. We use visual classification, as
well as quantitative CAS parameters to estimate the fraction f_int of strongly interacting galaxies, which are likely candidates for interactions
of stellar mass ratio M1/M2>1/10. Our findings are as follows

(1) We find, based on visual classification, that the fraction (f_int) of strongly interacting galaxies is 0.049 +-0.013, with at least 0.015+-0.005
being major interactions (1/4<M1/M2<=1), at least 0.012+- 0.005 being minor interactions (1/10< M1/M2<= 1/4), and 0.022+-0.007 being
ambiguous cases of major or minor interactions. We compare f_int to groups and clusters at other redshifts.

(2) The strongly interacting galaxies lie outside the cluster core in the region between the core and viral radius, at clustocentric radii 0.25
Mpc<R<=1.2 Mpc. We suggest that this is due to the velocity dispersion of cluster galaxies falling outside the core, or/and due to groups being

accreted by the A901/902 clusters. Our number and distribution of strong interactions shows fair agreement with those predicted by N-body simulations of accreting groups in the A901/902 clusters.

(3) The fraction f_blue of bright galaxies that lie on the blue rises from 0.09+-0.03, to 0.41+-0.05 as we move from the cluster core to the virial radius. For strongly interacting galaxies, f_blue is 0.61+-0.14 (23/38) versus 0.33+-0.07 (257/774) for non-interacting galaxies, implying that strongly interacting galaxies are preferentially blue.

(4) The average SFR, based on UV and IR data, is enhanced by a factor of ~2 to 4 in strongly interacting galaxies compared to non-interacting galaxies. However, strongly interacting galaxies only contributes 20% of the total SFR density in the A901/902 clusters. The remaining SFR density comes from galaxies whose SFR is significantly depressed at a given stellar mass compared to field galaxies of similar redshifts. The SFR is depressed in the core (R<=0.25 Mpc), but also out to the virial radius (R<=1.2 Mpc). This implies that the processes responsible for the depression must be effective over a large range of radii.

II) EPO PROGRAM

In the process of planning the educational activities, we were introduced to the NASA Virtual Design Center (VDC), a service of the Mid-Atlantic Region Space Science Broker, at the Astronomical Society of the Pacific meeting in September 16-18, 2006. Using the VDC design template, our team began by conducting a survey of high school students to determine their current level of astronomical knowledge and to identify the areas of astronomy that interest them most.

Shortly after the survey was conducted, on October 9, we contacted Dr. Laurie Ruberg at the VDC to formally request facilitation. The education team met with Dr. Ruberg and her staff by telecon on October 13, December 13, and May 8, and by videoconference on November 17. In addition, Dr. Hemenway met with Dr. Ruberg for two hours in Seattle on January 6, 2007 when both were attending the AAS/AAPT national meeting.

The VDC has provided written assessment of our product. Their suggestions have been of great value in developing our product, including both implementation and assessment. It is our intention to continue using their design process as we continue with the other activities that complete the package for this project.

During the original planning meeting, we identified an opportunity to submit a proposal to the FAST Tex program at the University of Texas Division of Instructional Innovation and Assessment (DIIA). As outlined above, the PI and Dr. Lester submitted a successful proposal, which was awarded 300 student hours to create the Galaxies and Cosmos Explorer Tool (GCET) for undergraduates

and K-12 students. The PI has
worked with two computer science and DIAA graduate students (Achal Augustine and Aaron Smith) to develop GCET. The testing of GCET
took place from July to Nov 2007 and a pilot version released for testing in classrooms in Feb 2008. Final improvements based on feedback are
being made in summer 2008 for the final version to be released in Sep 2008. The tool is described in detail under the section 'Publications and
Products'.

Training and Development:
I) RESEARCH PROGRAM

Graduate students I. Marinova, T. Weinzirl, A. Heiderman, and postdoctoral fellow Barazza have developed proficiency in programming with
the Interactive Data Language (IDL); statistical analyzes; isophotal analyzes of images with the IRAF package; 2D bulge-disk-bar structural
decomposition with Python scripts and the GALFIT software, and a deeper understanding of the orbital structure of rotating barred potentials.
They have also developed better communication skills through multiple oral presentations of their research in seminars and at conferences.

II) EPO PROGRAM

While developing GCET with the PI, graduate students Achal Augustine (in computer science) and Aaron Smith (in instructional technologies)
learn about research in astronomy based on large galaxy surveys conducted with HST, and developed new skills in programming with Flash,
Ajax, and Java for instructional innovation.

Outreach Activities:
A short course entitled Evolving Galaxies/Evolving Science was presented to high school teachers at the Conference for the Advancement of
Science Teaching in Austin, Texas on November 17, 2007. Another short course has been proposed for the November 2008 meeting in Fort
Worth, Texas.
Journal Publications
Marinova, I. & Jogee, S, "Characterizing Bars at z~0 in the optical and NIR: Implications for the Evolution of Barred Disks with Redshift",
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Barazza, F., Jogee, S., & Marinova, I, "Bars in Disk-Dominated and Bulge-Dominated Galaxies at z~-0: New Insights from 3600 SDSS
Galaxies
", ApJ, p. , vol. , (2007). Submitted,
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cluster and field galaxies at intermediate redshifts from EDisCS", Astrophysical Journal, p. , vol. , (2008). Submitted,
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STAGES", Astrophysical Journal, p. , vol. , (2008). In preparation (submission by Aug 10/2008),
Marinova, I.; Jogee, S; the STAGES collaboration, "The Properties of Barred Disks in a Supercluster Environment: Constraints from Abell
901/2 with STAGES", Astrophysical Journal, p. , vol. , (2008). In preparation (submission by Aug 10/2008),

Books or Other One-time Publications

Barazza, F.~D., Jogee, S., & Marinova, I, "Constraints on Bars in the Local Universe from 5000 SDSS Galaxies
", (2007). Book, Published
Editor(s): F. Combes and J. Palous
Collection: Galaxy Evolution Across the Hubble Time, Proceedings of the International Astronomical Union 2, IAU Symposium #235
Bibliography: Barazza, F.~D., Jogee, S., & Marinova, I. 2007, IAU Symposium, 235, 76

Penner, K. Jogee, S., Miller, S., and GEMS collaboration, "Constraining the interaction history of galaxies over 8 Gyr", (2007). Book,
Published
Collection: BAAS
Bibliography: Penner, K., Jogee, S., Miller, S., & GEMS collaboration, 2007, BAAS
Hemenway, Mary Kay; Jogee, S; Augustine, A; Smith, A; and Lester, D, "The Galaxy and Cosmos Explorer Tool", (2007). Book, Submitted
Collection: 2007 COSMOS in the Classroom Meeting on Aug 2-5, 2007
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Galaxies in a Different Light? Activity (abstract submitted to t

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Editor(s): J.~G.~Funes, S.~J., & E.~M.~Corsini (San Francisco: ASP)
Collection: Formation and Evolution of Galaxy Disks
Bibliography: Jogee, S. et al. 2008, in Formation and Evolution of Galaxy Disks, ed.~J.~G.~Funes, S.~J., & E.~M.~Corsini (San Francisco:
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Bibliography: BAAS 211, 88.01
Jogee, S., et al., "Star Formation in Interacting and Normal Galaxies over the last 7 Gigayear.", (2008). 211th AAS meeting BAAS, Accepted
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Collection: ASP conference proceedings of the Frank N. Bash Symposium 2007: New Horizons in Astronomy
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2007: New Horizons in Astronomy", Editors A. Frebel, J. Mau
Miller, S.; Jogee, S.; and the GEMS collaboration
, "Exploring the Impact of Galaxy Interactions over Seven Billion Years with CAS", (2008). Book, Accepted
Editor(s): A. Frebel, J. Maund, J. Shen, M. Siegel
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New Horizons in Astronomy", Editors A. Frebel, J. Maund, J

Heiderman, A.; Jogee, S; the STAGES collaboration, "Galaxy Evolution in the A901/02 Supercluster: Constraints from Galaxy-Galaxy and
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Editor(s): A. Frebel, J. Maund, J. Shen, M. Siegel
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Bibliography: Weinzirl, T., Jogee, S, & Barazza, F. 2008, ASP conference proceedings of the "Frank N. Bash Symposium 2007: New
Horizons in Astronomy", Editors A. Frebel, J. Maund, J. Shen, M. S

Web/Internet Site

URL(s):

http://www.as.utexas.edu/gcet/

Description:

Website 1 featureS the Galaxy and Cosmos Explorer Tool (GCET). The testing phases of the tool took place from July to Nov 2007 and a pilot
version released for testing in classrooms in Feb 2008. Final improvements based on feedback are being made in summer 2008 for the final
version to be released in Sep 2008.

Other Specific Products

Product Type:

Teaching aids

Product Description:

The PI has been working with two computer science and DIAA graduate students (Achal Augustine and Aaron Smith) to develop the Galaxy
and Cosmos Explorer Tool (GCET). We are in the final phases of testing in June and July and we will release the tool in August 2007. GCET
is an online web-based tool that allows students to actively engage in the exciting adventure of exploring the evolution of galaxies over a large
fraction of the age of the Universe. GCET allows students to perform quantitative analyses of HST images from the Galaxy Evolution from
Morphology and SEDs (GEMS) survey, one of the widest-area galaxy surveys conducted with HST to date. The tool allows students to access
HST images of over 8,000 galaxies over the last eight billion years, an interval covering two thirds of the age of the Universe. Students can surf
the vast cosmos and for galaxies of inte, they can measure the size, determine the lookback time for concordance cosmology, perform
morphological classification on images at two rest-frame wavelengths, and gauge the different stellar populations present. Students can record
their measurements, as well as reference information (such as coordinates and redshift) of each galaxy into spreadsheets for further analysis.
The celestial coordinates can be used to extract further multiwavelength data from existing archives and upcoming virtual observatories. GCET
provides a powerful tool for discovery learning in undergraduate science and introductory classes, as well as high schools.

Sharing Information:

The Galaxy and Cosmos Explorer Tool (GCET) is an online web-based tool, whose final version will be released in Sep 2008

Contributions

Contributions within Discipline:

The results described under the section 'Activities and Findings' have advanced our knowledge in the principal disciplinary field of Astronomy, as well as created inquiry-based activities for high school students and undergraduates

Contributions to Other Disciplines:

The creation of the Galaxy and Cosmos Explorer Tool (GCET) has contributed to knowledge of graduate students Achal Augustine (in computer science) and Aaron Smith (in instructional technologies).

Contributions to Human Resource Development:

The activities undertaken under this grant have contributed to the knowledge of the following people:

(1) Astronomy graduate students I. Marinova, T. Weinzirl, A. Heiderman, and postdoctoral fellow F. Barazza, who worked on the research activities

(2) Astronomy graduate student, Randi Worhatch, who worked on the EPO activity on multi-wavelength light

(3) Graduate students Achal Augustine (in computer science) and Aaron Smith (in instructional technologies) who helped to develop 'The Galaxy and Cosmos Explorer Tool'

Contributions to Resources for Research and Education:

A new tool (GCET) has been developed that will provide undergraduate students and K-12 students with the ability to use cutting-edge data from space and ground-based telescopes to conduct a research project.

Contributions Beyond Science and Engineering:

We are currently having discussions with Google Sky about offering the products produced with this grant at their website.

Special Requirements

Special reporting requirements: None

Change in Objectives or Scope: None

Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported: