Annual Report for Period: 09/2006 - 08/2007 **Submitted on:** 05/21/2007

Principal Investigator: Jogee, Shardha . **Award ID:** 0607748

Organization: U of Texas Austin

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:

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:

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:

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:

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.

Undergraduate Student

Technician, Programmer

Name: Fricke, Kyle

Worked for more than 160 Hours: No

Contribution to Project:

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.

Other Participant

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, and Dr Chien Peng.

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).

Activities and Findings

Research and Education Activities:

I) RESEARCH PROGRAM

Bars are widely recognized as the single most important internal factor that redistributes the angular momentum of the baryonic and dark matter component of disk galaxies, thereby driving their evolution. Yet, our attempt to put bars in a cosmological context remain in its infancy, and we have yet to address the fundamental question of how bars evolve and impact disk galaxies over cosmological times. Our NSF-funded program pioneers some important steps in this direction by addressing the evolution of bars and their impact on disk galaxies over the the last 8 Gyr. In the first year of this program, we have focused on the following activities. In order to discuss the evolution of bars with time, an essential first step is to characterize bars at redshift z~0 using the same quantitative methods as those used at intermediate redshift (e.g., Jogee et al. 2004; Elmegreen et al. 2004). This step is particularly important given the advent of intermediate redshift HST surveys, such as the Tadpole field (Tran et al. 2003; Elmegreen et al. 2004), the Galaxy Evolution from Morphology and SEDs (GEMS; Rix et al. 2004; Jogee et al 2004), the Great Observatories Origins Deep Survey (GOODS; Giavalisco et al. 2004), and COSMOS (Scoville et al. 2006), which trace bars in the rest-frame optical band out to z~1. We have conducted two independent large studies (Marinova & Jogee 2007; Barazza, Jogee, & Marinova 2006, 2007) in order to provide the reference baseline for bars at z~0 both in the optical and NIR band. The B-band and R-band point are the anchor for HST ACS studies, while the H-band point is the local reference for future JWST studies. Our exciting results and their implications are summarized under point 2.

Furthermore, in collaboration with other co-team members from the GEMS, GOODS and Hubble Ultra Deep Field (HUDF), Dr. Jogee has

worked on and co-authored papers that address the evolution of galaxies in the last 13 billion years, in particular the history of their star formation and AGN activity, and their structural development on and off the Hubble sequence. The refereed papers are listed in the section 'Publications and Products'.

II) EPO PROGRAM

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 will build 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'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 & 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. 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. We are in the final phases of testing in June to July and we expect to release the tool in August 2007.

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 & Cosmos 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 & Cosmos Explorer Tool

Findings:

I) RESEARCH PROGRAM

We provide below a summary of our results

A) Characterizing Bars at ~0 in the optical and NIR: Implications for the Evolution of Barred Disks with Redshift (from Marinova & Jogee 2007, ApJ, 659, 1176):

Critical insights on galaxy evolution stem from the study of bars. With the advent of high redshift HST surveys (GEMS, GOODS, COSMOS) that trace bars in the rest-frame optical band out to z~1, it becomes increasingly important to provide a reference baseline for bars at z~0 in the optical band. We present results on bars at z~0 in the optical B band and near-infrared H band, based on 180 spirals in the OSUBSGS survey. The B-band point is the anchor for HST ACS studies, while the H-band point is the local reference for future JWST studies. Below are our results:

(1) The deprojected bar fraction at z~0 is ~60% +- 6% in the NIR H-band, and ~44% +- 6% in the optical B-band images.

(2) The results before and after deprojection are similar, which is encouraging for high redshift studies that forego deprojection.
(3) Studies of bars at z~0.2--1.0 (lookback times of 3--8 Gyr) have reported an optical bar fraction of f_opt2 ~ 30% +- 6%, after applying cutoffs in absolute magnitude (M_V <-19.3), bar size (a_bar>=1.5 kpc), and bar ellipticity (e_bar >=0.4) in order to ensure a complete sample, adequate spatial resolution, and reliable bar identification out to z~1. Applying these exact cutoffs in magnitude, bar size, and bar ellipticity to the OSUBSGS data yields a comparable optical B-band bar fraction at redshfit z~0 of f_opt3 ~ 34% +- 6%. This rules out scenarios where the optical bar fraction in bright disks declines strongly with redshift.
(4) We investigate bar strengths at z~0 using the maximum bar ellipticity (e_bar) as a guide. Most (70%) bars have moderate to high ellipticity (0.50 <= e_bar <= 0.75), and only a small fraction (7%-10%) have 0.25~ <= e_bar <=~0.40. There is no bimodality in the distribution of e_bar. The H-band bar fraction and e_bar show no substantial variation across RC3 Hubble types Sa to Scd.
(4) RC3 bar types should be used with caution. Many galaxies with RC3 types `AB' turn out to be unbarred and RC3 bar classes `B' and `AB' have a significant overlap in e_bar.
(5) Most (68% in B and 76% in H) bars have sizes below 5 kpc. Bar and disk sizes correlate, and the ratio (a_bar/R_25) lies primarily in the range 0.1 to 0.5. This suggests that the growth of bars and disks is intimately tied.

B) Bars in Disk-Dominated and Bulge-Dominated Galaxies at z~-0: New Insights from 3600 SDSS Galaxies (From Barazza, Jogee, & Marinova 2006; 2007, ApJ, submitted) :
We present a study of large-scale bars in the local Universe, based on a large sample of ~3692 galaxies, with -18.5 <= M_g < -22.0 and redshift 0.01 <= z <= 0.03, drawn from the Sloan Digitized Sky Survey (SDSS). This is the largest study of bars conducted to date at z~0, and uses an SDSS sample that is a factor of 10 larger than those in previous studies. Furthermore, while most studies to date have focused on bars in bright relatively early type (Sa to Sc) galaxies with bulge components, the SDSS study is the first quantitative study that explore bars in late-type disk-dominated quasi-bulgeless galaxies. We used a color cut in the color-magnitude diagram to select ~2000 disk galaxies. We identify and characterize bars and disks using r-band images and a method based on ellipse fits and quantitative criteria. After the standard procedure of excluding highly inclined (>60 deg) systems, we find the following results.
(1) The optical r-band fraction (f_opt_r) of barred galaxies, when averaged over the whole sample, is ~48%. However, when galaxies are separated according to half light radii (r_h) or r_h/R24, a remarkable result is found: the optical r-band fraction rises sharply, from ~40 % in galaxies that have small r_h/R24 and are bulge-dominated, to ~70% for galaxies that have large r_h/R24 and are disk-dominated. These results show that disk-dominated galaxies with no bulge or a very low bulge-to-disk (B/D) ratio display a significantly higher optical bar fraction than galaxies with prominent bulges. In particular, the results may be the empirical evidence for the long-standing idea that hot components like classical bulges can help to stabilize a disk against bar formation. This has important implications for disk stability and for the assembly of the Hubble sequence.
(2) The optical r-band fraction is significantly higher for bluer galaxies (~60%) than for red galaxies (~32%). It also rises towards lower masses or fainter luminosities.
(3) Our study of bars at z~0 in the optical r-band provides a reference z~0 baseline for intermediate redshift HST ACS surveys that trace bars in bright disks in the rest-frame optical bands out to z~1. By applying the same cutoffs in magnitude (M_V <-19.3), bar size (a_bar >= 1.5 kpc), and bar ellipticity (e_bar>=0.4), which are applied in z~0.2--1.0 studies to ensure a complete sample, adequate spatial resolution, and reliable bar identification, we obtain an optical r-band bar fraction of 34%. This is comparable to the value of ~30% reported at z~0.2-1.0, thus ruling out scenarios where the optical bar fraction in bright disks declines with redshift.

C) In collaboration with other co-team members from the GEMS, GOODS and Hubble Ultra Deep Field (HUDF), Jogee has worked on and co-authored papers that address the evolution of galaxies in the last 13 billion years.The refereed papers, listed in the section 'Publications and Products', focus on the following:
- 'Cosmological weak lensing with the HST GEMS survey'
- 'Dry Mergers in GEMS: The Dynamical Evolution of Massive Early-Type Galaxies'
- 'The Hubble Ultra Deep Field'
- An Explanation for the Observed Weak Size Evolution of Disk Galaxies'

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 been working with two computer science and DIAA graduate students (Achal Augustine and Aaron Smith) to develop GCET. We are in the final phases of testing in June and July and we expect to release the tool in August 2007. The tool is described in detail under the section 'Publications and Products'.

Training and Development:

I) RESEARCH PROGRAM

Graduate student Marinova, 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; 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:

Outreach activities will take place in the future.

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", ApJ, p. 1176, vol. 659, (2007). Published

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

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
Bibliography: Hemenway, Mary Kay; Jogee, S; Augustine, A; Smith, A; and Lester, D.; The Galaxy and Cosmos Explorer Tool (abstract submitted to the 2007 COSMOS in the Classroom Meeting on Aug 2-5

Hemenway, Mary Kay; Jogee, S.; Fricke, K.; Worhatch, R.: Ruberg, L. F, "Developing the `Multiwavelength Astronomy: Galaxies in a Different Light' Activity
", (2007). Book, Submitted
Collection: 2007 ASP Annual Conference on Sep 5-7, 2007
Bibliography: Hemenway, Mary Kay; Jogee, S.; Fricke, K.; Worhatch, R.: Ruberg, L. F.; Developing the ?Multiwavelength Astronomy: Galaxies in a Different Light? Activity (abstract submitted to t

Smith, A., Rhodes,S., and Jogee, S, "The Galaxy and Cosmos Explorer Tool", (2007). Book, Submitted
Collection: Instructional Technology showcase http://www.utexas.edu/academic/diia/itshowcase/)
Bibliography: Smith, A., Rhodes,S., and Jogee, S., 'The Galaxy and Cosmos Explorer Tool' (abstract submitted for the 2007 Instructional Technology showcase)

Smith, A., Rhodes,S., and Jogee, S, "The Galaxy and Cosmos Explorer Tool", (2007). Book, Submitted
Collection: Innovations in Online Learning conference, to be held on June 25, 2007, Austin
http://www.telecampus.utsystem.edu/index.cfm/4,1653,82,32,html#teaching
Bibliography: Smith, A., Rhodes,S., and Jogee, S., 'The Galaxy and Cosmos Explorer Tool' (Abstract submitted for the Innovations in Online Learning conference, to be held on June 25, 2007, Aust

Web/Internet Site

URL(s):

Website 1 = GCET website to be released in August 2007
Website 2 = http://www.as.utexas.edu/~sj/interactions-mergers.html

Description:

Website 1 will feature the Galaxy and Cosmos Explorer Tool (GCET) and will be officially deployed in August 2007. It is currently in the final testing phase.

Website 2 was developed to illustrate the morphological classifications of distant galaxies over the redshift range 0.2 to 1.0 (lookback times of 3 to 8 Gyr) at different rest-frame wavelengths. The morphological types include Ellipticals (E), Spirals (Sa/S0, Sb/Sc/Sd), Irregulars (Irr), and Interacting. This website can be used as a training site before students use the Galaxy and Cosmos Explorer Tool (GCET) to perform similar morphological classifications.

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 that will be released in August 2007.

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 student Marinova, and postdoctoral fellow 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:

Special Requirements

Special reporting requirements: None

Change in Objectives or Scope: None

Unobligated funds: $ 0.00

Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Contributions: To Any Beyond Science and Engineering