Inferring Galaxy Morphology Through Texture Analysis
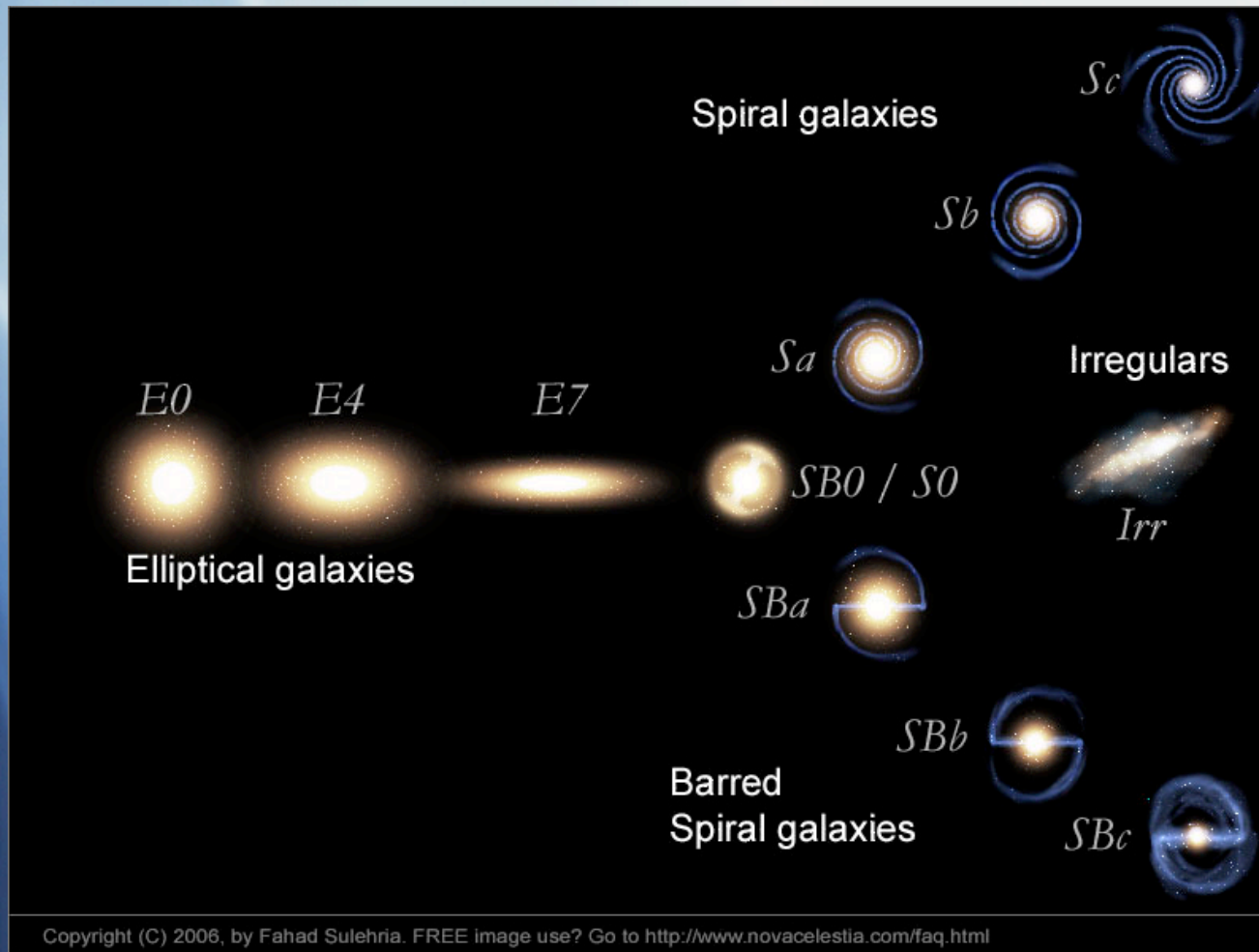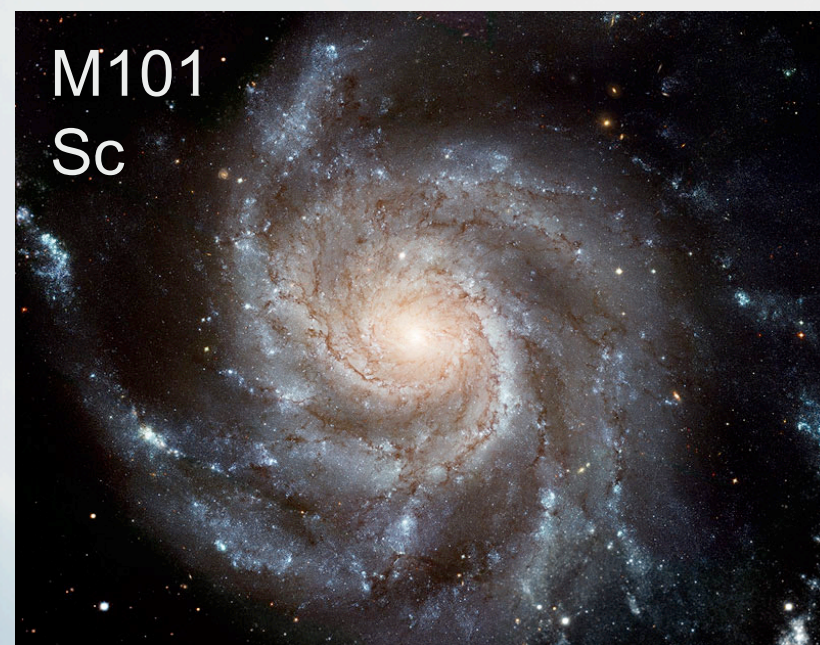
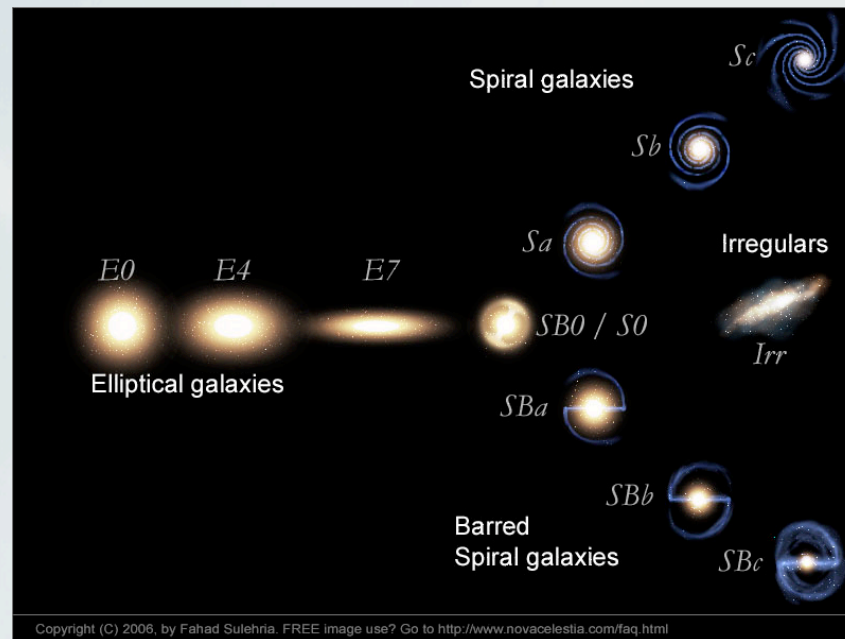## Oriented Filters vs. Ridgelets
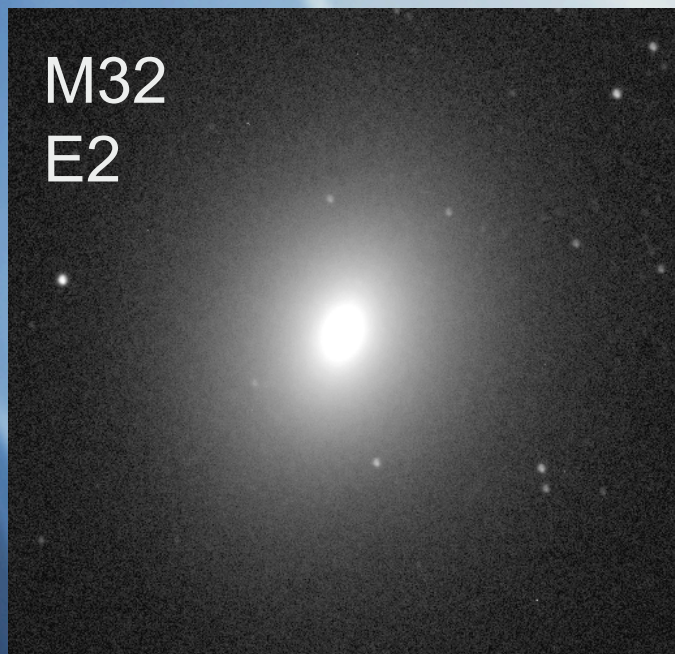
Joey Richards

Andy Connolly, Google

January 22, 2007

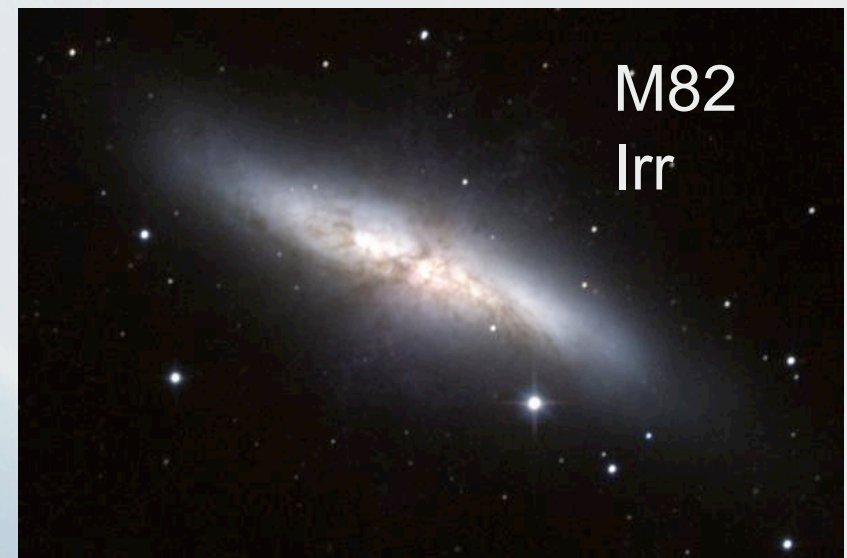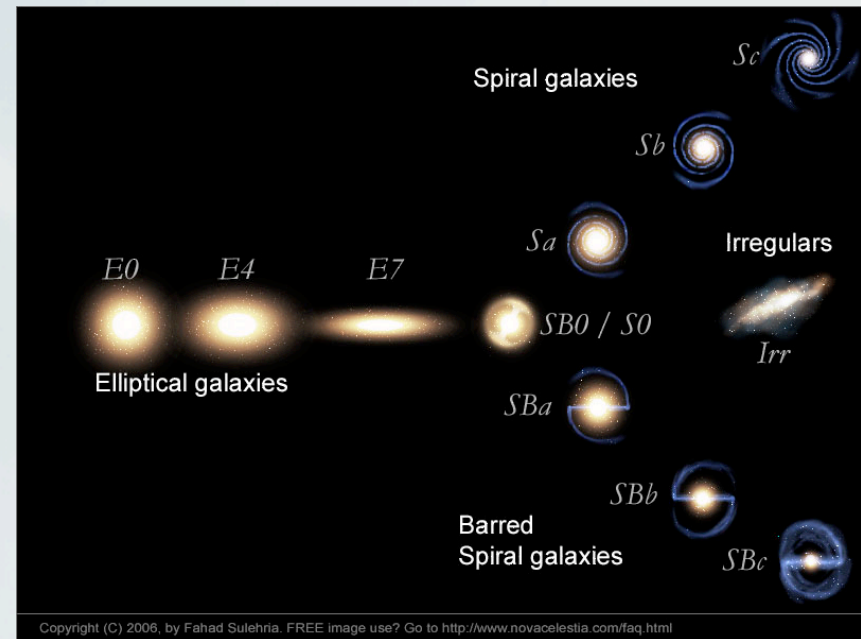# Introduction: Galaxies

- Gravitationally-bound collections of 10^7-10^{12} stars

- Morphological types classified into 3 main groups: elliptical, spiral (normal or barred), and irregular

- Evolve through gravitational interactions with other galaxies

- Presently galaxies are morphologically classified only through visual inspection of galactic images.

Hubble's Classification Scheme (1936)

M32
E2

NGC
1300
SBb

M101
Sc

Spiral galaxies

Sc

Sb

Sa

Irregulars

E0   E4   E7

SB0 / S0

Irr

Elliptical galaxies

SBa

SBb

Barred
Spiral galaxies

SBc

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M95
SBb

NGC
1291
SBa

M82
Irr

Spiral galaxies

Sc

Sb

Sa

E0   E4   E7

Elliptical galaxies

SB0 / S0

Irregulars

Irr

SBa

Barred
Spiral galaxies

SBb

SBc

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Scientific Questions of Interest

1) How has the distribution of morphologies changed with time? (i.e. how have galaxies evolved over time?)

   - in Astronomy, we can simultaneously view the entire chronology of the Universe

2) How does the local density of galaxies affect the distribution of morphological types? (i.e. how does the galactic collision rate influence morphology?)

Sloan Digital Sky Survey (SDSS)

- When completed, SDSS will have obtained detailed optical images covering more than a quarter of the entire sky
- Will eventually capture digital images from millions of galaxies
- Impossible for scientists to visually inspect such a vast amount of data
- Need a quantitative approach that can automatically and quickly extract important features of a galaxy from an image

Methods: Texture Analysis

- Our approach is to extract local structure to subsequently model the important morphological features of a galaxy (Au, 2006)
- In this project we will compare the method of oriented filters (Au, 2006) to that of ridgelets (Starck et al., 2002, Donoho, 2000, 2001) in the ability to extract anisotropic features of a galaxy from digital images

Oriented Filters (Au, 2006)

- Measure signal strength along a variety of different orientations; adopt strongest signal at each position

- Repeat for three different spatial scales to capture local structure for various levels of fineness

- Merge the information from the three levels to obtain a unified representation of all the information extracted from the three scales (Kalman filtering)
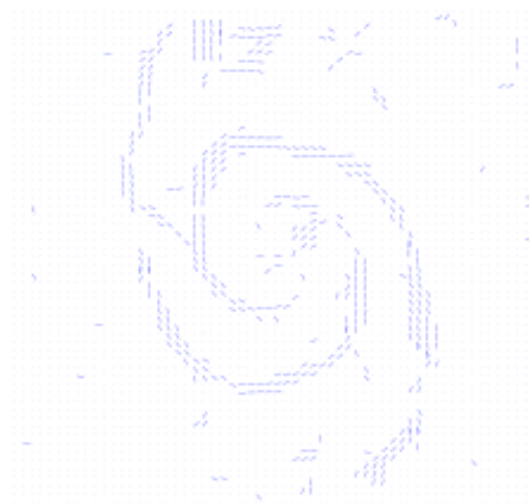
Level 1
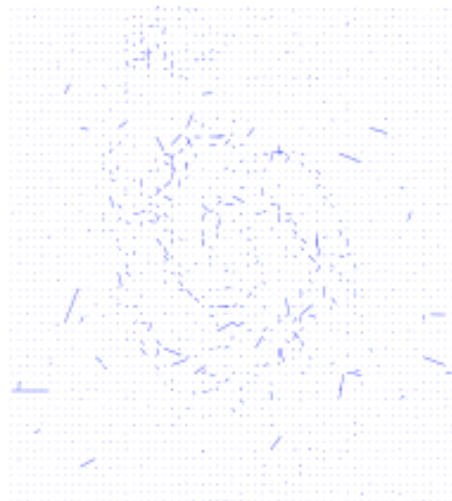
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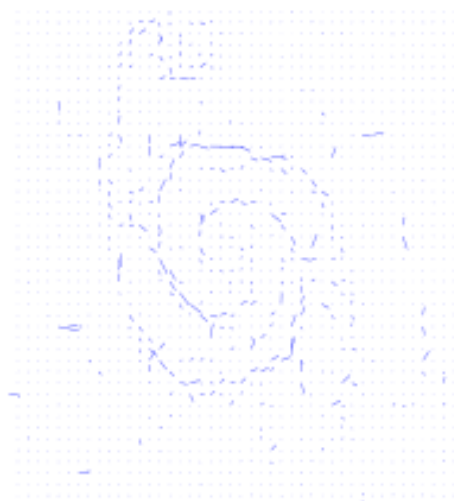
Level 3

Galaxy M51

Merged

Ridgelet Analysis (Starck et al., 2002)

- The ridgelet transform computes integrals over lines with different orientations and positions

- Original image is ridgelet transformed

- Thresholding on ridgelet coefficients is performed

- Finally, ridgelet transform is inverted to reconstruct the image

- MatLab code: BeamLab200 (Donoho, et al.)
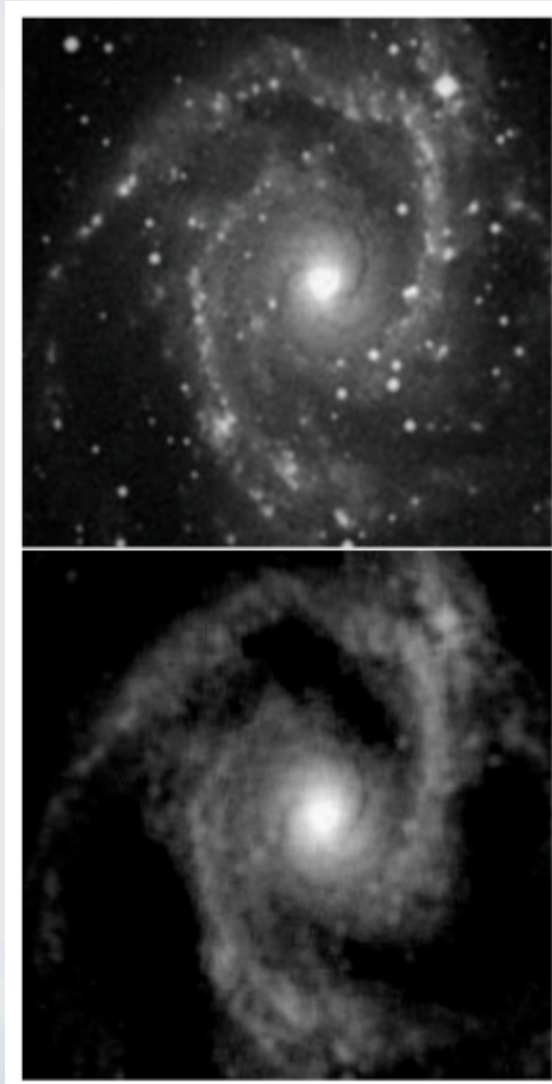
Morphological Model Fitting

- Use morphological model that follows the Grand Design model, i.e. two spiral arms that attach to two ends of a bar at the center of the galaxy (Au, 2006)
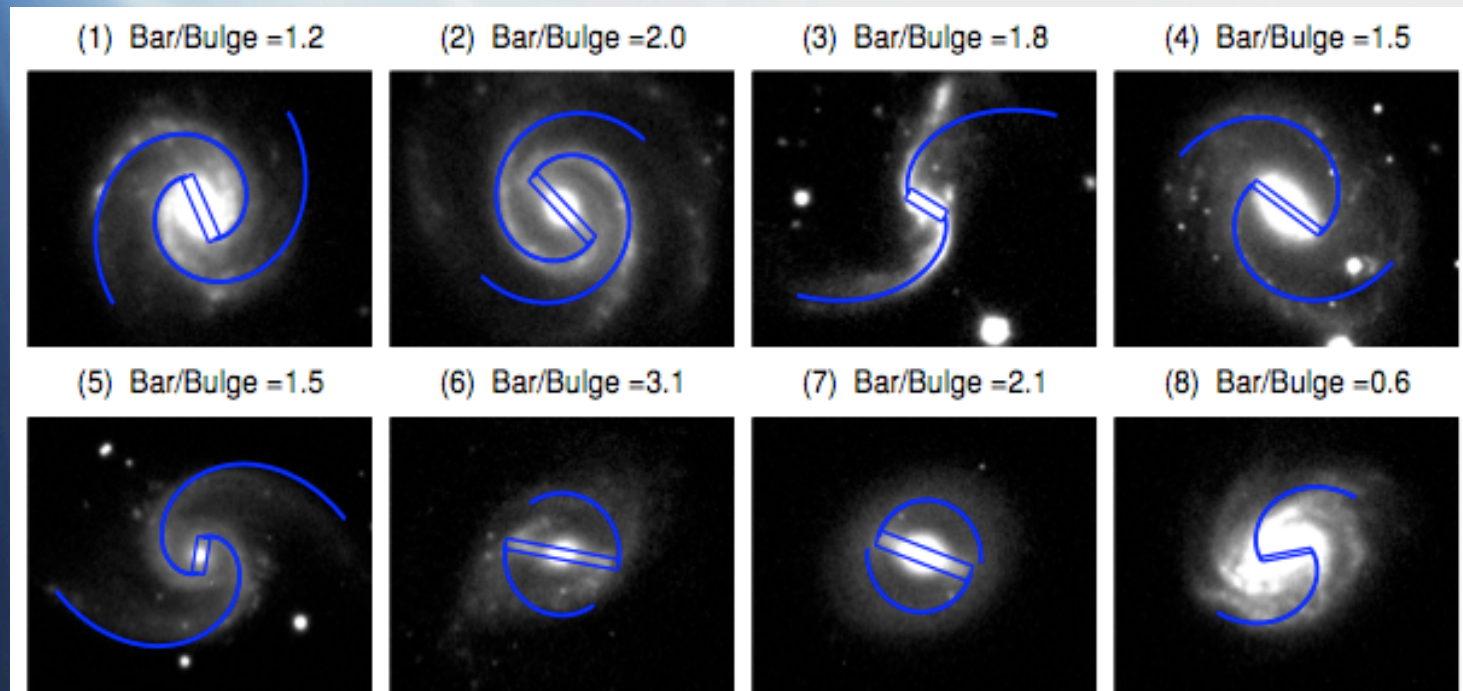
Project Outline

- Learn how to implement computer programs of Au and Donoho
- Apply both methods to a variety of images of well-understood (close-by) galaxies
- Fit morphological model to textural information extracted by each method
- Compare the two models to determine which method of texture analysis performs better (agreement with physical properties, computing time needed, sensitivity to resolution and/or S/N, etc., etc., etc.)

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