Determining the Local Black Hole Mass Function from the Pitch Angles of Nearby Spiral Galaxies

Lucas Johns
Reed College, Portland, OR 97202

Daniel Kennefick, Joel C. Berrier, Benjamin L. Davis, and Douglas W. Shields
University of Arkansas, Fayettevile, AR 72701

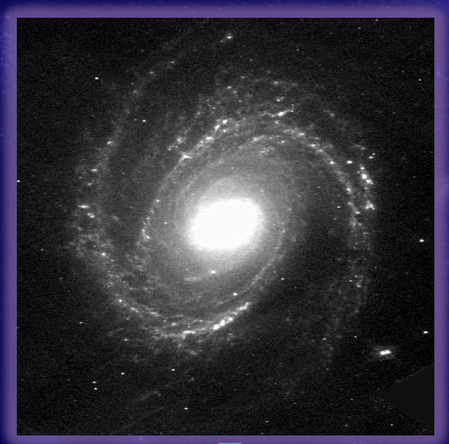
Introduction

It is now widely accepted that a supermassive black hole resides at the center of most, if not all, disk and elliptical galaxy bulges. For spiral galaxies, recent work [1] has demonstrated a correlation, called the M-P relation, between the mass of the central black hole and the pitch angle of the host galaxy's spiral arms. By taking a census of pitch angles for local spiral galaxies and applying the M-P relation, we have determined the black hole mass function for spiral galaxies in the local universe.

Measuring Pitch Angles

Our volume-limited sample consists of 140 spiral galaxies in the statistically complete Carnegie-Irvine Galaxy Survey [2] satisfying $z < 0.0068$ and absolute B-band magnitude $M_B < -19.528$. The image analysis process is illustrated below. The two major steps are **deprojecting** the image and performing a **two-dimensional fast Fourier transform**.

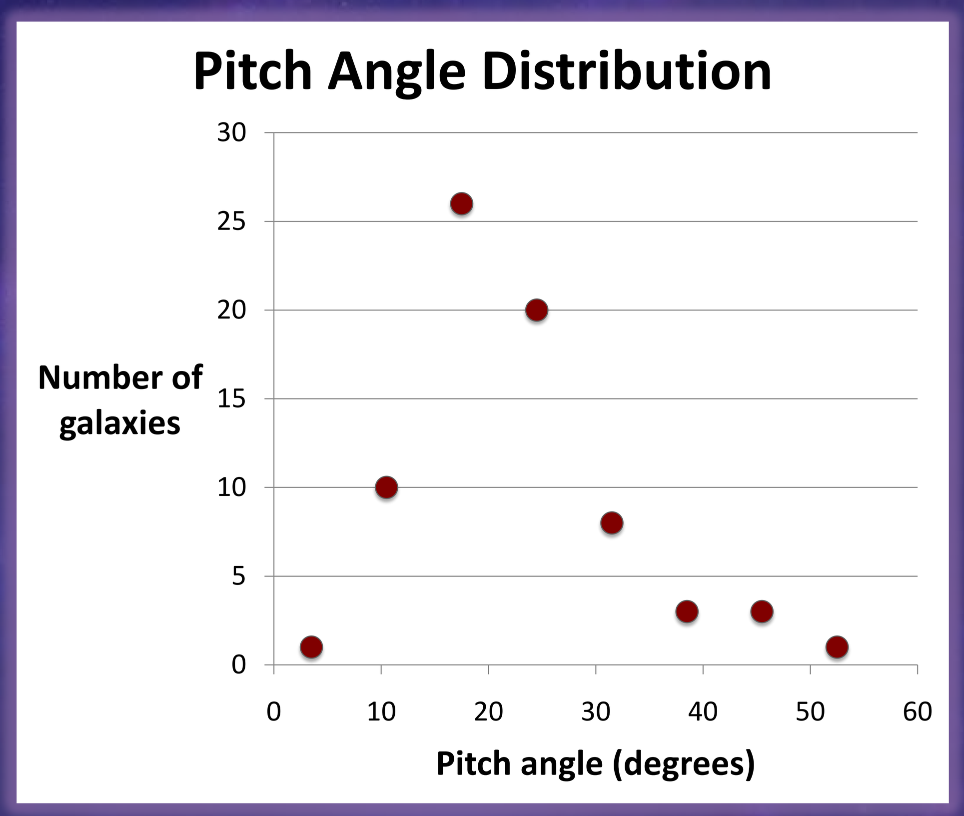
Original image of NGC 3031



Same image after deprojection with IRAF

Deprojected image overlaid with 2DFFT contour (in red)

First Result: Local Pitch Angle Function



The figure above shows the distribution of pitch angles that we measured for the sample. The plot includes measurements for 72 spiral galaxies; the remaining galaxies in the sample could not be measured due to high inclination angle, poor image quality, or distorted morphology. Each data point represents the number of galaxies that were measured to have a pitch angle within the respective 7° bin. No galaxies were found to have a pitch angle exceeding 60°.

The M-P Relation

We adopt the **M-P relation** from Seigar et al. 2008:

$$\log_{10} M = (8.44 \pm 0.10) - (0.076 \pm 0.005)P,$$

where M is the mass, in solar masses, of the supermassive black hole and P is the pitch angle, in degrees, of the host galaxy. A smaller pitch angle amplitude (hence, more tightly wound arms) corresponds to a more massive central black hole.

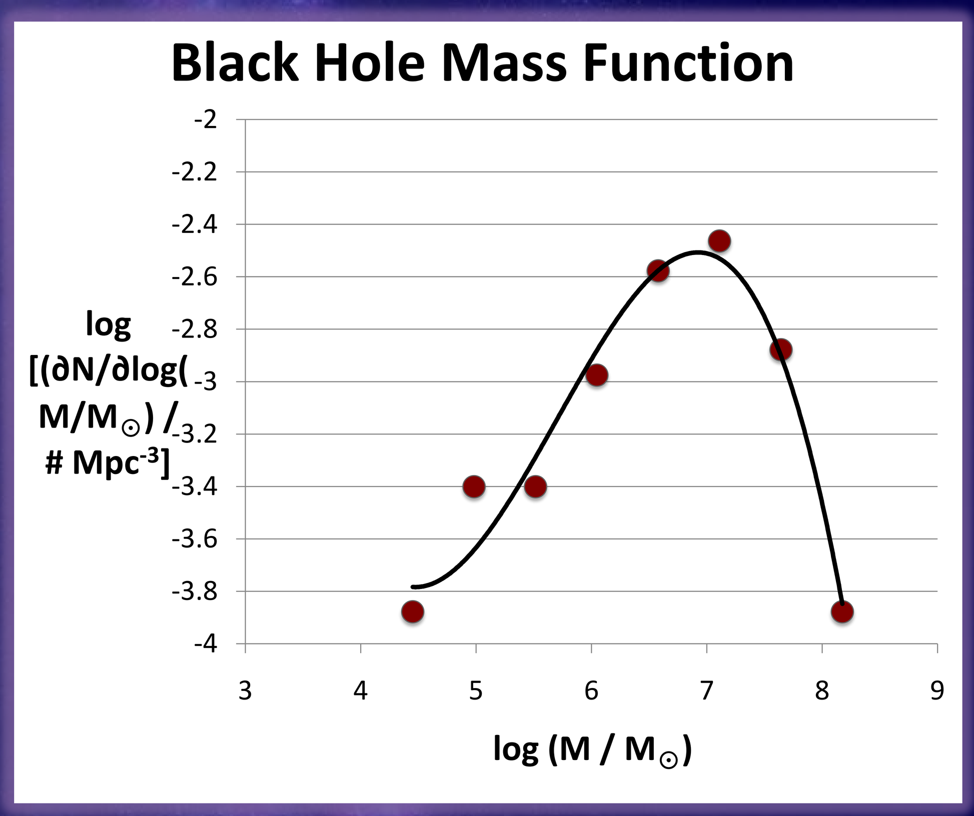
Using the M-P relation, we transformed the distribution of galaxies by pitch angle (shown in the plot above) into a **black hole mass function** for local spiral galaxies.

The black hole mass function is our second major result. Following the literature (e.g., [3]), it is calculated from

$$\frac{\delta N}{\delta M} = \frac{\delta N}{\delta P}\frac{\delta P}{\delta M},$$

where N is the total number of galaxies per volume.

Second Result: Local Black Hole Mass Function



The plot above was obtained by applying the M-P relation to the local pitch angle function. Our result resembles the mass function found for all galaxy types by Greene & Ho using AGN luminosities [4]. However, our function falls off more steeply. We propose these explanations:

- The most massive galaxies tend to be giant ellipticals.
- Our volume-limited sample excludes the dimmest galaxies (i.e., those with the smallest black holes).

Future Research

The results presented here will help to answer a number of questions about galactic evolution:

- How has the black hole mass function changed over time?
- How does the black hole mass function differ for field versus cluster galaxies?
- How does the black hole mass function for spiral galaxies compare to the mass function for elliptical galaxies?

References

[1] M. Seigar, D. Kennefick, J. Kennefick, & C. Lacy, ApJ **678**, L93-L96 (2008).
[2] L. Ho, Z. Li, A. Barth, M. Seigar, & C. Peng, submitted to ApJS.
[3] J. Gair, C. Tang, & M. Volonteri, Phys. Rev. D **81**, id. 104014 (2010).
[4] J. Greene & L. Ho, ApJ **667**, 131-148 (2007).

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