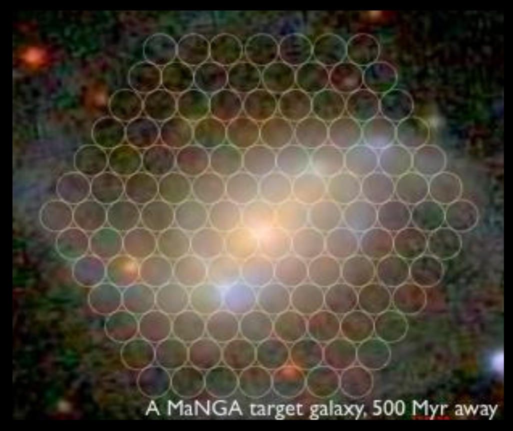
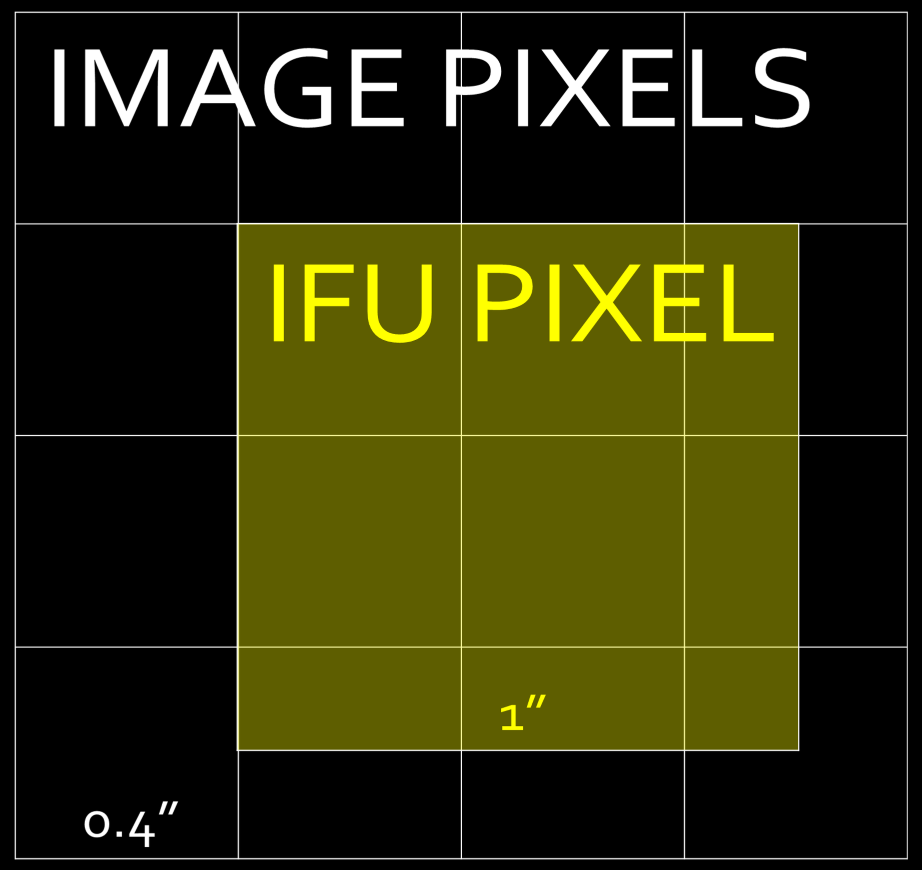
Super-Resolution of Galaxy IFU Spectra

IDIES Annual Symposium, Baltimore, 2014

Ching-Wa Yip [1]
Carlos Sing-Long [2]
Alexander Szalay [1]
Emmanuel Candès [3]
Rosemary Wyse [1]
Tucker Brownell [1]
(1) Physics & Astronomy, Johns Hopkins University
(2) Institute of Computational & Mathematical Engineering, Stanford University
(3) Department of Statistics; Department of Mathematics, Stanford University



Integral Field Unit (IFU) spectra are starting to accumulate in astronomy and have the promise to revolutionize our understanding on galaxy evolution by resolving the gas, star, and dust on the galaxies. The spatial resolution of these spectra are currently limited by technology and cost. We are developing a Compressive-Sensing based algorithm to super-resolve the IFU spectra from their native spatial resolution.



Imaging is less expensive than spectroscopy and can offer smaller pixel sizes in many astronomy surveys. Our approach aims at combining the strength of both types of data, in order to obtain the highest resolution representation of galaxies both spatially and in wavelengths.

The CALIFA IFU spectra have 1 square arc-second per pixel. The SDSS images have 0.4 square arc-second per pixel.

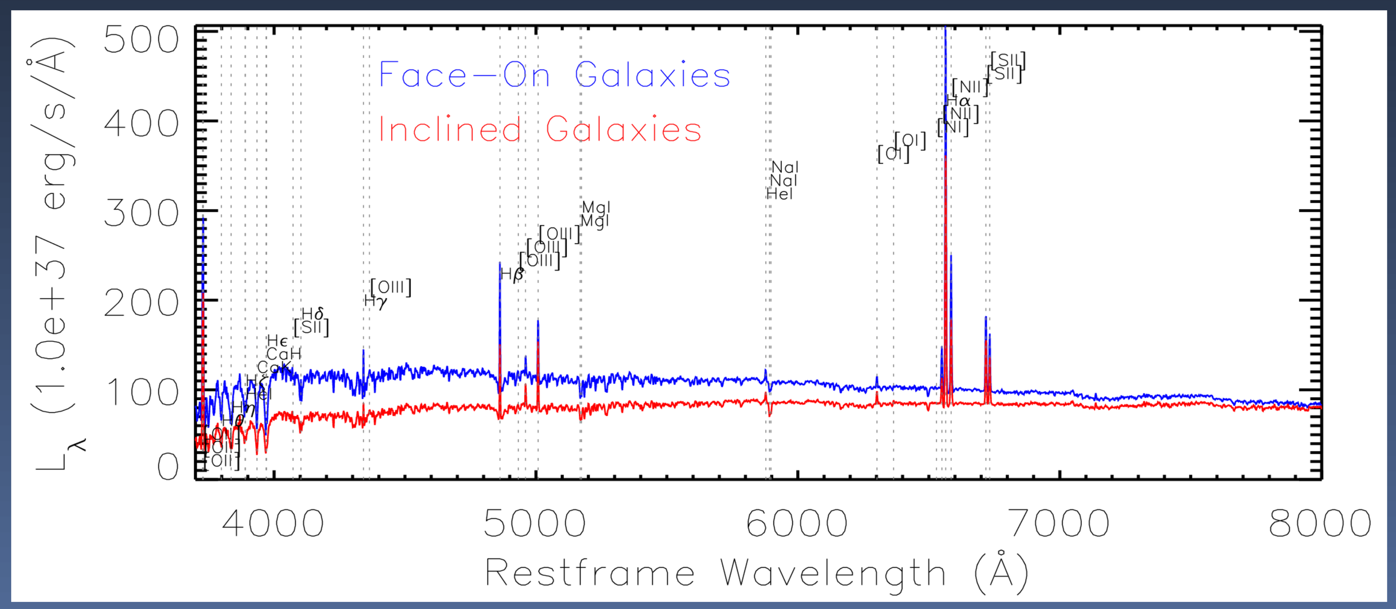
Compressive Sensing Based Algorithm

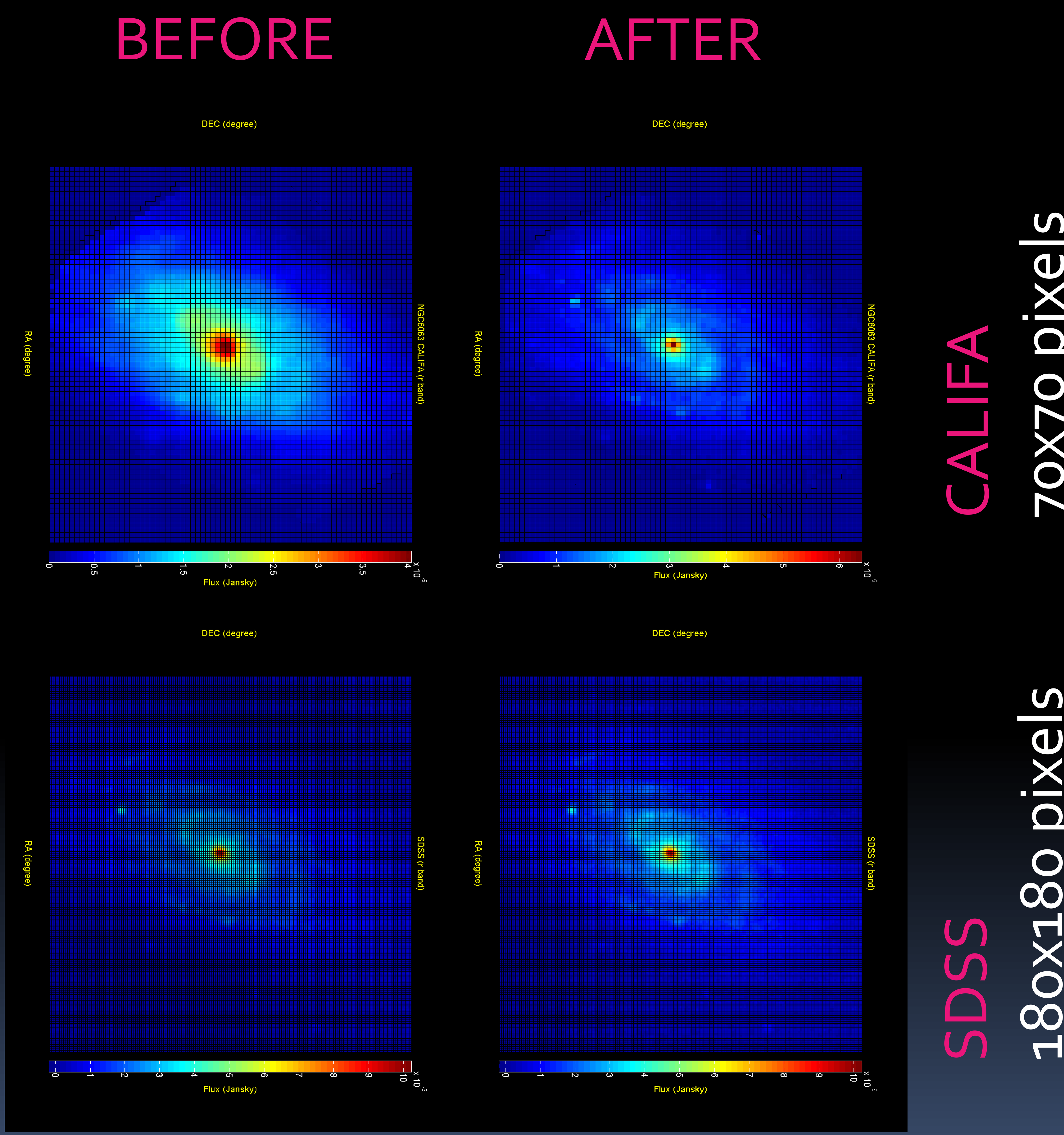
From the IFU spectrum for each of the N pixels in a galaxy image, $I_{LR} = (y_1, y_2, y_3, \dots y_N)$, we would like to recover the signal $I_{HR} = (x_1, x_2, x_3, \dots x_M)$ in an upsampled image as such:

$$A I_{HR} = I_{LR} \, .$$

In the first application, $N < M$, where $N \approx 5000, M \approx 30000$, correspond respectively to the image size of the low-resolution CALIFA and high-resolution SDSS image. This linear system is underdetermined and hence unsolvable for arbitrary signals. But if the signal is "sparse", or the multi-dimensional signal space has a few interesting places only, Compressive Sensing (Candes, Romberg, Tao 2006a,b; Donoho 2006) can recover the true signal. Seeing that a galaxy spectrum can be expanded as a linear combination of a few PCA eigenspectra, $e_i(\lambda)$ (Connoly et al. 1995, Yip et al. 2004), the IFU spectra are also sparse.

A spectrum– flux vs. wavelength– tells us about the star, gas and dust content of a galaxy.





A pilot study shows very promising results. The (SDSS r band filter-convolved) broadband image of CALIFA reveals much more details after we apply a stand-alone flux conservation constraint, at matched pixel size and position, between the CALIFA IFU spectra and the SDSS image. Using Compressive Sensing, our work plans to super-resolve the CALIFA IFU spectra to meet the SDSS spatial resolution, and at the same time, retain the wavelength resolving power.