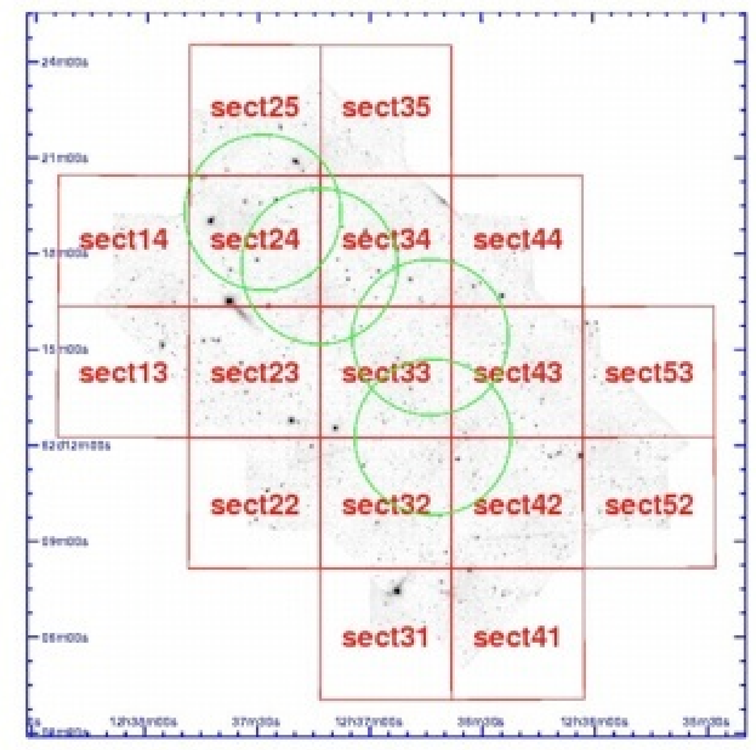
Mass Estimates of high redshift emission lines and V drops in the PEARS-N and PEARS-S fields

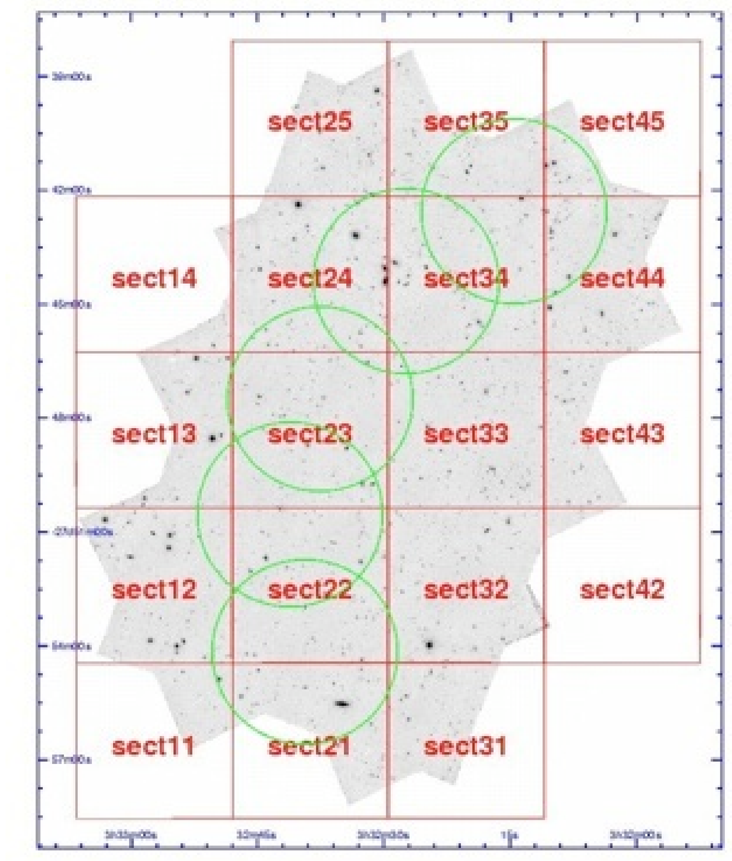
Pirzkal, N., Malhotra, S., Rhoads, J. and the PEARS team

Abstract

The PEARS projects (Probing Evolution and Re-ionization Spectroscopically) has identified upward of 50 high redshift lyman break sources in the GOODS-N and GOODS-S fields. Some of these object show Lyman-Alpha in emission in the low resolution spectra we have obtained, while others were selected based on the presence of a strong spectral break in the V band (V-drops).

We report on our latest technique to determine the stellar masses of these objects, as well as to constrain the age of their stellar populations, the amount of extinction present and whether a significant amount of the mass of these objects could be accounted in the form of an older stellar population. Using a new Markov Chain SED fitting technique, we are able to get a better understanding of the overall degeneracy that these parameters present. This work is a 5-fold increase in the number of such sources compared to our previously published GRAPES work.





PEARS description

The GOODS northern (GOODS-N) and southern (GOODS-S) fields (Giavalisco et al. 2004) have been observed over a wide range of wavelength and down to very faint magnitudes during the past few years. As part of the PEARS pro ject (PI:Malhotra), we have observed 9 fields within the GOODS regions, each 11.65 arcmin 2. These new observations provide spectroscopic data for more than 10,000 sources, and cover a wavelength range of 6000˚A to 9500˚A(40˚A per pixel or R ≈ 100) . Ultimately, the effective resolution of these slitless spectra is determined by the physical size of each source, as projected on the sky.

PEARS observations were obtained as part of a large HST proposal (200 orbits, Proposal 10530, PI: Malhotra) that was closely modeled after the previously very successful GRAPES (Pirzkal et al. 2004) observations of the much smaller subset of the GOODS-S field: the Hubble Ultra Deep Field (Beckwith et al. 2006). Each of the 9 PEARS fields (11.65 arcmin^2 each) was observed for approximately ≈ 40000 seconds (20 orbits), split evenly between observations taken at different position angles on the sky (typically 3). One of the five PEARS-S fields contains additional observations of the previous GRAPES/HUDF field. Of the eight remaining observed fields, four are within GOODS-N and four are within GOODS-S. The combined areas of the PEARS-N and PEARS-S fields are 50.17 and 70.61 arcmin^2, respectively.

The PEARS data were reduced using the latest version of the ACS slitless extraction pro gram, aXe (Kummel et al. 2008, http://www.stecf.org/software/slitless software/axe/), following the recipe described in Pirzkal et al. (2004). A few aspects of the data reduction process differ somewhat however: First. the background subtraction was improved, and the spectra were extracted using optimal extraction. More significantly, the amount of contamination, caused by overlapping spectra of nearby sources was quantitatively estimated for each spectrum. These changes allowed us to reach slightly higher signal-to-noise levels at any given broad band magnitudes than for the GRAPES pro ject. The PEARS data reduction is described in more detail in a companion paper by Malhotra et al. (2008). The extraction was based on an object catalog that, crucially, was derived using newly available and deeper broad band images of the GOODS fields. These observations, known as GOODS 2.0 combine the older GOODS observations with additional ACS i775 and z850 band images subsequently obtained as part of a large supernova search program (PI: Riess). A total of 4081 and 5486 spectra were extracted from the PEARS-N and PEARS-S fields, respectively. As a general rule, spectra obtained at different position angles were not combined together. Instead, specific fitting and measurements were made separately and then averaged, allowing us to estimate the error in the fit or measurements by computing the standard deviation of the mean.

V Drop Selection

V drops were selected using the criteria:

(V-i)>0.9, i<27.7, and B > 27.

29 sources were identified in PEARS-N, and 19 in PEARS-S

Redshift of the V drops were determined from the grism spectra themselves.The resulting redshifts are shown in Figure 1

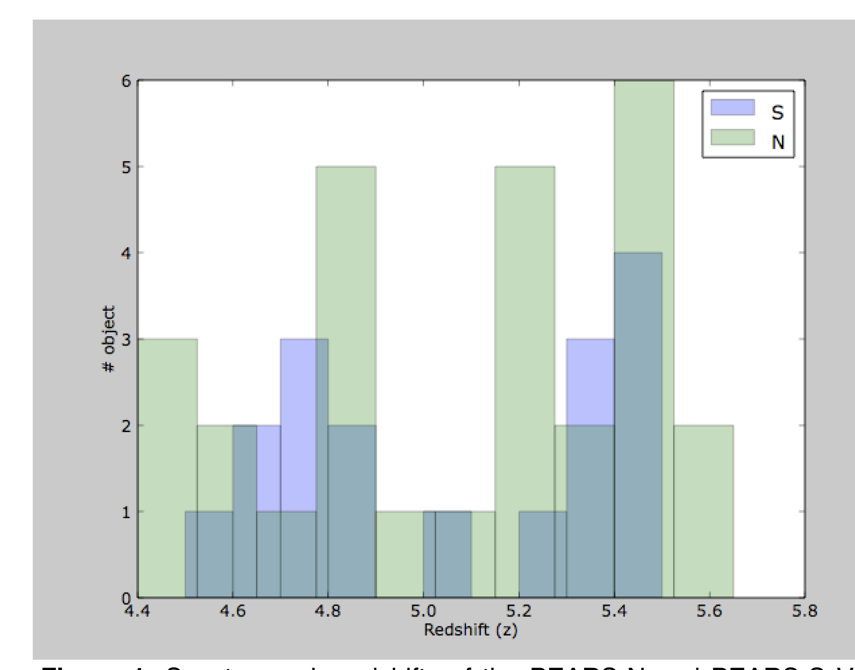


Figure 1: Spectroscopic redshifts of the PEARS-N and PEARS-S V-drop

MCMC SED fitting

We followed the methodology of Pirzkal and al., 2005. As such, we allowed for two epochs of star formations occuring at arbitrary redshift and with arbitrary values of the age of the two starbursts (ltime, ltburst), the two starbursts mass ratios (brst1m), exctinsion (Av).

A new Markov Chain Monte Carlo code was written to try to determine the ages and the stellar masses inour PEARS sample, and Av. MCMC allows us to not only find the best fitting model but also the maximum stattistically acceptable mass for these objects, or their mass with a stellar population as old as possible. Example of such fits are shown in Figure 2.

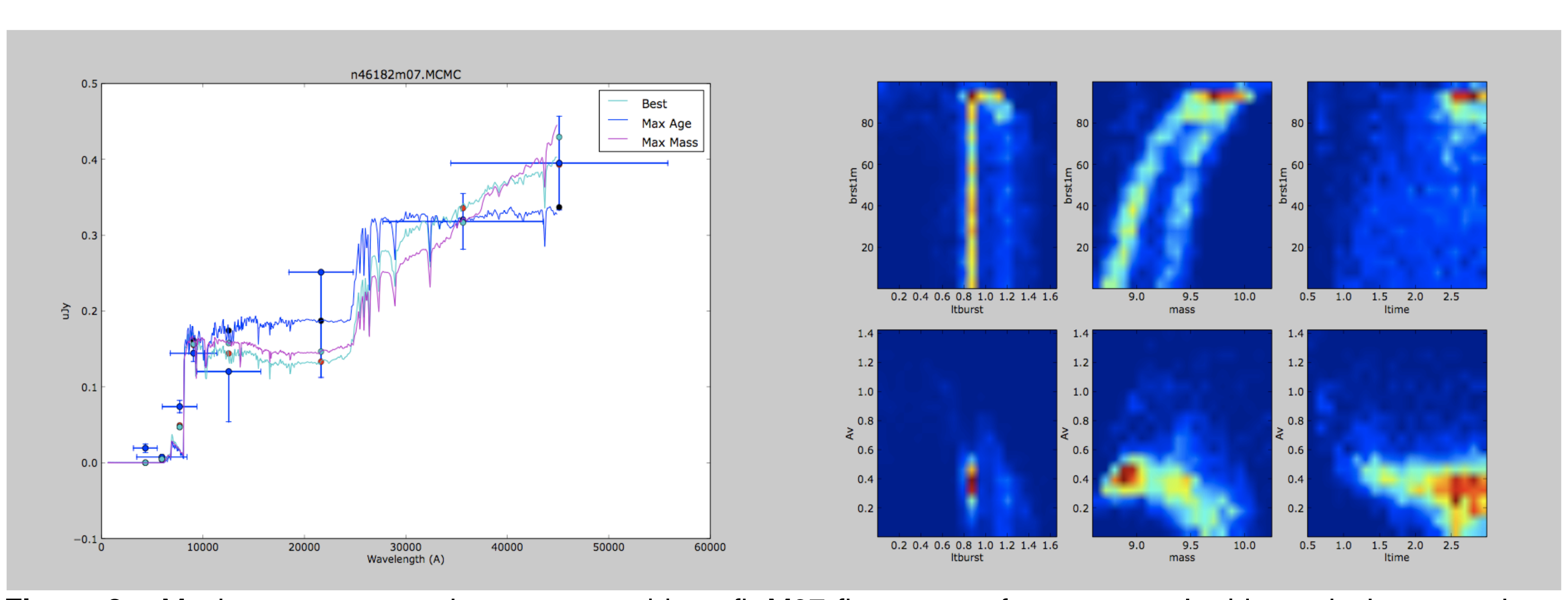


Figure 2a: Maximum mass, maximum age, and best fit M07 fits to one of our source. In this particular example, mass estimates are 1.8x10^10 (best), 1.84x10^9 (max age), and 8.7x10^9 Msun. The panel on the right shows a 2D histogram of the probability distribution of the parameters ltime, ltburst, brst1m, Av and mass as determined using MCMC.

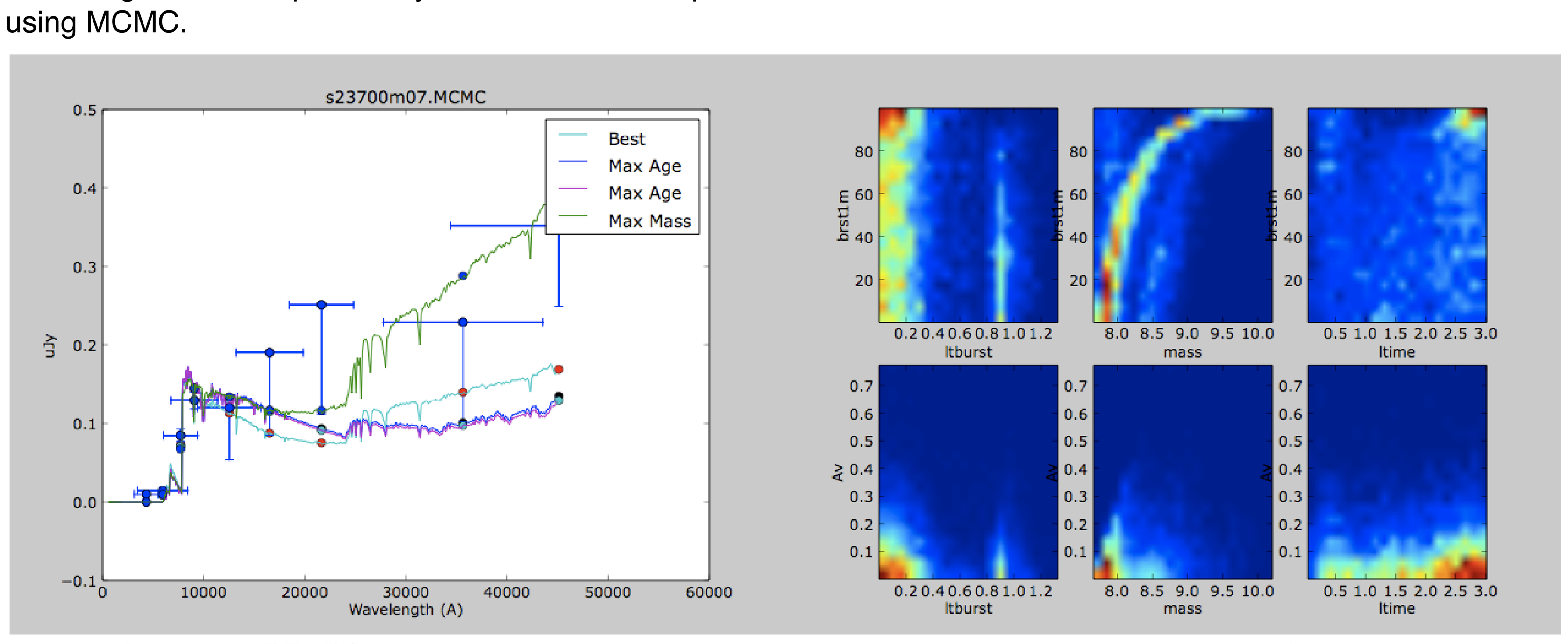


Figure 2b: z=5.4 PEARS V drop. Mass estimates are 5.5x10^9, 4.9x10^9, 1.6x10^10 Msun for the best, max age, and max mass models respectively.

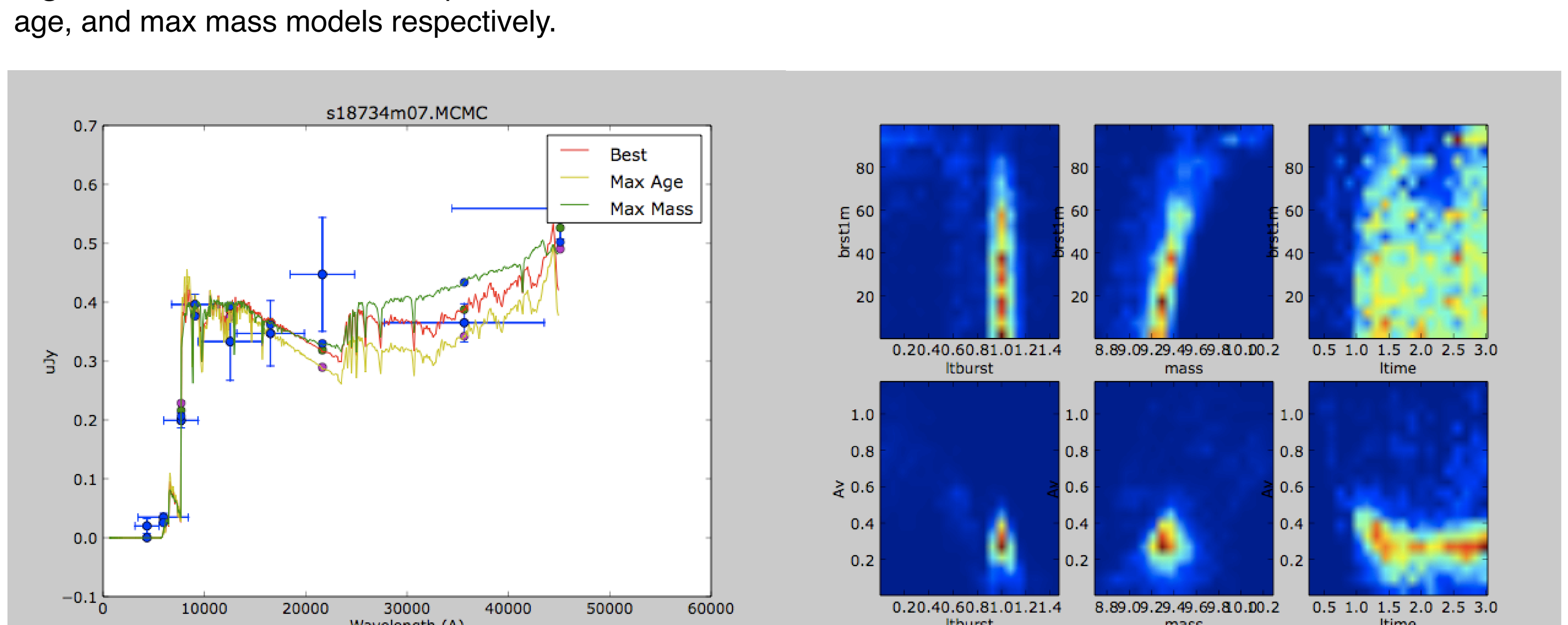


Figure 2c: z=5.3 PEARS V drop. Mass estimates are 1.7x10^9, 2.1x10^9, 1.9x10^10 Msun for the best, max age, and max mass models respectively.

Choice of stellar library

We have estimated stellar population ages, masses, ratio and Av assuming a Salpeter IMF and the stellar libraries from bc03, cb07 and m07. In general the bc03 and cb07 give similar stellar mass estimates while the m07 lead to smaller (by 1-5% percent) stellar mass estimates. An example is shown in Figure 3.

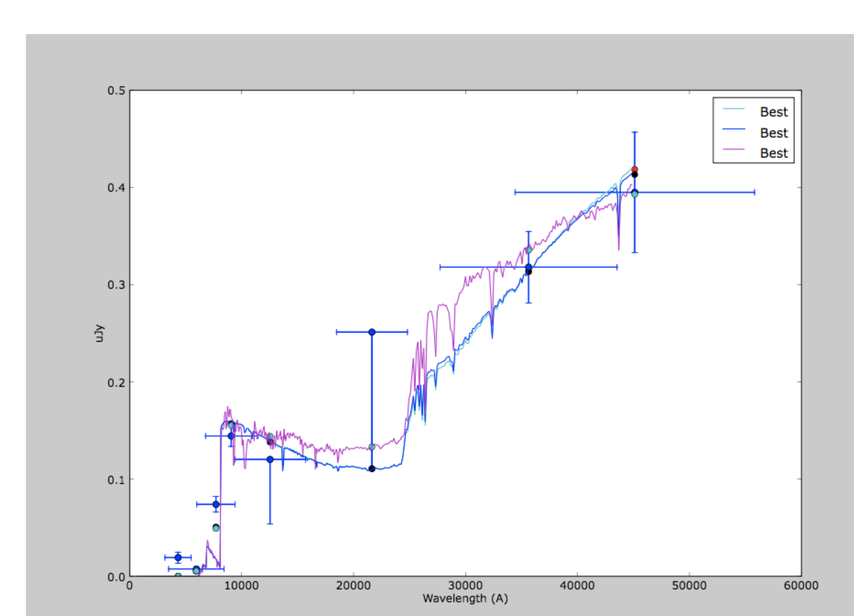


Figure 3: Effect of using the bc03, cb07 or m07 stellar evolution libraries to find the best fit mass estimates. The best fit masses vary from 4.5x10^8 (bc03), 4.3x10^8 (cb07) and 8.7x10^9 (m07).

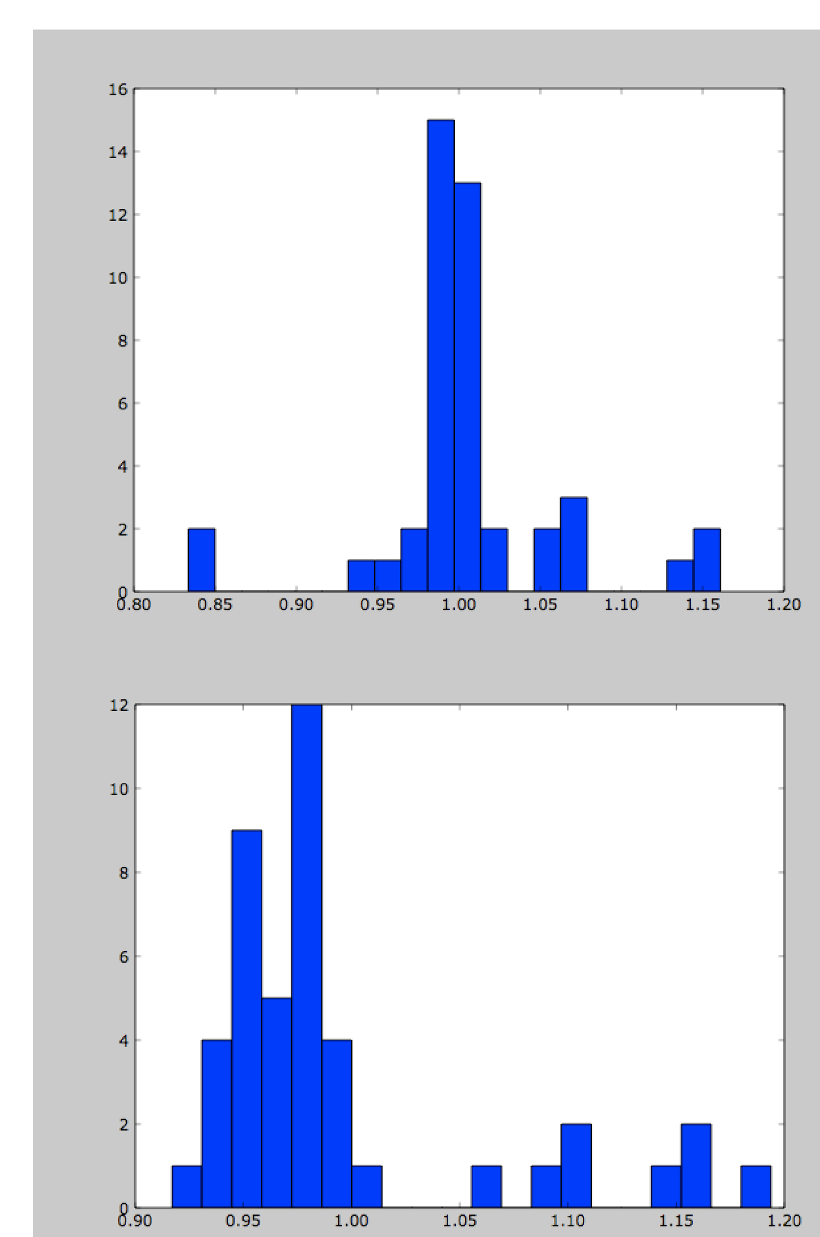


Figure 4: Histograms of the ratio of the CB07 mass estimates to the BC03 mass estimates (top panel) and of the ratio of the M07 to MC03 mass estimates (bottom panel)

PEARS Mass Estimates of V drops

The best fit masses estimates for the PEARS V drops are shown in Figure 5. As shown in this Figure, we found a wide range of
masses, ranging from a few 100 millions solar masses to 10^11 solar masses.