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CLOUD STRUCTURE OF PLANETARY MASS COMPANION AB PIC-B

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ABSTRACT

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Subject headings: kw1, kw2, ...

1. INTROCDUCTION

2. OBSERVATION

3. DATA REDUCTION

3.1. *Cosmic Ray Identification*

The WFC3 `calwf3` pipeline produces two types of calibrated files per exposure, the `ima` file and the `flt` file. The `ima` file contains all calibrated non-destructive readouts. The `flt` file is additionally processed with an up-the-ramp fit that combines every readout into a single image with a linear regression for every pixel. In the meanwhile, up-the-ramp fit identifies cosmic ray by searching for outliers from the fitting result and makes correction coordinately. Mandell et al. suggested that WFC3 IR time series extract from `flt` files have a rms 1.3 times larger than that obtained from `ima` files with their transit spectroscopic data analysis. Similar result was found in our analysis of WFC3 IR images. We speculate the larger scattering measured from `flt` files is caused by jitter of the telescope, especially when number of sample per exposure is small. Swain et al. also recommended to use non-destructive readouts in data reduction.

We use the last readout in which the peak pixel of AB Pic b's image is not saturated for every exposure to carry out photometry measurement. For cosmic ray identification, we take a linear fit to the sums of pixels in a 7×7 box centered on the peak pixel for all readouts that do not have unsaturated pixel in that region. We identify exposures that have reduced χ^2 values greater than 2.5 as being contaminated by cosmic ray Using this method, there are 9 out 348 exposures that cosmic ray hits were found in the AB Pic b's image region with this criterion. We did not make correction for these exposures considering the small number of readouts. Instead we exclude these images in further analysis. The scatterings of photometry measurements using files processed in this method is reduced by factors of 1.65 and 1.41 for F125W data set and F160W data set coordinately comparing to those measured with `flt` files, which is consistent with Mandell et al. (2013).

For 2M1207 system, we decided to use the `flt` file. The image of 2M1207 A quickly saturated after several non-destructive readouts. The `flt` file keeps non-saturated file, making precise photometry for both 2M1207 A and B possible.

3.2. *Continuous Bad Pixels Identification*

Pixels with data quality flags 'bad detector pixels' (DQ = 4), 'unstable response' (DQ = 32), and 'bad or uncertain flat value' (DQ = 512) were masked out as suggested by previous exoplanet transit spectroscopic observations(e.g. Berta et al. 2012; Kreidberg et al. 2014).

3.3. *Flat Field Correction*

3.4. *AB Pic B: Primary Star PSF Subtraction*

We removed the point spread function (PSF) of the primary star with standard roll subtraction method. For one target image, every other image that was taken with the same filter and different roll angle of the telescope was selected to form a PSF image cube. The PSF of primary star was subtracted by its own PSF in the PSF image. The position offset of the target image and the PSF image was calculated with cross correlation. The PSF image was shifted using bilinear interpolation to align with the target image. By optimizing with least rms residual in the shaded region shown in Figure 1, the amplitude scale of the PSF image was calculated. The PSF image provided the smallest subtraction residual among images in the PSF cube was selected as final PSF to be subtracted from target image.

Using images with primary star subtracted with above method, an average background residual is reached as 2.1 e^-/s, which is more than one order of magnitude smaller than the photon noise. Therefore, our photometry is photon noise limited and we did not attempt to use more sophisticated PSF subtraction strategy.

3.5. *AB Pic B: Aperture Photometry*

We performed aperture photometry using images processed with above procedures. Centroids of PSFs of AB Pic b were located by 2 dimensional Gaussian fit with IDL routine `mpfit2dpeak` (Markwardt 2009). Then aperture photometry was calculated using `aper` with aperture radius of 3 pixels. Aperture size is determined by taking into account both minimizing noise level as well as excluding bad pixels.

Photometry uncertainty is the combination of three independent components, readout noise, photon noise, and fluctuation in the background. We take the square root of the sum of the squares of the three components as the uncertainty of one photometry measurement. In fact, the uncertainty is denominated by photon noise.

3.6. *2M1207: Multi-component PSF photometry*

The small angular separation of 2M1207 A and B makes precise primary star subtraction and photometry very difficult. On the under-sampled WFC3 IR detector, the primary and the secondary only separate by ~ 6 pixels, which is about 5 times of the FWHM of the PSF. In

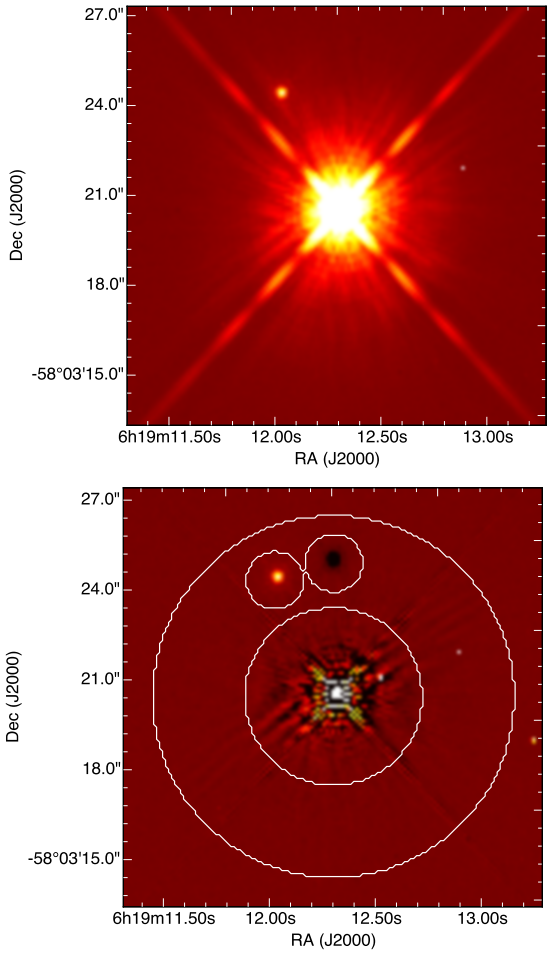

FIG. 1.— One example of the original(upper panel) and primary star subtracted (lower panel) images of AB Pic system. In the lower panel, white contour defines a region of an annulus with circle excluded. The rms residuals were optimized in this region when calculation the amplitude scales of PSF images when doing primary star image subtraction.

addition, under-sampling of the PSF causes significant artifacts when shifting the PSF to align with image to be subtracted no matter what interpolation method is used.

To over come above problems, we used several approach to reach high precision photometry in this extreme case. Our first approach makes use of Tiny Tim PSF simulator. Tiny Tim can produce model PSF based on the filter, spectrum of target, focus status, and the telescope jitter. One advantage of Tiny Tim PSF over observed PSF is that Tiny Tim can produce over-sampled PSF, which makes the shifting and interpolation rather straight forward. However, Tiny Tim has systematic errors in producing model PSFs. E.G. the diffraction spikes and coma are not well simulated in Tiny Tim PSFs (Biretta 2014).

4. RESULT

5. DISCUSSION

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