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Measurements of Relative Positions and Proper Motions of η Carinae's Weigelt Blobs C and D

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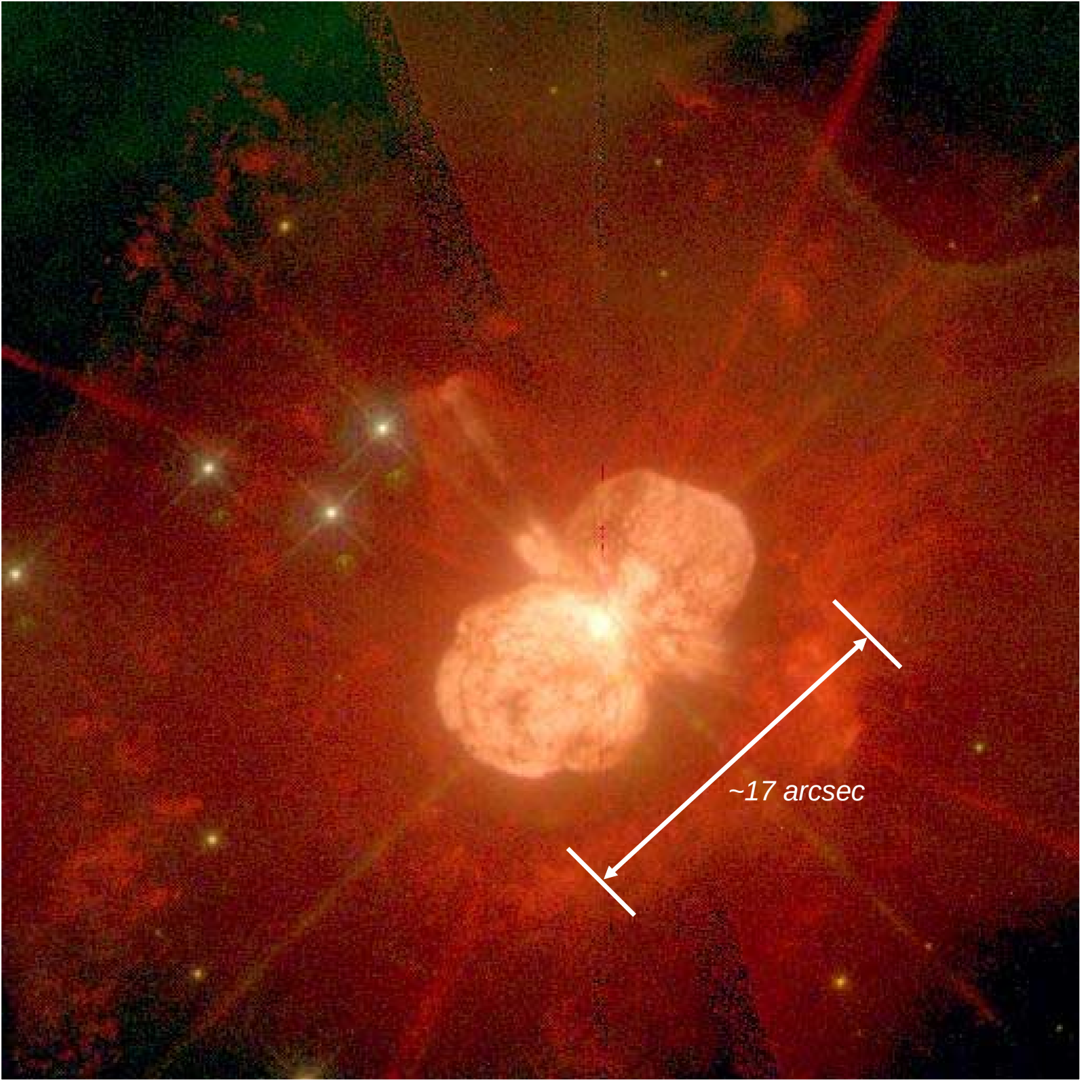
Fear the turtle!

ABSTRACT

We report astrometric measurements of η Carinae's Weigelt blobs C and D (also known as Speckle Objects C and D) derived from historical observations with HST's WFPC2. Using a total of seven WFPC2 exposures with a temporal baseline of approximately six years, we employed a grid search method to determine central star and blob centroids and their relative separations. The separations were used to derive proper motions for both blobs, which in turn were used to derive a date of origin. In this poster we present our methodology and summarize our results.

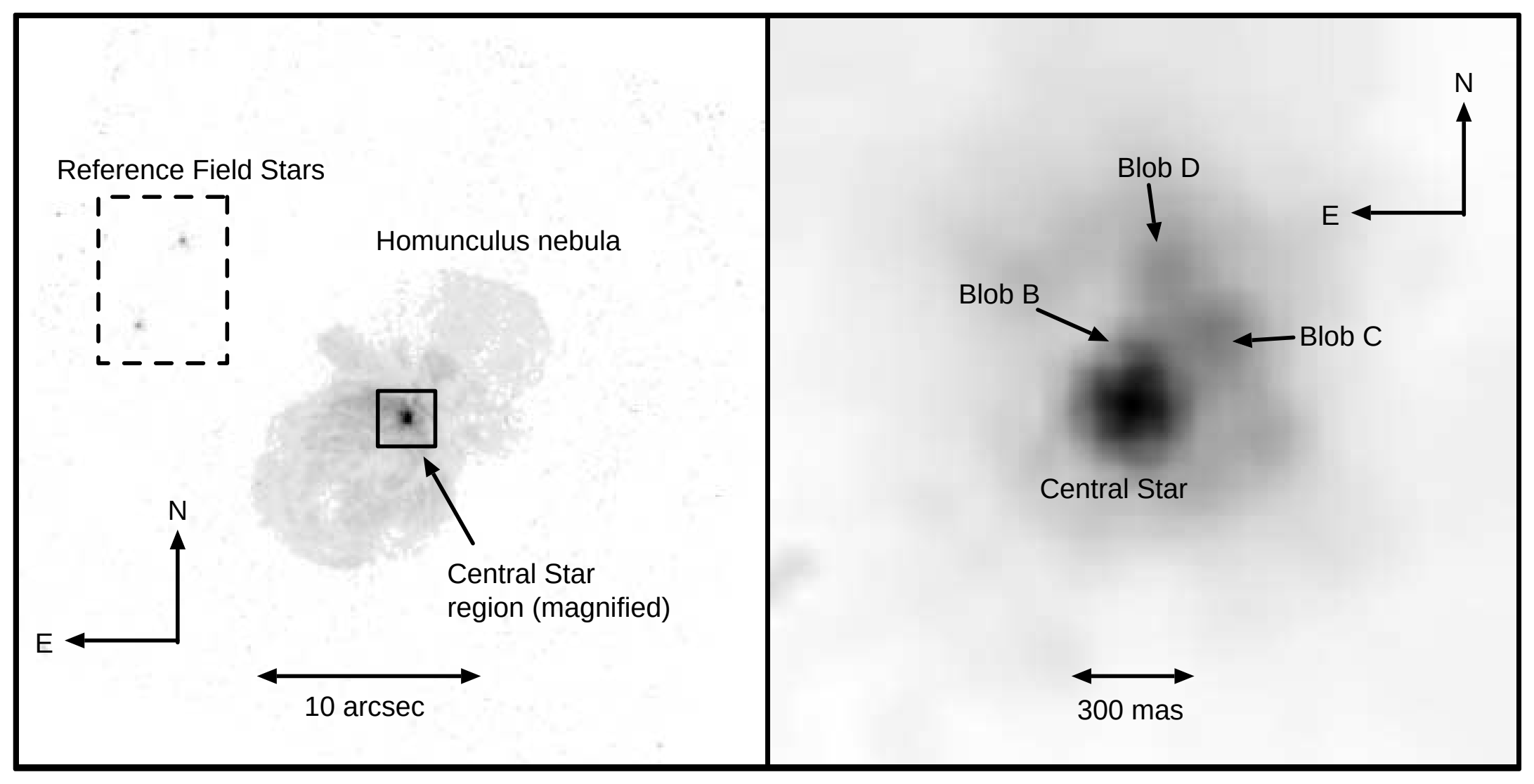
I. η Carinae and the Weigelt Blobs: Background

Carina Nebula



η Carinae and the Homunculus observed with HST.

One of the most massive and luminous stars in our galaxy, η Carinae is also generally recognized as one of the most enigmatic. One of its many mysteries involves the origin and nature of the three close-in ejecta, originally called the "Speckle Objects" but now known as the "Weigelt blobs," shown below.



(left) η Carinae and Homunculus; (right) central star detail showing position of Weigelt blobs (HST).

These three objects (commonly referred to as blobs B, C, and D) were first discovered using speckle techniques as described by Weigelt & Ebersberger (1986) and Hofmann & Weigelt (1988). The separation between the blobs and the central star has been successfully resolved using HST/WFPC2 (Morse et al. 1998). Combined, these observations indicate that the three objects all lie within 300 millisarcseconds (mas) of the central star, and are less than 50 mas in diameter. Adopting a distance of 2.2 kpc (Allen & Hillier 1993) corresponds to a separation of 660 AU and a maximum diameter of 110 AU. These clumps of ejecta are thought to be compact knots of gas ejected from the central star at some point in the past (Davidson et al. 1995).

In order to determine the precise date of origin of the blobs, astrometric measurements must be made of the relative separation between the blobs and central star over multiple epochs; these results must then be combined to determine proper motion values for the blobs relative to the central star, which in turn lead to date or origin inferences.

II. Relative Separation Measurement Methodology

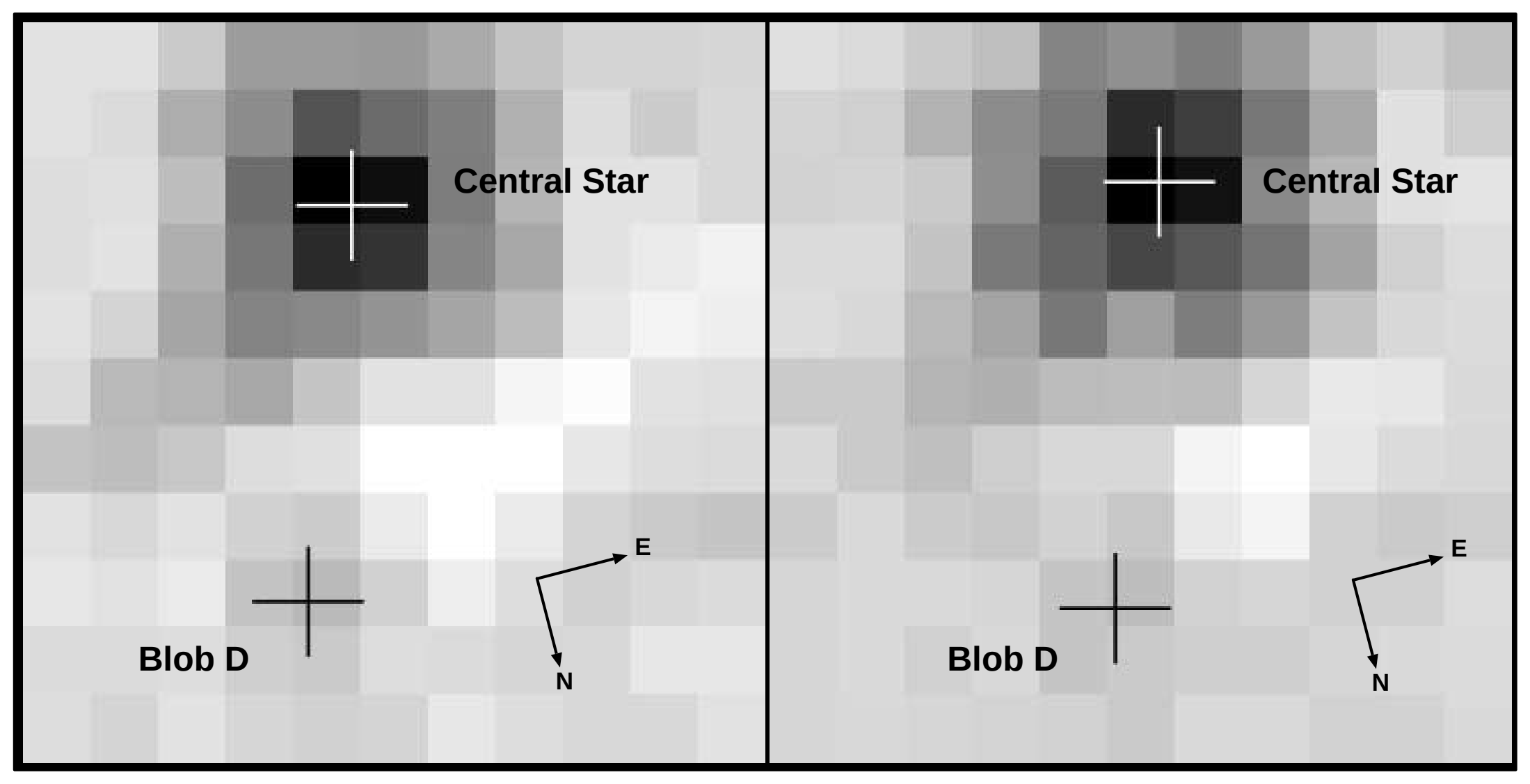
We selected data for astrometric analysis based on the following criteria:

1. At least two epochs of data had to exist for a given WFPC2 filter. This was motivated by a desire to avoid spurious motions that might arise when using different filter data for the two epochs. This could occur, for example, when different line emissions originate in different physical locations in the blob due to local astrophysical conditions.
2. All the observations had to have been made with the PC2 CCD in order to take advantage of its enhanced spatial resolution.
3. The image in the vicinity of both the blobs and the central star had to be unsaturated. Some images we considered were rejected because the single pixel containing the photocenter of the central star appeared to be saturated.

The seven images we found that satisfy these criteria are:

Image Ref. Name	*Date*	*WFPC2 Filter*	*Exposure (sec)*	*V3 angle (deg)*	*Blob measured*
95_631a	1995.723	F631N	0.5	19.0	C, D
95_658a	1995.441	F658N	0.11	300.0	D
95_658b	1995.441	F658N	0.11	300.0	D
97_631a	1997.435	F631N	1.2	286.4	C, D
97_631b	1997.435	F631N	1.2	286.4	C, D
01_658a	2001.424	F658N	0.11	300.0	D
01_658b	2001.424	F658N	0.11	300.0	D

Initial processing of the data consisted of distortion correction with the appropriate Trauger coefficients using the IRAF/STSDAS drizzle procedure. Astrometric reduction was achieved using the following procedure: median images were created by passing a 5 x 5 kernel over each source image. The median images were then subtracted from the source images, producing a set of median-subtracted images with significantly suppressed background. Using a 5 x 5 grid search, a least-squares three parameter fit of a 2D Gaussian with fixed width (FWHM = 1.6 pixels) was used to determine the positions of the central star and the blobs in each median-subtracted image. Centroid positions of the central star and blobs were then used to solve for relative separation and position angle (PA) in each image. Results for two of the analyzed images are shown in the figure below.



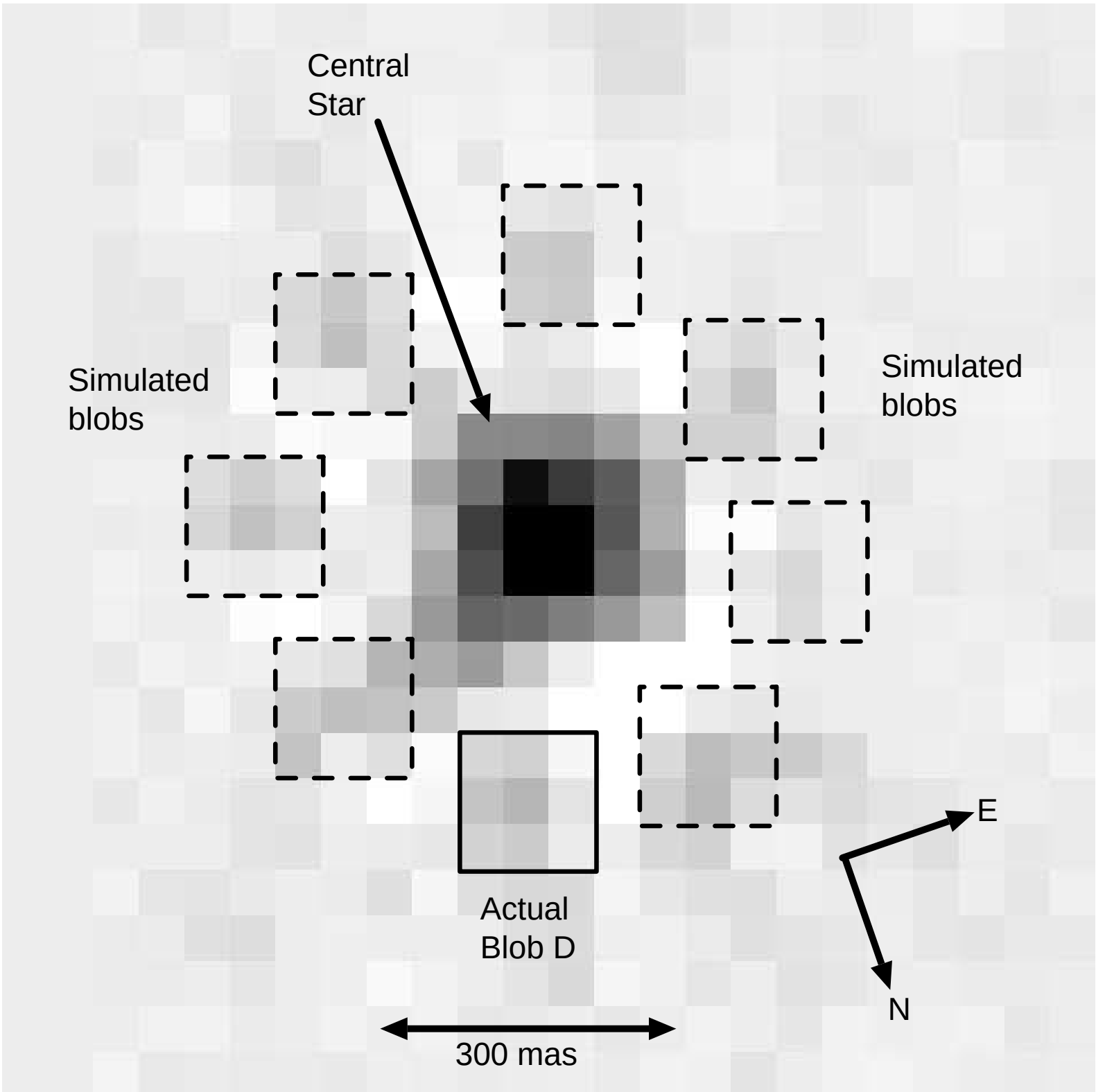
Example images used for relative separation measurements. Central star centroids are marked with white crosses; Blob D centroids with black crosses.

1995 WFPC2 F658N Image

2001 WFPC2 F658N Image

III. Error Analysis

We performed an extensive error analysis on the images in the analysis in order to validate the median-subtraction method and quantify the resultant errors. This error analysis consisted of adding simulated blobs (modeled as a two-dimensional Gaussian using the parameters appropriate to the observed blob in the image) at seven different field positions in each image. The simulation positions were defined by rotating the separation vector about the central star position in increments of 45 degrees spanning the range 45-315 degrees. This process effectively creates an "annulus" of seven field positions surrounding the central star at a radius equal to the central star-blob separation, shown in the figure at right.



F631N image showing "injected" blobs around the central star. Each injected blob was measured as if it were an actual blob; the resultant centroiding errors were used to predict error for the actual blob measurement.

Each simulated blob image image was then processed as described above (Sect. II). The centroid was determined for each position around the annulus and separation and angle with respect to the central star were calculated. A few of the regions around these positions (<18 %) were observed to be manifestly anomalous (due, for example, to the presence of unusually bright background features) with respect to the actual blob region and were rejected using an objective signal-to-noise criterion. For the simulated positions that passed the filtering test, the "observed" separations and angles of the simulated blobs were subtracted from the true (input) values, producing O-C residuals for each position. For each image, the separation and angle errors listed in the results section were given by the standard deviation of the O-C distributions.

IV. Results

The results from the median-subtraction method are shown below. These include the measured separation between the central star and the blobs, the predicted error for the measurement, and the resultant PA. We successfully measured separations for blob D in both filter bands, but were only able to obtain unambiguous results for blob C in the F631N images.

Individual Image Solutions

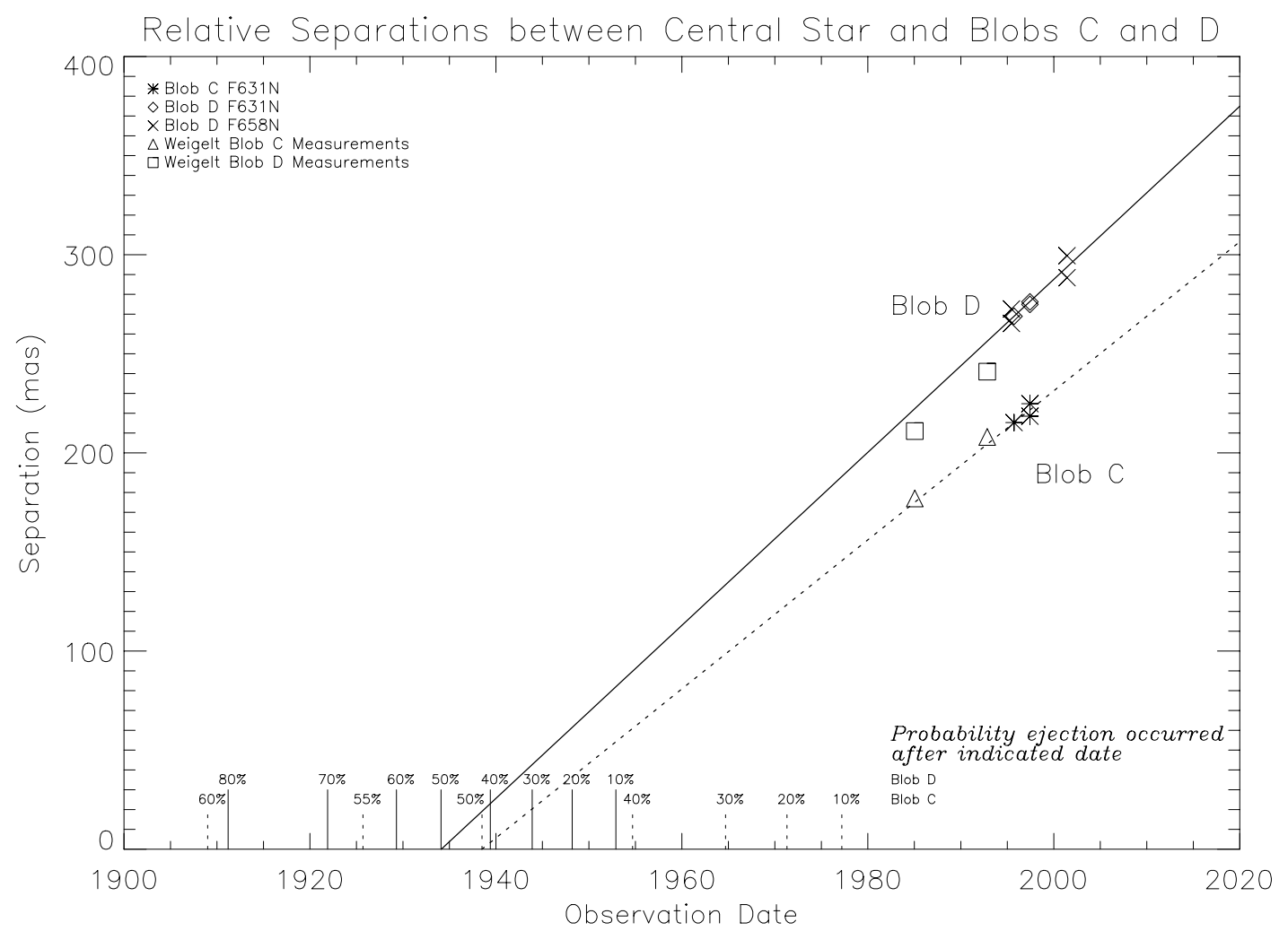
	Blob C		**Blob D**	
	Separation (mas)	**PA (deg)**	**Separation (mas)**	**PA (deg)**
95_631a	**215.3±8.3**	**301.9±0.9**	**268.9±12.8**	**337.4±1.4**
95_658a			**272.6±9.8**	**338.3±1.2**
95_658b			**265.3±8.6**	**339.1±2.1**
97_631a	**224.8±6.6**	**299.6±0.9**	**276.2±6.4**	**336.1±0.5**
97_631b	**218.5±6.6**	**300.0±1.1**	**274.9±7.9**	**334.1±1.2**
01_658a			**299.5±8.9**	**339.3±1.4**
01_658b			**288.4±9.3**	**338.7±1.8**

Epoch Solutions

	Blob C		**Blob D**	
	Separation (mas)	**PA (deg)**	**Separation (mas)**	**PA (deg)**
1995.5			**267 ±6**	**338 ±1**
1995.72	**215 ±8**	**302 ±1**		
1997.4	**222 ±5**	**300 ±1**	**276 ±5**	**336 ±1**
2001.4			**294 ±6**	**339 ±1**

Weighted solutions for the observation epochs are shown in the bottom half of the table. There is no evidence of non-radial motion based on the PA results.

Using the weighted solutions, we calculate the proper motions for blobs D and C to be **pm_D = 4.4±1.4 mas yr^{-1}** and **pm_C = 3.8±5.6 mas yr^{-1}**. The relatively low precision for the blob C proper motion measurement is due to a combination of the short observational baseline (1.7 years) and the limited number of images from which we were able to measure separation. The results are shown graphically in the figure on the right. We plot the separation results along with the best fit proper motion slopes. Individual errors are suppressed. Also shown, for reference purposes, are the Weigelt et al.'s (1995) positions.



The separation and proper motion results imply a date of origin of the 1930s for both blobs (assuming ballistic motion). A coeval, pre-1910 ejection is ruled out at ~ 90% confidence level. The results agree with the proper motion and position measurements from Weigelt et al. (1995) (though in the paper, the authors conjecture that "the simplest interpretation is that the components C and D were thrown out from the star at some time between 1880 and 1930"). Our results disagree with the c.1890 date derived in Davidson et al. (1997).

VI. References

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