Hires: Super-resolution for the Spitzer Space Telescope

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Description of hires algorithm

Some hires tactical considerations

Examples of hires results

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Why Yet Another Deconvolution Program?

Spitzer provides good SNR, critically sampled, with relatively small telescope, 85cm.

Observation strategies provide redundant coverage.

Goal: Pool the information from redundant coverage, increase resolution.

Requirements:

- **Statistically appropriate use of redundant coverage**
- **Photometric accuracy**
- **Speed- Large data quantities mandate a fast program**
- **Distortion management- Required by Spitzer optics**
- **Ease of use- Turnkey program run in batch mode**

Hires: Richardson-Lucy Algorithm for Redundant Coverage

Single coverage

$$f^{n} = f^{n-1}\left[\frac{D}{f^{n-1} * P}\right] * \tilde{P}$$

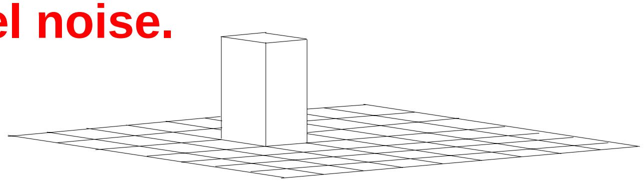
D acquired image
P assumed PSF, * is convolution
$\tilde{P}$ reflected psf, $\tilde{P}(v) = P(-v)$
f^{n} ***nth*** image estimate

Redundant coverage- **A simple extension using weighted averaging**

$$f^{n} = f^{n-1}\frac{\sum_{j=1}^{N_{images}}\left[\frac{D_j}{f^{n-1} * P_j}\right] * \tilde{P}_j}{\sum_j \tilde{P}_j * U_j} = f^{n-1}\frac{\sum_{j,k} c_{jk}(\tilde{P}_j * u_{jk})}{\sum_{j,k} \tilde{P}_j * u_{jk}}$$

Assume spatially invariant psf's and uniform pixel noise.

Linearities enable evaluation using two convolutions for each psf orientation.



Use FFT's for convolutions.

u_{jk} **same as data pixels but set to 1.**

Important Properties of hires Algorithm

No negative flux- $f_i^n > 0 \Rightarrow f_i^{n+1} > 0$

Conservation of flux- With caveat about smoothing edge effects

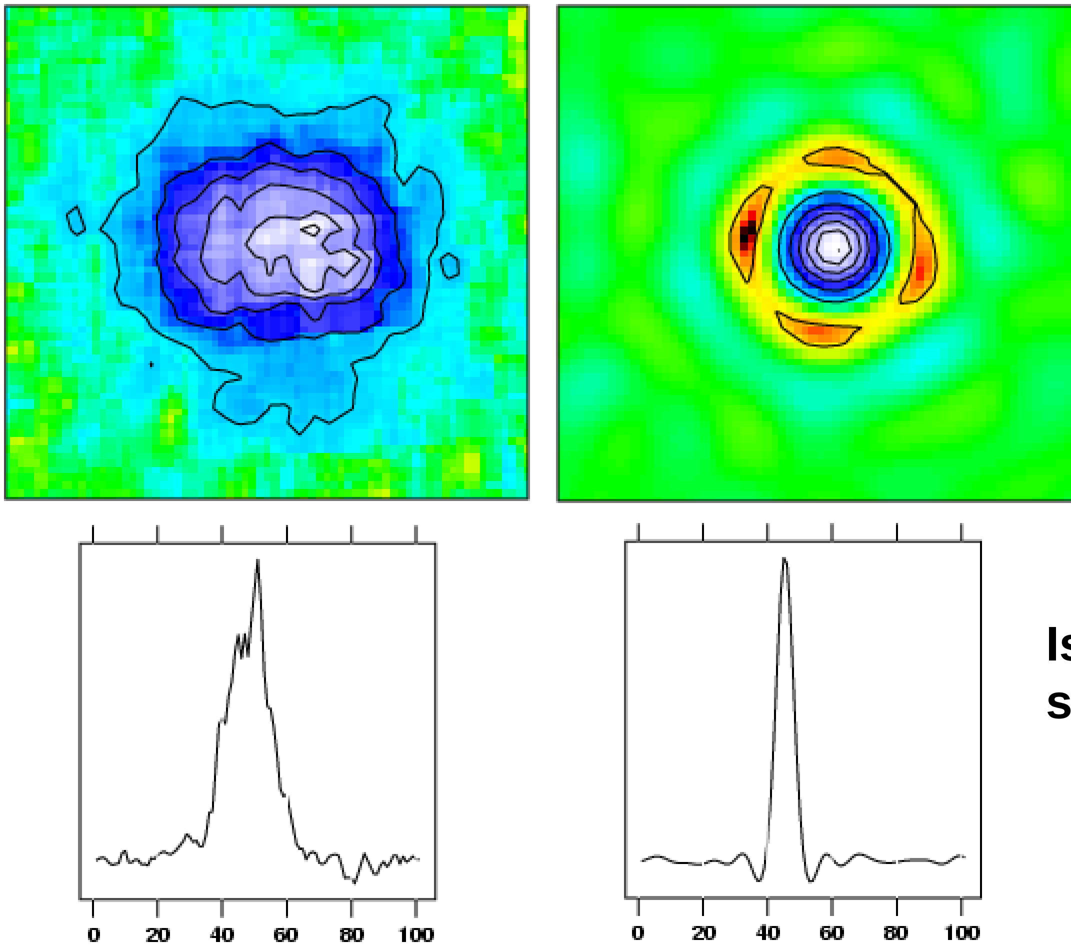
Likelihood of image at each iteration is increased.

Low frequencies are recovered first.

A decision to stop, when high frequency content appears unreasonable, is in fact an imposition of prior information.

Hires Response with Background and Noise

Coadd **100 hires iterations**



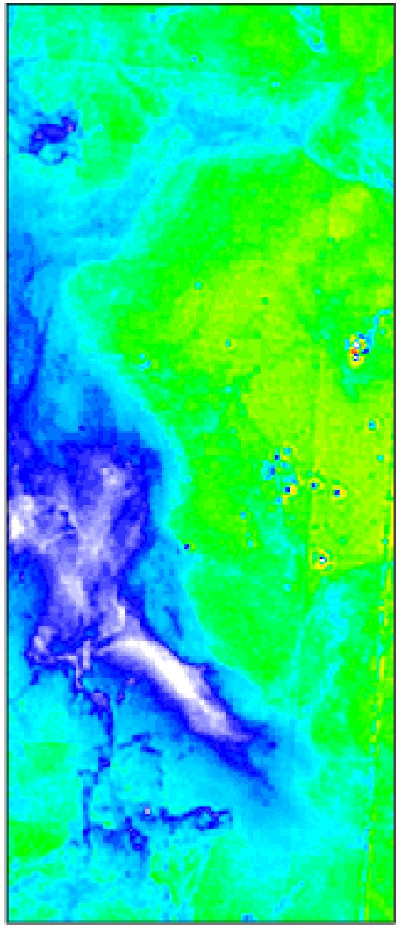
0.5 arcsecond pixels

3:1 reduction in half-power width of point source response

Isolated 24 micron point source covered by 10 images

Invocation- Run a Simple Script with Switches

hires survey_data.lis	BCD list file
mips_24_500c.fits	PSF file
-o \!survey	Output filename
-n 50 -m 25	50 iterations
-p 0.5	0.5" pixels
-w 600x2000	Output dims in arcsec
>> survey.log &	Log file



Data courtesy of Glimpse Project, University of Wisconsin

Input

File listing the BCD filenames- Fits files

PSF Fits file

Runtime options specify output image referencing, size, orientation, and resolution

Output- Fits files

Sequence of result images

Sequence of correction ratio images

Performance

Input:

Several hundred BCD images

3000 160μ images have been run.

Output:

Can run output image at 4096 x 4096 pixels.

Speed:

Driven primarily by output image size- About 5 minutes an iteration for 250 256 x 256 images on 4096 x 4096 output image. Goes with something like n log n.

Depends on RAM, and on number of CPU's, as threaded FFT's improve throughput.

Affected by psf orientation- Coaligned input images run much quicker because linearity enables convolutions of sums. 2 or 3 degrees is probably close enough.

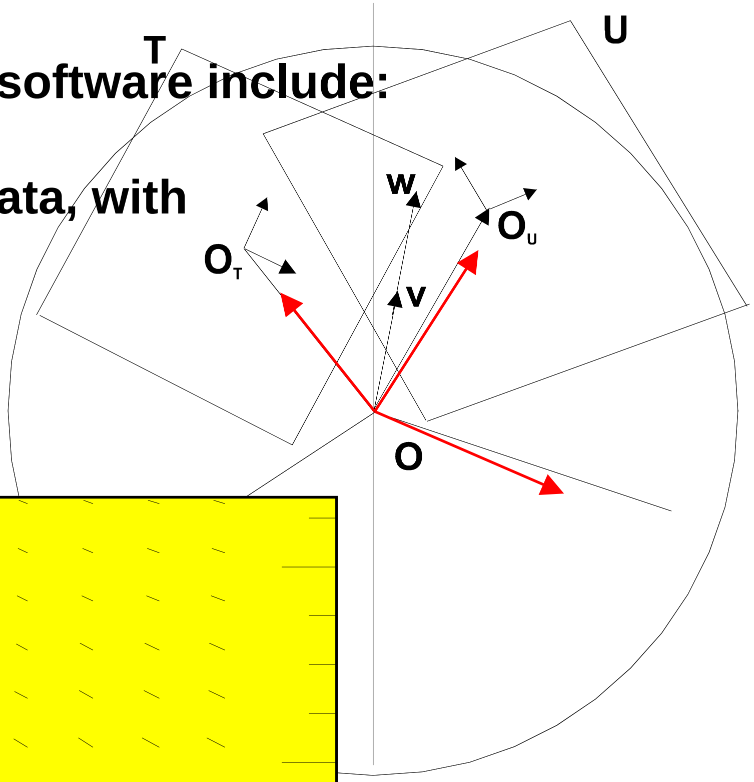
Services Performed by hires

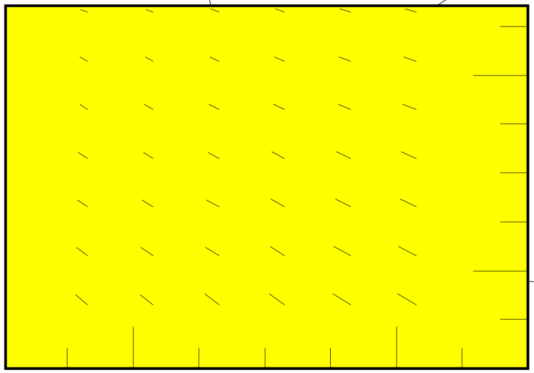
Richardson-Lucy algorithm is over 30 years old, and is not difficult to implement for a single observation image, e.g. in IDL:

```
h1 = h0*fft( n*fft( f/(n*fft( q*fft( h0 ), /inv )  )  )*q,  /inv )
```

Internal services provided by the present software include:

- **Rotation and resampling of the input data, with a fast resampling algorithm**
- **Projection calculation between adjacent tangent planes**
- **PSF rotation and resampling**
- **Distortion transformations**

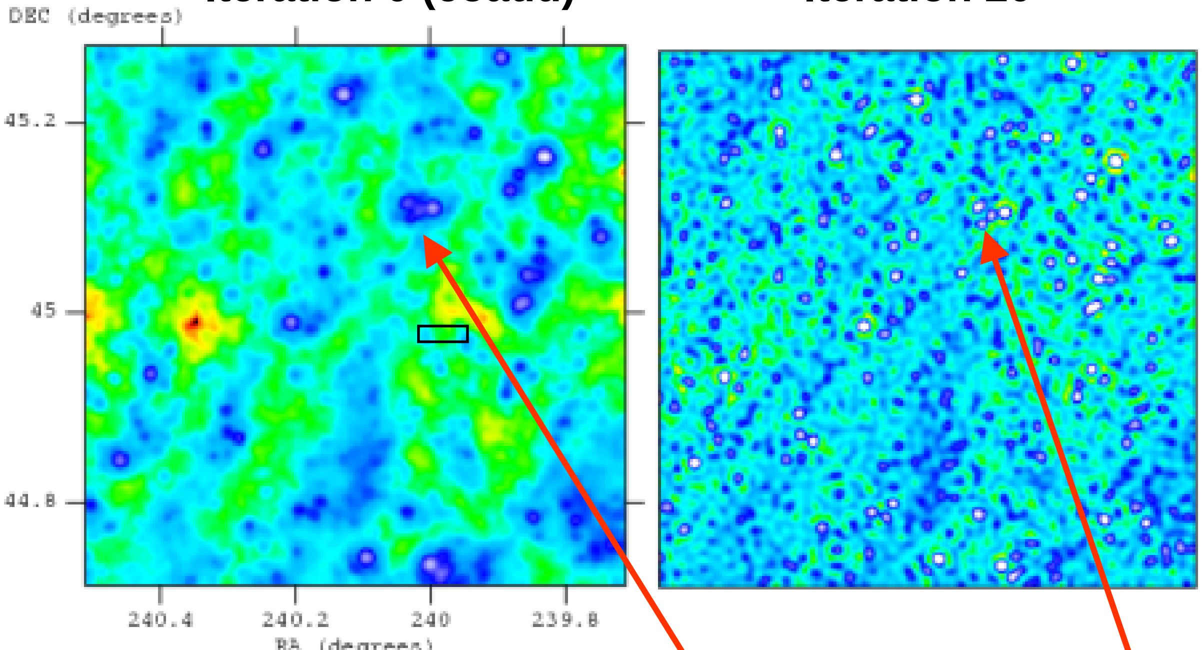


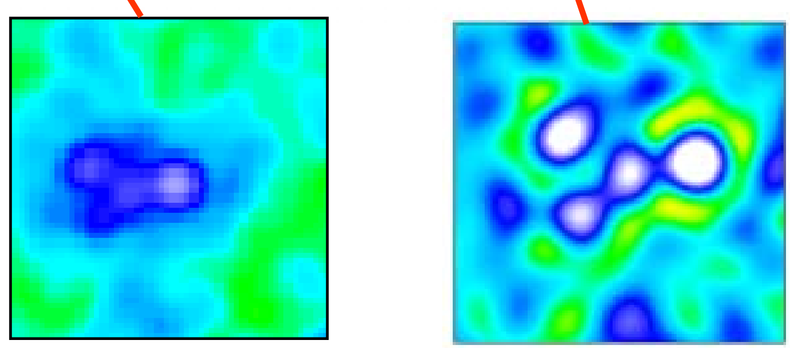


MIPS 160μm Simulation- Confusion Reduction

Pool large amount of very coarsely sampled data

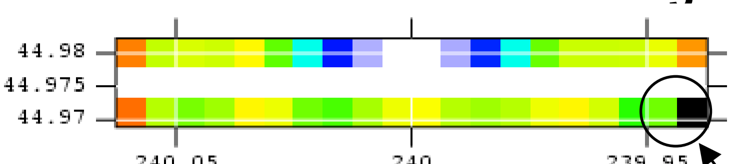
Iteration 0 (coadd) **Iteration 20**





0.6° x 0.6° field 2048 x 2048 pixels

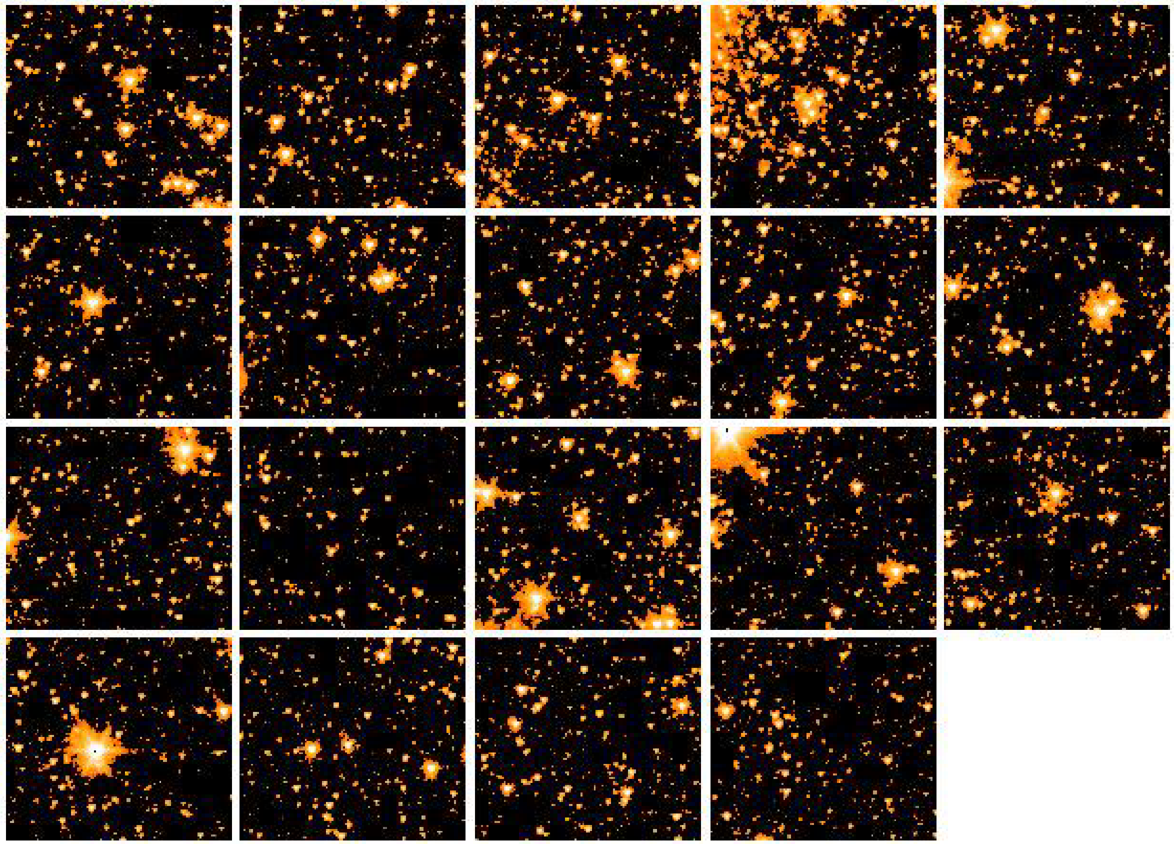
3000 BCDs double coverage



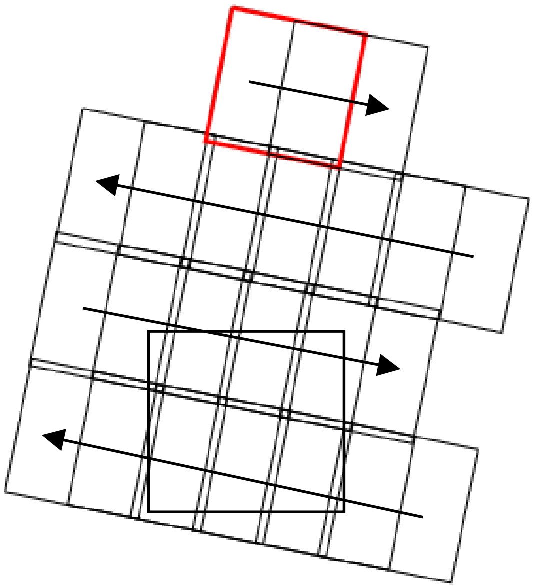
16” pixels

36” HPBW

Globular Cluster Observation Images



IRAC 3.6 microns- 256x256 1.2” pixels

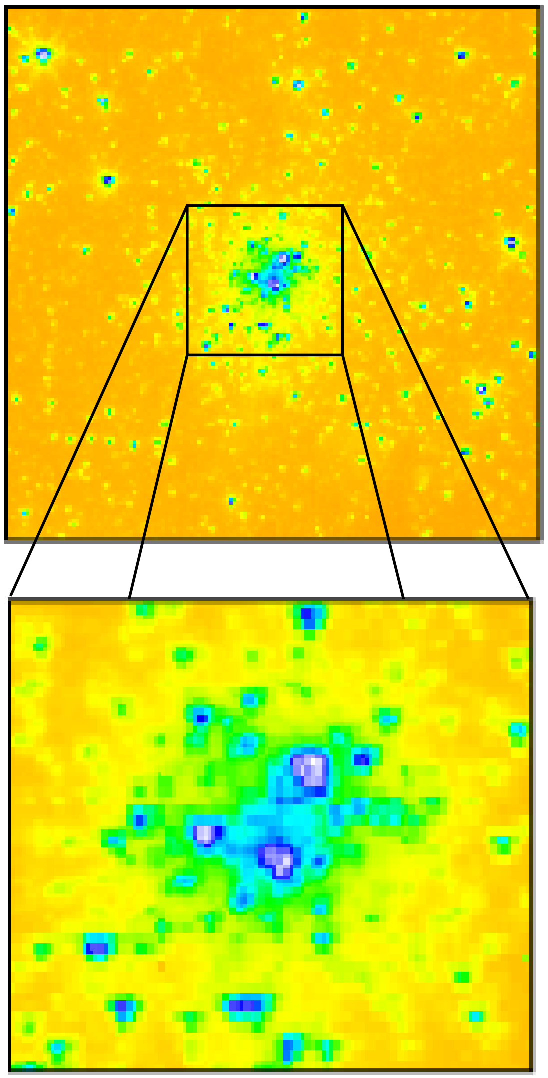


Coverage proceeds in Scan legs

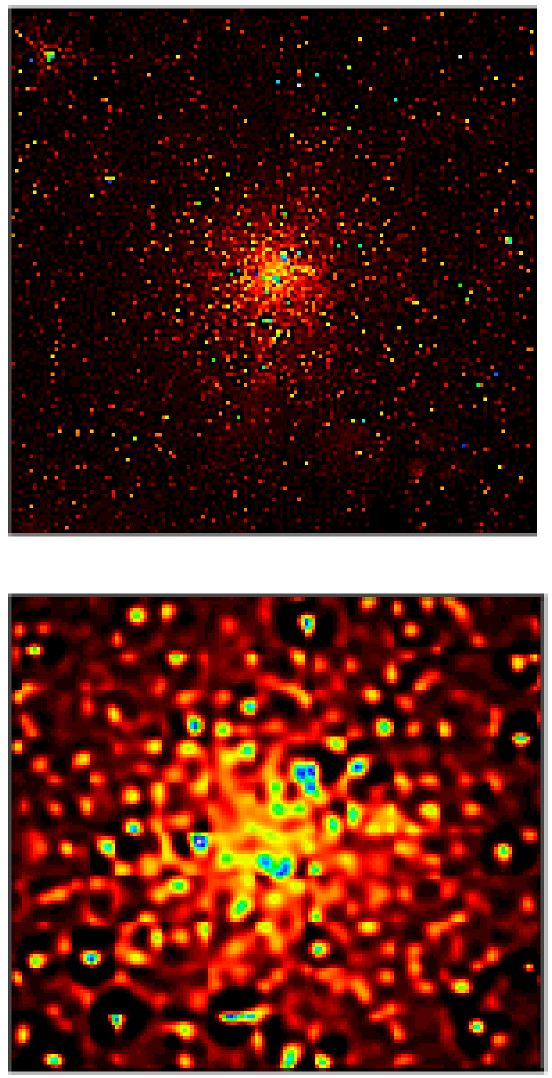
Data courtesy of Glimpse Project, University of Wisconsin

Globular Cluster with Hires

Coadd



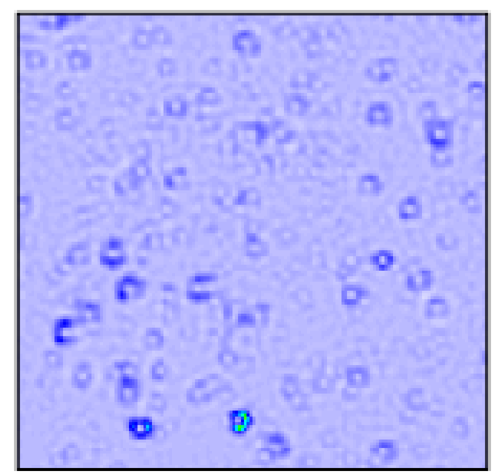
Hires



Zoom about 1 sq arcmin

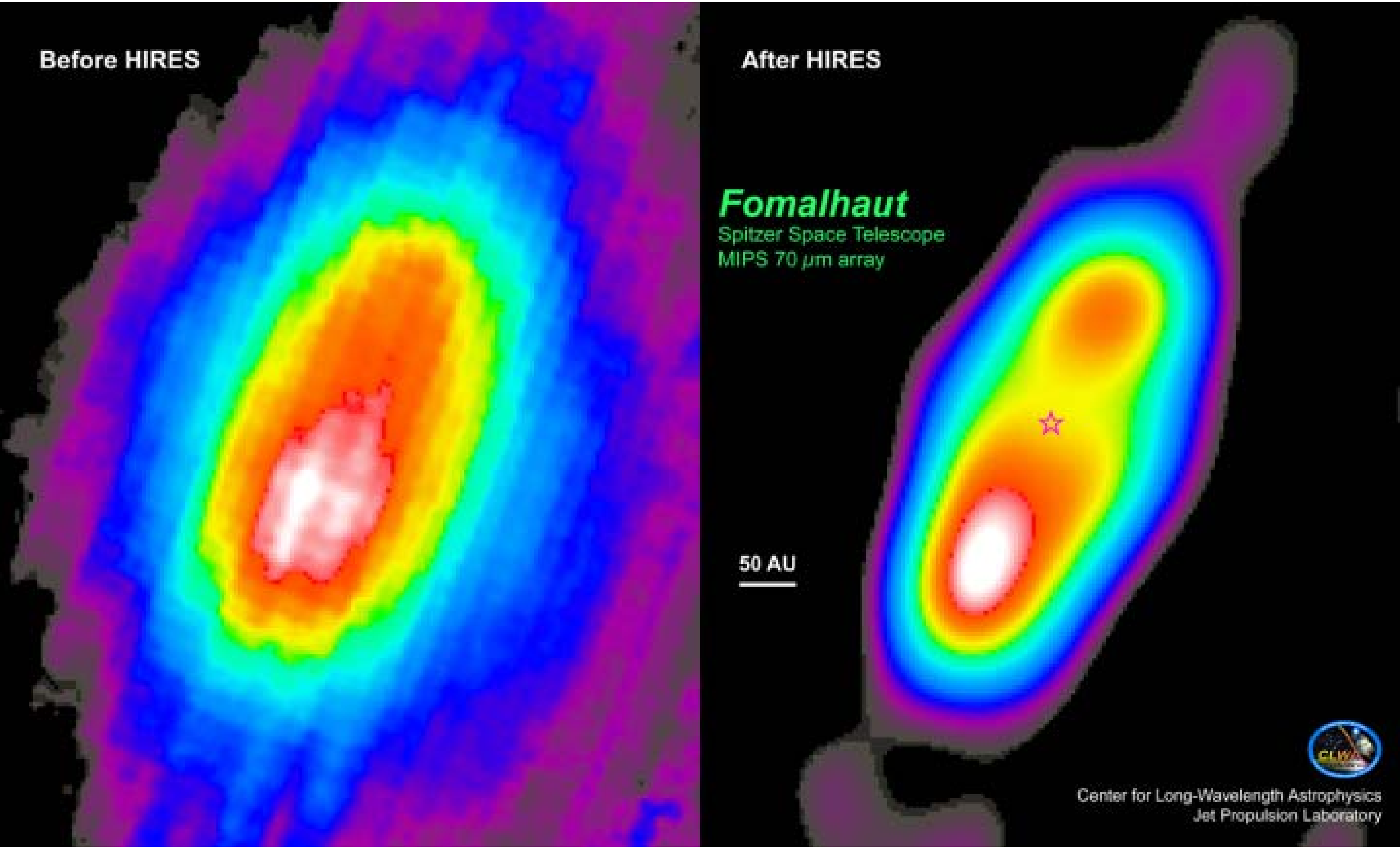
50 hires iterations

Correction factor image



Courtesy of Glimpse Project, University of Wisconsin

Fomalhaut Debris Disk



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