I. ChaRT Overview

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ChaRT (Chandra Ray Tracer) is a user friendly web interface that allows the user to simulate High Resolution Mirror Assembly (HRMA) Point Spread Functions (PSFs) at any off-axis angle and for any energy or spectrum.

http://cxc.harvard.edu/chart/

- **ChaRT provides the user with access to the best available mirror model, including many of the details of the HRMA's physical construction and a detailed model of the reflective properties of the mirror surface.**
- **ChaRT runs remotely the** *SAOsac* **set of routines (used internally at the CXC for studies and calibration of the HRMA optics).**
- **The s/w verifies and submits user's simulation parameters and notifies the user when their files are available for download via FTP.**

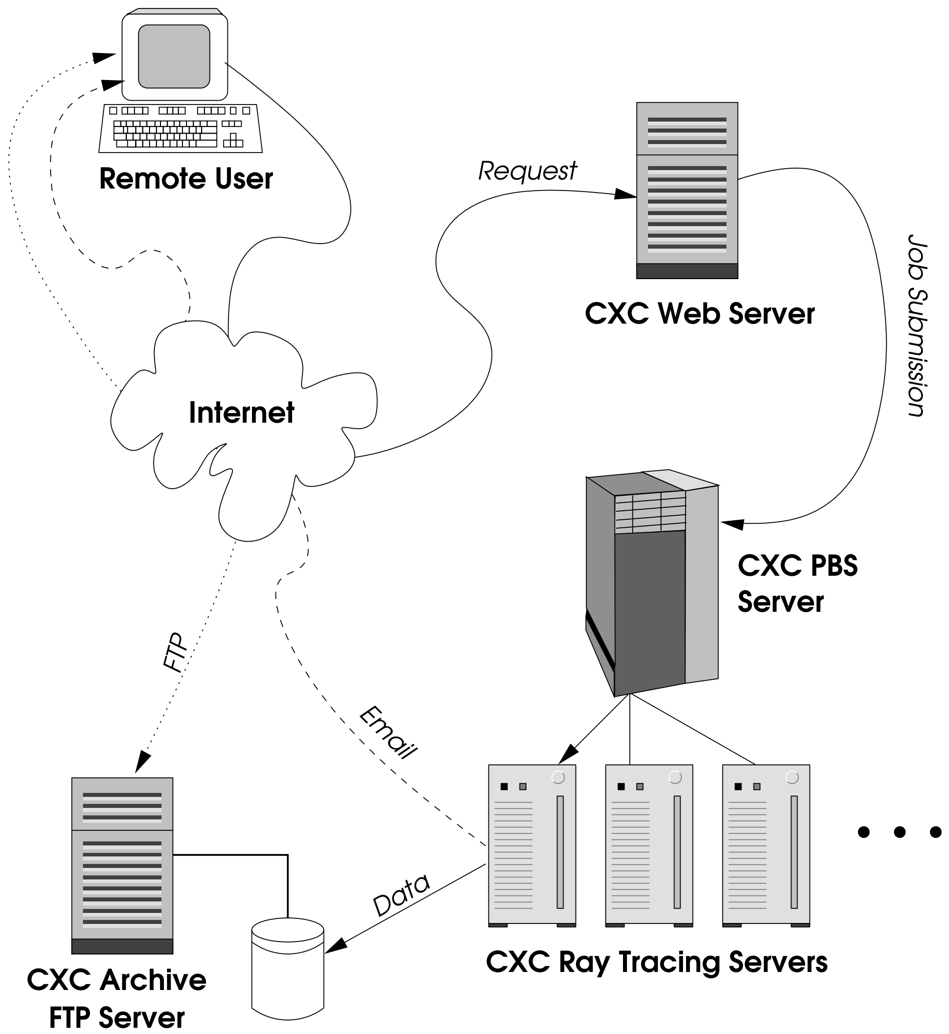

Fig. 1.— ChaRT software and hardware architecture

The output of ChaRT is a FITS table containing a collection of rays. In order to create a model PSF image it is necessary to project the rays onto the detector and take account of detector effects. This is achieved using The ChaRT rays as an input to MARX.

A set of ChaRT threads accessible from the ChaRT web page were designed to guide the user

http://cxc.harvard.edu/chart/threads

II. ChaRT Web Pages

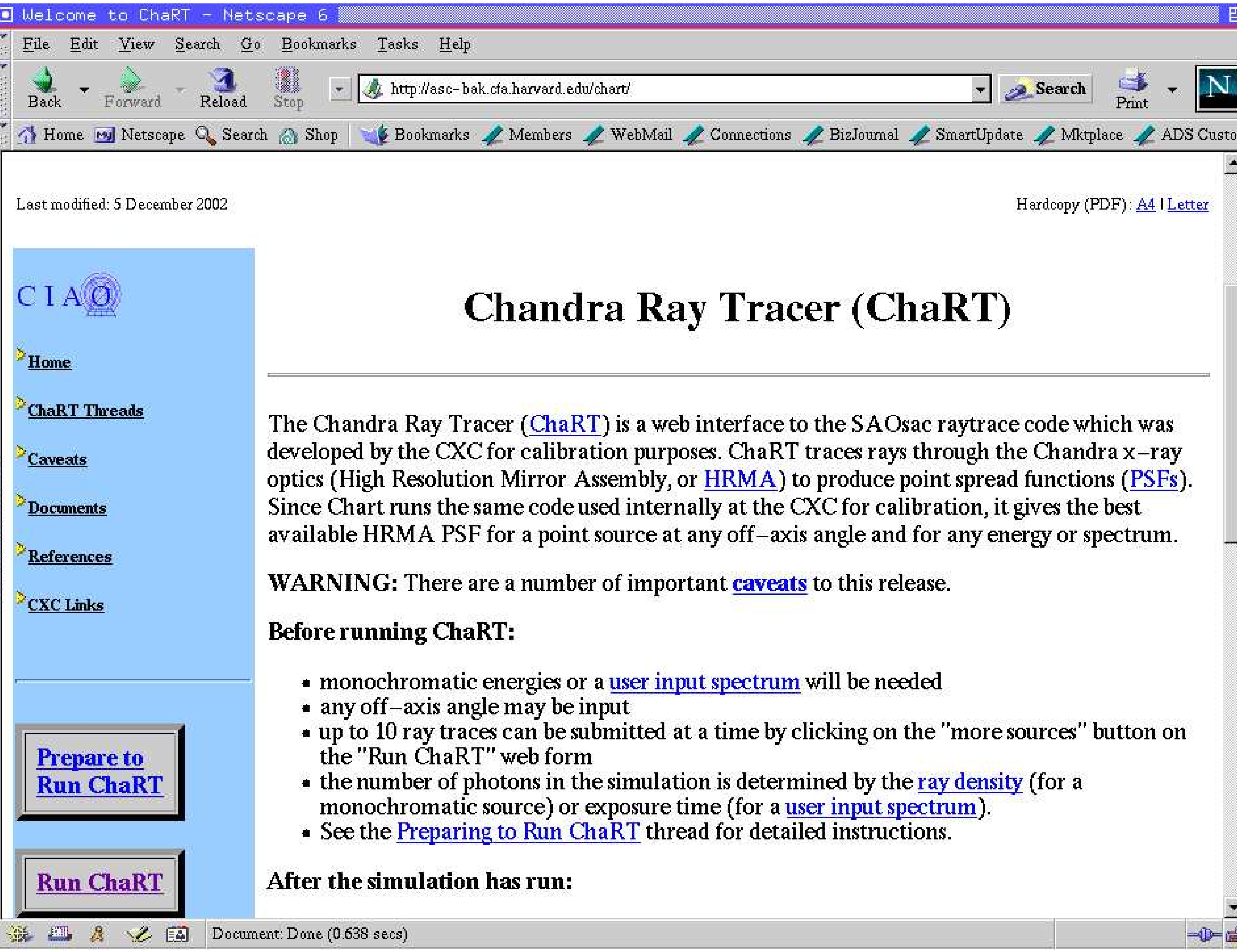

Fig. 2.— ChaRT web page - 1

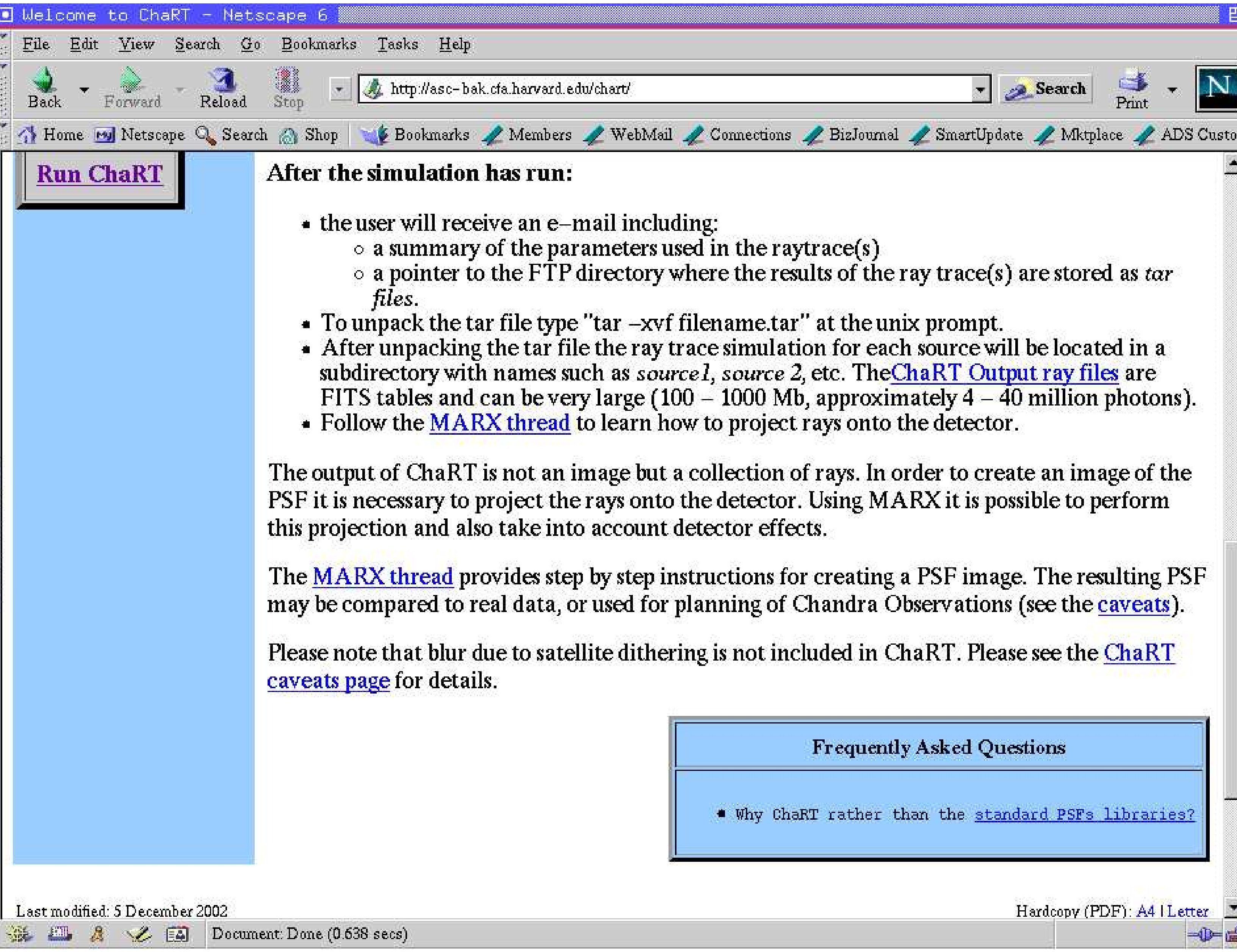

Fig. 3.— ChaRT web page - 2

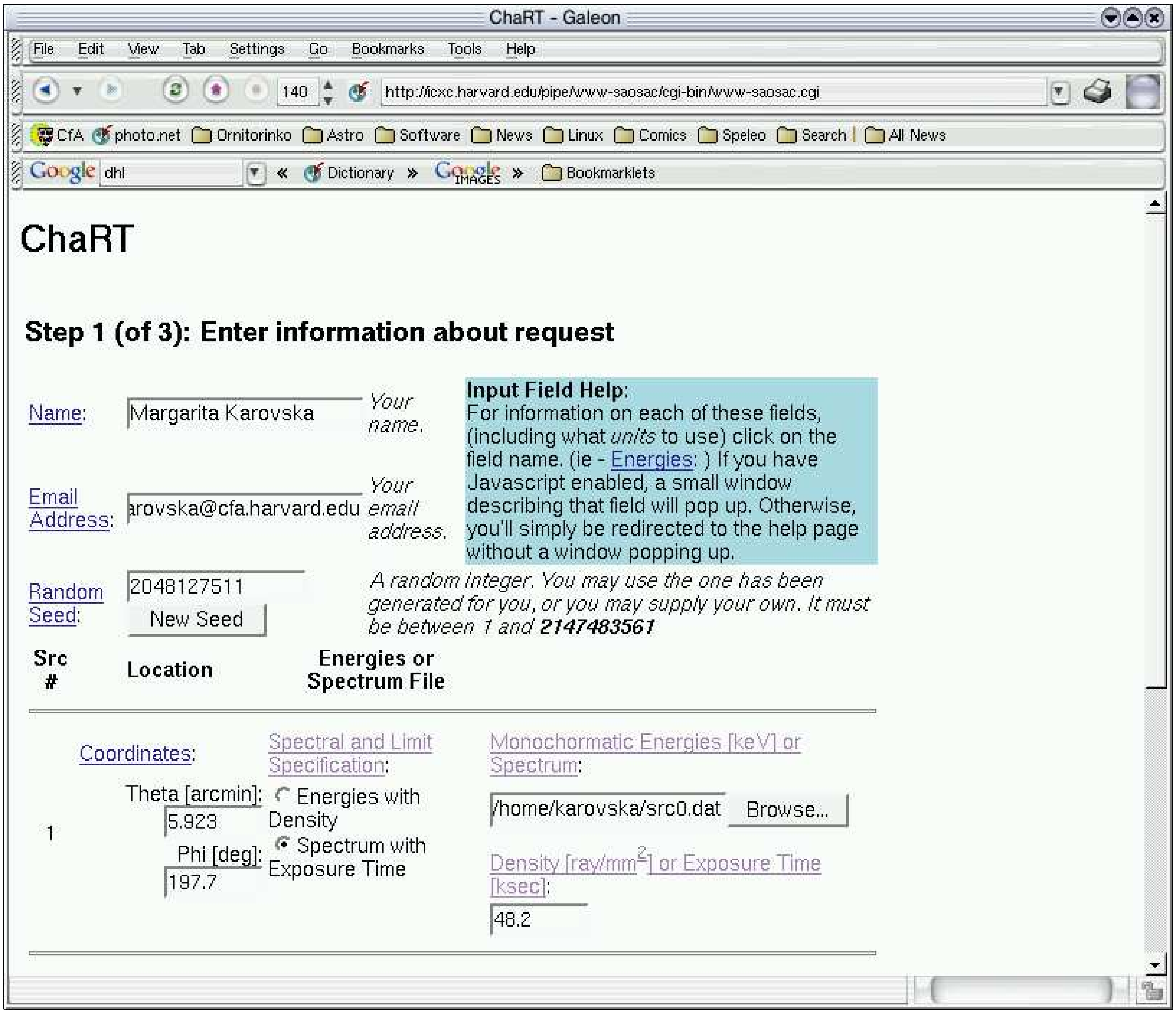

Fig. 4.— ChaRT parameter interface

```
From: ChaRT <cxc_rays@head-cfa.harvard.edu>
Message-Id: <200212122036.PAA13443@young.cfa.harvard.edu>
Content-Type: text

Your job has completed.  You may retrieve your files from our
anonymous ftp data server, where they will be stored for no more then
2 days.  Pertinent information is listed below.  Thank you.

===[ This is an automated email.   Do not respond to this address. ]===
===[ If you need help, please contact cxchelp@head-cfa.harvard.edu ]===

Host: cda.cfa.harvard.edu
Username: anonymous
Password: karovska@cfa.harvard.edu
Directory: /pub/traceftp
Filename: karovska-20021212-153643.tar.gz
File size (approx, untarred, [MiB]): 0
URL: ftp://cda.cfa.harvard.edu/pub/traceftp/karovska-20021212-153643.tar.gz
Job Parameters:

Name  = Margarita Karovska
Email  = karovska@cfa.harvard.edu
Random Seed  = 1337910590

Source 1

Coord Sys  = Theta/Phi
Theta [arcmin]  = 5.923
Phi [degree]  = 197.7
Spectrum  = src0.dat
Exp. Time [ksec] = 48.2
```

Fig. 5.— E-mail to the user

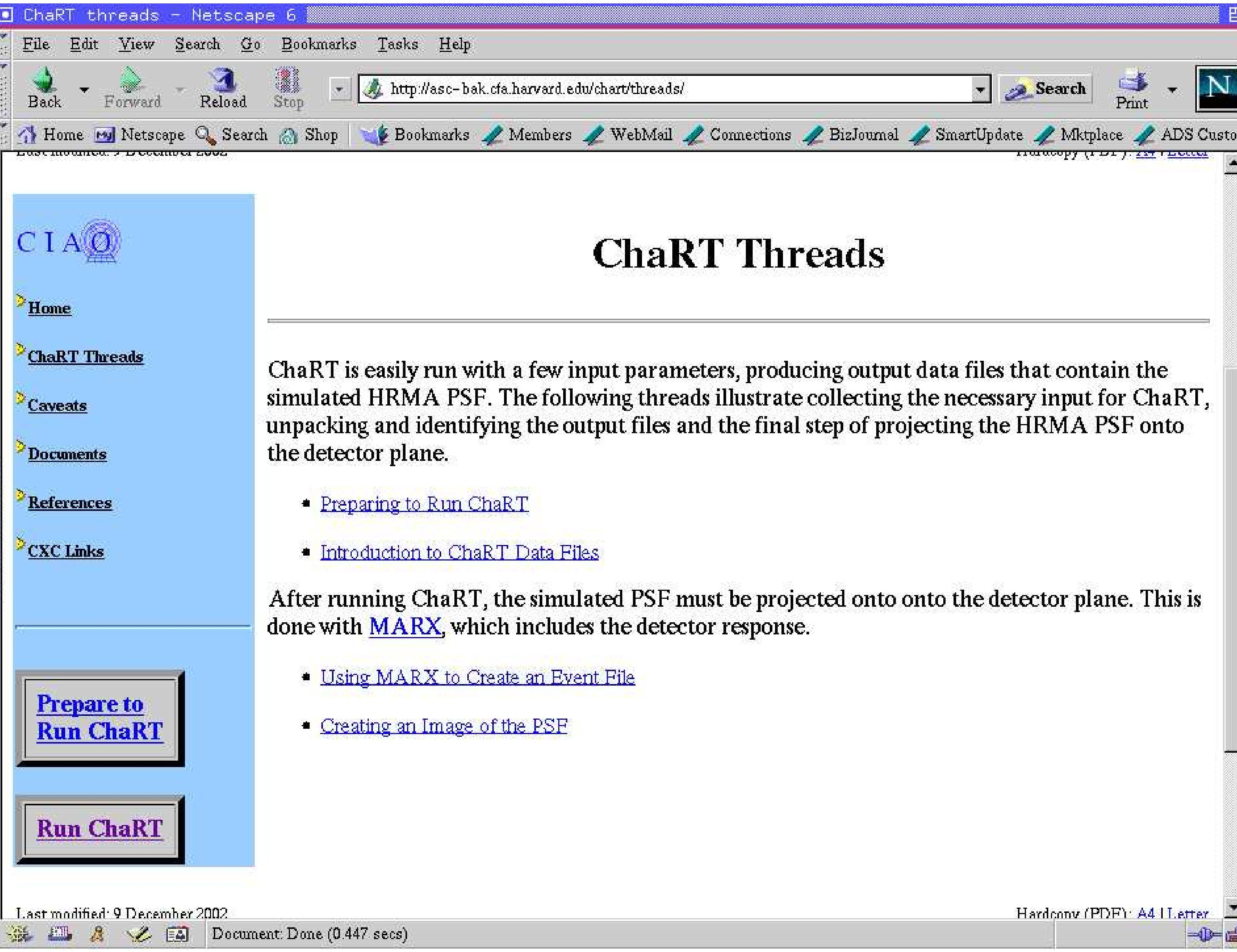

Fig. 6.— ChaRT threads

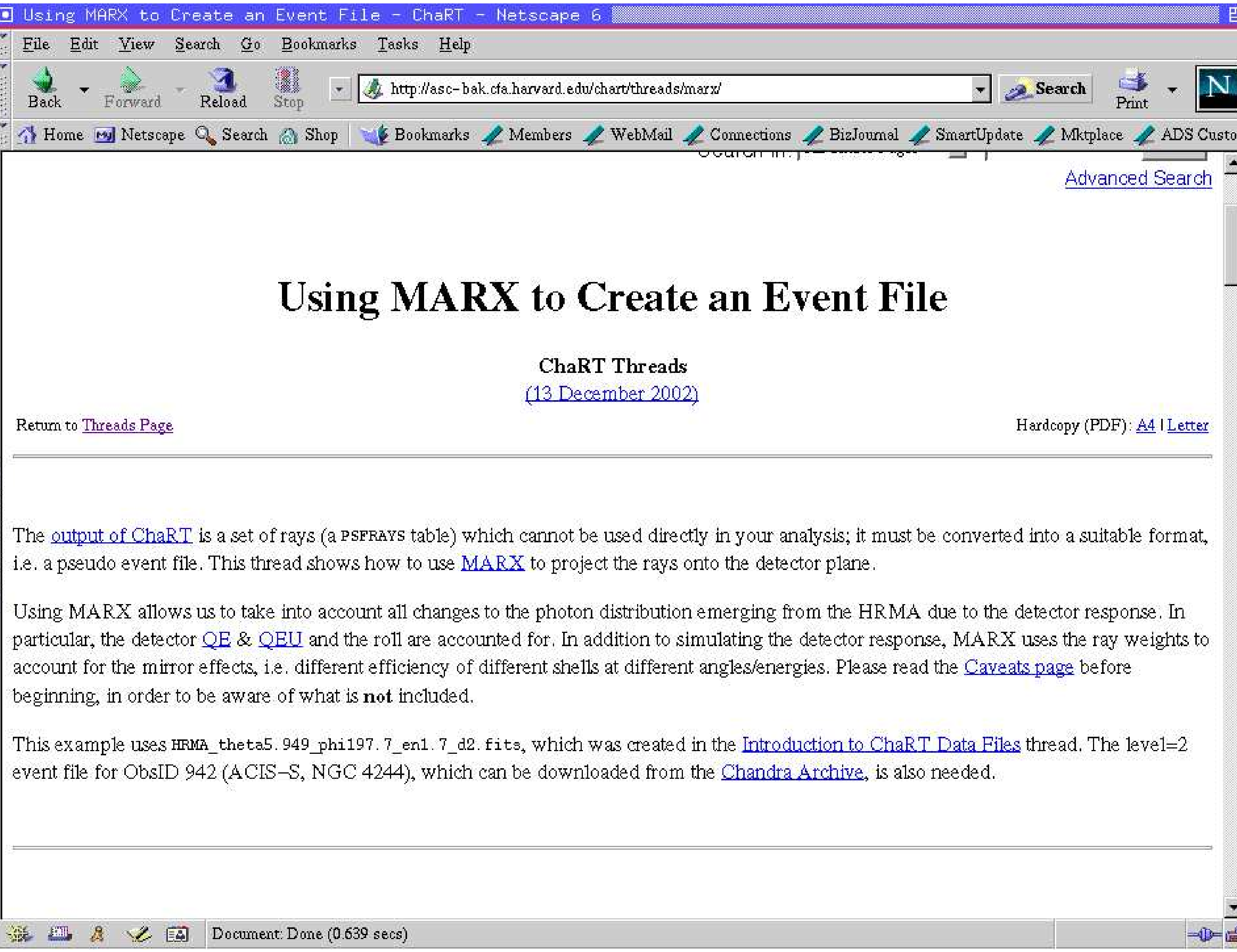

Fig. 7.— ChaRT-MARX thread

III. Examples

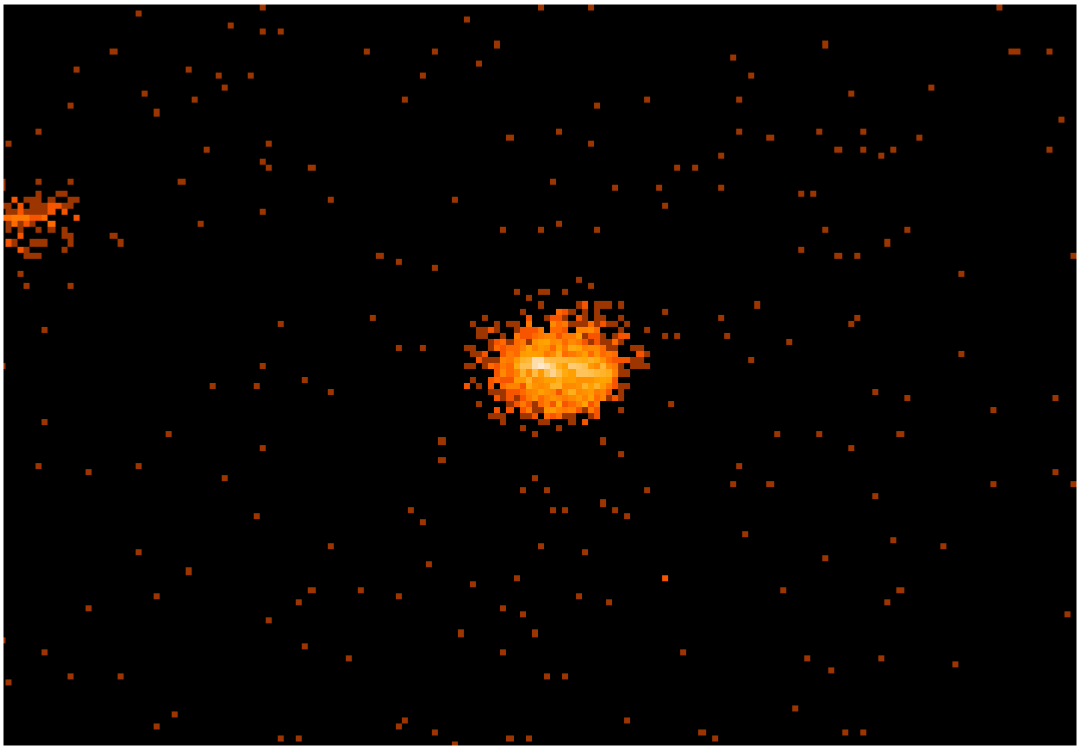

Fig. 8.— ACIS-S observation of a source at 6' off-axis angle (source 1)

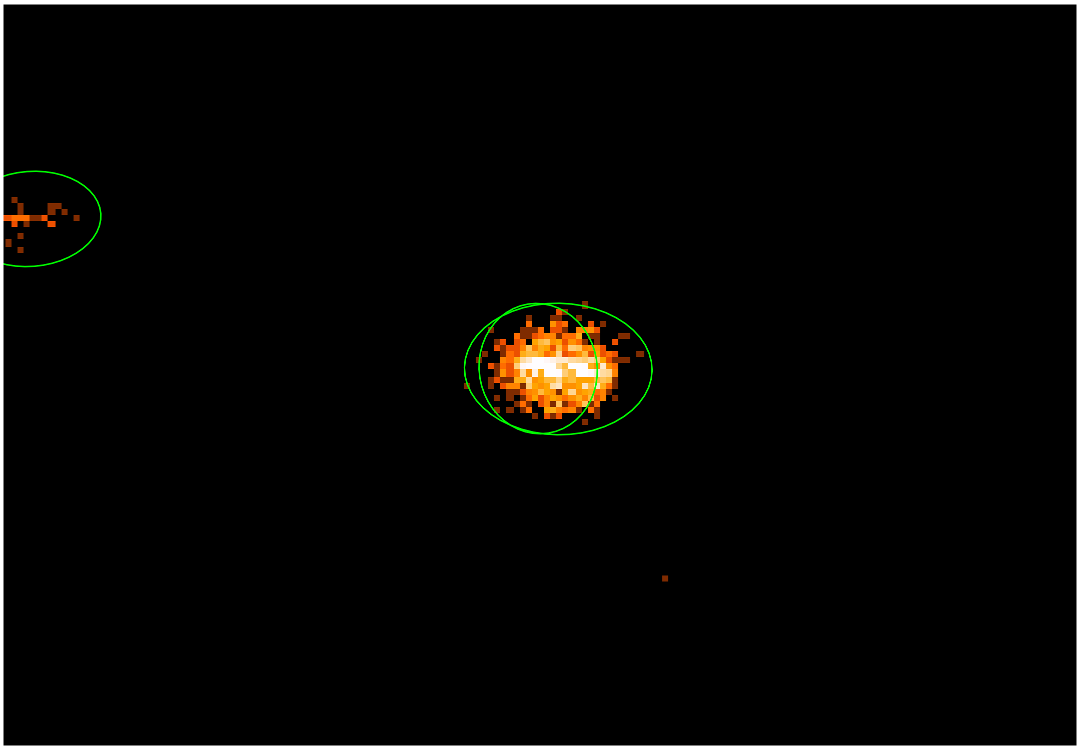

Fig. 9.— Wavedetect result for source 1

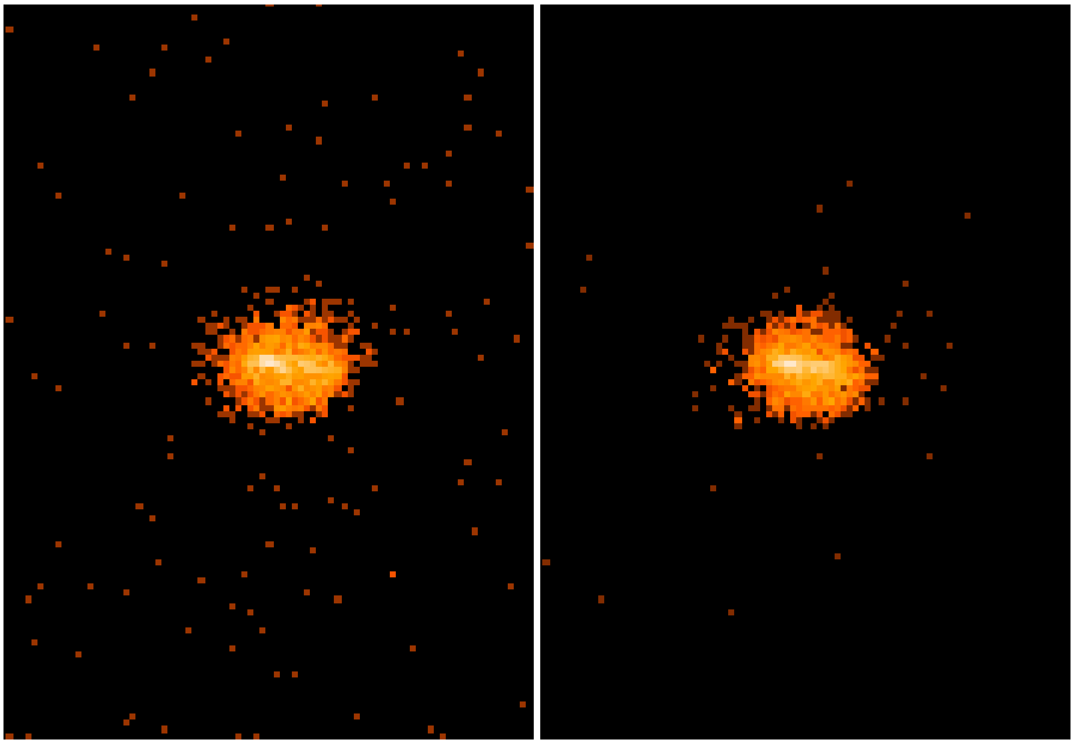

Fig. 10.— Source 1: observation vs. PSF

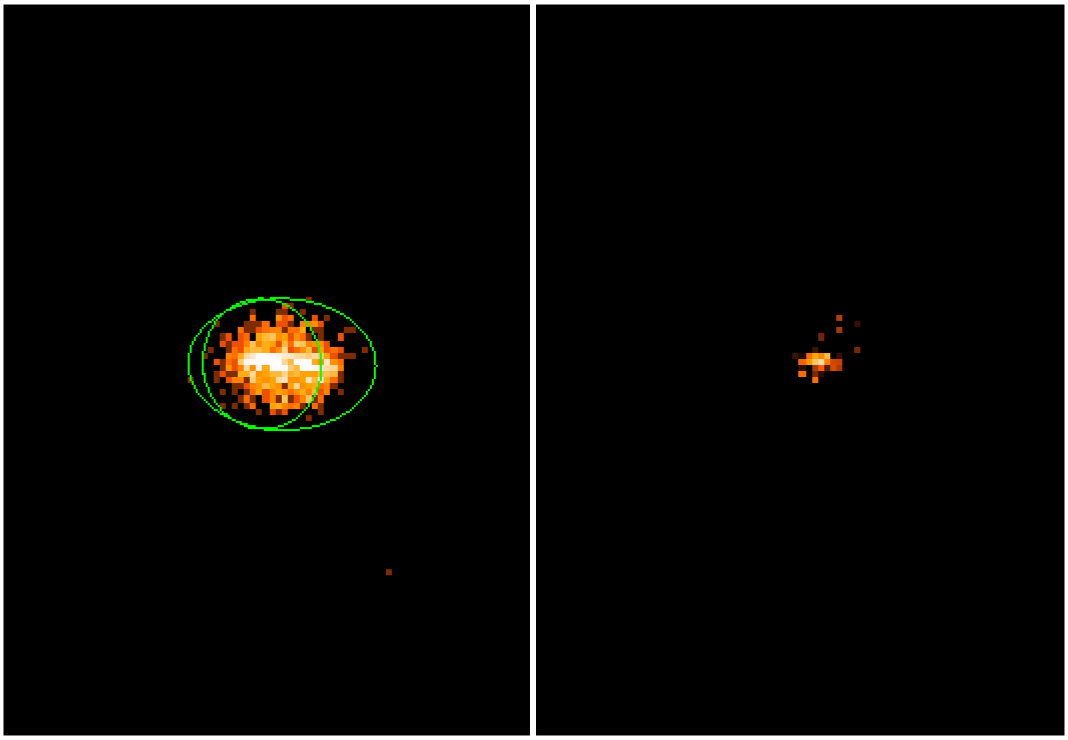

Fig. 11.— R-L deconvolution of source 1 with ChaRT PSF

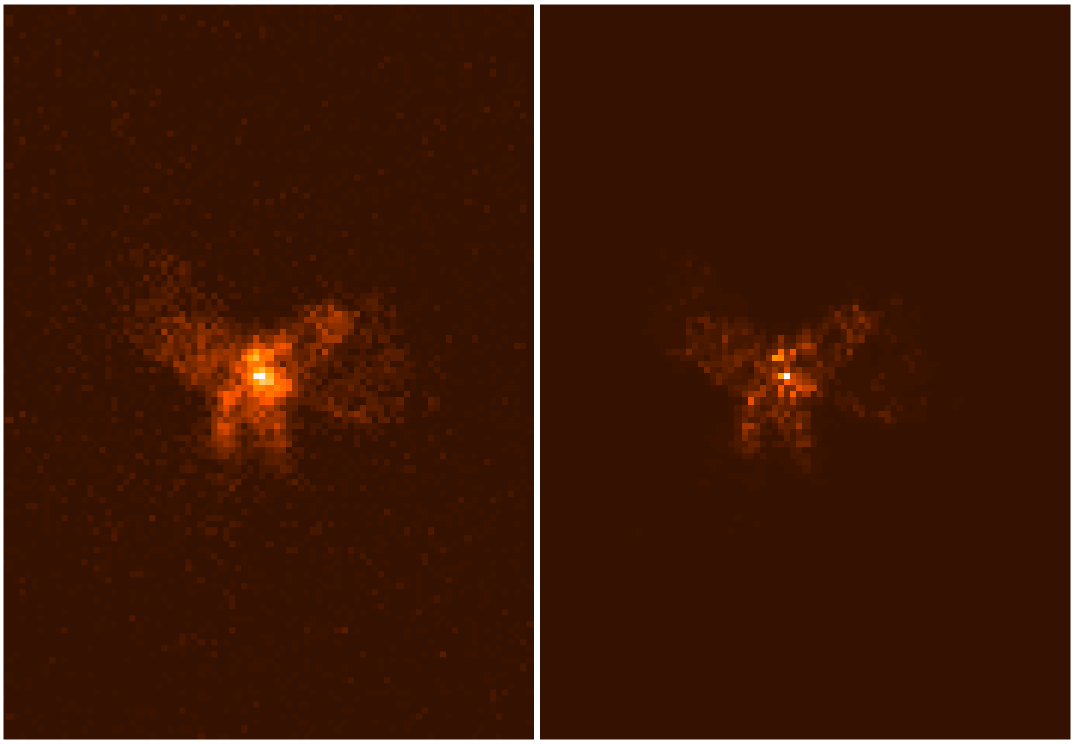

Fig. 12.— NGC6240 - galaxy with two giant black holes 2" apart: (left) original ACIS-S observation, (right)- a deconvolution using ChaRT/MARX PSF

IV. Why ChaRT rather than the standard PSFs libraries?

PSF libraries/mkpsf:

The standard PSF library files consist of 2-D simulated monochromatic PSF images "postage stamps" (only for 5 monochromatic energies ranging from 0.277 keV to 8.6 keV), made using SAOsac and projected onto ideal detector planes. They are stored in multi-dimensional FITS hypercubes with az and el steps (in telescope fixed system) of either 1 arcminute or 5 arcminutes. The user can extract a PSF model image from a library file by interpolating within the energy and off-axis angle grids, using *mkpsf*. The usage of the standard PSFs libraries (with *mkpsf*) for a detailed spatial/spectral analysis has limitations including:

- **interpolation over the coarse energy and spatial grids, especially for large off-axis angles.**
- **monochromatic energies only**
- **number of photons (rays) fixed**
- **no instrument effects included**

ChaRT

The main advantages of ChaRT include:

- **ChaRT simulates a PSF for ANY POINT on the detector and any energy (OR SPECTRUM) with no interpolation**
- **the user selects the number of photons (rays)**
- **ChaRT-MARX thread allows the user to make the best currently available model PSF for their analysis, including instrumental effects**

V. Future Development

- **adjust the limits based on users requirements (eg. No. of sources, exposure, density)**
- **include aspect simulation in SAOsac**
- **provide a set of precomputed spectral models**
- **FITS image file input as the image model**
- **canned PSFs (cashed ChaRT simulations)?**
- **usage of scripts, future of hypercubes, mkpsf (and other users suggestions)**