# A Multiwavelength Study of Cassiopeia A

## Emphasizing the Separation Between Forward and Reverse Shock Material

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## Abstract

We have performed a multiwavelength comparison of Cas A using VLA, HST, and CXO images. By separating components spectrally, we find clear associations between the emission at the three wavebands on scales of 10" to 1'. This breaks down at the 1" (.016 pc) level indicating that there is not microscopic mixing of the different temperature plasmas. We separate the emitting material into two components - shocked CSM and shocked ejecta, which show the same respective morphologies and proper motions in the different bands. In the shocked CSM, we find matched X-ray low-energy emission and optical QSFs, and X-ray continuum-dominated emission matched with filamentary radio structures. In the ejecta, as defined by X-ray and optical O, Si, and S line emission and flat-spectrum radio emission, there are large scale structures likely resulting from the explosion. There is also a great deal of material that is seen only in a single band; these show distinct kinematic structures as well. These different temperature components may represent varying density conditions and/or post-shock evolutionary states.

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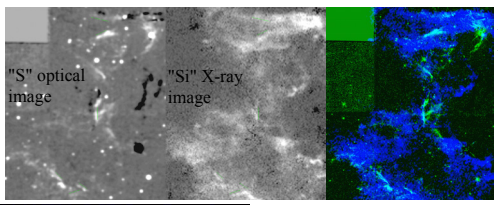
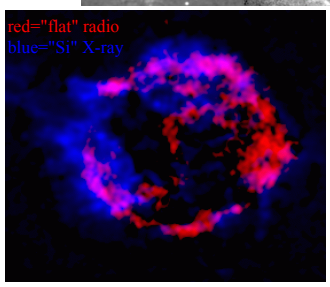
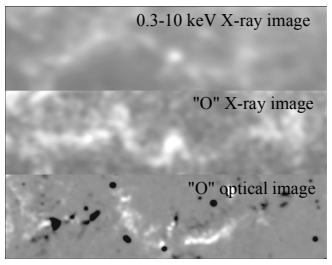
## Shocked Ejecta: Reverse Shock Material

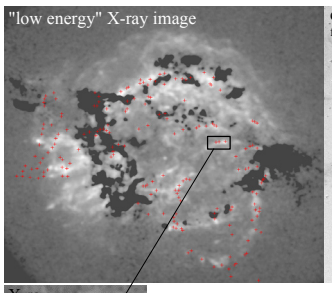


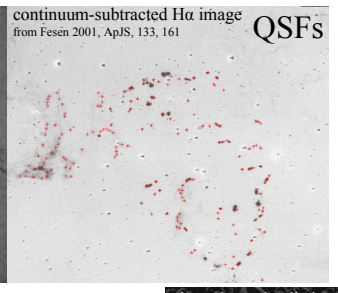

FMKs

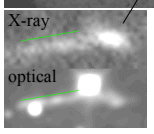



## Shocked CSM: Forward Shock Material



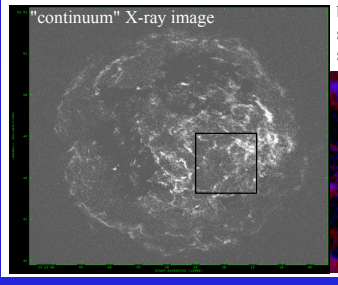



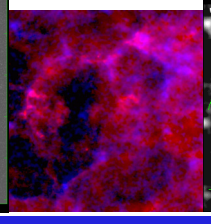



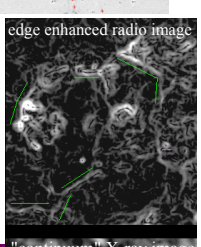

CSM2

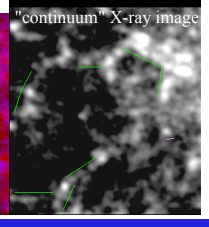
CSM1

The "continuum" X-ray emission is most likely forward shock material because it has similar spectra to the forward shock filaments.






## Spectral Component Separation

Cas A is composed of many different components each with different spectral signatures.

To understand the complex relationships in Cas A, we **must** separate the spectral structures and then compare the different wavebands. Otherwise, the task is nearly impossible.

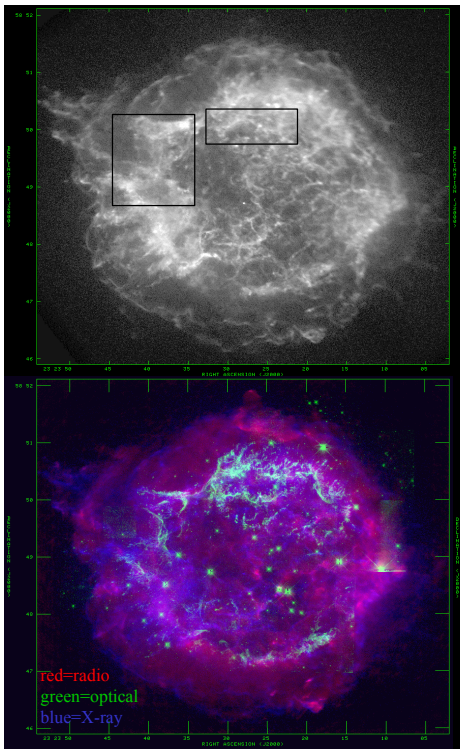
We construct a gallery of images from scaled subtractions of two input images:

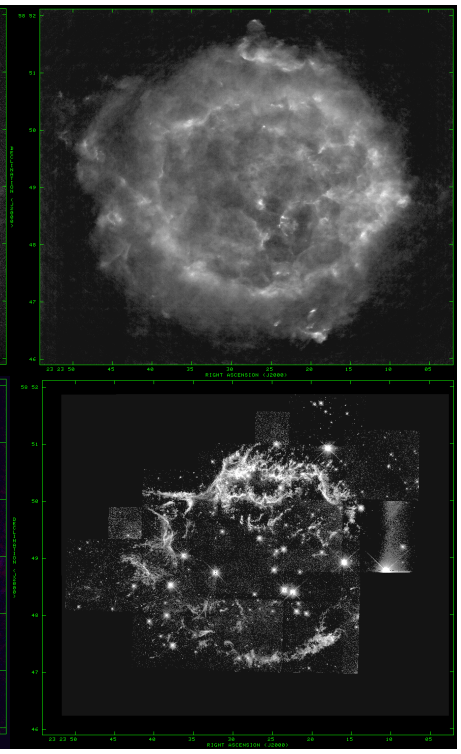
$$M_t(A)=M_1-AM_2$$

We then select the image that most represents the dominant behavior of the chosen spectral signature.

0.3-10 keV *Chandra X-ray Observatory* image
Epoch: 2000, Exposure: ACIS-S3 50 ks
Hwang et al. 2000, ApJ, 537, L122

6 cm Very Large Array image
Epoch: 2000-2001
Configurations: ABCD



## Broadband Images

*Hubble Space Telescope* WFPC2 image
Epoch: 2000, Filter: F675W
Primary Lines: SII, OII, OI, NII, Hα
Fesen et al. 2001, AJ, 122, 2644

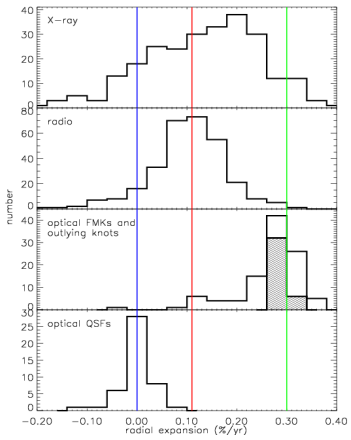
## Kinematic Analysis

Proper motions measured for 261 X-ray knots and features

The X-ray proper motions match those of clearly associated radio or optical features with published proper motions

The histograms to the right show that there are also kinematically distinct singleband X-ray, optical, and radio features

These singleband emitters may simply represent emission properties changing with time as features decelerate and/or change density




Proper motion references: FMKs: Kamper & van den Bergh 1976, ApJS, 32, 351; QSFs: van den Bergh & Kamper 1985, ApJ, 293, 537
optical outlying knots: Thorstensen et al. 2001, AJ, 122, 297; radio: Anderson & Rudnick 1995, ApJ, 441, 307

## Summary

### Emission Components in Cas A

| Type | X-ray | Optical | Radio | Nature | Kinematics |
|---|---|---|---|---|---|
| Ejecta | strong lines (Si) | FMKs | flat spectrum | dense shocked ejecta | 0.2-0.35 %/yr |
| CSM1 | continuum | -- | filaments, edges | diffuse shocked CSM | 0.05-0.25 %/yr |
| CSM2 | enhanced low energy | QSFs | -- | dense shocked CSM | -0.05-0.05 %/yr |