

# Spectacular Results from Recent Spitzer Observations of Cas A

Tracey DeLaney (CfA)

P. I. Larry Rudnick (Minnesota)

Jessica Ennis (Minnesota)

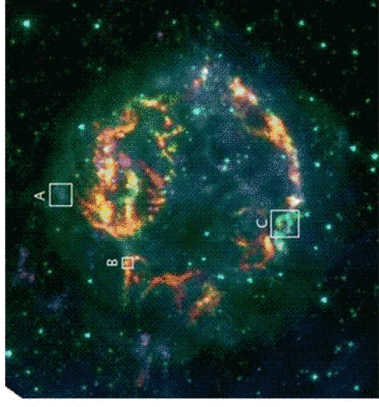
JD Smith (Arizona)

Jeonghee Rho (Caltech/SSC)

Bill Reach (Caltech/SSC)

Takashi Kozasa (Hokkaido)

Haley Gomez (Cardiff)



IRAC 3-color



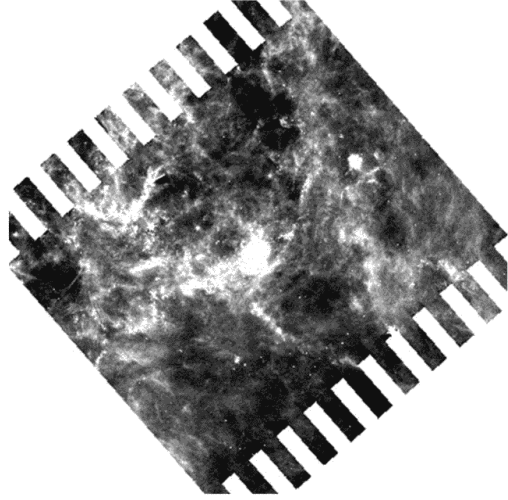
KITP 10 Feb 2006

## Outline

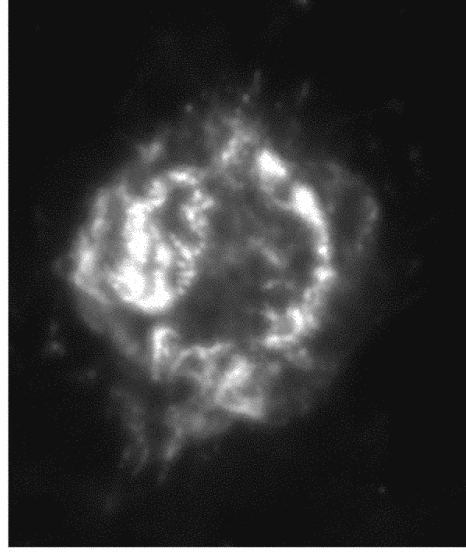
1. 24 micron image (Hines et al 2004) – jets
2. Light echoes (Krause et al 2004) – something funny
3. Our observations – IRAC, IRS
4. Once-shocked ejecta – composition, dynamics
5. Possible progenitor wind shell
6. Bipolar Ne-rich outflow – Doppler mapping, 3D structure
7. Spectral index – curvature, shock modification
8. Dust/Nucleosynthesis – J. Ennis poster

KITP 10 Feb 2006

# 24 micron, MIPS



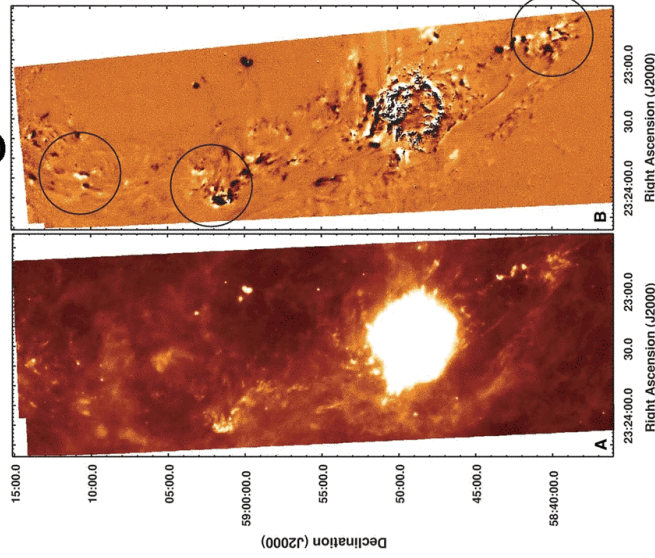
Lots of ISM structure  
Most not related to Cas A



Mostly dust emission  
Lines of [FeII] and [OIV]  
Look, a counterjet!

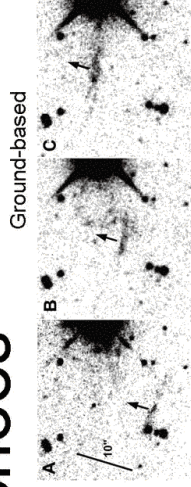
KITP 10 Feb 2006

# Light Echoes



MIPS 24 micron

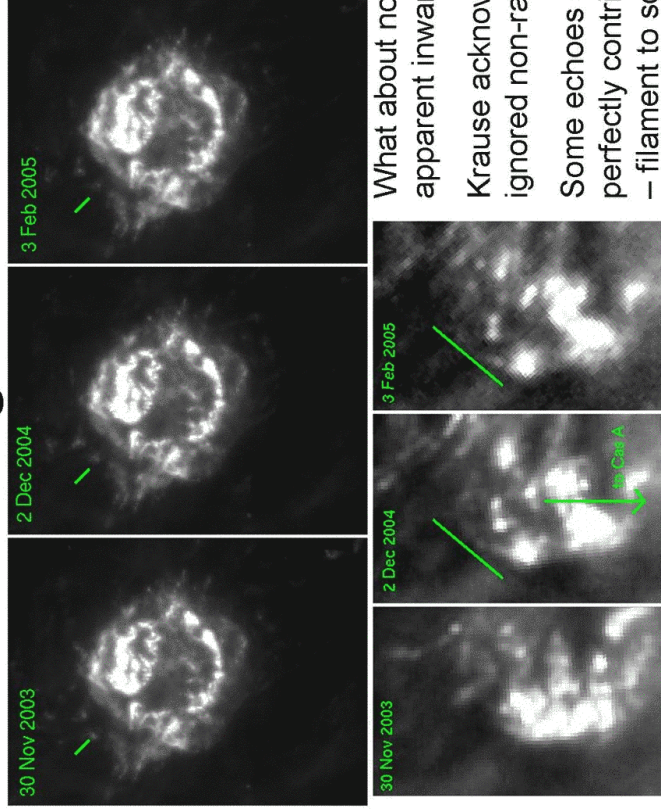
KITP 10 Feb 2006



Apparent proper motions with  $v \sim c$   
Interstellar dust is heated by the explosion and by short duration (few weeks) episodic flares from the CCO, possibly beamed  
Echoes are due to re-radiation, N and S "lobes" are in the plane of the sky and due to outburst in 1953

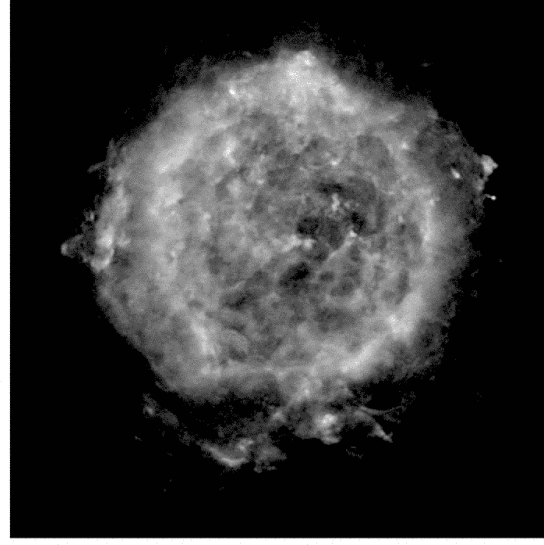
Momentarily quiescent SGR  
But something's funny here!

# Light Echoes



What about non-radial and apparent inward motions?  
 Krause acknowledged and ignored non-radial motions  
 Some echoes seem to require perfectly contrived ISM structures – filament to south

# Light Echoes



Radio knot to south used as evidence of outburst of relativistic particles from CCO moving at 0.6c – but not moving and where is counterpart to north?

KITP 10 Feb 2006

# Observations

Broadband observations in the 4 IRAC bands

3.6, 4.5, 5.7, 8 microns

1.2 arcsec spatial resolution

Spectral mapping with IRS

~5-40 microns, low resolution spectra

spatial resolution ~2 and ~6 arcsec

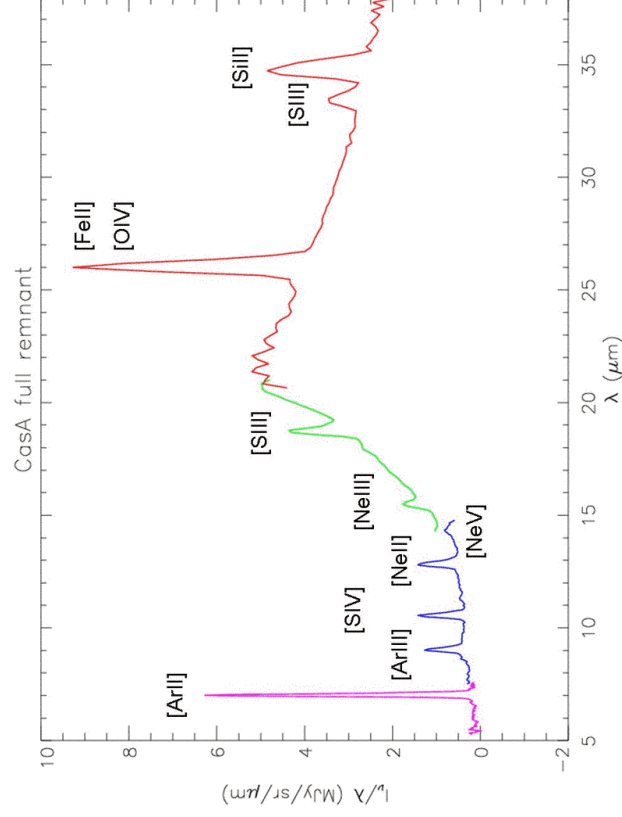
required over 1200 pointings for SL mapping

largest spectral mapping with Spitzer to date - CUBISM

Selected spectra of outlying blobs from MIPS

KITP 10 Feb 2006

## Global IR Spectrum



KITP 10 Feb 2006

## Once-Shocked Ejecta

Combined line image of Ar, Ne, S, Si

Emission at center from Si, S, Fe – once-shocked (unshocked) ejecta

No associated dust component

Photo-ionized by X-ray and UV emission from twice-shocked ejecta (e. g. Hamilton et al 1997)

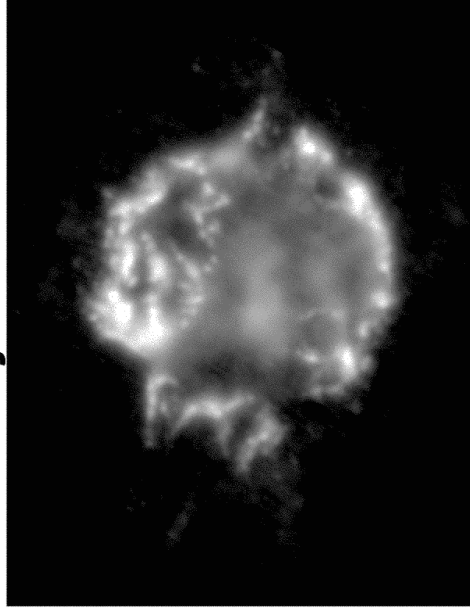
Two [SIII] lines to use as density indicator

Same lines observed in PWN of 0540-693 in LMC (Reynolds AAS)

Hidden PWN?

Stromgren Sphere around pulsar?

KITP 10 Feb 2006



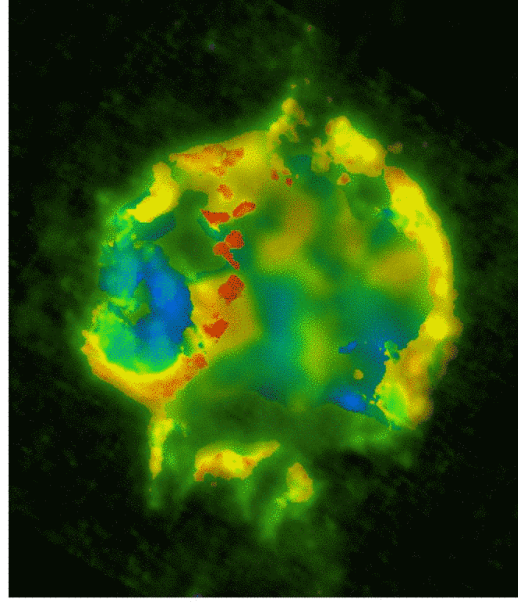
## Once-Shocked ejecta

Red=6000 km/s

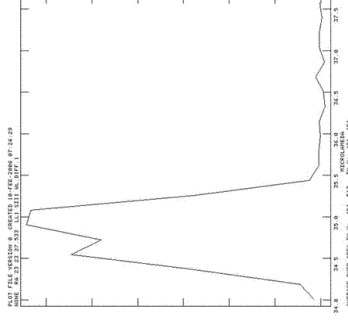
Blue=-3000 km/s

Doppler structure of once-shocked ejecta may be used to determine explosion geometry

Current best guess – cavity – front and back edge

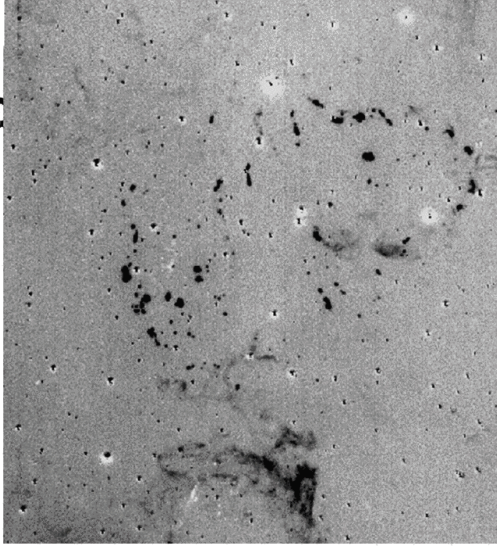


Doppler image using [ArIII], [SIII]

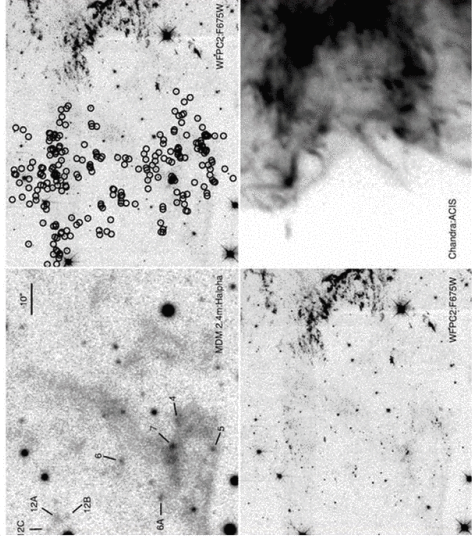


KITP 10 Feb 2006

# Progenitor Wind



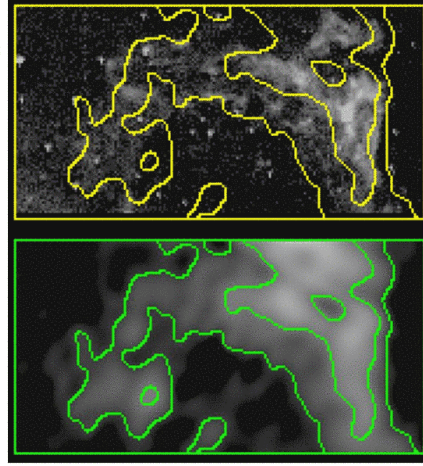
Fesen 2001  
H $\alpha$ +NII]



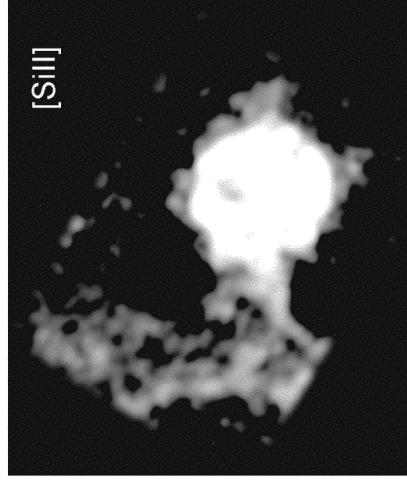
location of outer ejecta to east  
(Fesen, this conference)

KITP 10 Feb 2006

# Progenitor Wind



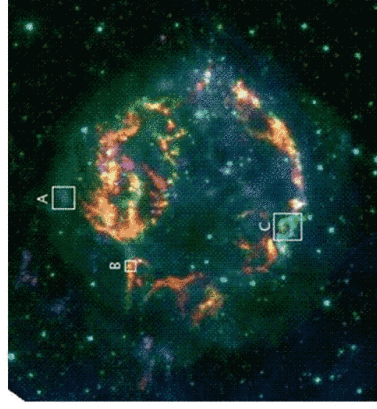
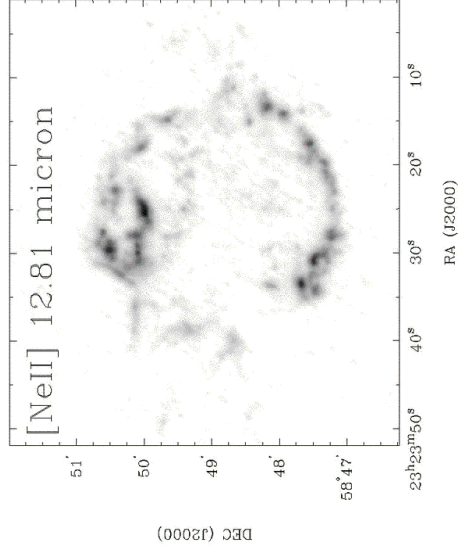
Association of [SIII] (left) with  
H $\alpha$  cloud (right)



Possible wind shell seen in [SIII],  
[SIII], [NIII]  
Ratios of these lines vary –  
temp/density

KITP 10 Feb 2006

## Bipolar Ne-rich Material

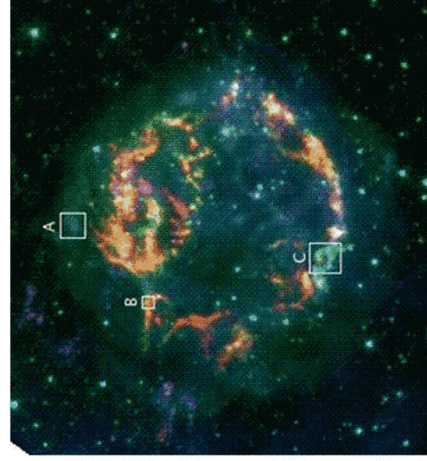


IRAC 3-color, Ne-rich=green

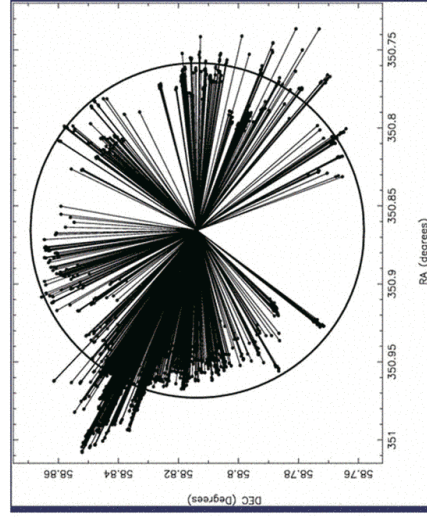
Ne appears in most locations around remnant where other IR ejecta reside  
To the north and south – Ne-rich emission (with O) – or perhaps merely absence of other ejecta – South is “hole” in the X-ray/optical

KITP 10 Feb 2006

## Bipolar Ne-rich Material



IRAC 3-color

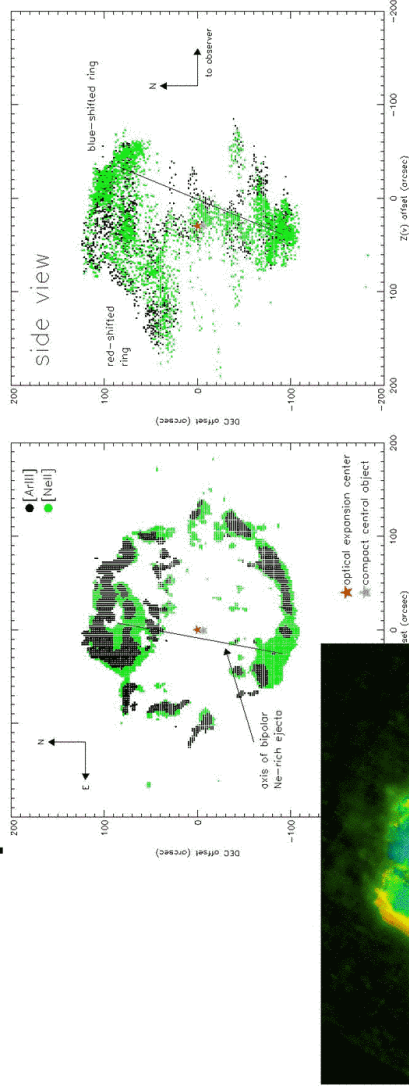


Distribution of outer optical knots (Fesen)

Possible association with outer ejecta “gaps”?

KITP 10 Feb 2006

## Bipolar Ne-rich Material



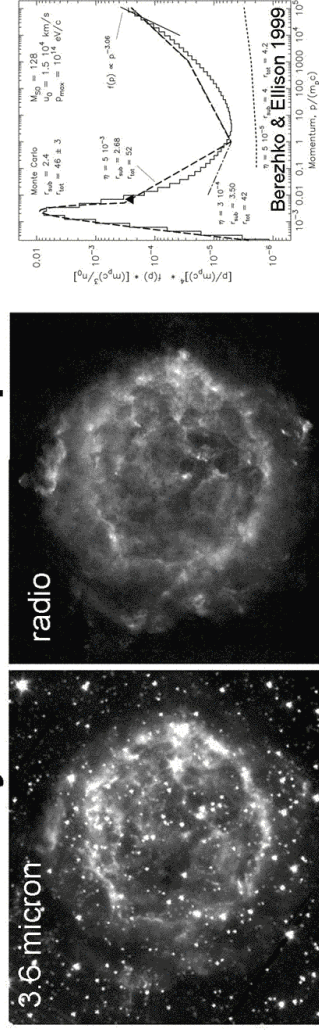
Perpendicular to jet

Parallel to inferred CCO proper motion

Doppler velocities opposite to X-ray Fe

KITP 10 Feb 2006

## Synchrotron Spectrum



IRAC Ch1 (3.6 micron) is dominated by synchrotron

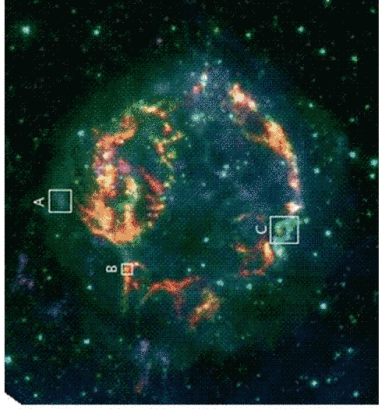
Spectral index measurements to radio image can be used to determine concave curvature and constrain shock modification models

Preliminary measurements show spectral index flattening by 0.05 to 0.1 compared to radio values

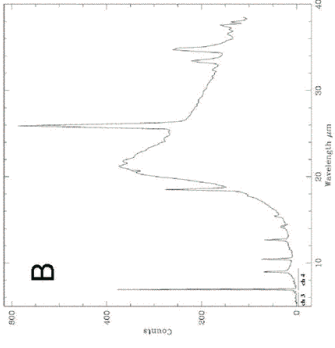
KITP 10 Feb 2006



# Dust/Nucleosynthesis



*Peak near 21  $\mu$ m from  $\text{SiO}_2$ (am), Mg silicates, and FeO*

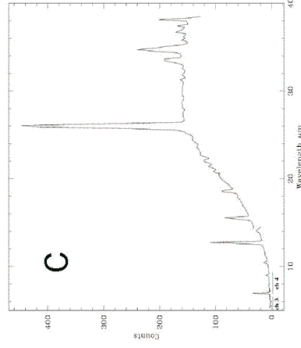


Dust composition changes, but temperature doesn't

Specific lines coupled to dust composition

Seeing different nucleosynthetic layers from progenitor

*Long-wavelength continuum-dominated by  $\text{Al}_2\text{O}_3$ ,*



KITP 10 Feb 2006