Far-Infrared Polarization and Dust Properties of Cas A using SOFIA HAWC+

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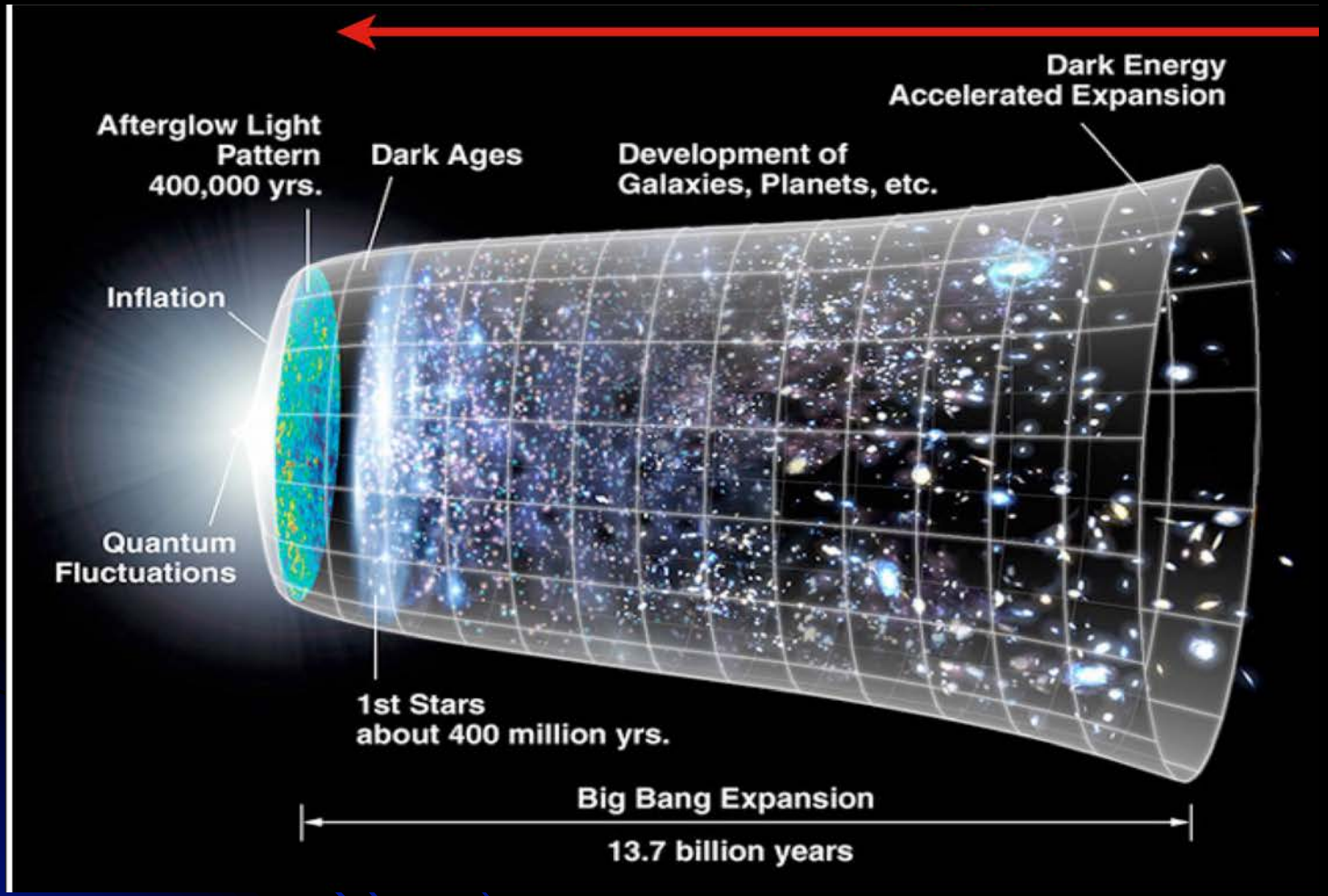
Mystery of Dust in the early Universe

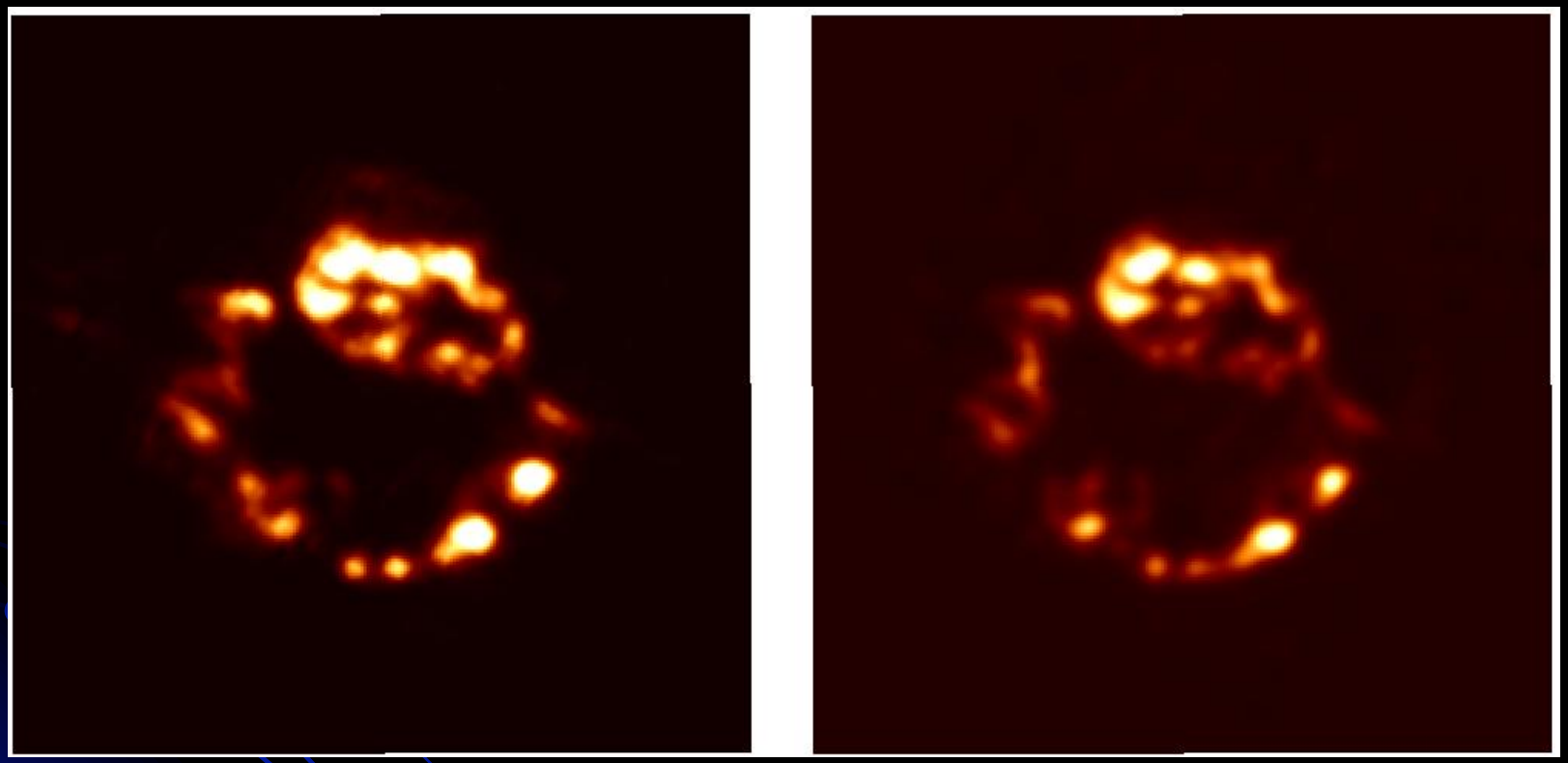


Cosmic Dust Rocks

- After Big Bang, the first stars are born and die as supernovae.
- A huge amount of dust is observed in high red-shifted galaxies
- The early Universe was too young for the well-known dust source of the evolved stars to exist. Where does the dust come from?

Cas A: Dust forms in Ejecta

Did dust grains form in the SN ejecta? pre-SN dust or ISM swept up dust



Dust (including Silica)

Ejecta (Ar)

Why Polarization?

letters to nature

No cold dust within the supernova remnant Cassiopeia A

350 yr old

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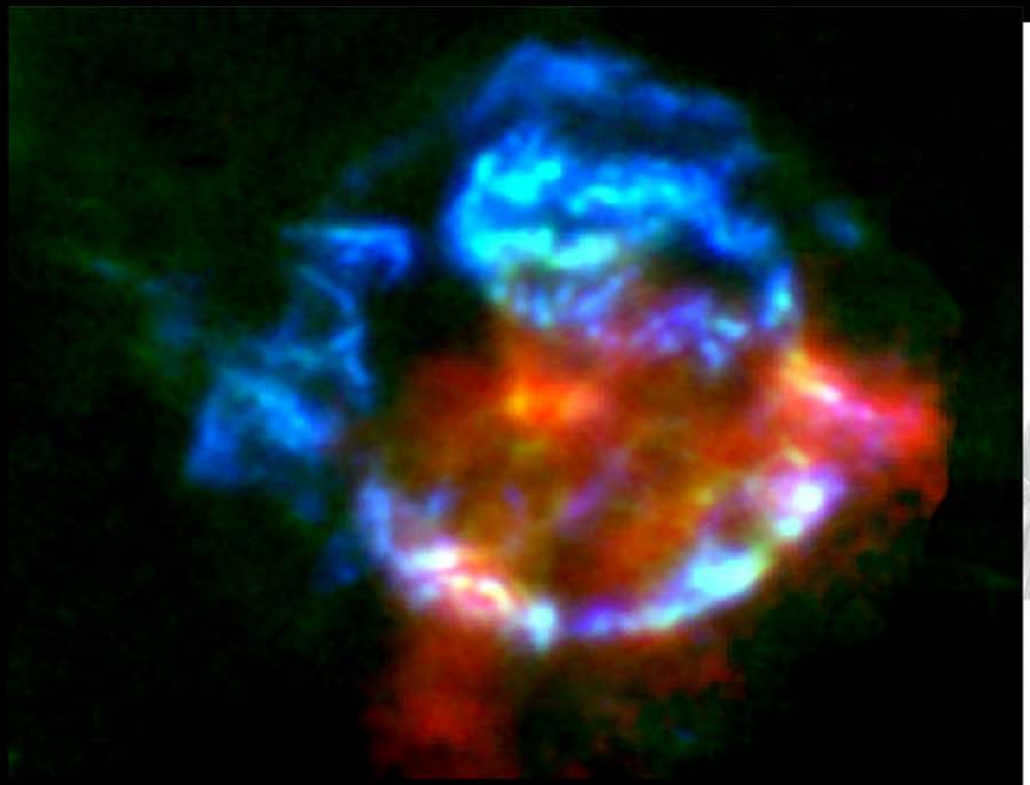
A large amount (about three solar masses) of cold (18 K) dust in the prototypical type II supernova remnant Cassiopeia A was recently reported[1]. It was concluded that dust production in type II supernovae can explain how the large quantities ($\sim 10^8$ solar

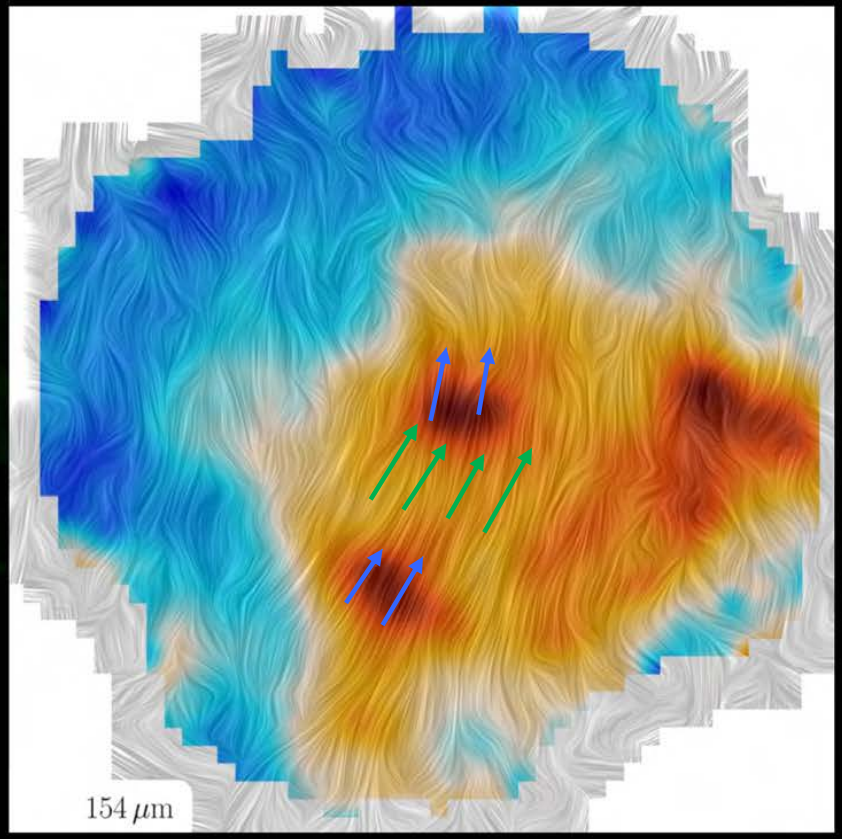
SOFIA HAWC+ (High-Resolution Airborne Wideband Camera Plus) Polarization observation

- How does the magnetic field flow?
- What type of dust grains are present?
- How large are the dust grains?
- What shapes are the dust grains?
- How does the dust align with the magnetic field?
- Are supernovae the number 1 dust producer in the early Universe?

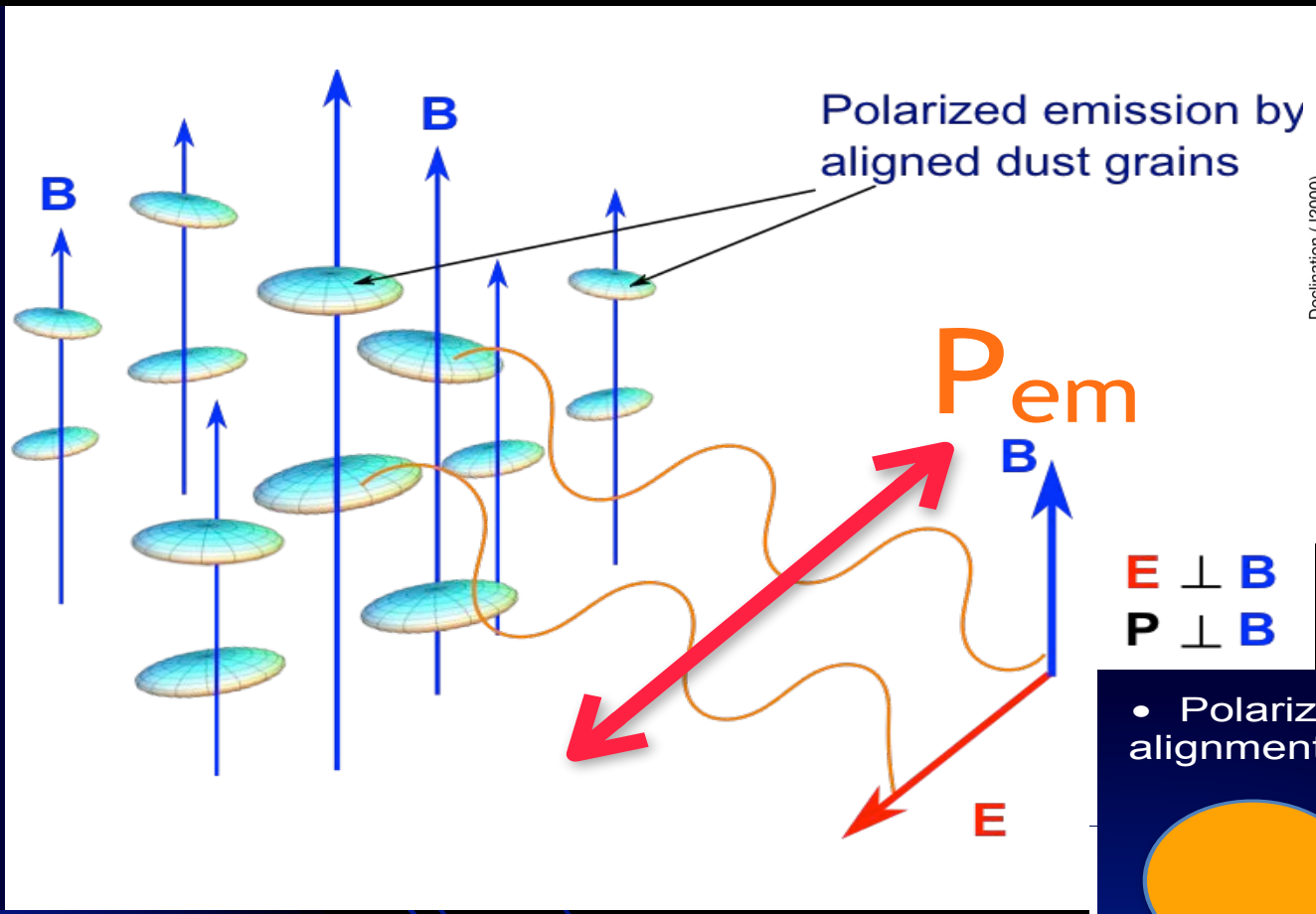
Mosaicked Image of SOFIA (154 microns in red), Heschel (70 in green) and Spitzer (24 in blue)

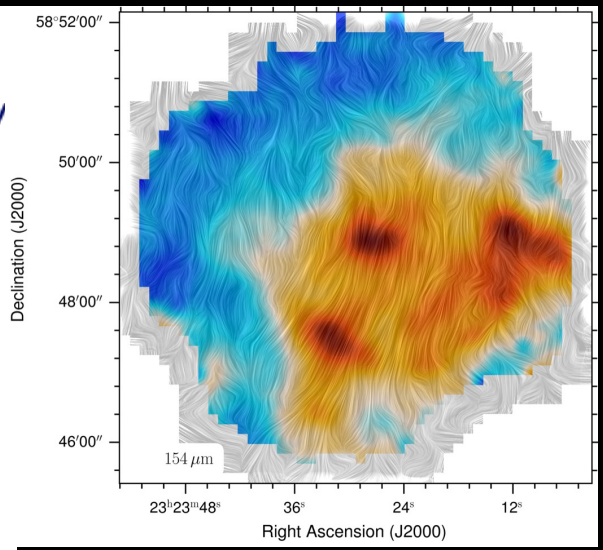


Magnetic field flow on the SOFIA HAWC+ map

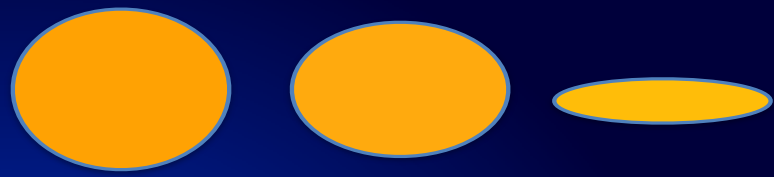


How dust grains produce polarization?





- Polarization depends on grain alignment degree & grain elongation

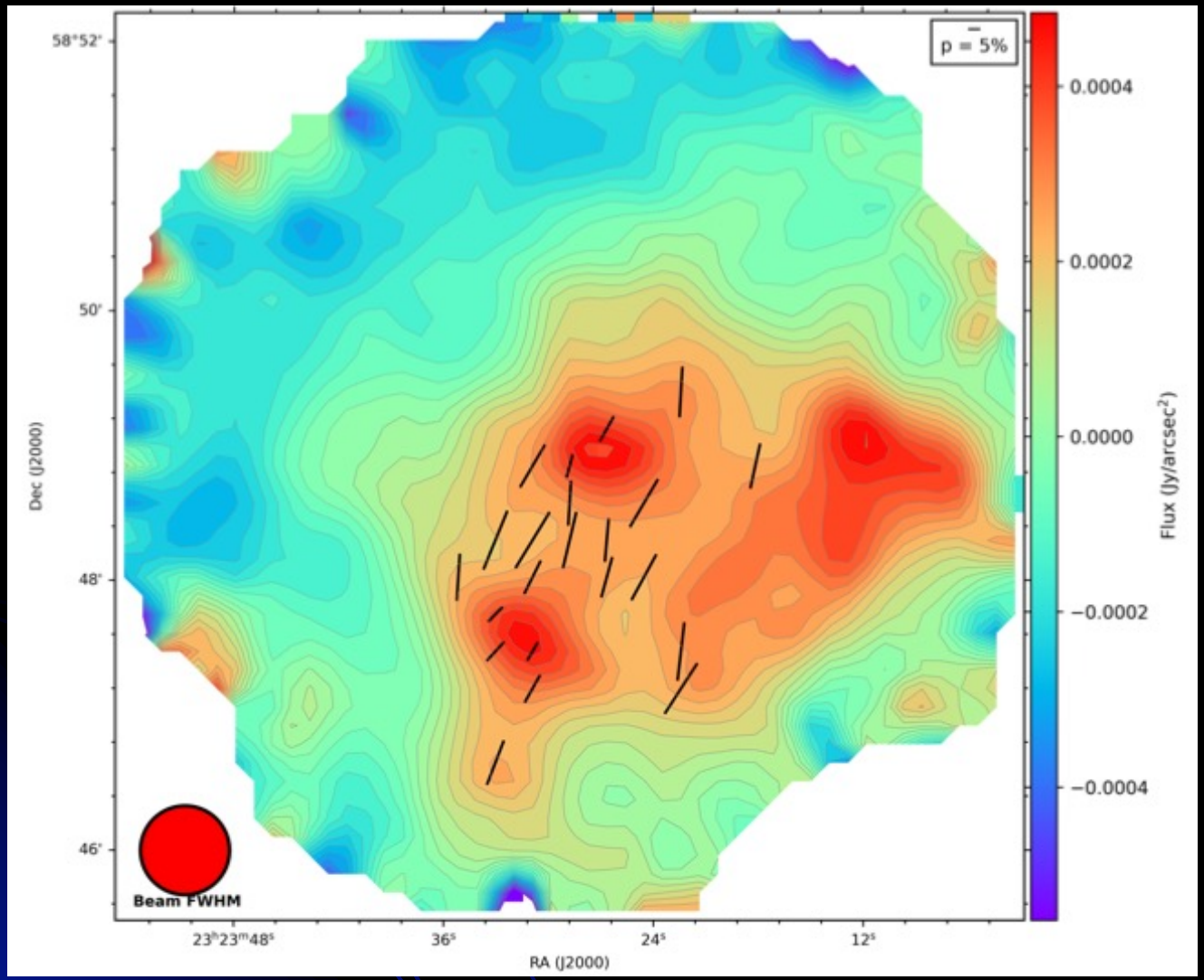


Dust Grains are Elongated in Cas A rather than spherical.

Polarization and Dust Properties

- We discover **high percent polarization** in Cas A (5 – 30%): one of the highest sources.
- **Large grains (> 0.14 microns) are formed in SNe**.
- **Silicate dust grains** are dominant grains (over carbon dust)

- **Sufficiently large amounts of dust (> 0.2 solar mass)** from the polarized regions of the SNR: **Supernovae are the significant dust producer in the early Universe**.



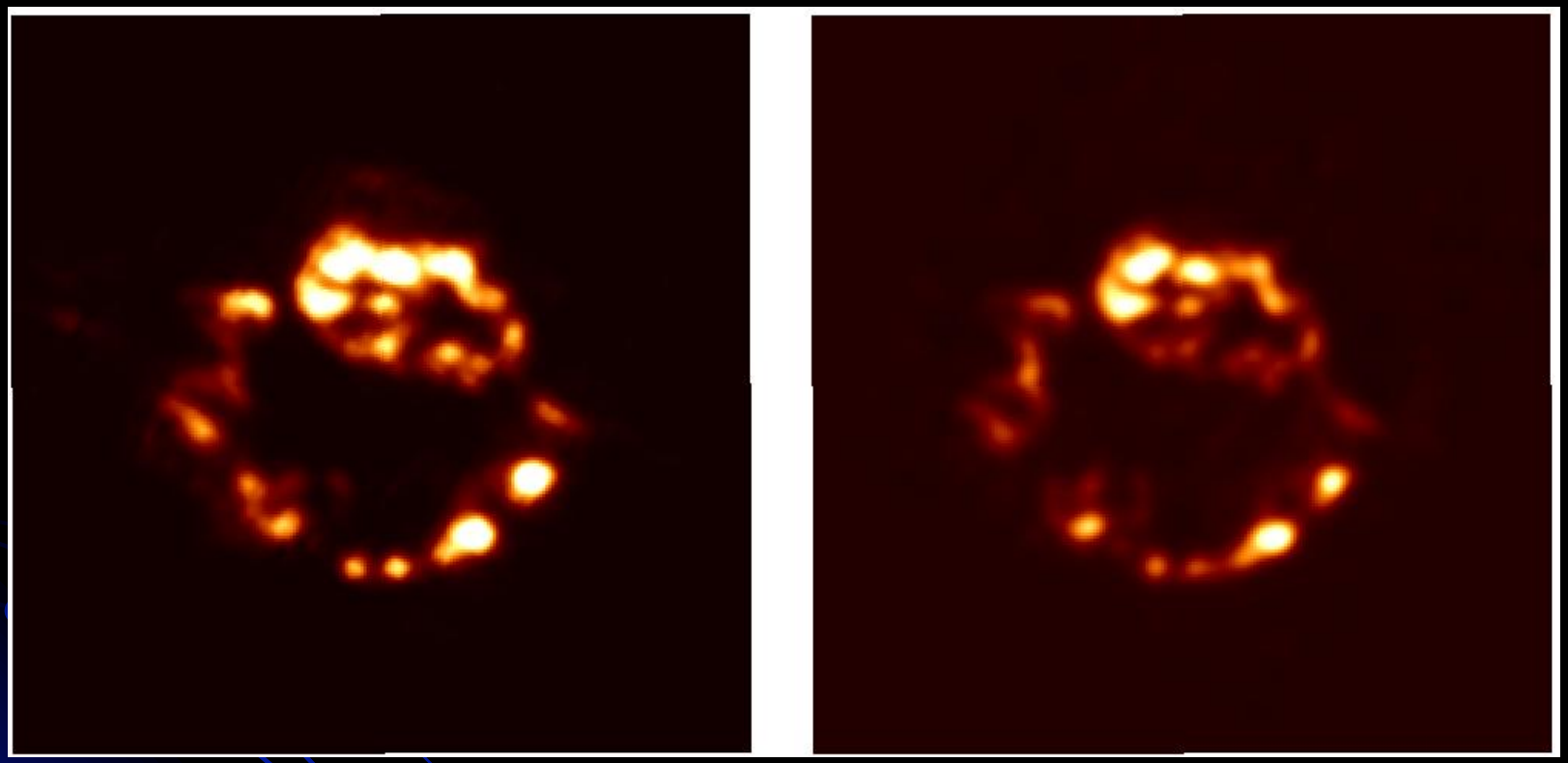
SOFIA HAWC+ observations at 154 micron (far-IR polarization)

High percent polarization (5-30%) was detected.

The lines show the magnetic field direction. The color map is 154 microns image.

Cas A: Dust forms in Ejecta

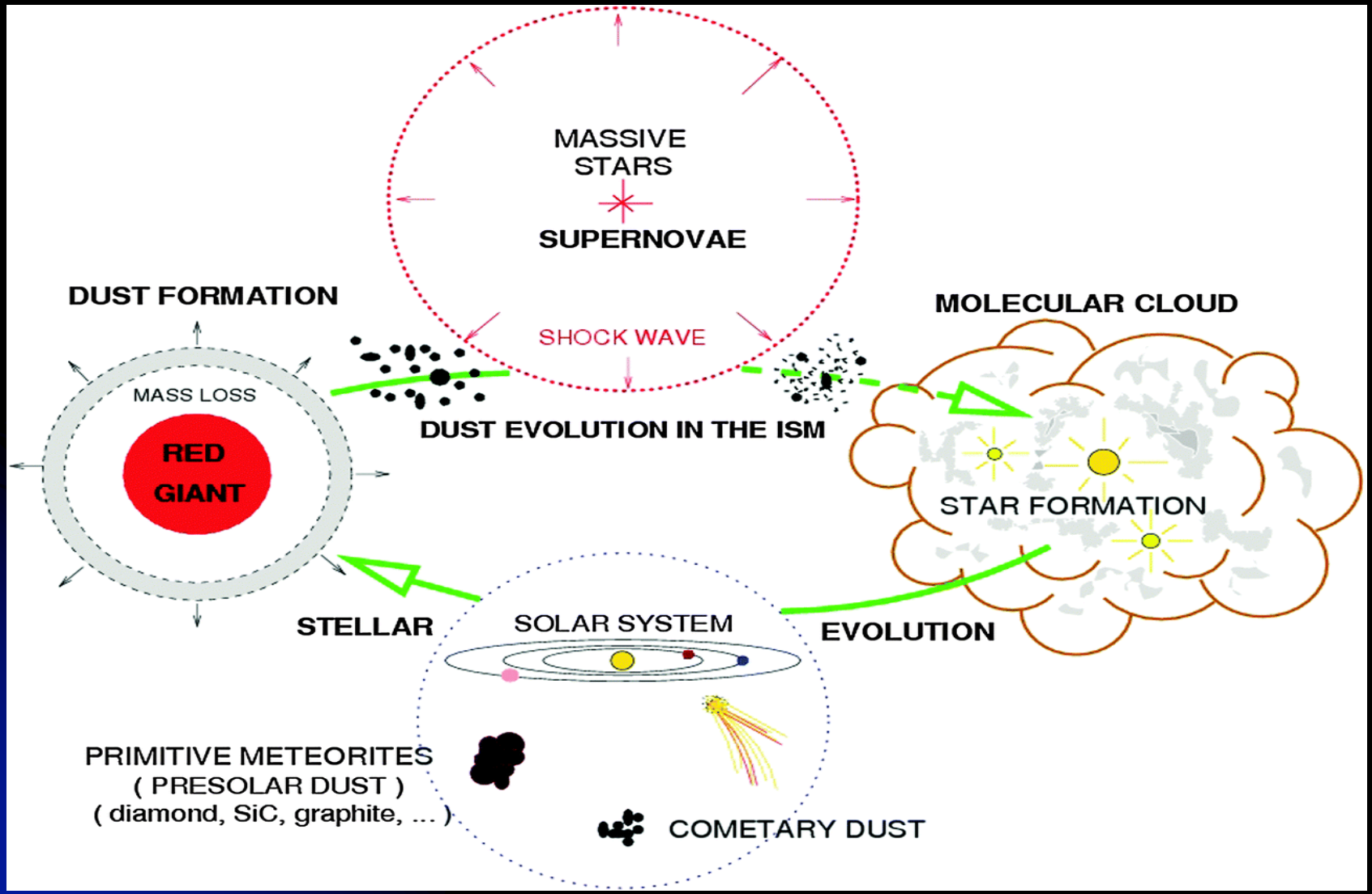
Did dust grains form in the SN ejecta? pre-SN dust or ISM swept up dust



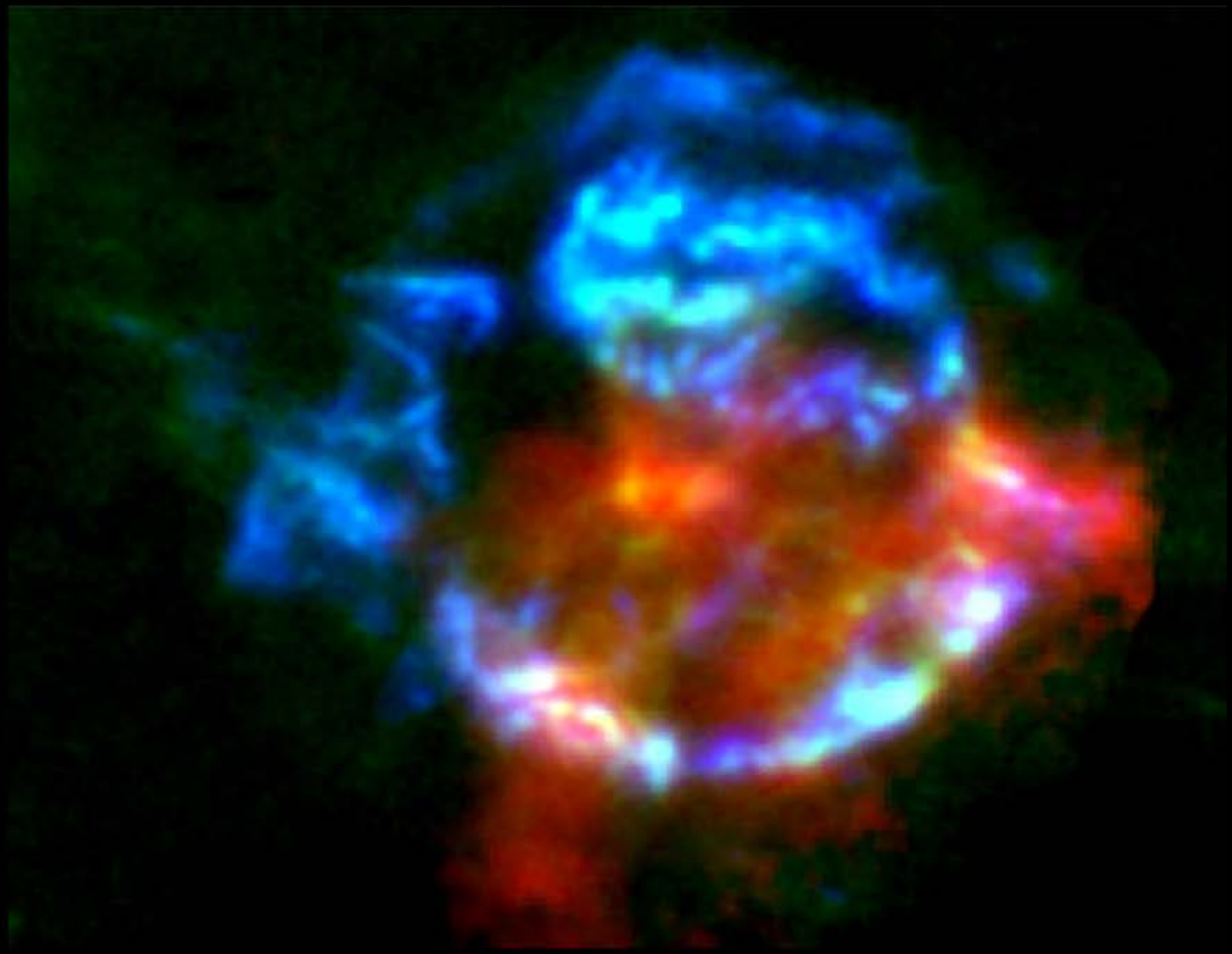
Dust (including Silica)

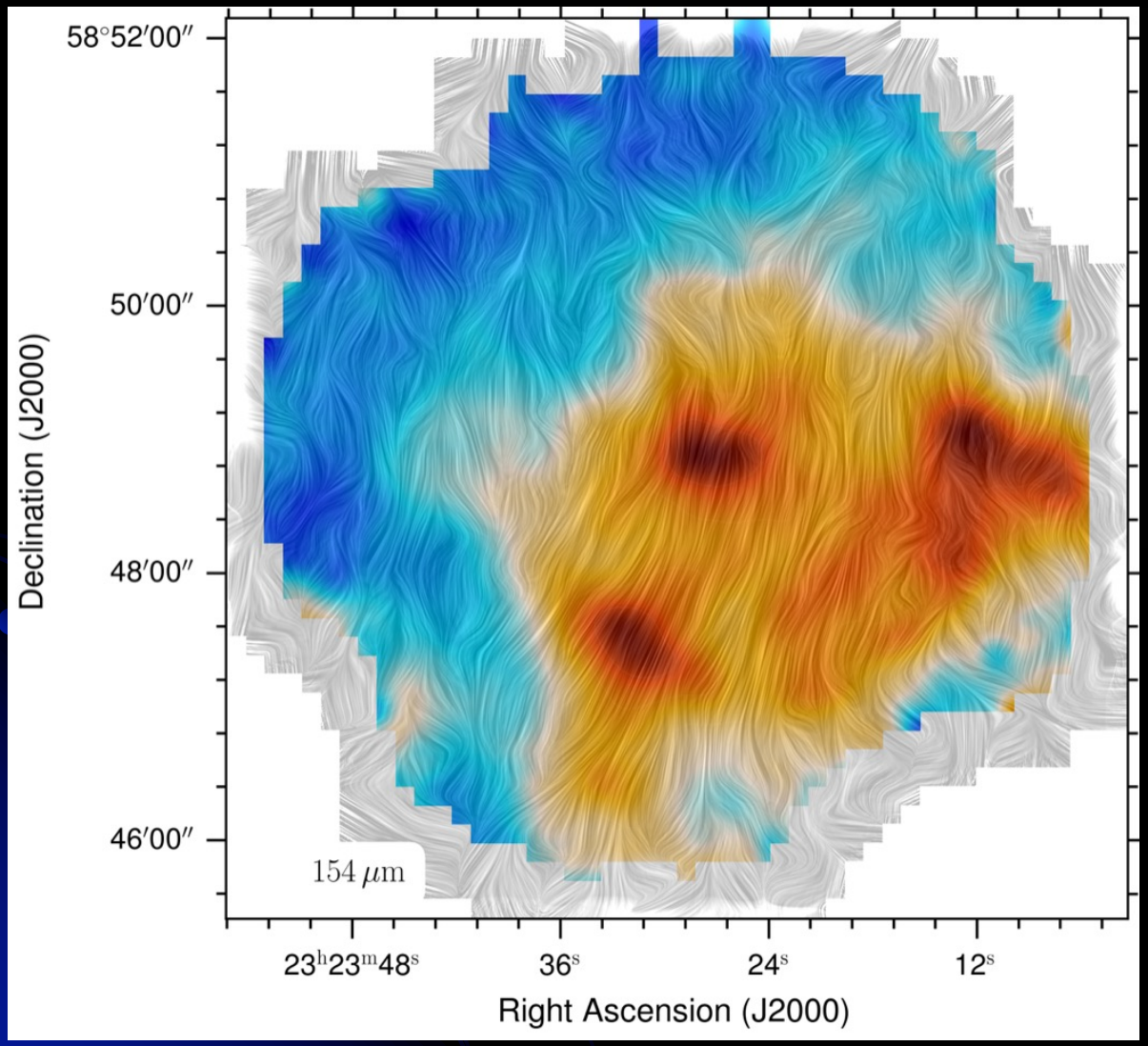
Ejecta (Ar)

ORIGIN OF DUST



The supernova remnant Cas A

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50′00″
48′00″
46′00″
Declination (J2000)
154 μm
23h23m48s
36s
24s
12s
Right Ascension (J2000)