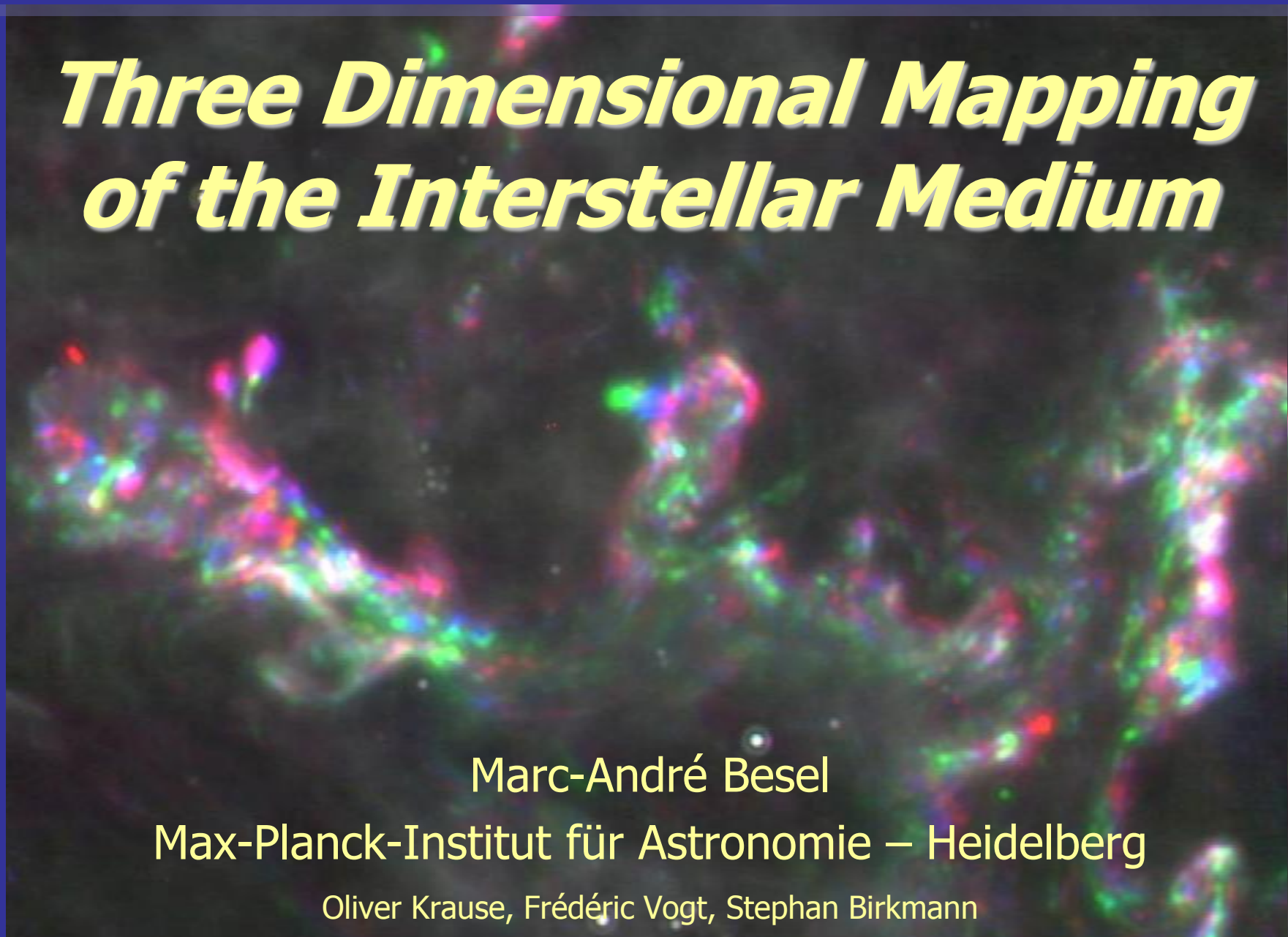

Three Dimensional Mapping of the Interstellar Medium

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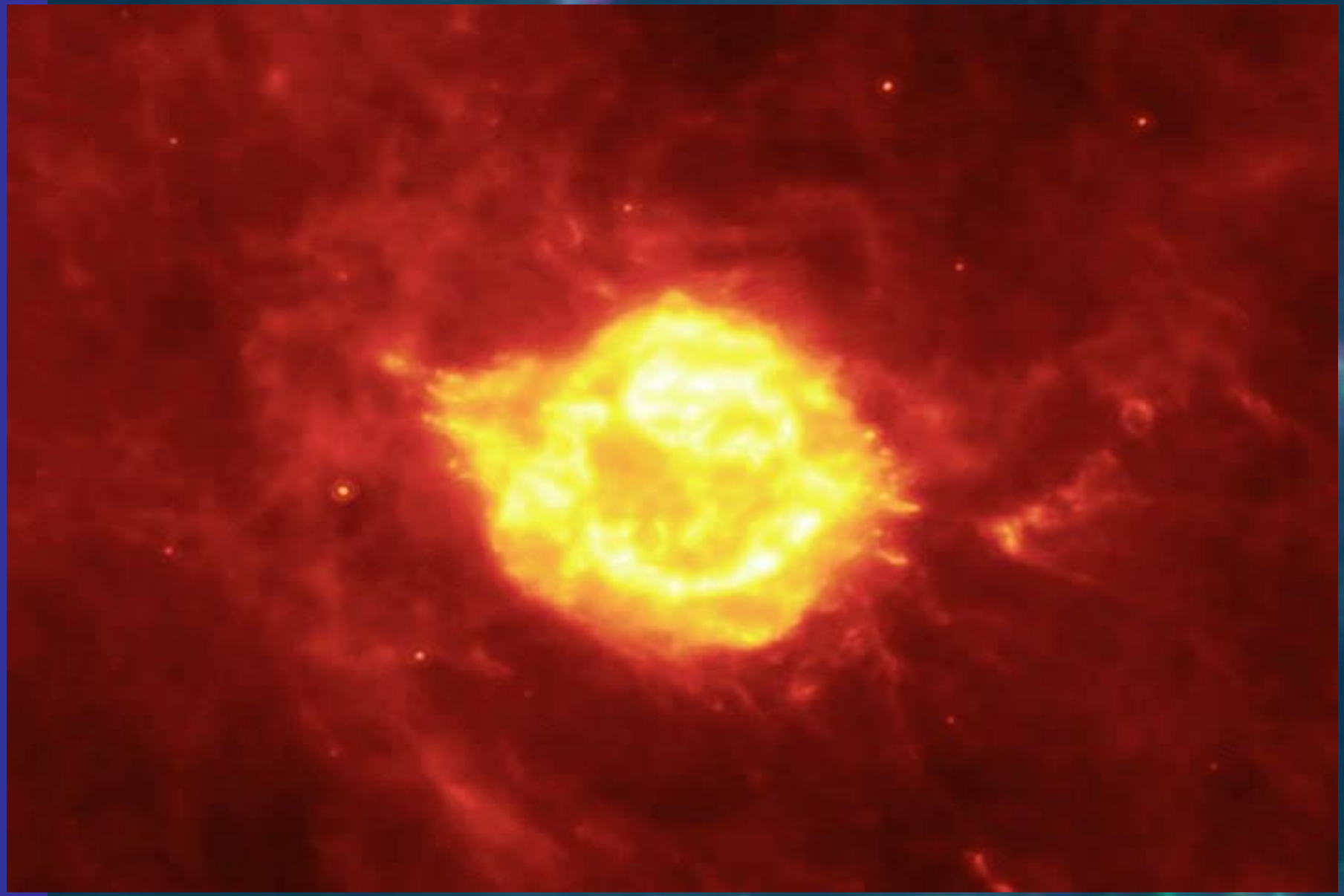
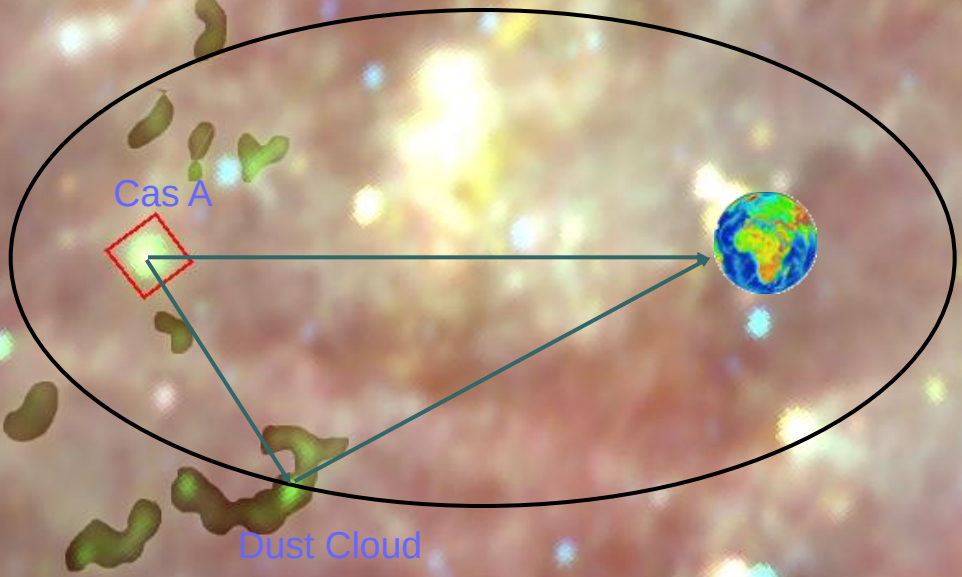
The Infrared Echoes around Cas A

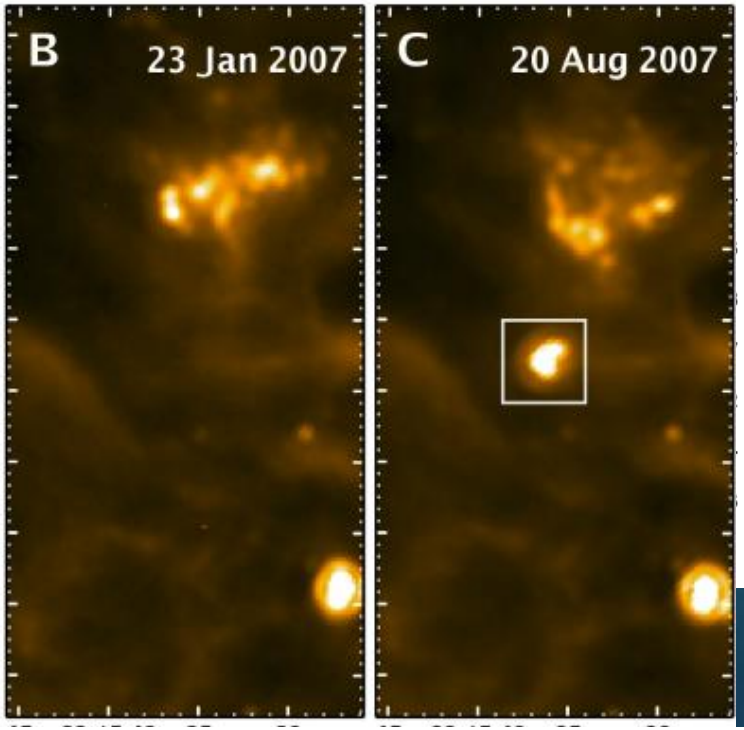


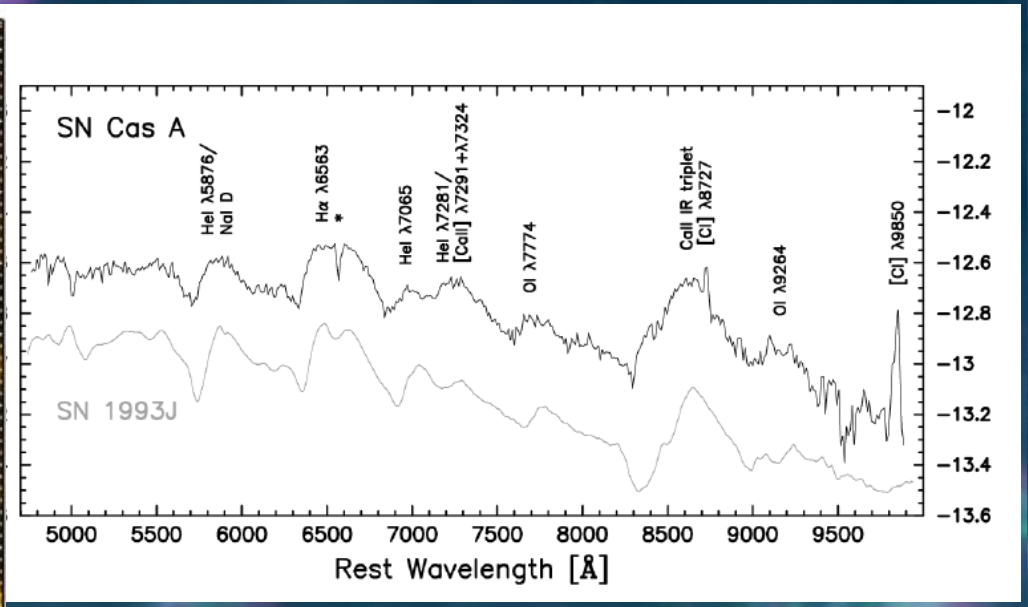
What are Infrared Echoes?

- Thermal re-radiation of dust heated by the SN outburst
- Scattered component – Optical Light Echoes - were first proposed by J. H. Oort and F. Zwicky in the late 1930's
- First discovery optical of an optical light echo around SN 1987A
- IR echoes from extragalactic SNe (Dwek; Graham)
- Light Echo Geometry allows the determination of x,y,z and thus enables a three dimensional reconstruction of the material in space

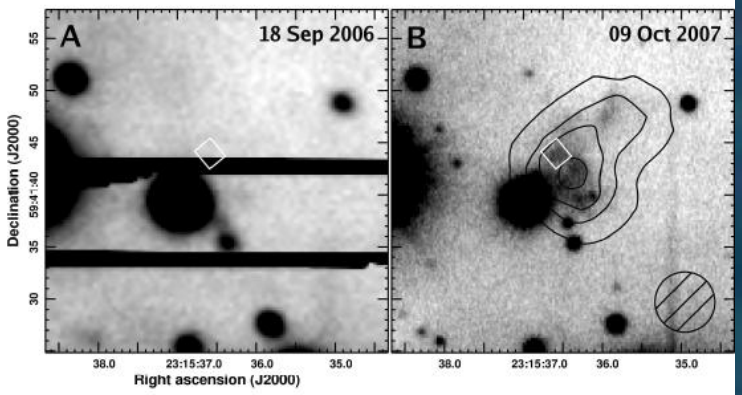


Cassiopeia A





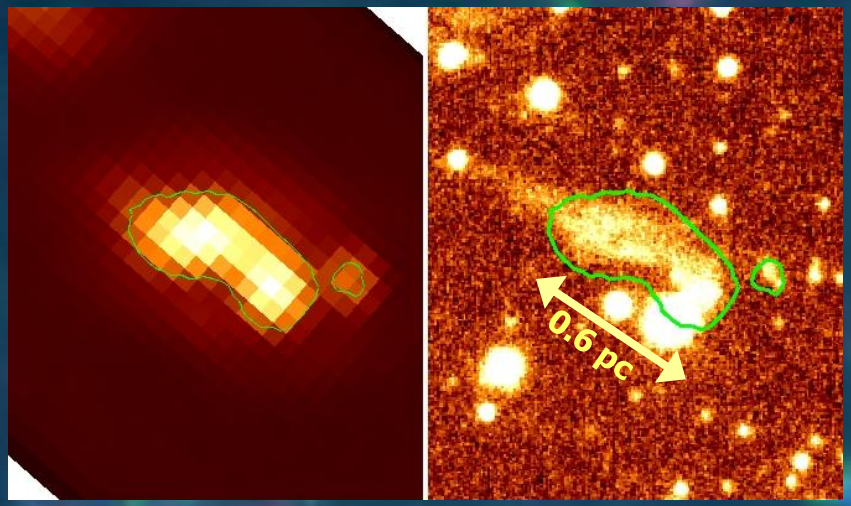
Krause(2008)

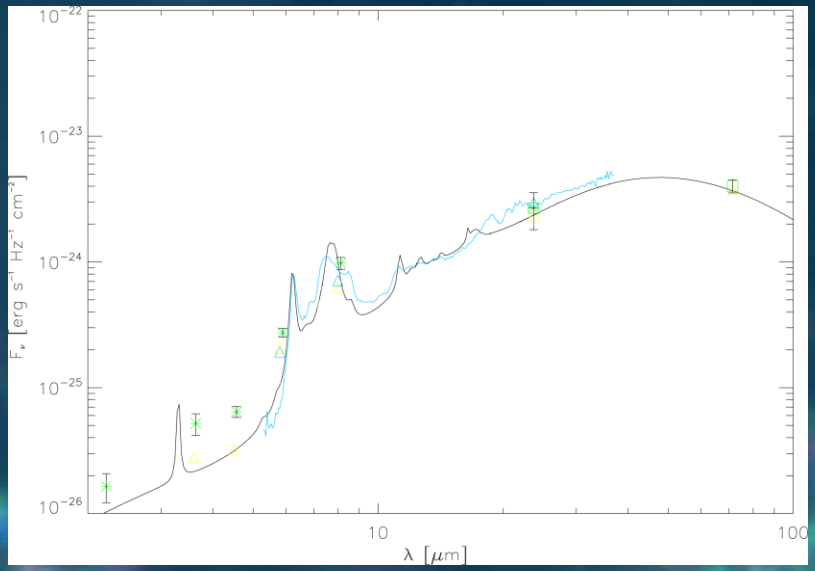


- Very close (~3.4 kpc) and large ~5 pc
- Explosion date ~ 325 years ago (Thorstensen 2001)
- Subaru FOCAS Spectra confirmed Cas A to be of Type IIb (hydrogen deficient core-collapse)

→ We know the input parameters very well, making the Cas A IR echoes a well defined "experimental setup"

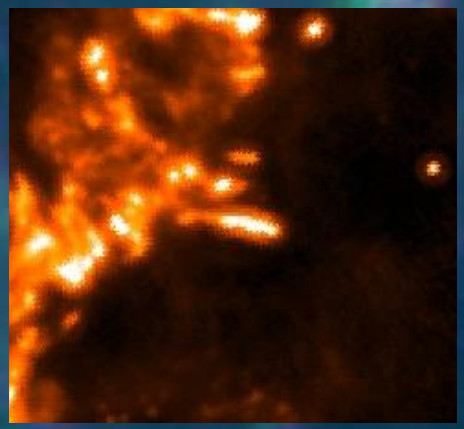
Modeling IR Echo Emission





- Use the input spectrum of the type IIb SN 1993J

→ Emission originates from dust excited by a combination of the UV and optical SN outbursts

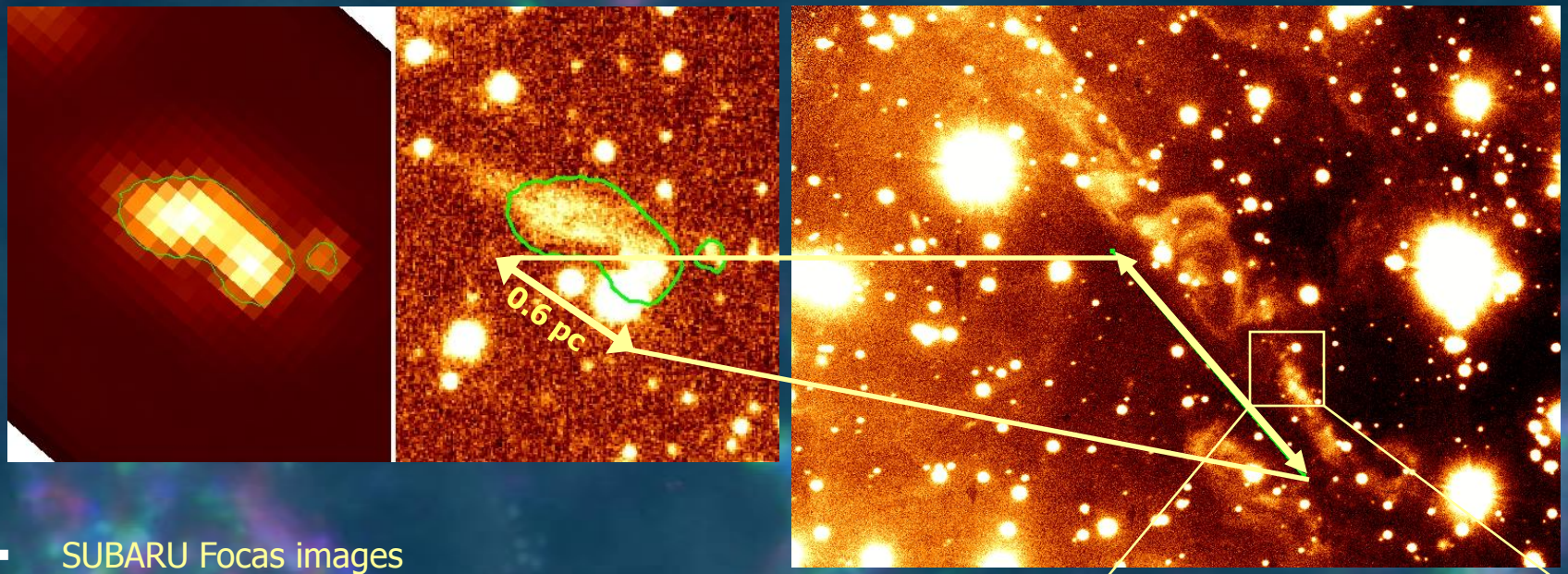


- Dust mass: ~ 1.6 x 10^{30} g
- Emitting volume: ~ 2.3 x 10^{52} cm^3
- Total density: ~ 3000 atoms / cm^3

- Evidence for dust processing (removal of small PAH's, dehydrogenation and ionization of PAH's)

→ sign of UV or shock processing ?

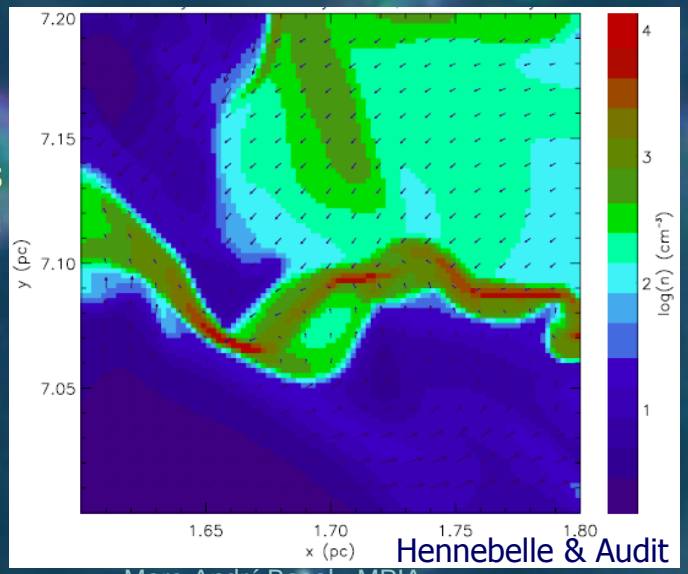
Modeling IR Echo Emission

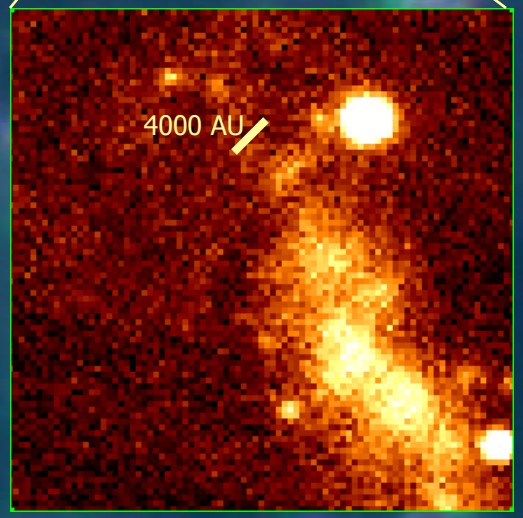


- SUBARU Focas images reveal tiny unresolved structures

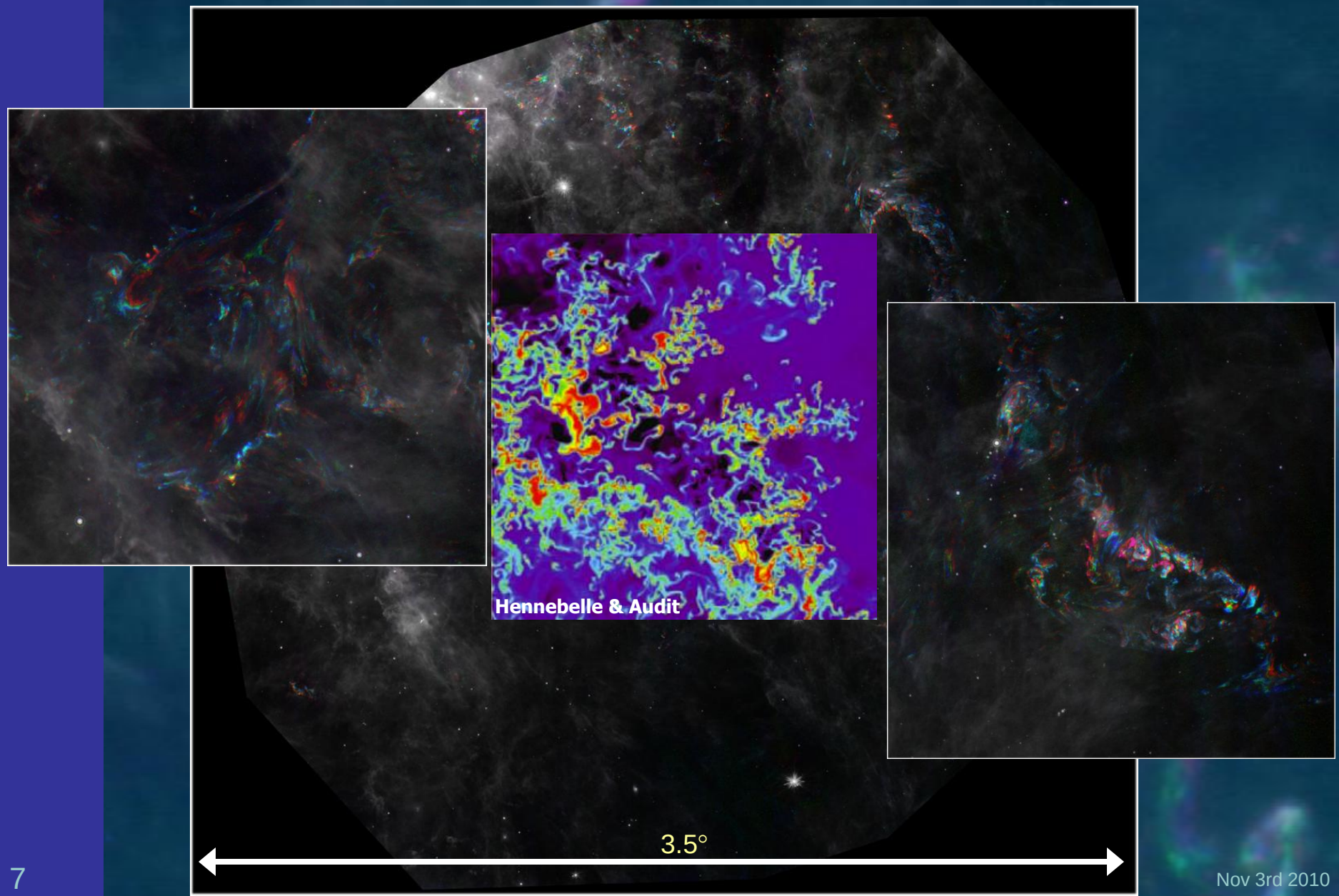
→ Density of echo structures could be even higher than 10^3 cm^3

→ TSAS ?
$10^{3\text{-}4}$ cm^3
~10-100's AU

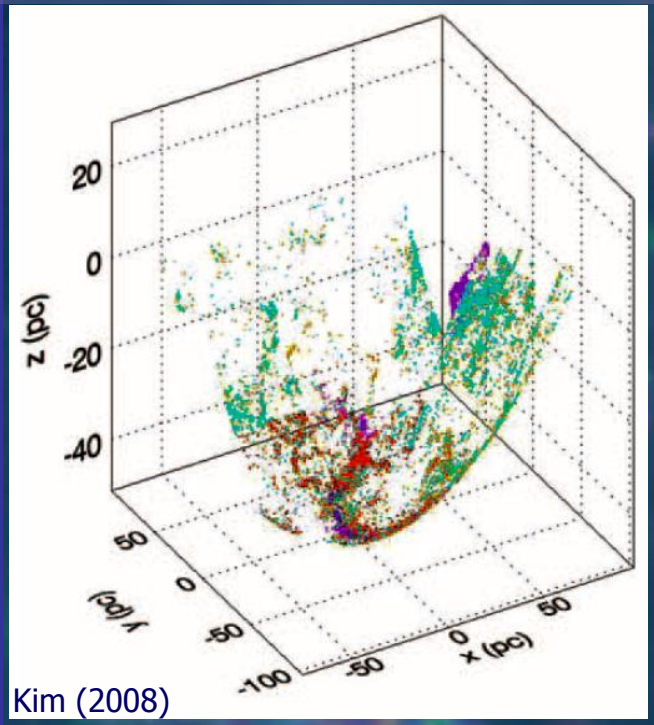




The Turbulent ISM

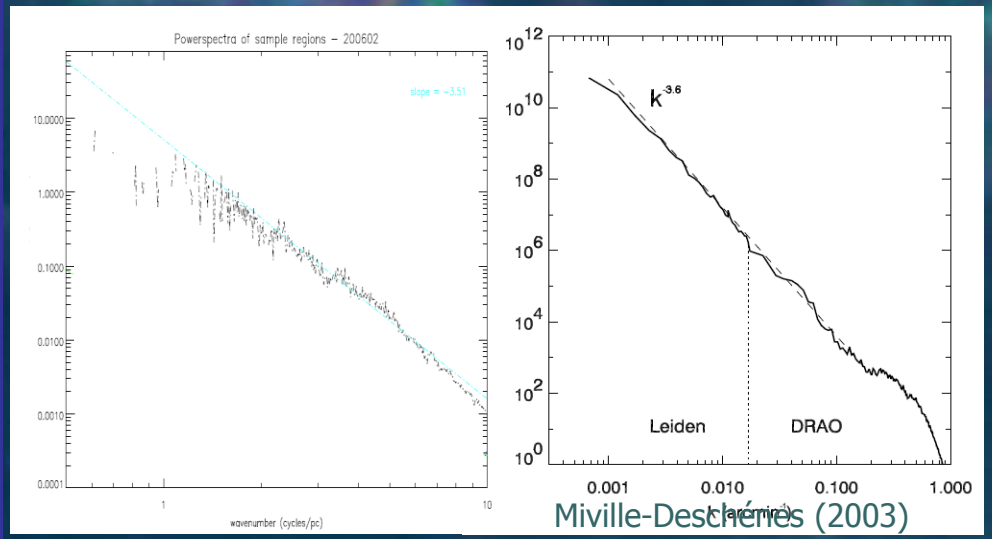


Three Dimensional Structure



Kim (2008)

- Filling factor of the IR echo features is ~0.4 % on average
- Compatible with the Hennebelle & Audit predictions for high density gas filling factors:
  - Fraction of gas denser than 10^3 cm^{-3} is about 1-3%
  - 0.1 % of LOS's cross gas denser than 10^4 cm^{-3}
- High density indicative of shocked medium



Miville-Deschênes (2003)

Power Spectral Index (β≈3.5-3.6) consistent with the Kolmogorov scaling of incompressible turbulence

Summary and Outlook

- We directly image 3D structure in the ISM via IR light echoes
- At any given size scale the interstellar medium appears filamentary and self similar
- We are looking at dense (~ 3 x 10^3 atoms/cm^3) regions of turbulent interstellar material
- Higher densities can be inferred when looking at high-resolution optical images
  → TSAS (?)
- Might shocks generated by turbulence in the CNM affect the dust evolution?
- High-Resolution data with SOFIA and JWST-MIRI will be ideal to further study unperturbed ISM features