CENTER FOR ASTROPHYSICS HARVARD & SMITHSONIAN

Investigation of the Massive Infrared Dark Cloud in Early Star Formation

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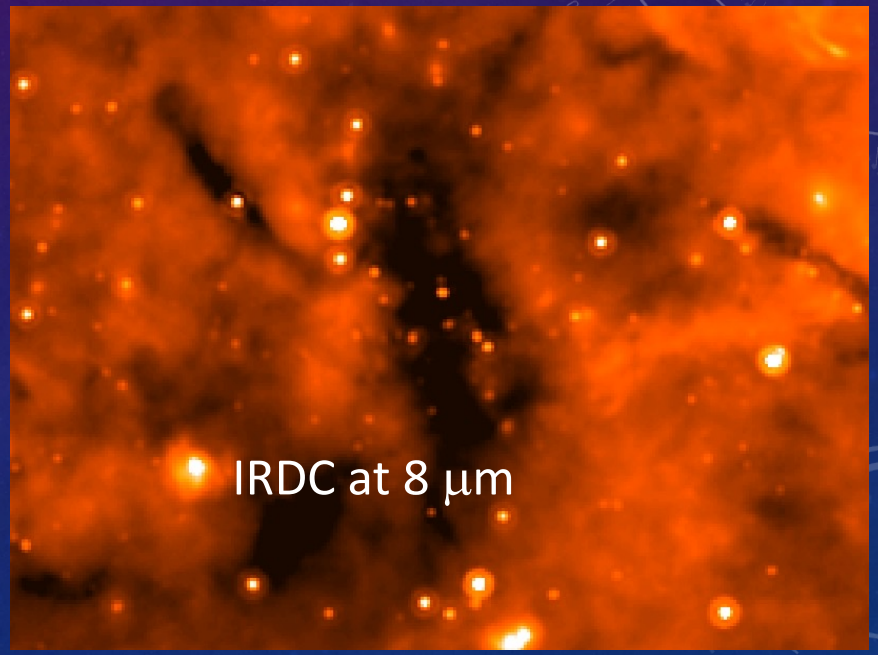
Image Credit: ESO/Y. Beletsky

Outline

- Introduction (IRDC, observation data)
- Method of Imaging
- Results
- Conclusion

Introduction – Infrared Dark Cloud (IRDC)

- Exhibit significant mid-IR opacity
- Extreme properties
  - Cold (< 20 K)
  - Enormous column densities (> 10^{23} – 10^{25} cm^{-2})
  - Some are dark at 7 to 100 μm
- Represent early stages of star formation

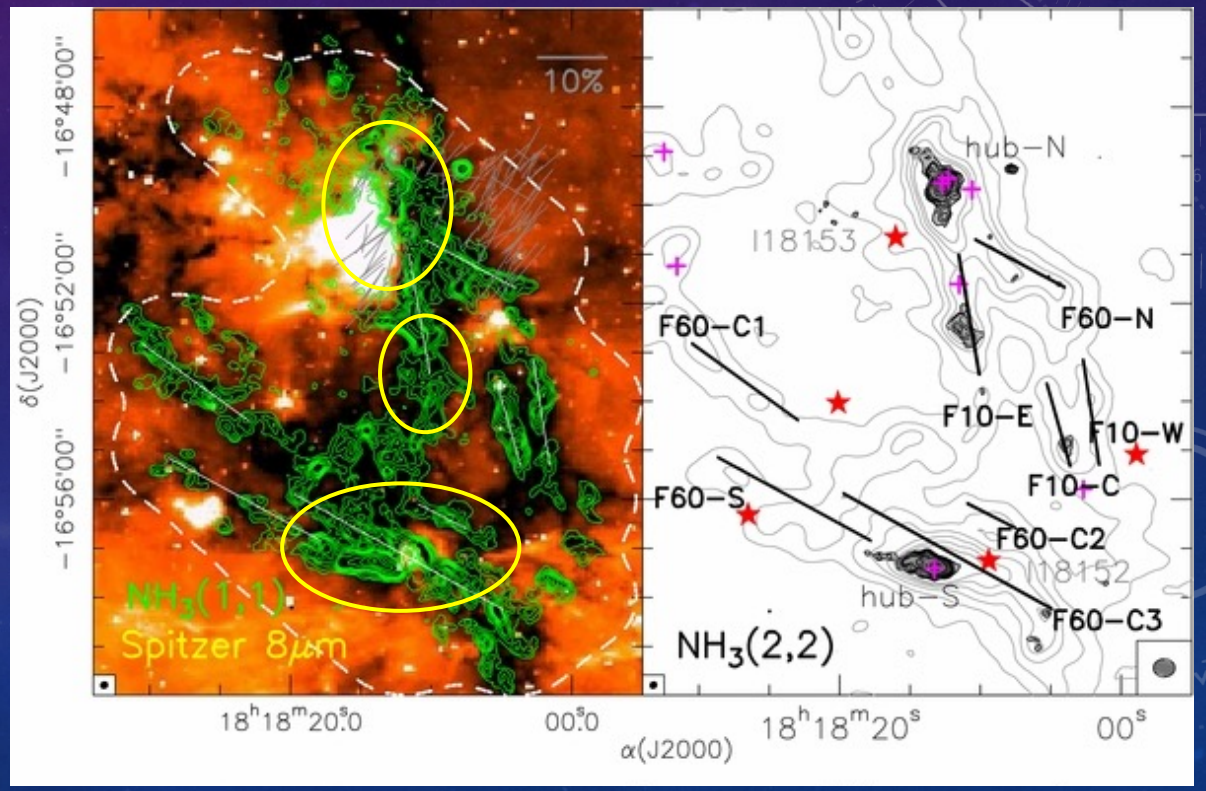


Perault et al. 1996; Egan et al. 1998; Carey et al. 1998, 2000; Hennebelle et al. 2001

Introduction - Observation data

- IRDC G14.225-0.506 by ALMA with mosaic and single pointing
- 1.3 mm dust continuum emission; spectral line emission (CO, N_2D^+, etc.)

Credit: ESO/C. Malin (christophmalin.com)



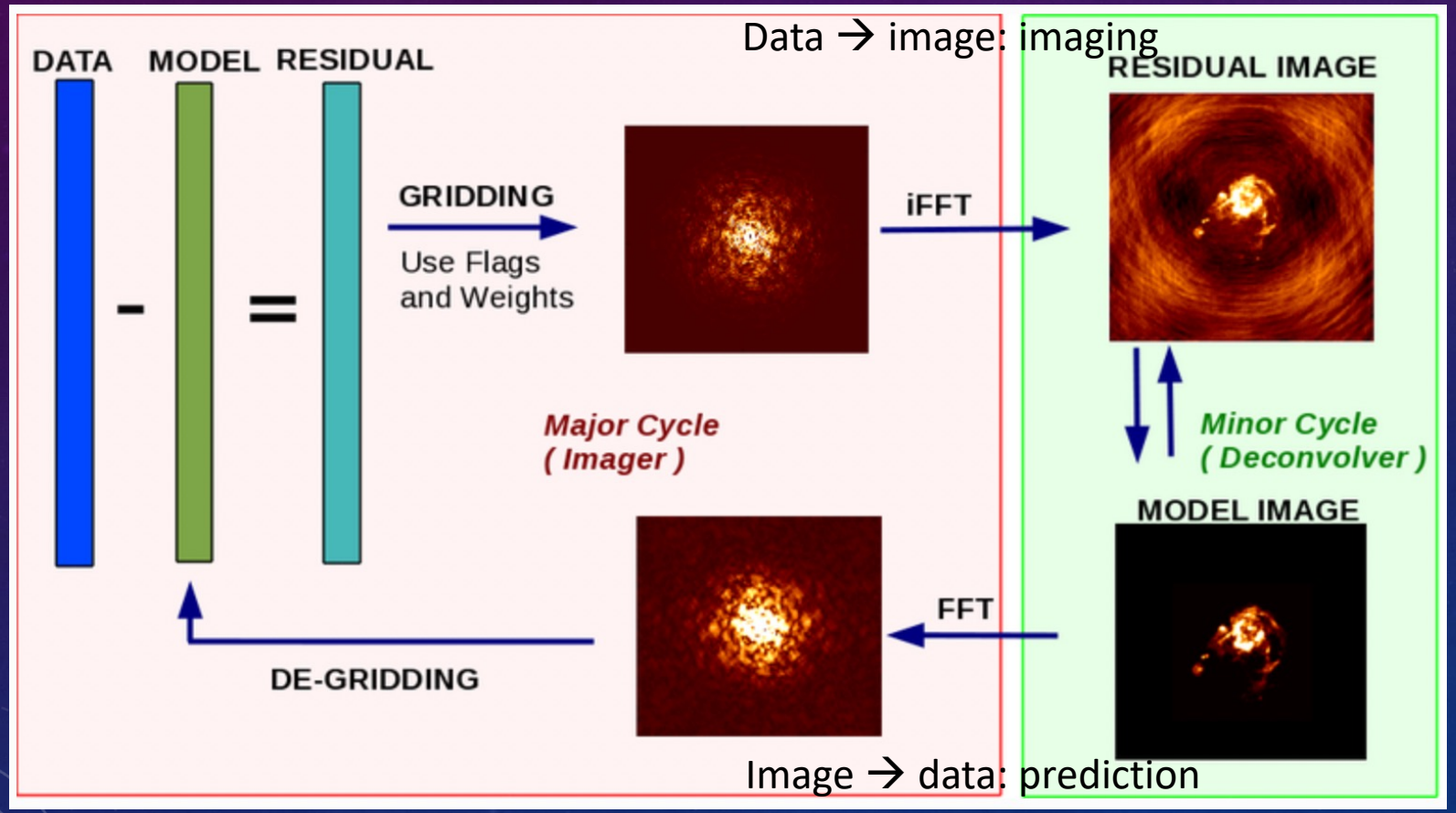
Busquet, Zhang et al. 2012

Method – Imaging by CASA

- Continuum subtraction → Cleaning → Images

Van Cittert-Zernike Theorem:

$$V_\nu(u,v) = \iint I_\nu(l,m) e^{-2i\pi(ul+vm)} dl dm$$



"true" brightness

↓

$$I_\nu^D(l,m) = I_\nu(l,m) \otimes B(l,m)$$

↑ Dirty image ↑ Dirty Beam

credit: https://casadocs.readthedocs.io/en/stable/api/tt/casatasks.imaging.tclean.html

Ay191 Fundamentals of interferometry, Qizhou Zhang & Eric Koch, 2022

Results - Images

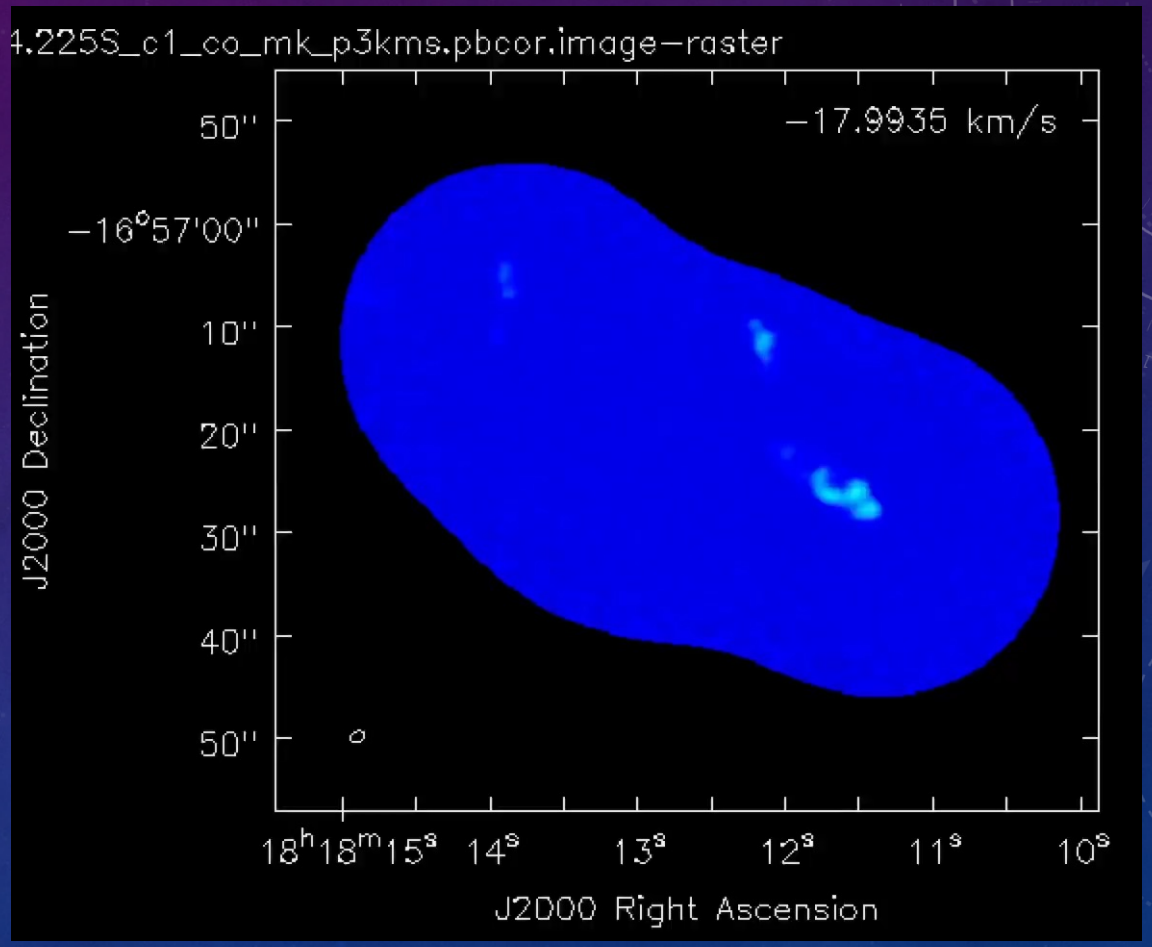
- A taste of CO image:

  - intensity map from spectral line window

  - velocity channels ranging from around -18 km/s to 57 km/s

  - further analysis:

spatially confined wings and structures appeared in consecutive channels identified as outflows



What can we learn from the images?

- Outflows identified from line emissions (e.g., CO, SiO, H_2CO, etc.):
  - outflow parameters, e.g., mass, momentum, energy, dynamical timescale
  - as an implication for high mass star formation by accretion

- Dense cores studied from continuum data:
  - identified by dendrogram
  - mass functions analysis, e.g., power-law index

(Ohashi et al. (2016), Zhang et al. (2005))

Conclusion

- The infrared dark cloud is cold, dense, and dark.

- Study on the infrared dark clouds (IRDC) could reveal structures and properties of filaments, dense cores, outflows, etc.

  → better understand the early-stage formation of stars

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