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py17icr@leeds.ac.uk
☺

A Multiwavelength Study of the VLA 1623-2417 Protostellar System with JWST, ALMA and the VLA

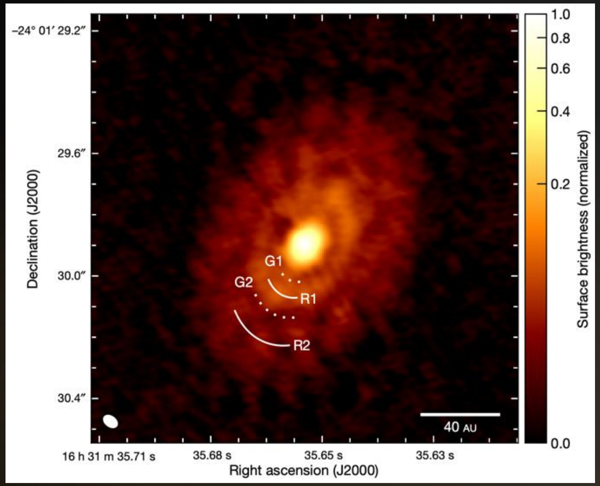
Isaac C. Radley (University of Leeds)

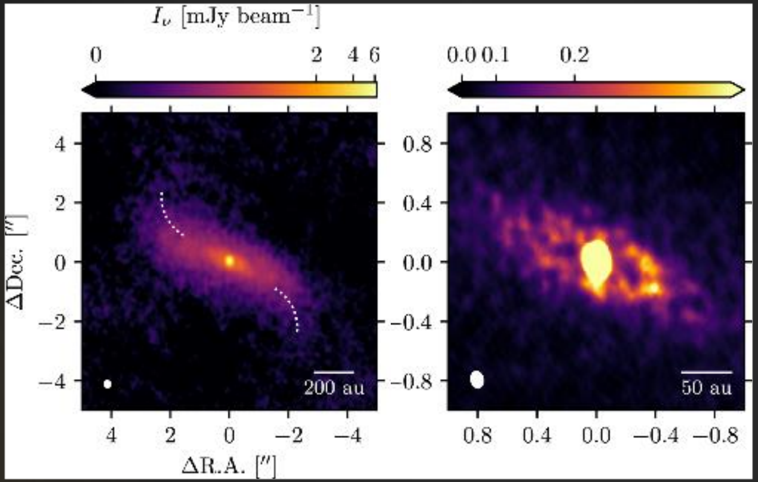
Supervisors: John D. Ilee, Gemma Busquet

Isaac C. Radley
University of Leeds

Planet formation

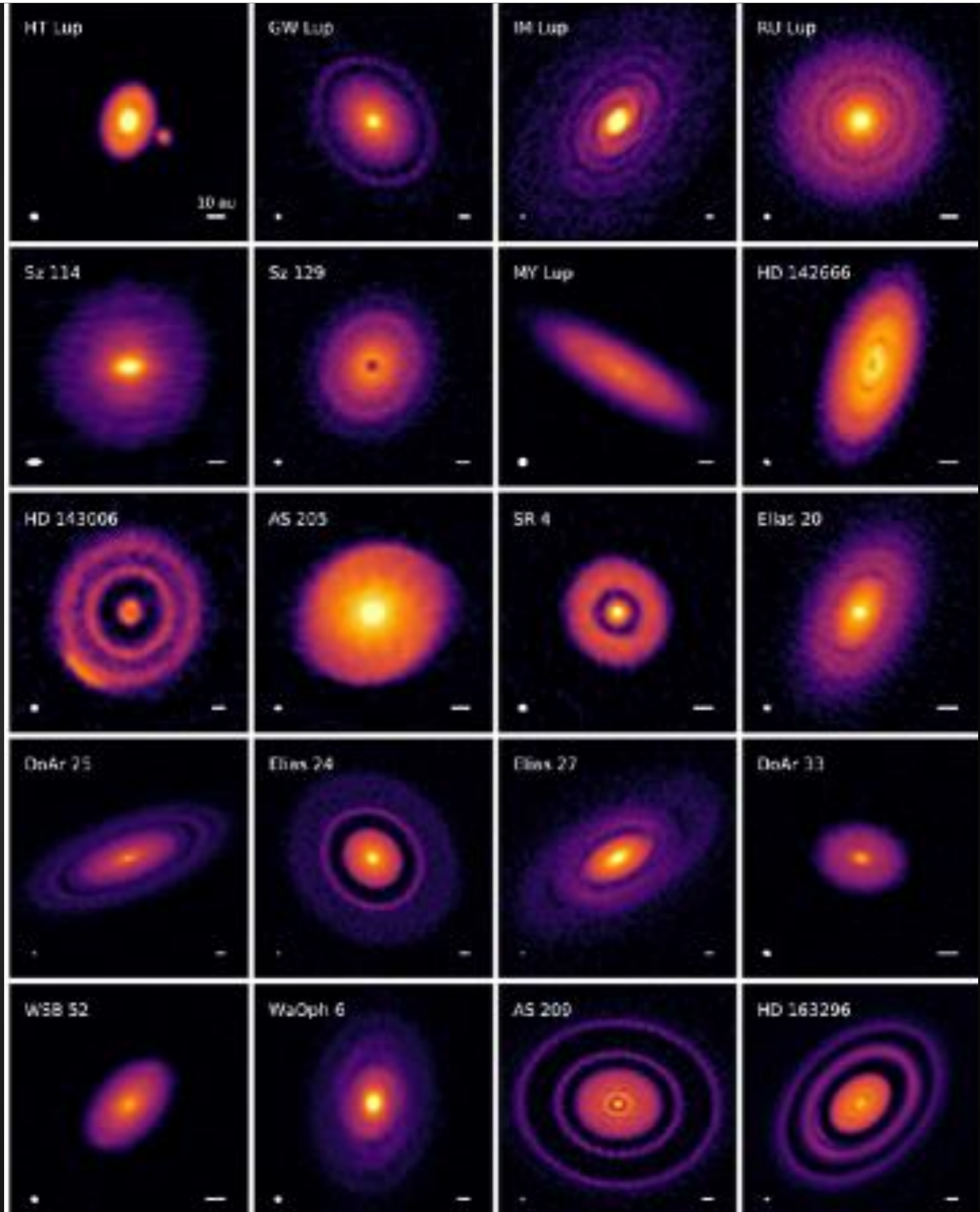
- Primarily thought to occur in the **class II phase** due to the **long timescales** associated with core accretion.
- Plethora of substructures, possibly of planetary origin?





- Substructures seen in Class I disks (Segura-Cox+ 2020, Yoshihide+ 2023)

- **Does dust growth occur early in a disk's lifetime?**



Andrews+ 2018

Ophiuchus

- **Nearest** star forming region (~138pc, Ortiz-León+ 2018)
- One of the **youngest** SFRs (Wilking+ 2008)
- Over 300 YSOs from class 0-III (Williams+ 2019)
- Provides an **intermediate SFR** - Neither isolated nor overpopulated however likely subject to external irradiation

Credit: NASA, ESA, CSA, STScI, Klaus Pontoppidan (STScI)

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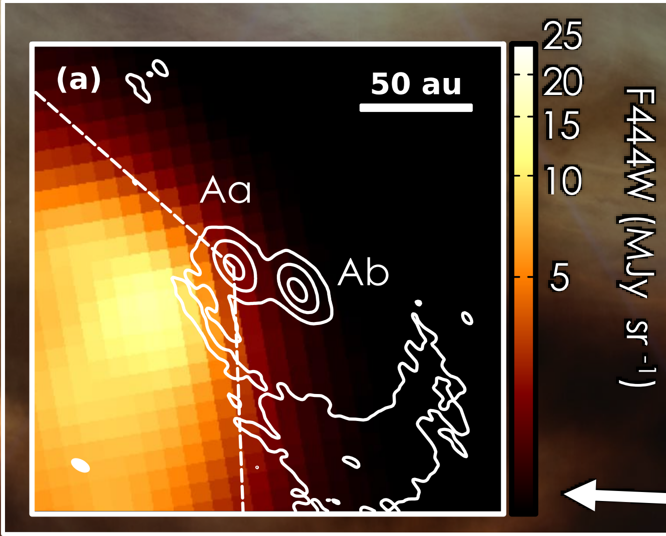
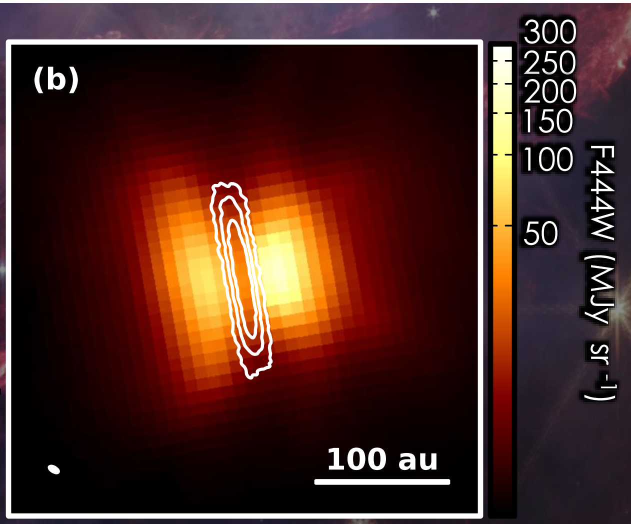
VLA 1623



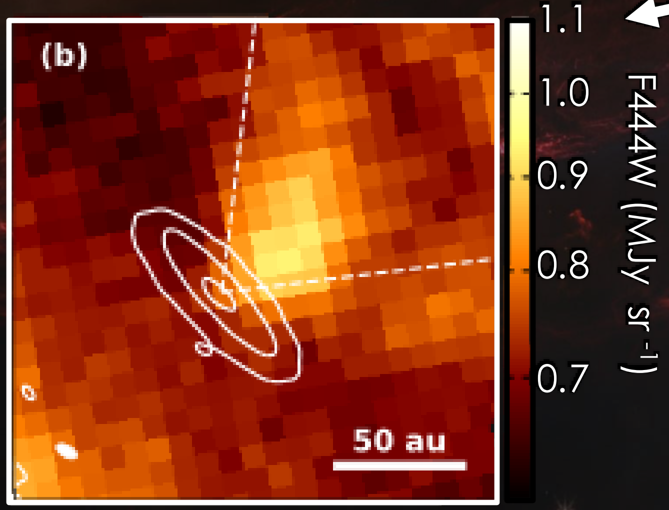
VLA 1623 A (Aa + Ab)

- Protobinary system with a circumbinary disk and one (or more?) outflows.
- Class 0



VLA 1623 West

- Previously thought to be a shocked cloudlet.
- Kinematics and continuum observations point to a disk-bearing protostar.
- Class I



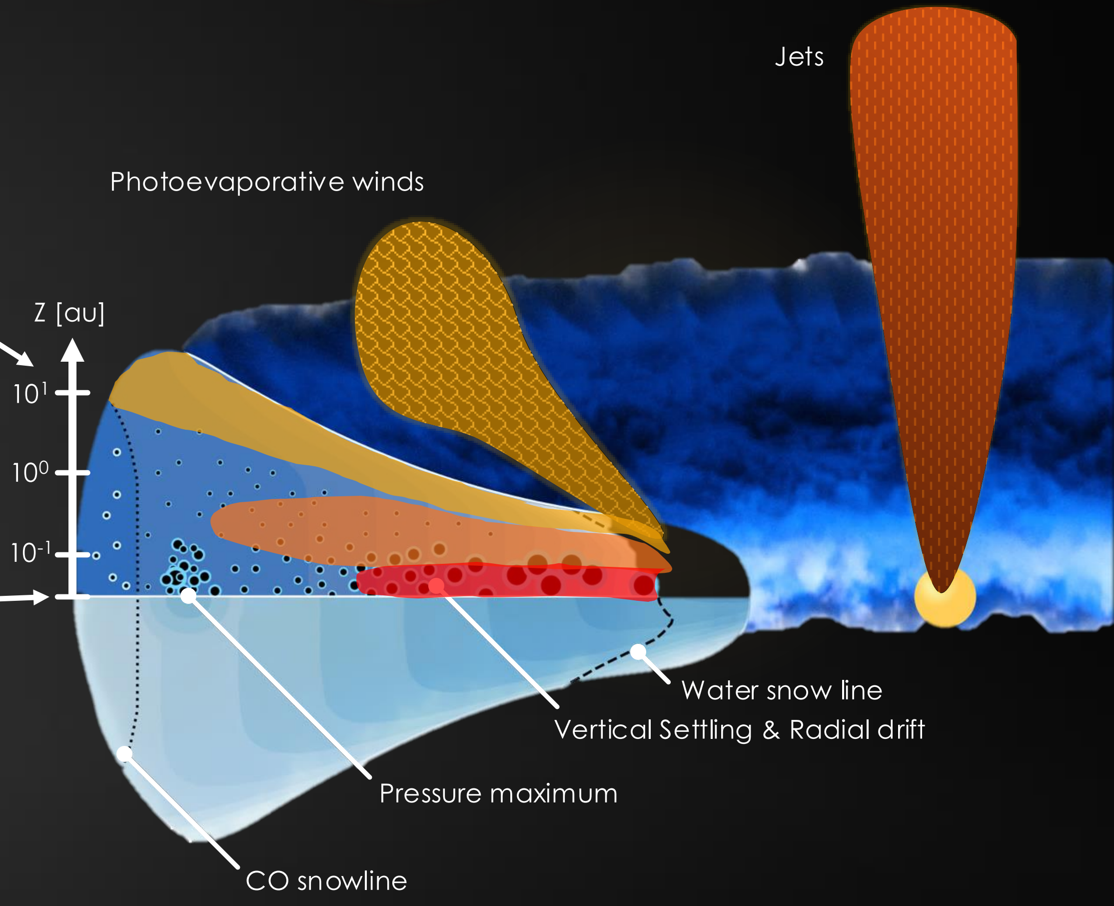
VLA 1623 B

- (Possible) Companion to VLA 1623 A
- Faint Ejecta
- Class 0

Radley+(submitted.)

Benefits of Multi-Wavelength

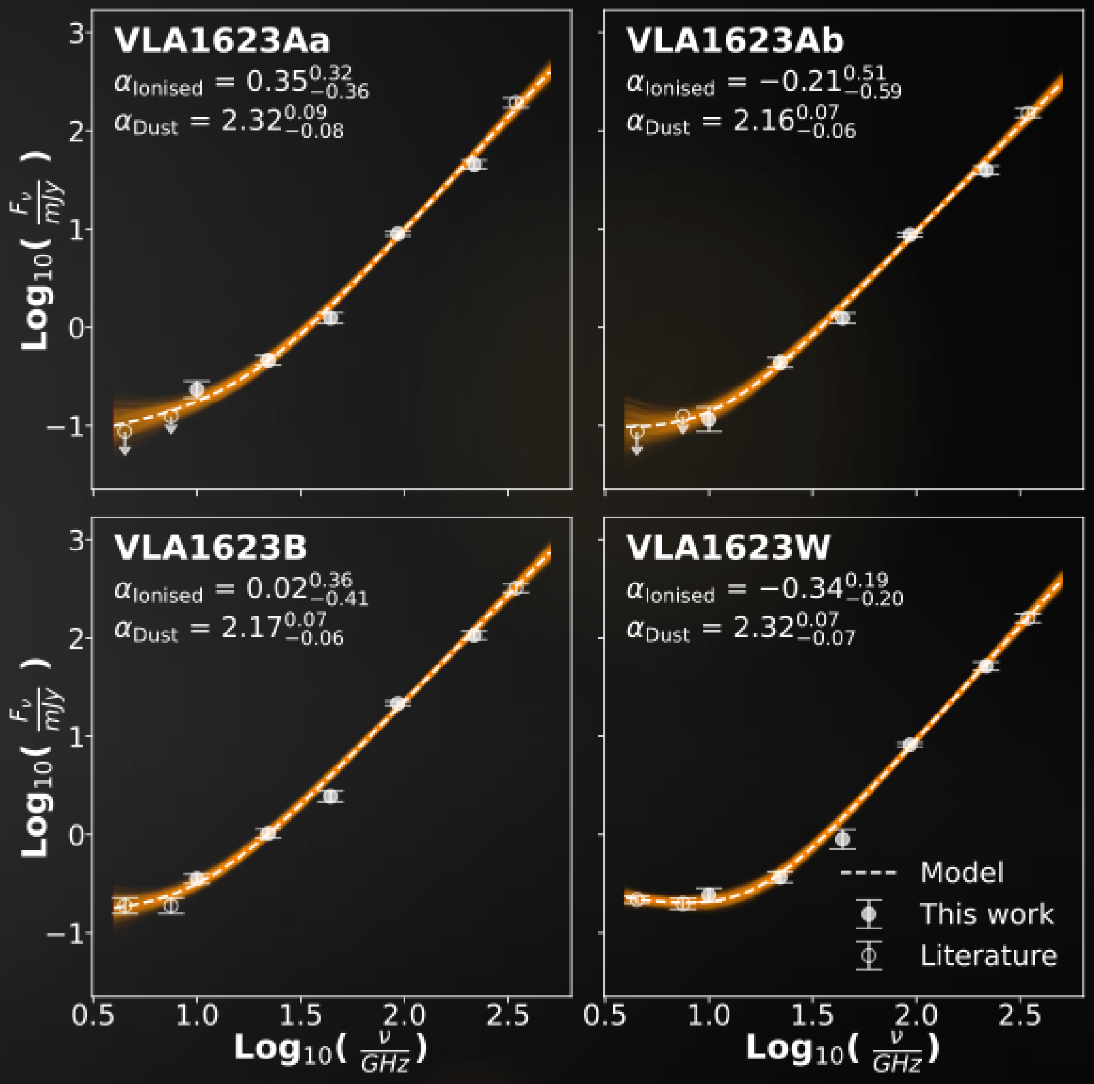
- **JWST** (F444W, 4.4 μm) – scattered light from ISM-like (< 1 mm) dust grains.
  - Subject to l.o.s extinction
- **ALMA** – small (~ 1 mm) dust grains ($a_{max} \approx \frac{\lambda}{2\pi}$).
  - **High optical depths** restrict our understanding of dust disks.
- **VLA** – large (> 1 mm) dust grain population.
  - Potential **Variability**
  - Non-dust emission
- Utilise **large wavelength range** to contextualise and decompose emission components.



Adapted from Miotello+2023

SED Modelling (1)

- Using a 2-component model of the SED we can estimate the dust and ionized gas spectral index individually.
- All objects indicate some degree of **dust growth** ($3 > \alpha_{\rm Dust} > 2$).
- $\alpha_{\rm Ionised}$ indicates potential **jet/wind emission** in most objects.

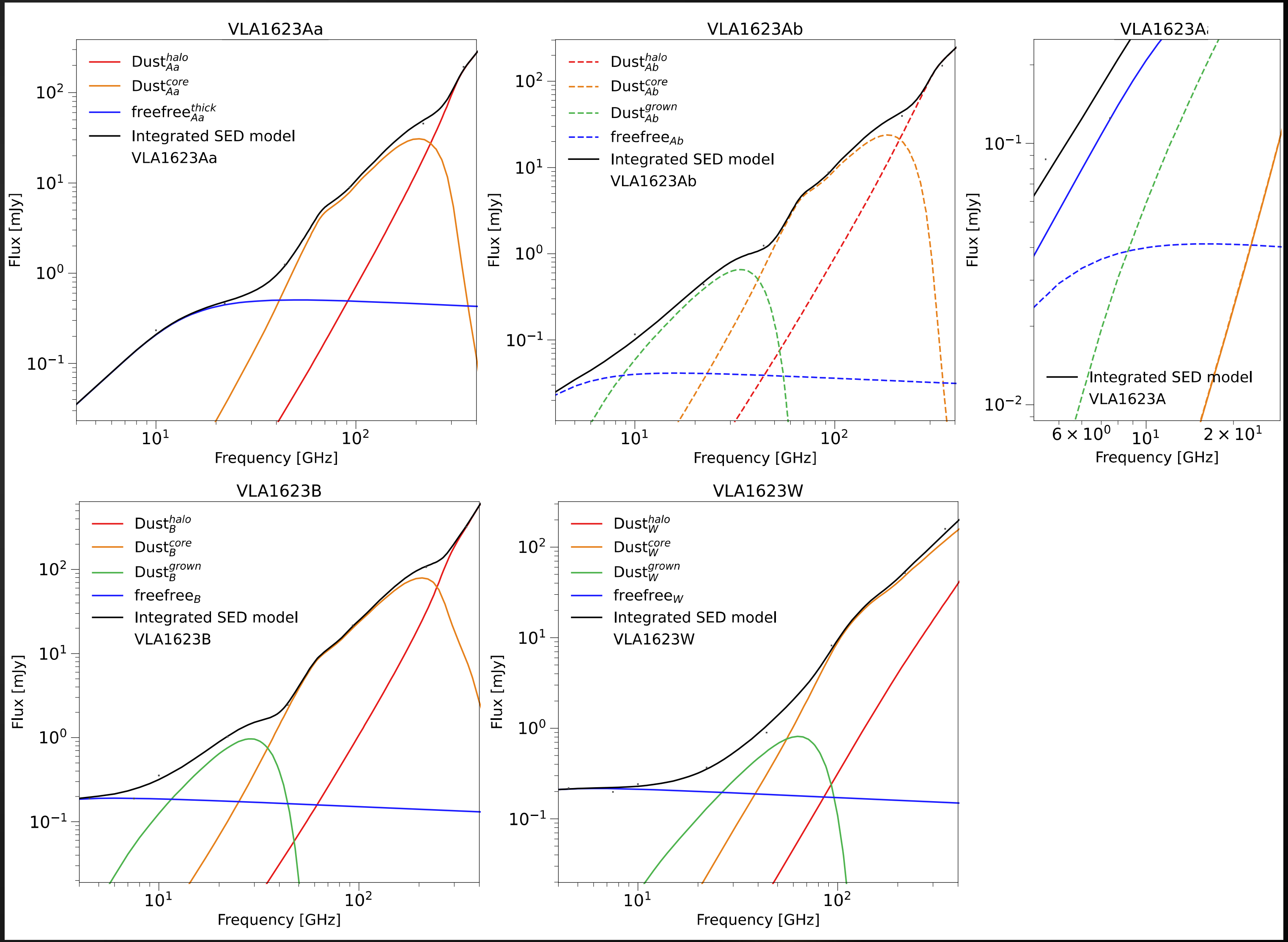


Data from Dzib+13, Harris+18, Radley+(submitted.)

SED Modelling (2)

- Using multiple dust components, mutual obscuration and an optically thick/thin ionized gas component.
- Aa consistent with significant free-free emission.
- 10's-100's of Earth masses in dust

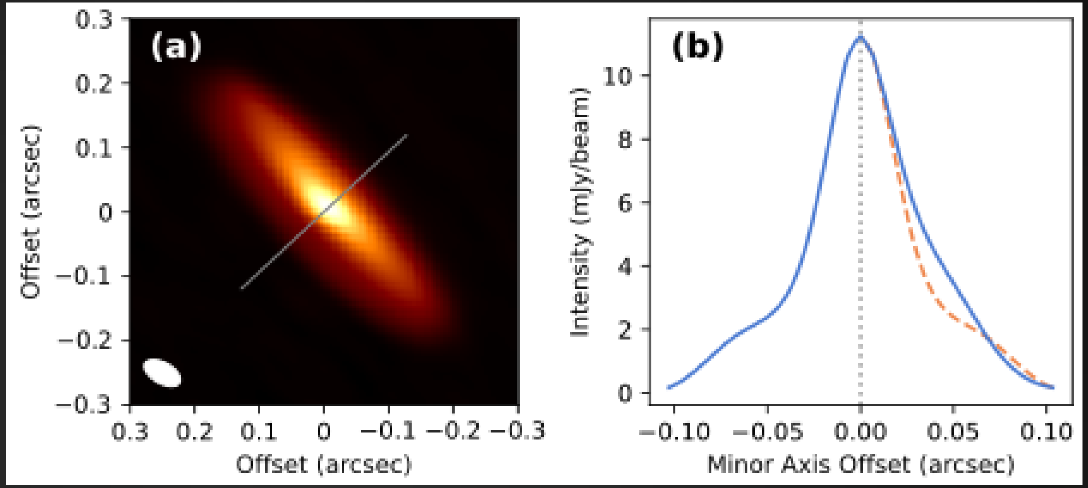
Object	M_{dust} $(M_\oplus)$
Aa	≥ 56.4
Ab	≥ 160
B	≥ 643
West	≥ 513



Data from Dzib+13, Harris+18, Radley+(submitted.)

The unsettled disk of VLA 1623 B

- Brightness asymmetry seen on the nearside of the disk.
- We estimate a z/r ~ 0.3.
- Similar morphology to that seen in CO isotopologues of class II disks (*Law +2023*).

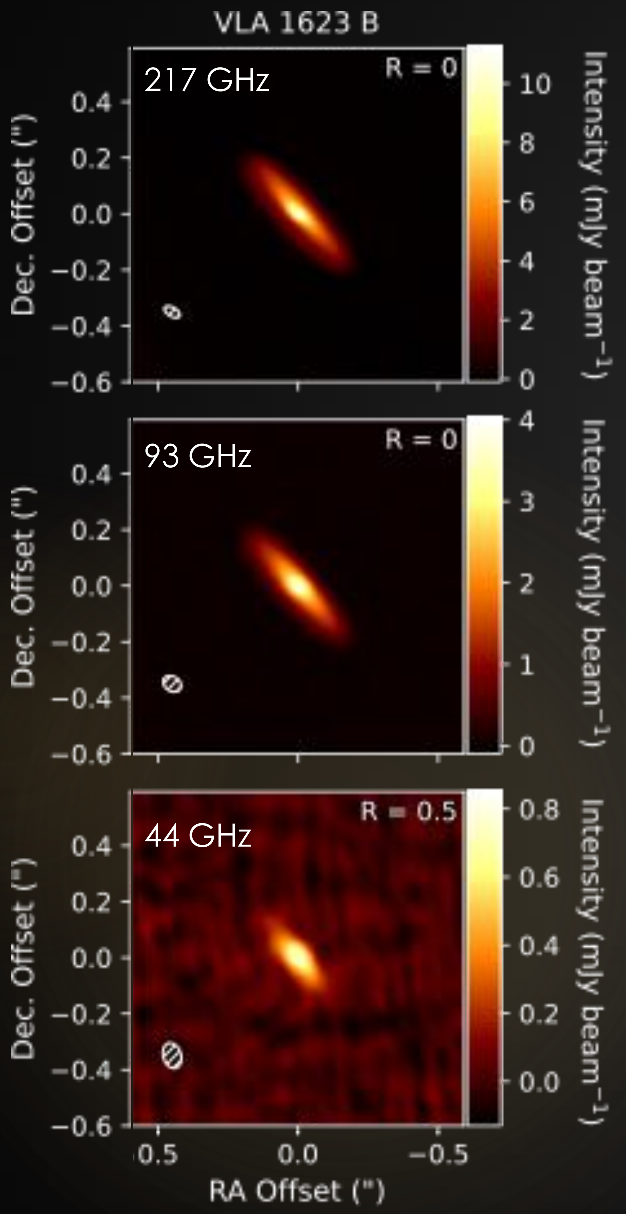


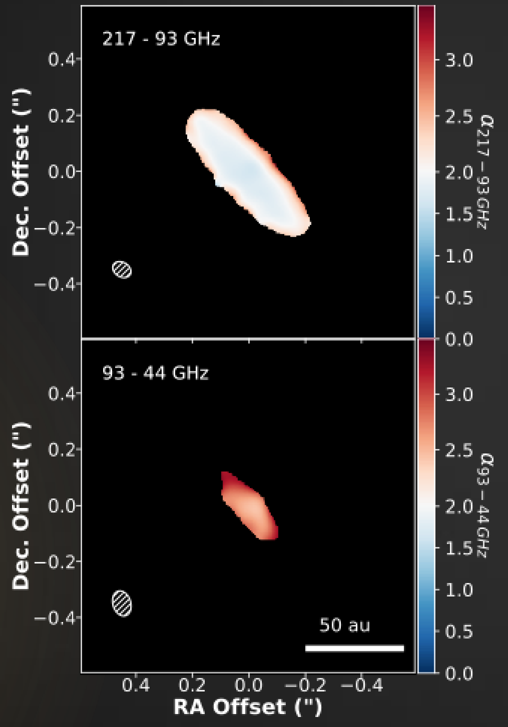
- $M_{Dust} = 643\ M_{\oplus}$
- $M_{*} = 1.9\ M_{\odot}$ (*Sadavoy+ 2024*)
- Dust to Gas = 1:100

Disk to star mass ratio ~ 0.1

Potentially gravitationally unstable?

The unsettled disk of VLA 1623 B

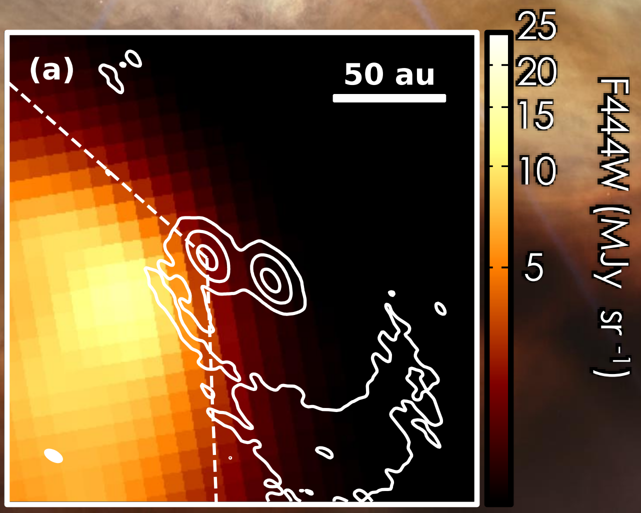




- If the disk is gravitationally unstable, are there any signatures?
- Need high resolution and high sensitivity at frequencies ≤ 44 GHz.

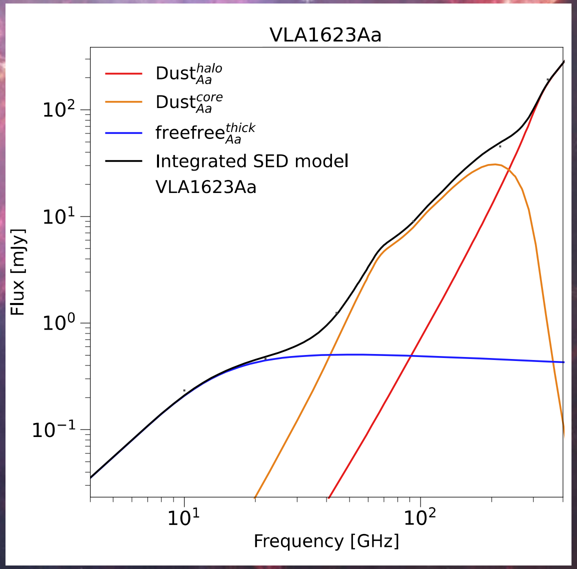
Isaac C. Radley
University of Leeds

The little protostar that could...

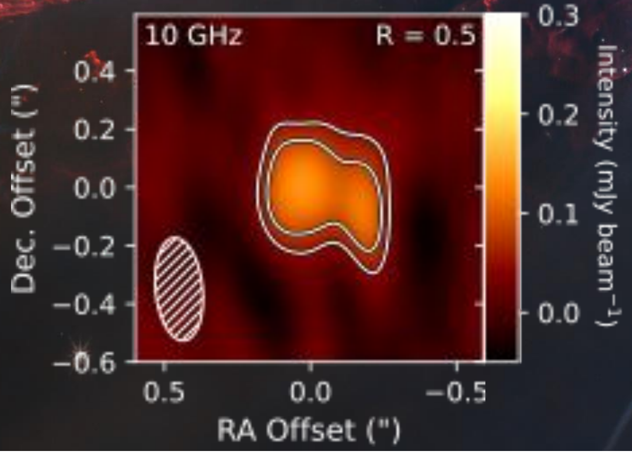


- 4.4 μm image indicates outflow originates closer to Aa than Ab

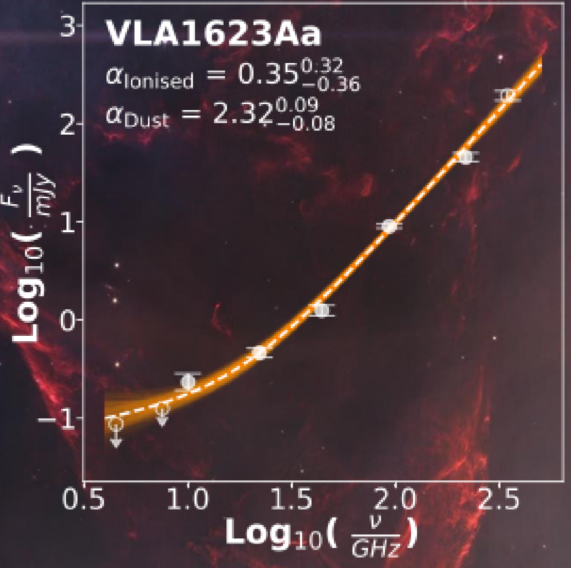
- SED modelling well represented by a significant ionised gas component



- Significant brightness enhancement at 10 GHz with a PA closely aligned to 4.4 μm outflow



- Spectral index consistent with jet or wind emission

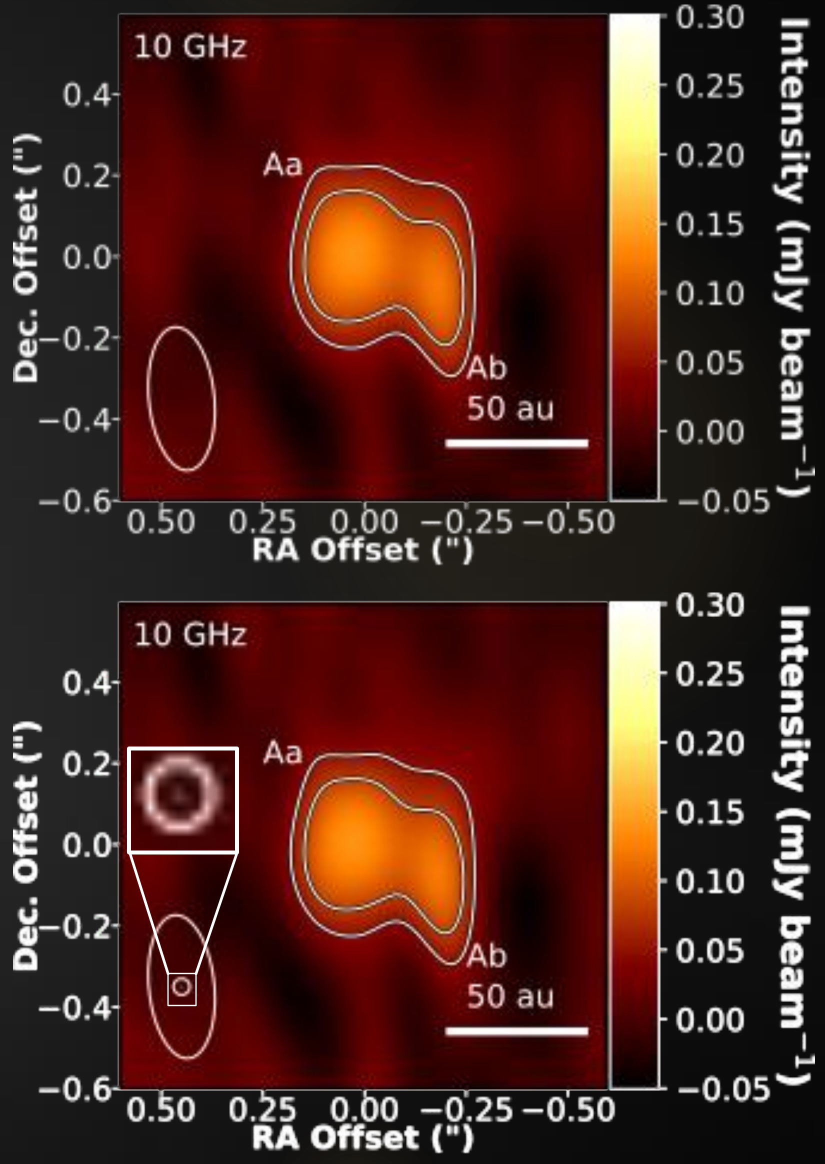


Future of Radio

- Even at the most extended (A) configuration, we are still resolution limited.

- The SKA and NGVLA will drastically improve both sensitivity and resolution allowing us to further decompose observations at frequencies < 22 GHz.

- SKA resolution (10 GHz) ~ 0.04 as
- NgVLA resolution (10 GHz) ~ 1 mas



Summary

VLA 1623:
- **Potential dust growth** in class 0 and class I phase.
- **Optically thick up to 44 GHz** and dominated by ionised gas emission beyond 22 GHz.

VLA 1623 B:
- Very unsettled dust disk seen at 217 GHz.
- Potentially **gravitationally unstable**?

VLA 1623 A:
- **Single jet** may be launched by Aa as opposed to both objects.

Future work:
- **Full survey 40 hr** of the Ophiuchus region :
  - **~20 objects** detected at 44-10 GHz.
  - Range from **Class 0 - III**
  - **SED modelling** using archival data (e.g. ODISEA)
  - **Variability study** from days to weeks
  - Comparison to other SFR
- Radiative transfer modelling
  - Focusing on dust dominated sources.
  - Utlising multi-frequency observations to **constrain dust mass.**

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