# Detection of a Millimeter Flare from Proxima Centauri


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# The Proxima Centauri System

## The Star

spectral type = M5.5V

distance = 1.3 pc

## The Planet

*from RV*

$m_p \sin i = 1.3\ M_\oplus$

a = 0.05 AU

(Anglada-Escudé et al. 2016)

## Dust Rings?

(1) warm dust at ~0.4 AU

(2) a cold belt from 1– 4 AU

(3) an outer belt at ~30 AU

(Anglada et al. 2017)

*from ALMA*

**12-m Array:** 2x on 2017 April 25

**ACA:** 13x on 2017 January 21 – March 24

ALMA project: 2016.A.00013.S (PI Anglada)

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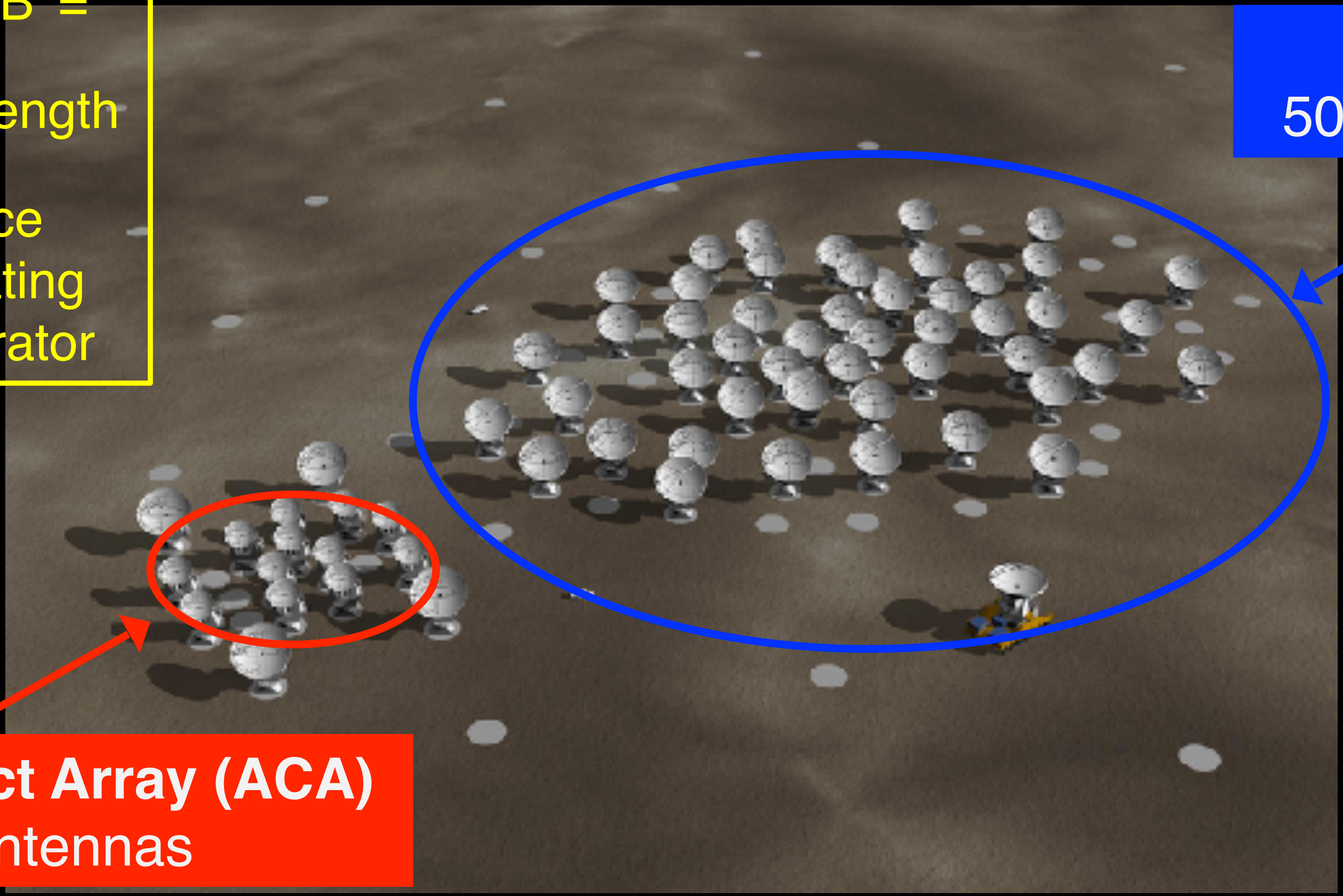
# The ALMA Array

Observation or ‘SB’ =

~1.5 hours in total length

6.5 min on-source integration alternating with a phase calibrator



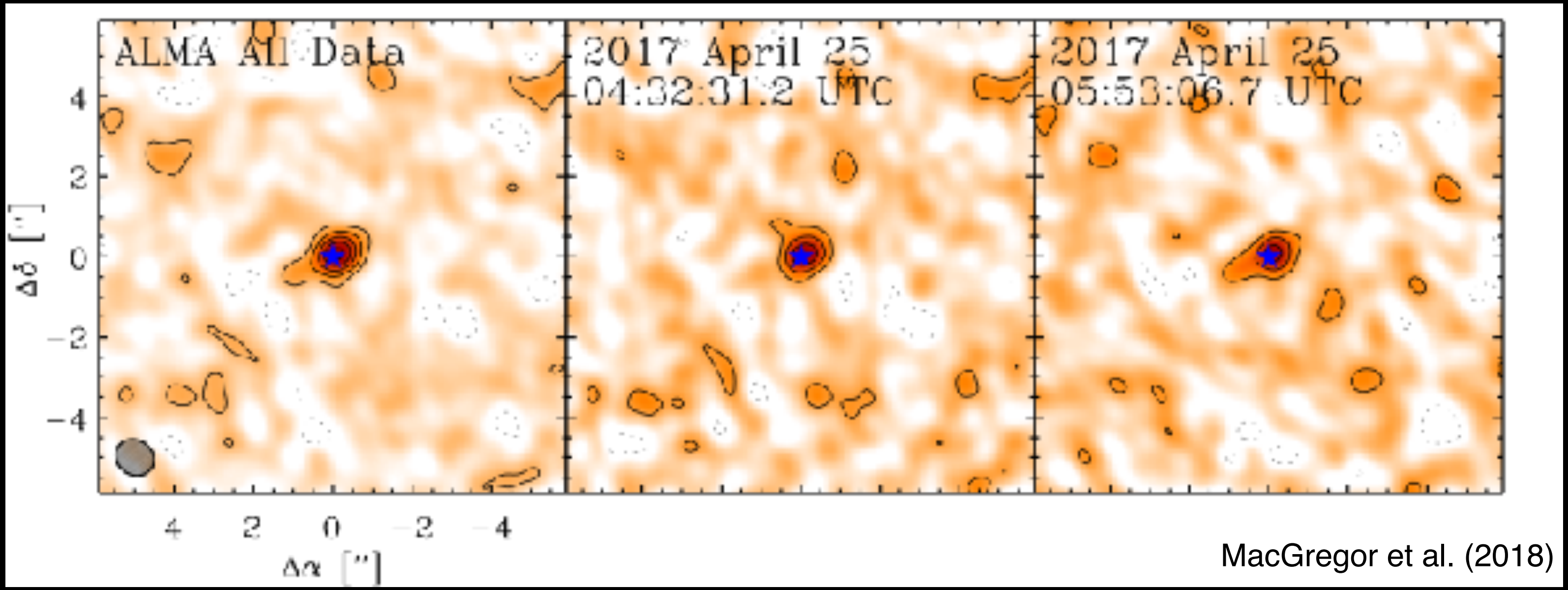
**Main Array**
50 x 12-m antennas

**Atacama Compact Array (ACA)**
12 x 7-m antennas

**All observations taken at 1.3 mm (230 GHz, Band 6) with 8 GHz of bandwidth and two linear polarizations (XX, YY)**

# ALMA 12-m Observations

Both Obs. Obs. 1 Obs. 2



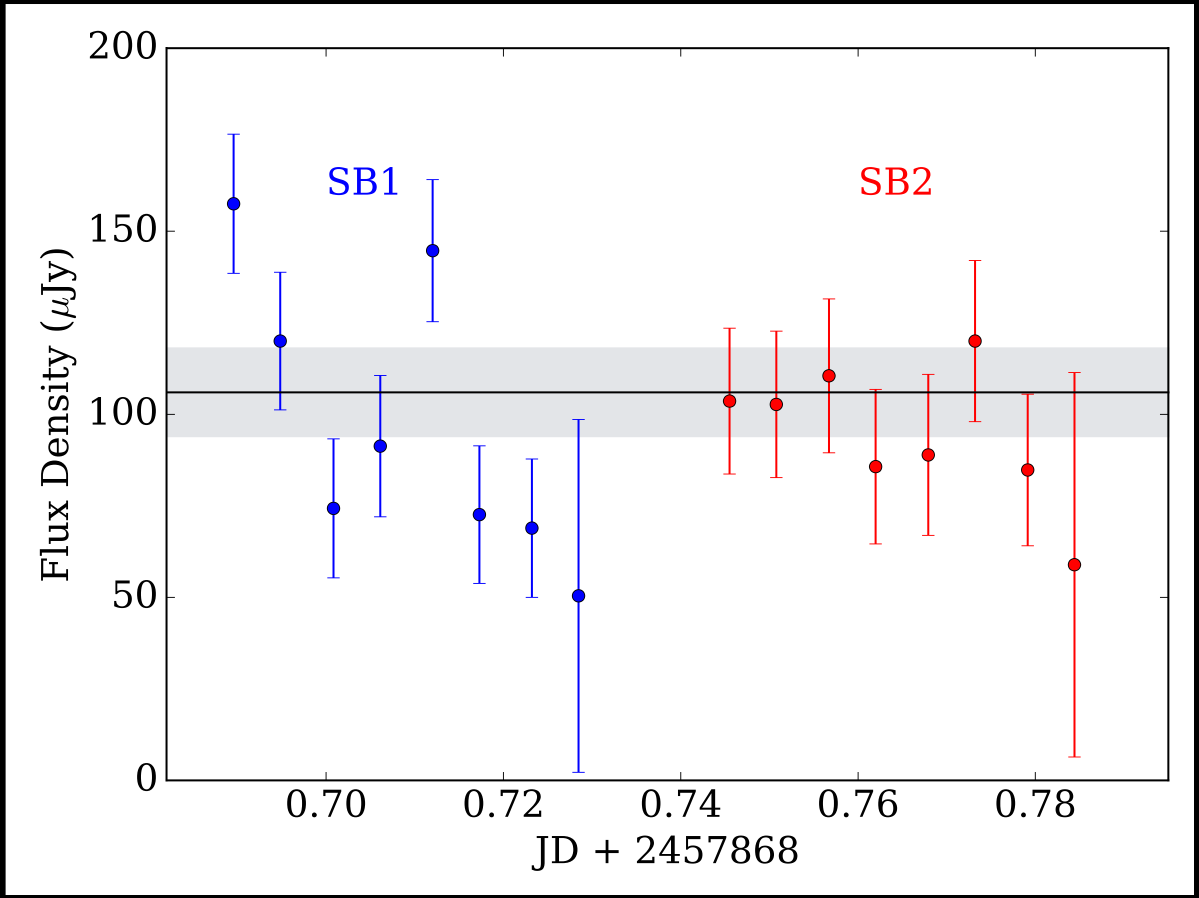

Flux = 101 ± 9 μJy

Flux = 110 ± 19 μJy

Flux = 94.1 ± 8.0 μJy

For reference: expected photospheric flux = 74 ± 4 *μ*Jy (Ribas et al. 2017)

# ALMA 12-m Observations




MacGregor et al. (2018)

**Flux fairly consistent between two observations**

Range from 50 – 157 µJy

Slightly above photospheric flux

**Spectral index consistent with Rayleigh-Jeans**

$\alpha = 2.58 \pm 2.05$

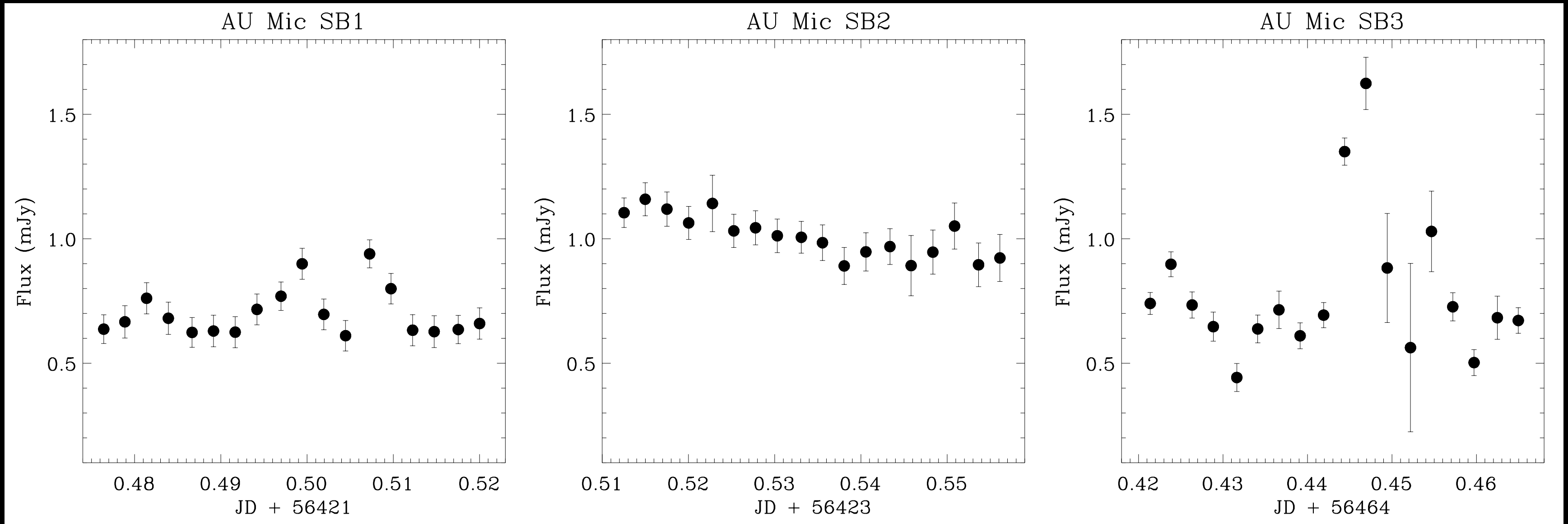
**No detected linear polarization**

$| Q/I | = 0.09 \pm 0.12$

For reference: expected photospheric flux = 74 ± 4 $\mu$Jy (Ribas et al. 2017)

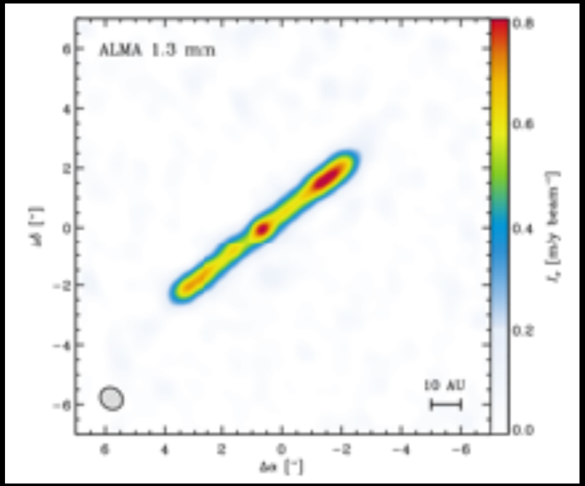
# A Comparison – AU Mic

**VLA Observations**




MacGregor et al. (2016a)

**ALMA Observations**



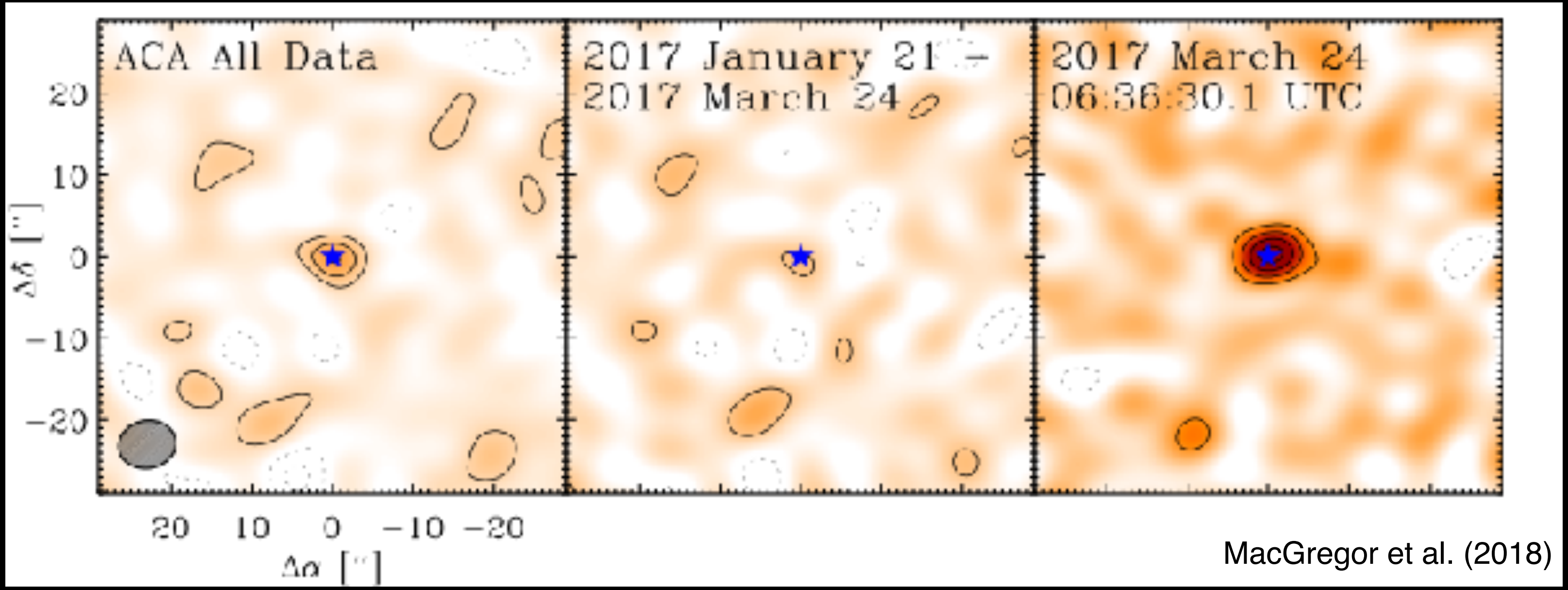

MacGregor et al. (2013)

ALMA observations show central peak above photosphere and VLA observations show significant variable emission from stellar activity

**Emission at X-ray through radio wavelengths explained by coronal heating from continual small flares (Cranmer, Wilner & MacGregor 2013)**

# ACA Observations

All Obs. Obs. 1 – 12 Obs. 13




Flux = 340 ± 60 µJy

Flux <200 µJy (3σ upper limit)

Flux = 1.17 ± 0.1 mJy

For reference: expected photospheric flux = 74 ± 4 *µ*Jy (Ribas et al. 2017)

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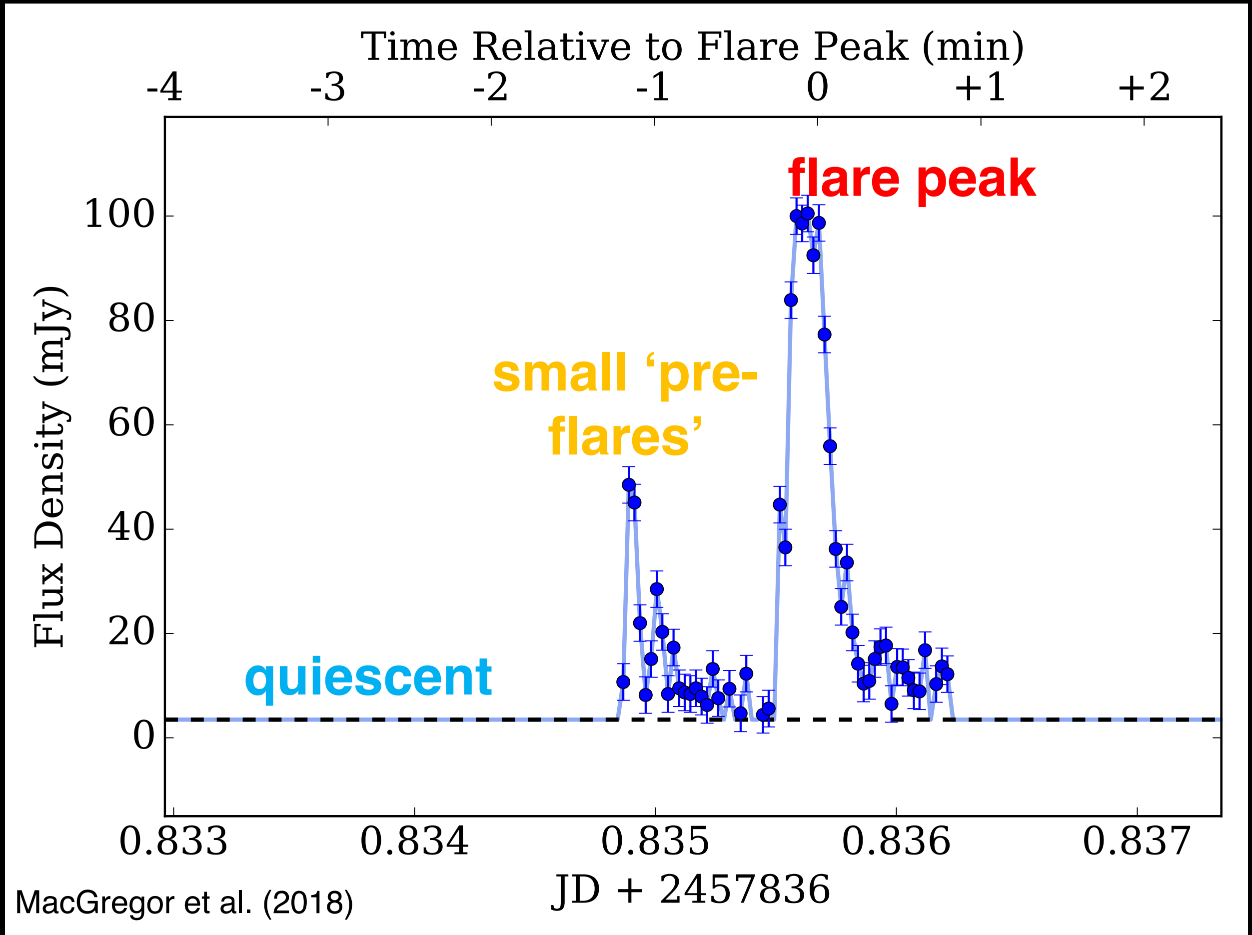
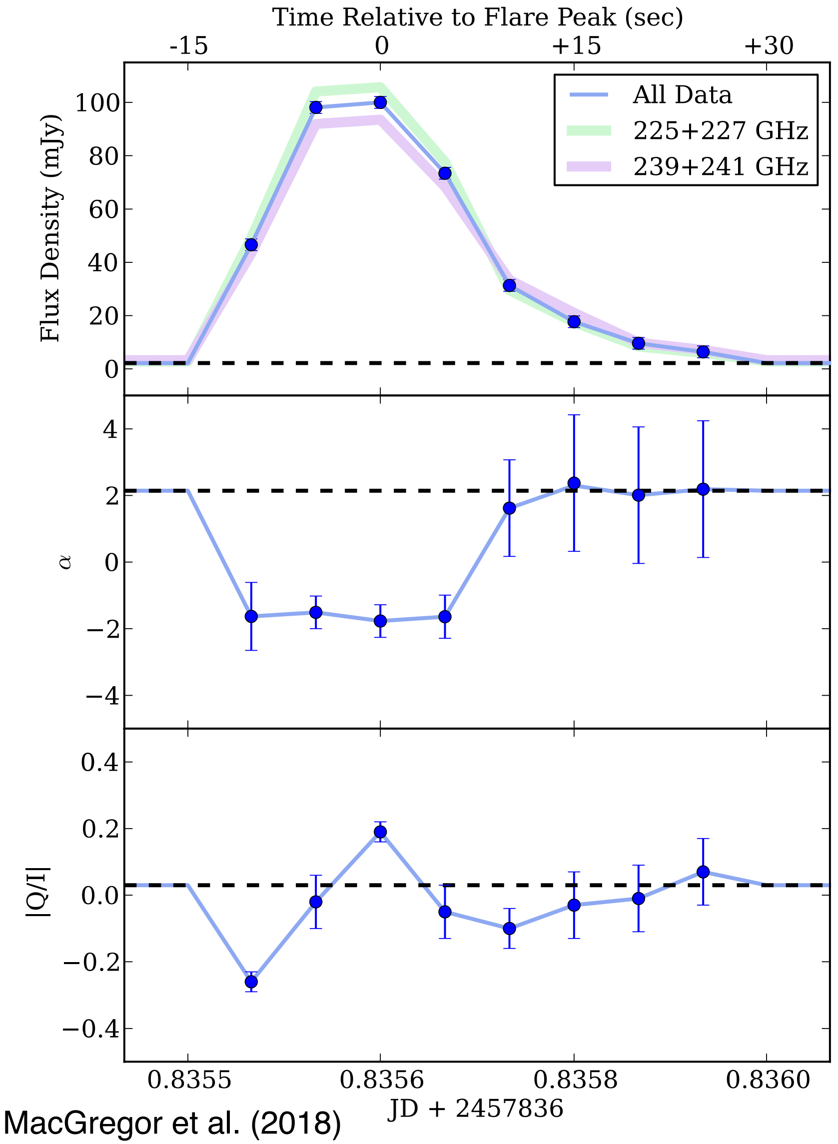
# Detection of a Millimeter Flare




**Proxima Centauri underwent a significant flaring event during the ACA observations**

# Millimeter Flare Properties




MacGregor et al. (2018)

**1000× brighter than quiescent emission**

$F = 100 \pm 4$ mJy

$L = 2.04 \pm 0.15 \times 10^{14}$ erg s$^{-1}$ Hz$^{-1}$

**Falling spectral index with frequency**

$\alpha = -1.77 \pm 0.45$

**Positive fractional linear polarization**

$|\,Q/I\,| = 0.19 \pm 0.02$

**10x brighter at peak than brightest solar flares at millimeter wavelengths**

$L = 2 \times 10^{13}$ erg s$^{-1}$ Hz$^{-1}$ $\quad \alpha = 0.3 - 5$

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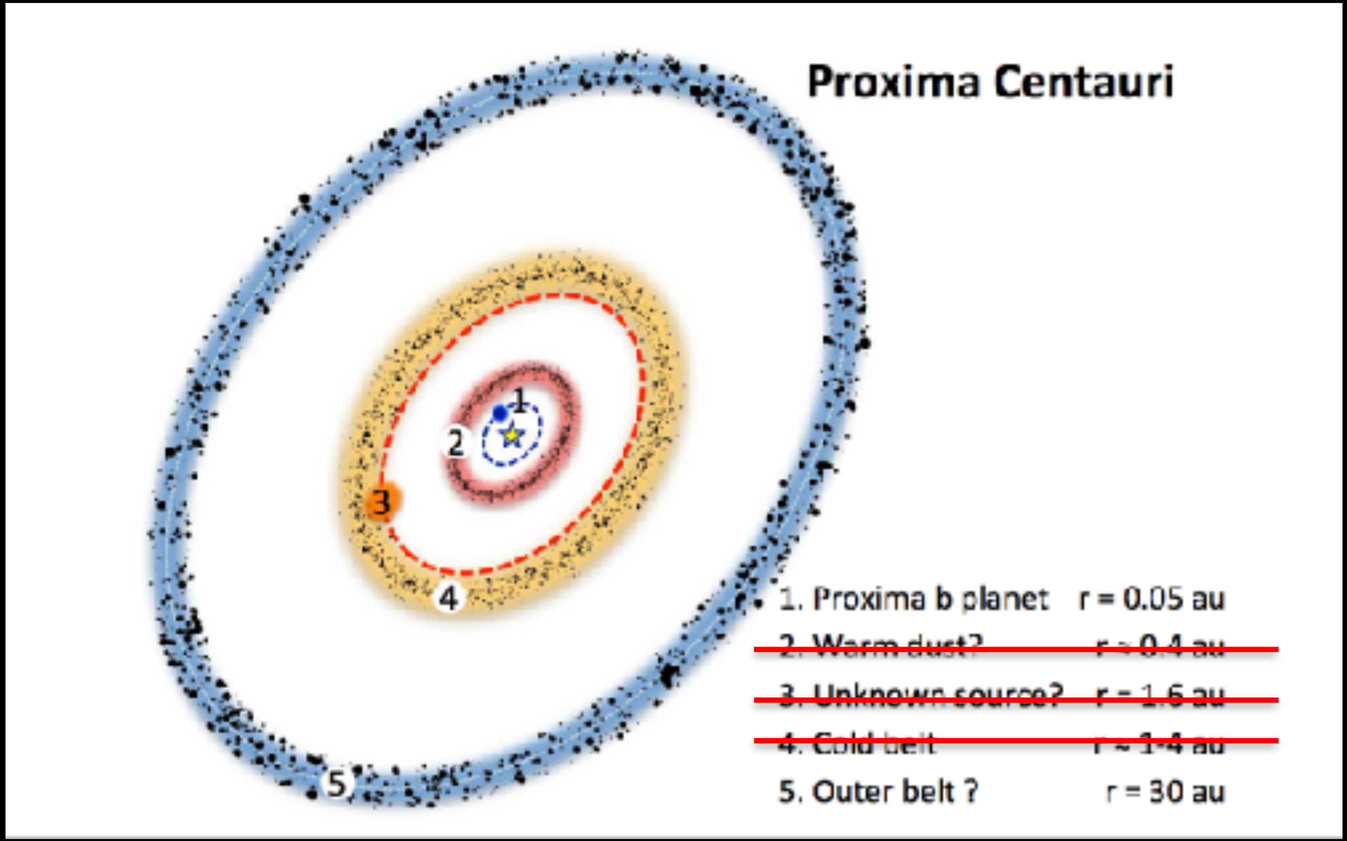
# Implications for Dust




Anglada et al. (2017)

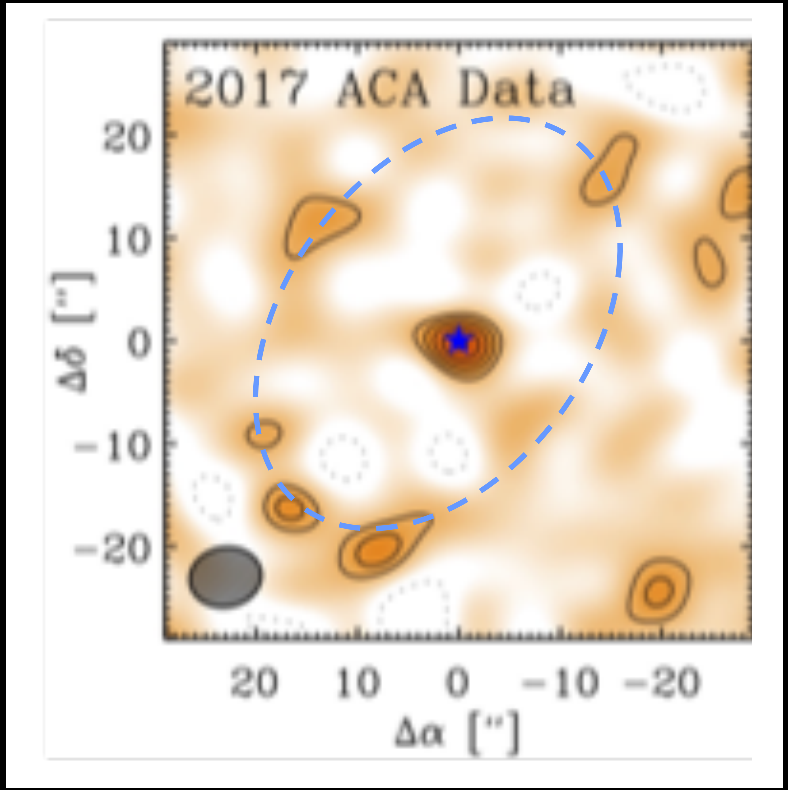
**Need to better understand millimeter stellar emission in order to characterize emission from unresolved (warm) dust belts!**

# The Outer Belt

**Current observations cannot prove or rule out the presence of an outer belt**

**BUT**

There are some significant caveats:




MacGregor et al. (2018); Anglada et al. (2017)

## Background Galaxies

From ALMA source counts (Carniani et al. 2015), expect 13 (+10, -8) background sources in image

## Galactic Plane

Region of high background cirrus, which confused Spitzer observations at 60 µm (Gautier et al. 2007)

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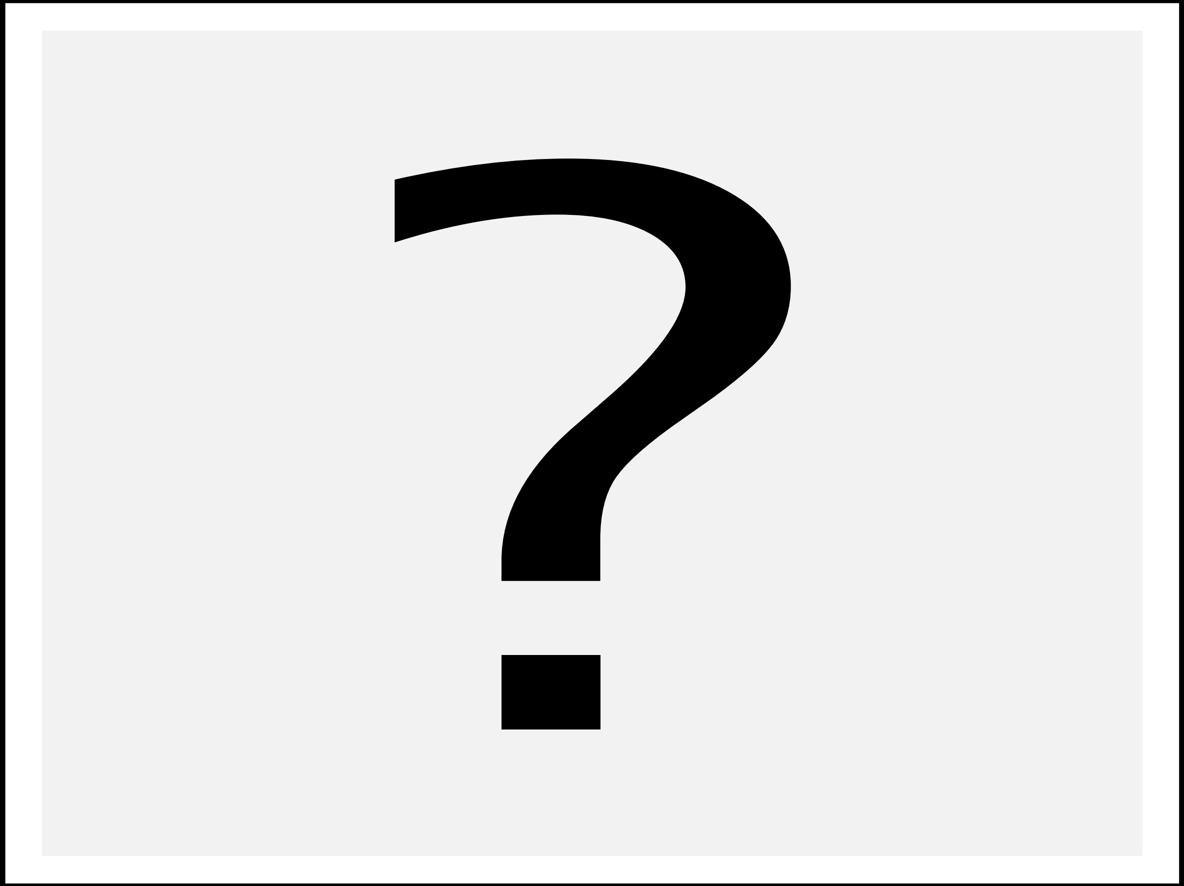
# AU Mic (Again)

Hard to determine emission mechanism with only one event

**Now, there's a 2nd millimeter flare detected by ALMA from AU Mic**




**10x brighter than Proxima flare!**

$F = 16.8 \pm 0.3$ mJy

$L = 1.96 \pm 0.04 \times 10^{15}$ erg s$^{-1}$ Hz$^{-1}$

**Again, falling spectral index**

$\alpha = -1.30 \pm 0.07$

***Analysis done by summer student Samantha O'Sullivan (Harvard undergrad)

Data from ALMA project: 2015.1.00866.S (PI Hughes)

# Take-Aways

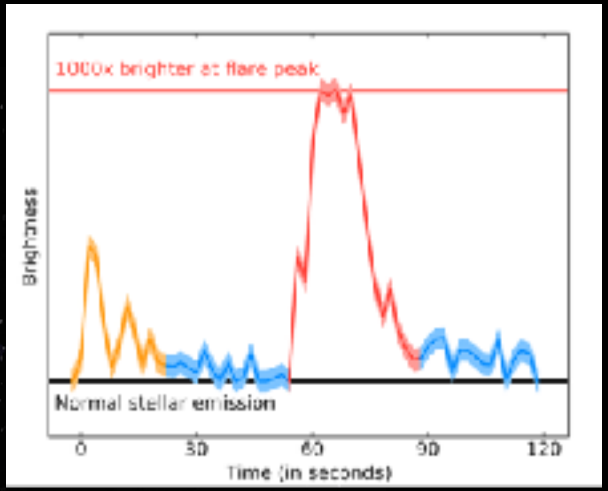
(1) Detected a stellar flare at millimeter wavelengths from Proxima Centauri with ALMA (and now another from AU Mic)

(2) No indication of dust emission interior to 4 AU

(3) Opens a new observational window on the mechanisms responsible for stellar flaring

(4) Caution needed when interpreting unresolved excess emission as dust

(5) Need additional observations at millimeter and complementary wavelengths to learn more




Future work: monitoring with ALMA during Cycle 6 for 40 hours (2018.1.00470.S, PI MacGregor) with simultaneous optical observations