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20180131

# The Transient survey:

# Detection of sub-mm variability in a Class I protostar EC 53 and the preliminary result of 450 μm data analysis

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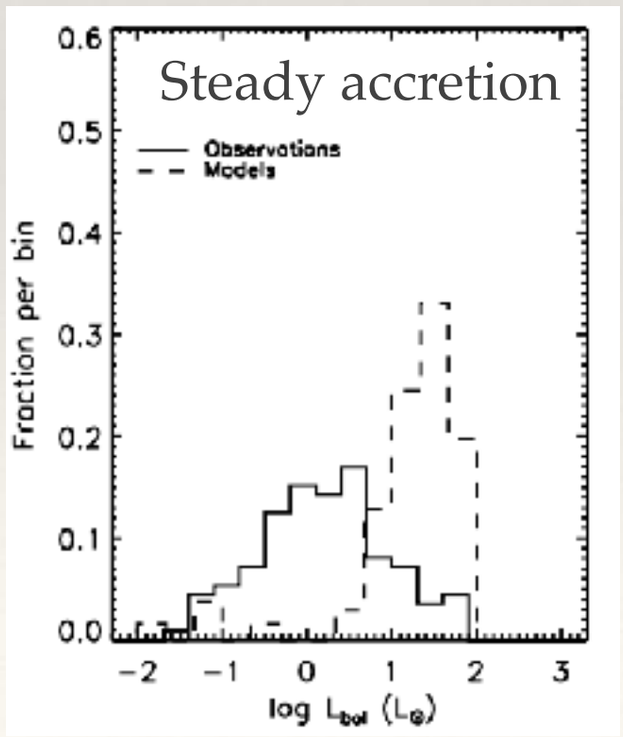
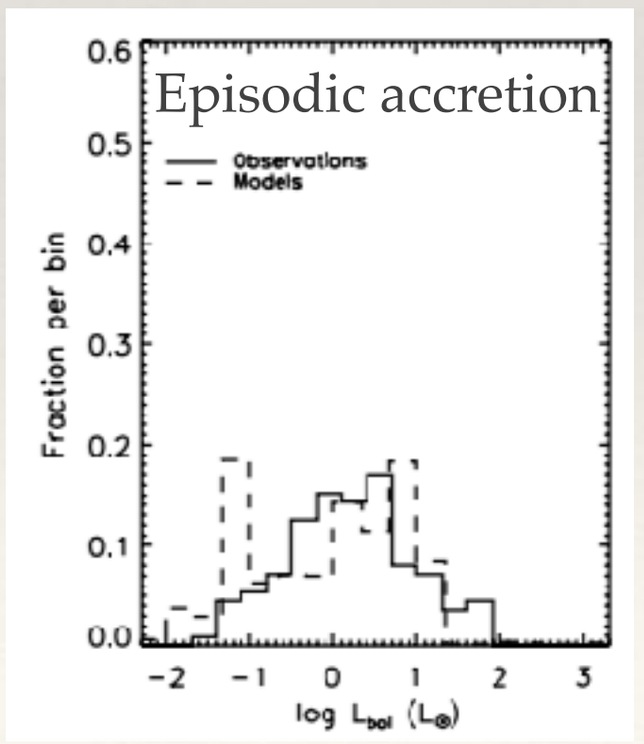
* Yoo et al. 2017, ApJ, 849, 69

# Luminosity problem

* Shu's model on gravitational collapse
  : young star grows from infalling envelope at steady rate ~ 2 x $10^{-6}$ $M_{\odot}$ $yr^{-1}$

* Kenyon et al. (1990)
  : luminosity of most protostars are far below than expected with steady accretion over protostellar lifetime ("**Luminosity problem**")
  : rapid accretion could occur in a series of very short burst with high accretion rate ("**Episodic accretion**")



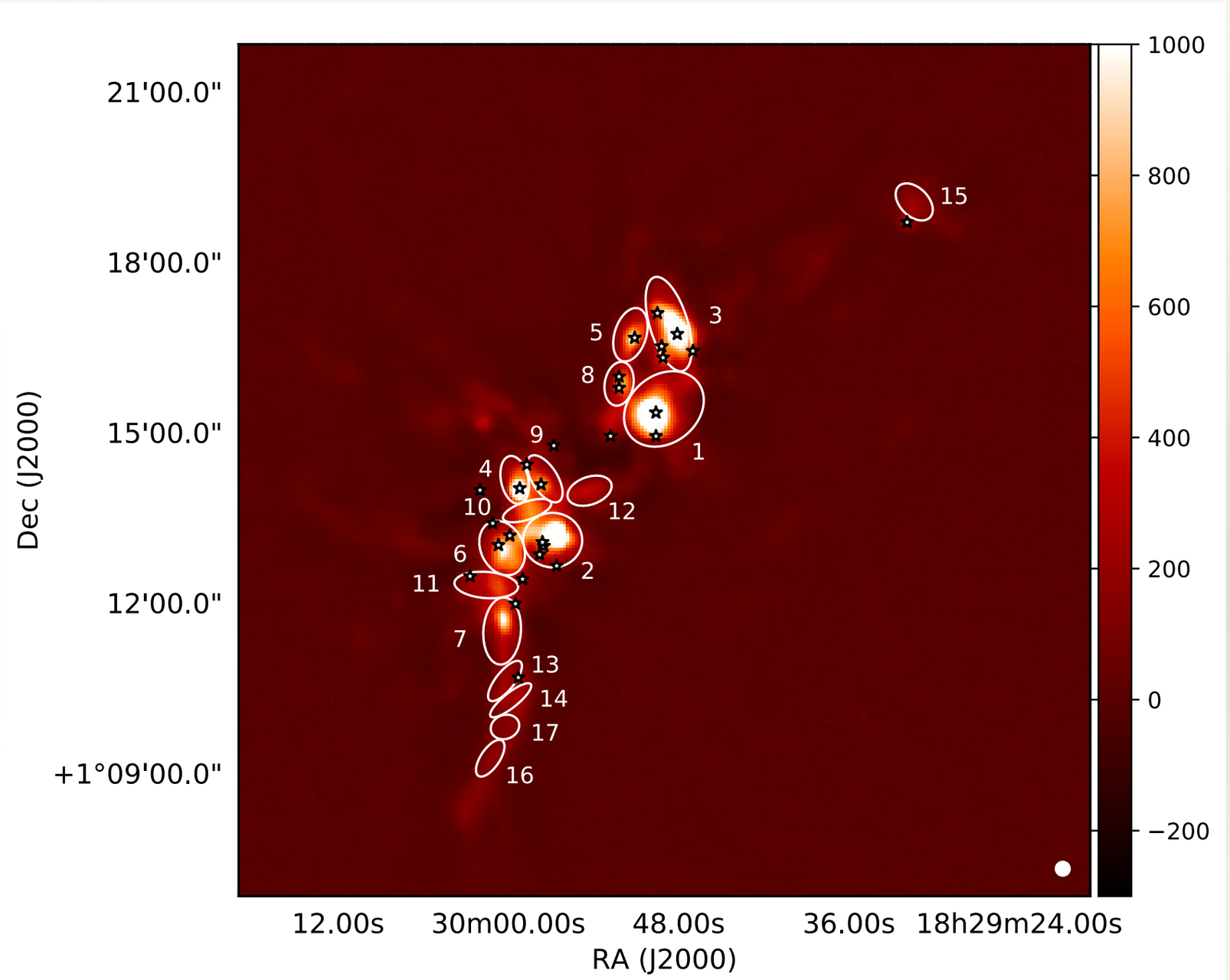

Dunham+10

# JCMT Transient Survey

* The aim of the project
  : episodic accretion is one solution of the luminosity problem
  : monitoring YSOs in 8 star forming regions to detect submm variability
    (monthly observation for 3.5+ years)

* Scientific merit
  : first ground-based program dedicated to surveying protostellar
    variability in submm wavelength to spend years
  : wide field-of-view (30 arcmin)
  : factor of 2.5 deeper than JCMT Gould Belt Survey

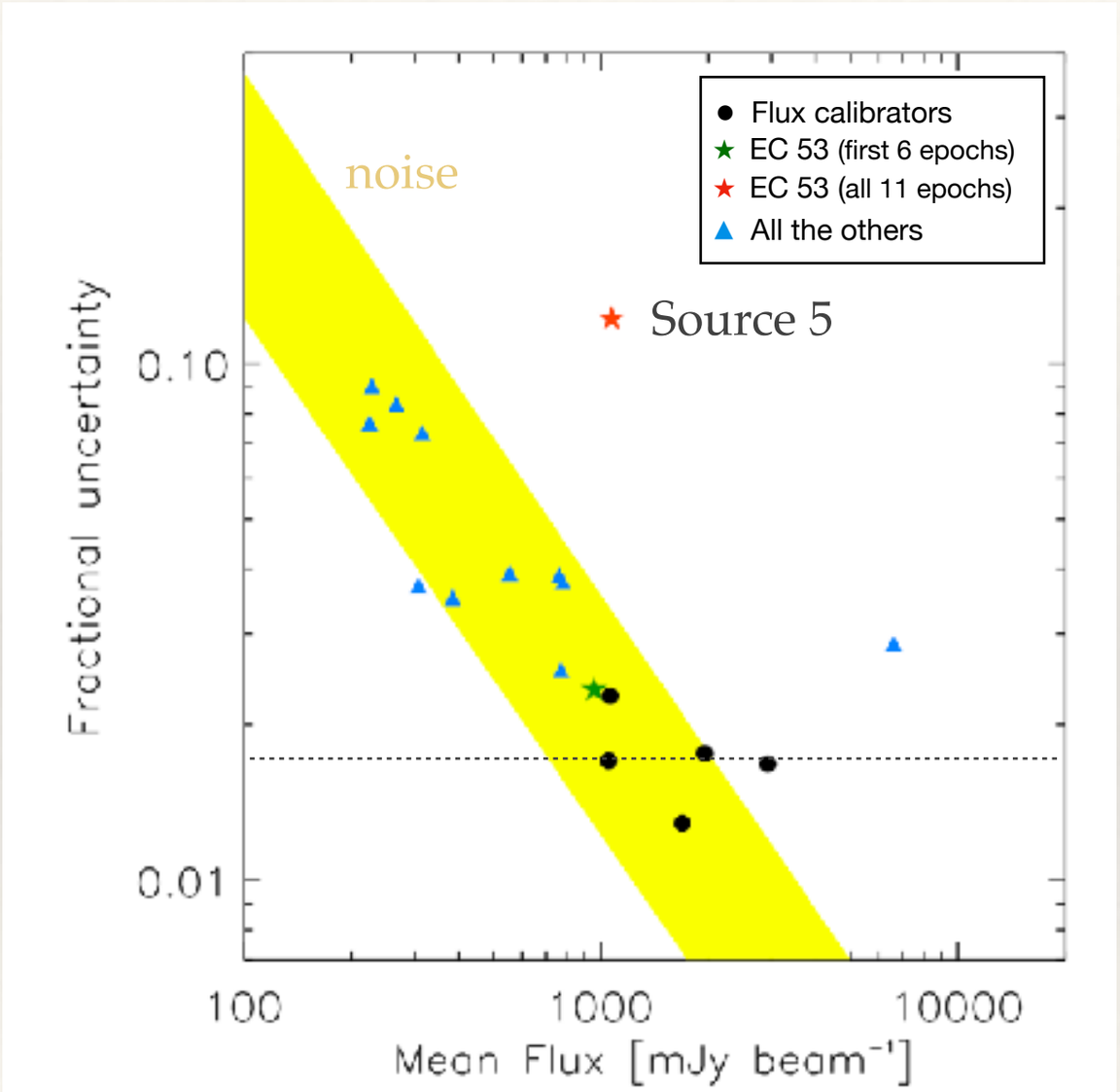
# Serpens Main

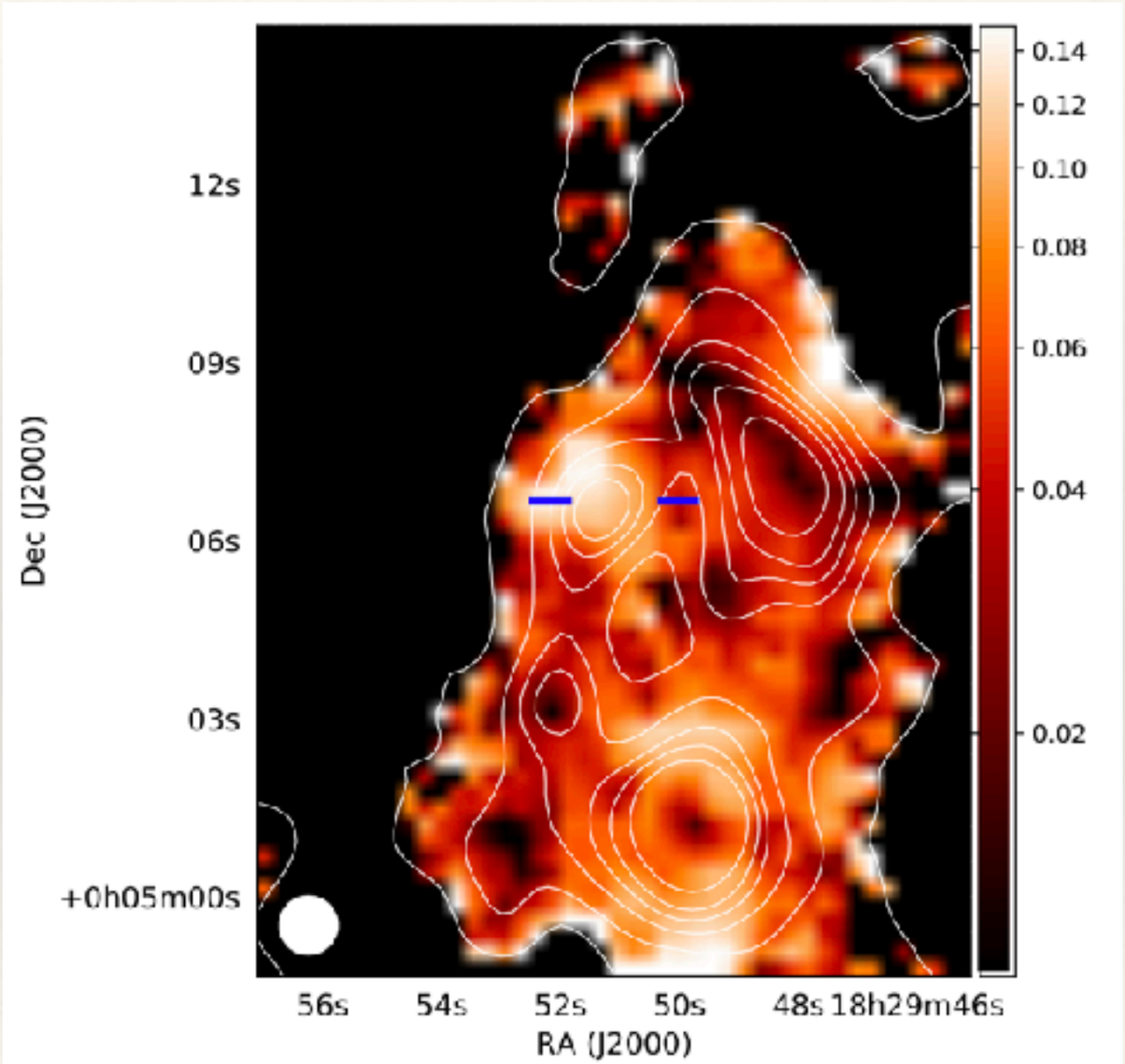



| Date (yyyy-mm-dd) | Julian Day |
|---|---|
| 2016 Feb 02 | 2457420.72 |
| 2016 Feb 23 | 2457441.68 |
| 2016 Apr 15 | 2457493.54 |
| 2016 May 21 | 2457529.39 |
| 2016 Jul 22 | 2457591.44 |
| 2016 Aug 27 | 2457627.23 |
| 2016 Sep 29 | 2457660.22 |
| 2017 Feb 22 | 2457806.66 |
| 2017 Mar 20 | 2457832.58 |
| 2017 Apr 03 | 2457846.56 |
| 2017 Apr 17 | 2457860.54 |

Yoo et al. (2017)

# Variation



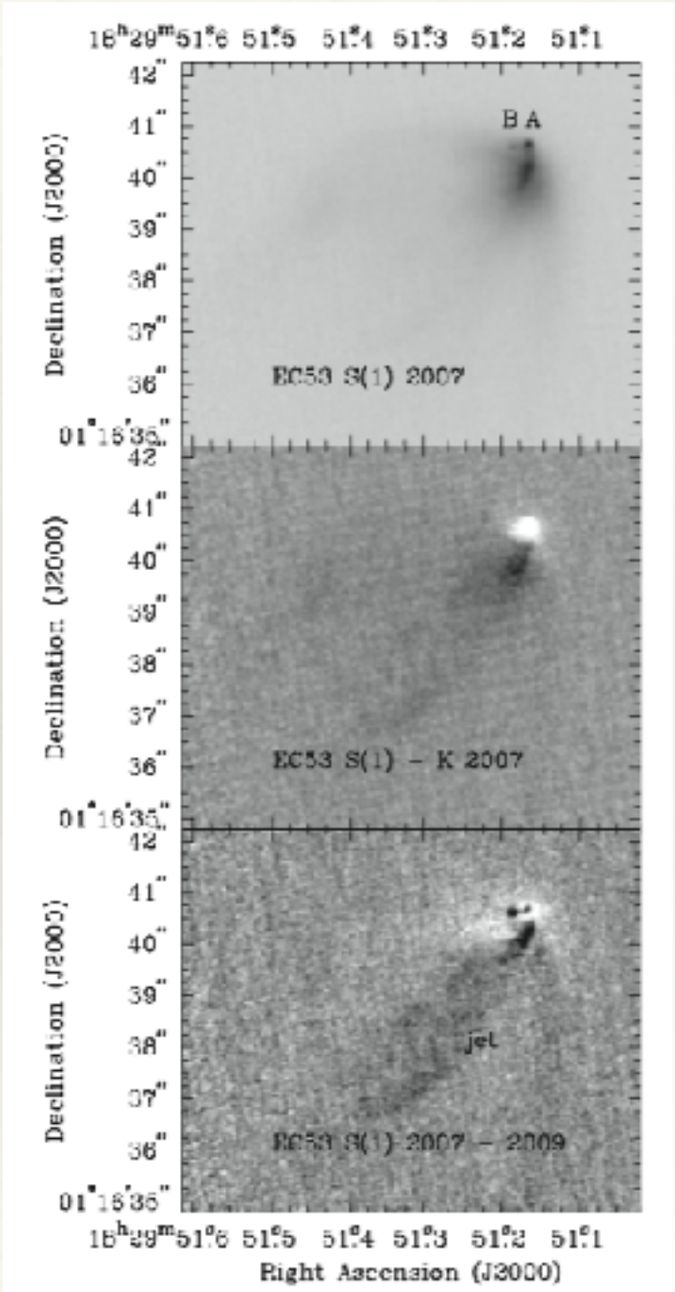



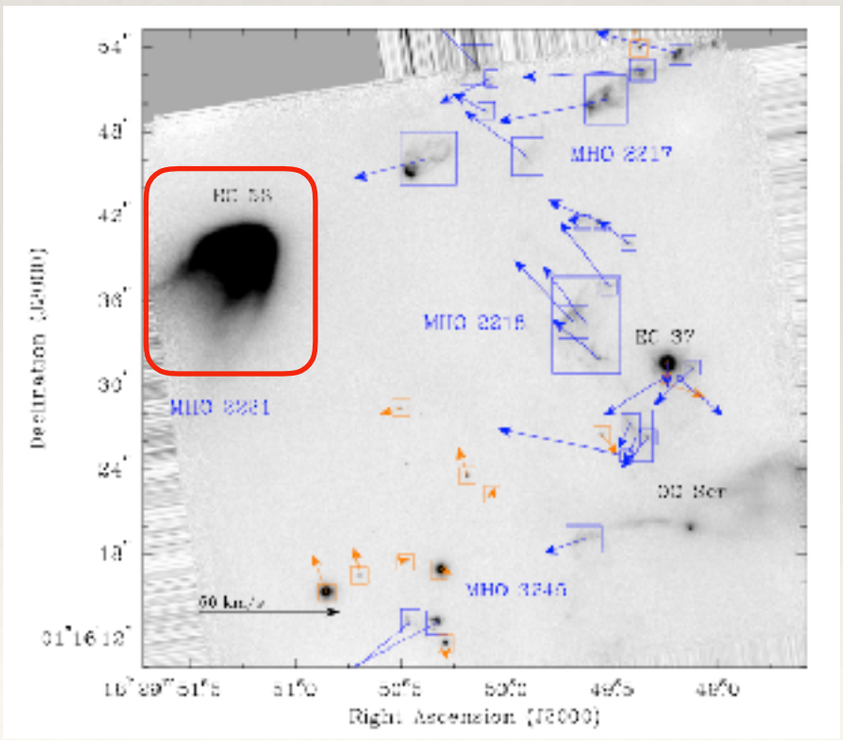

Fractional uncertainty
= standard deviation over 11 epochs / mean flux

Coincidence with a protostar (EC 53)

# EC 53

* **EC53** (V371 Ser)
 - Class I source
 - variable in K-band
 - strong indication of periodicity from ~ 20 yrs monitoring (P ~ 543 days)
 - multipllicity



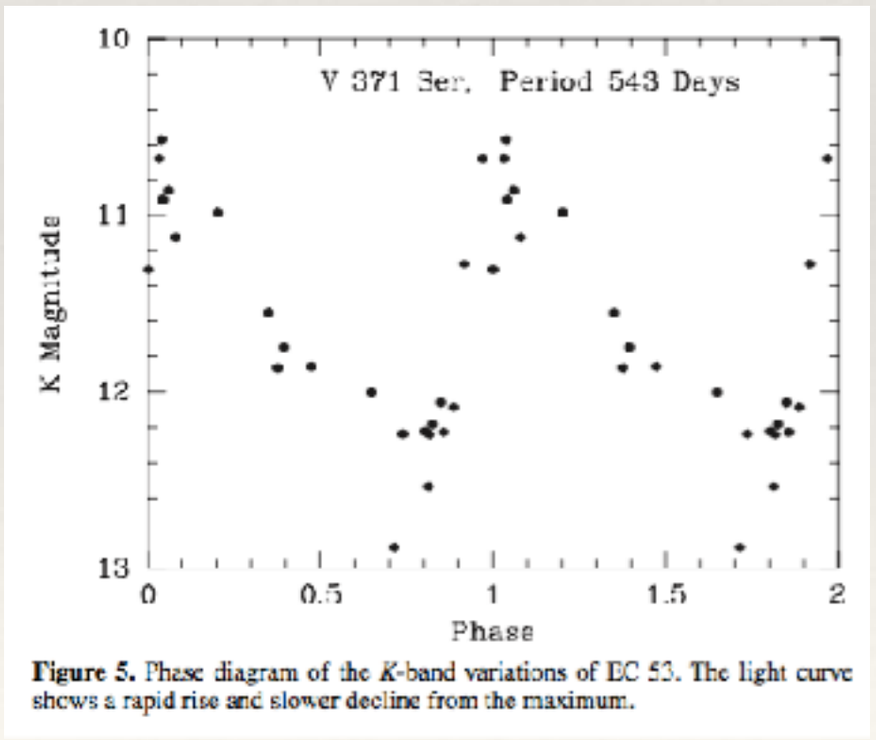



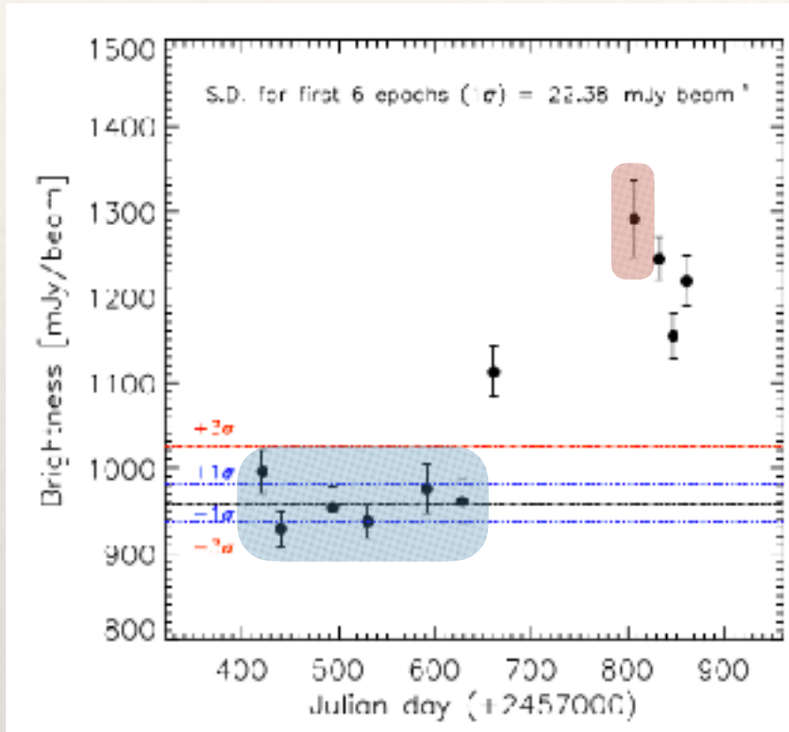

**Figure 5.** Phase diagram of the *K*-band variations of EC 53. The light curve shows a rapid rise and slower decline from the maximum.

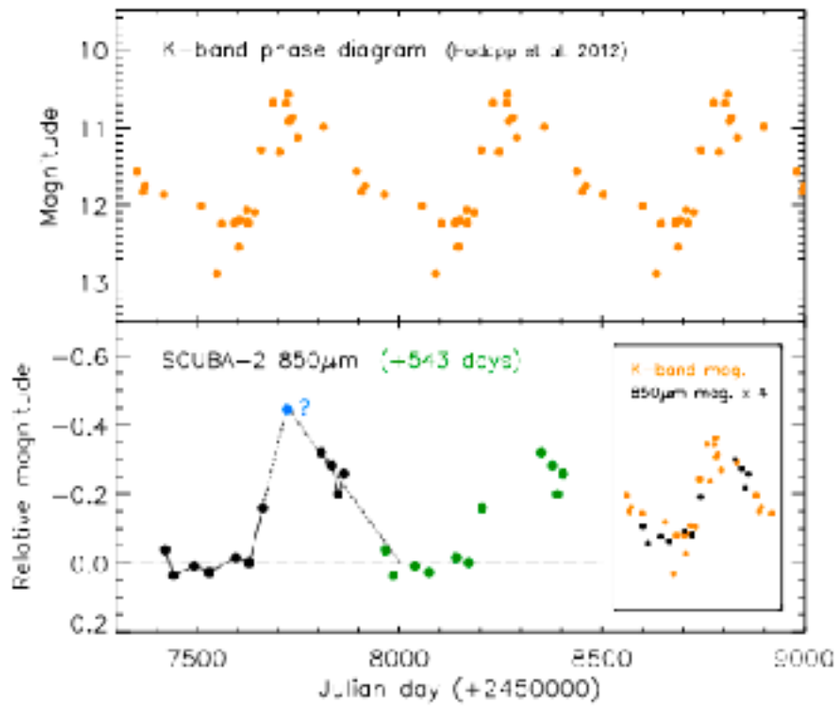
Keck/NIRC2 2.12μm

Hodapp+2012

# Sub-mm variability of EC 53

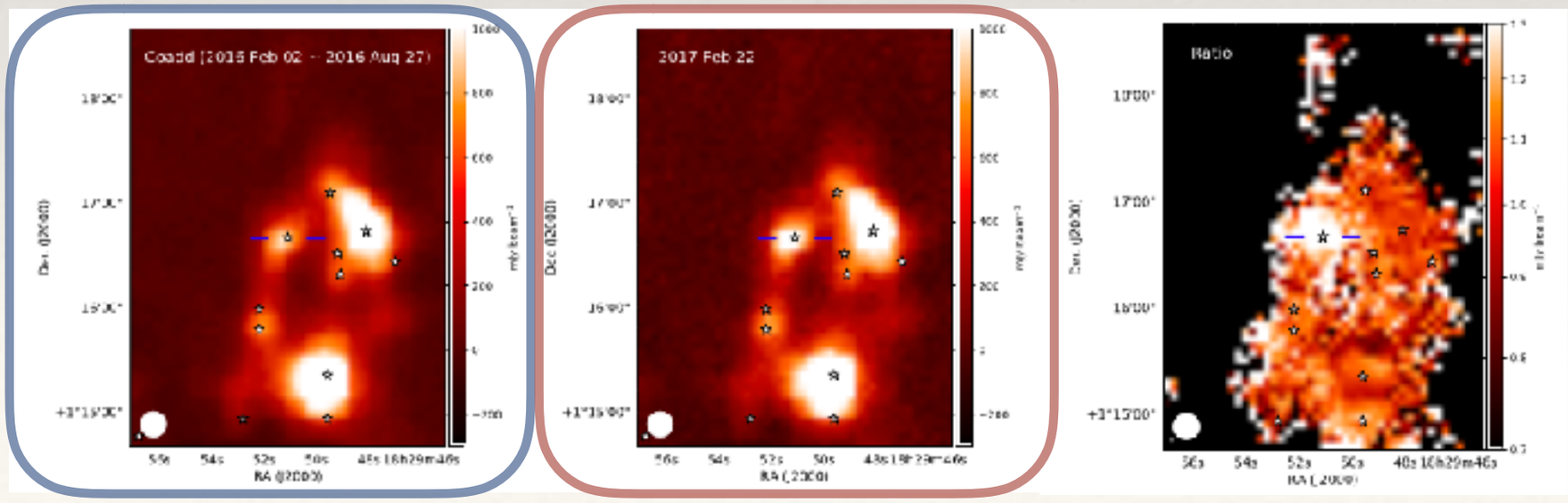
* The first protostellar variable source observed from JCMT Transient 850 μm data




**Similarity of light curve** between K-band and sub-mm (850 μm)

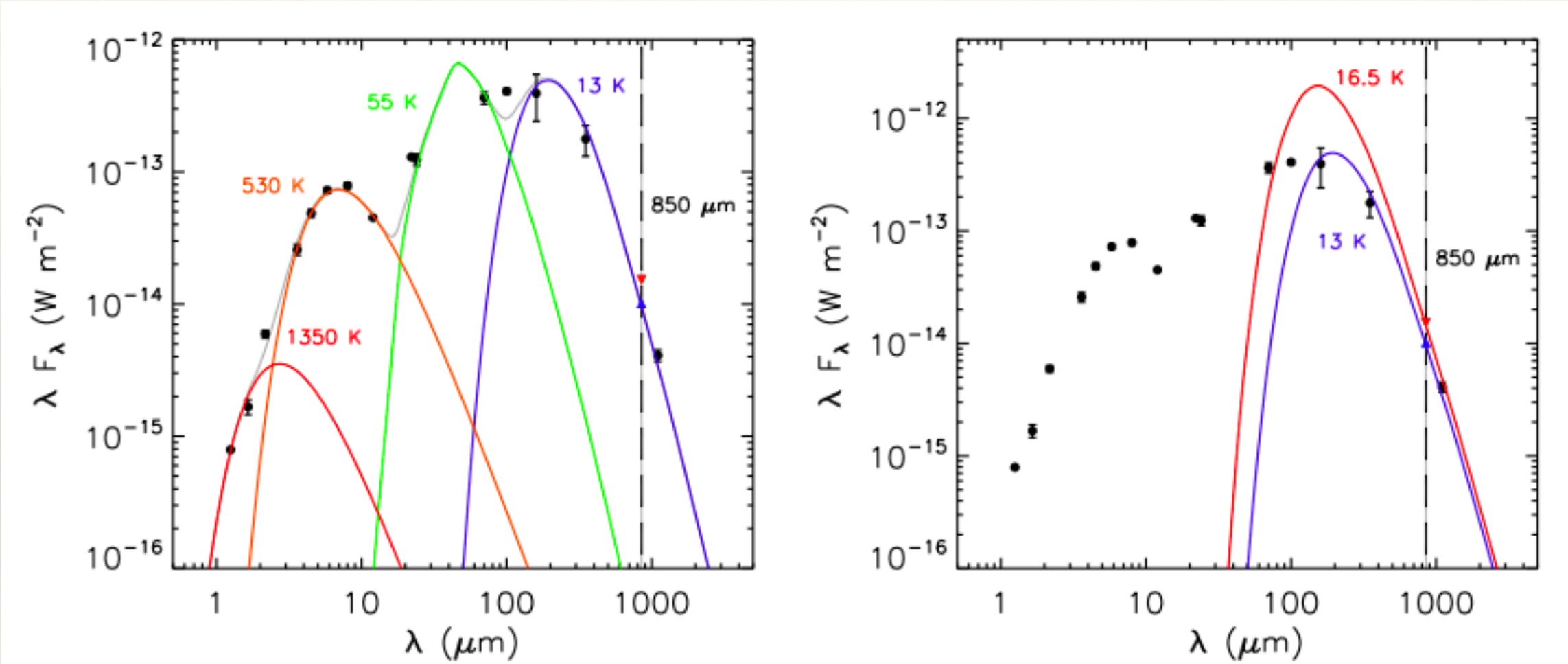
**Periodic** light curve (period of ~ 543 days ; Hodapp et al. 2012)




flux increase at 850 μm ~ factor of 1.3 (expected maximum ~ factor of 1.5)

# Spectral energy distribution

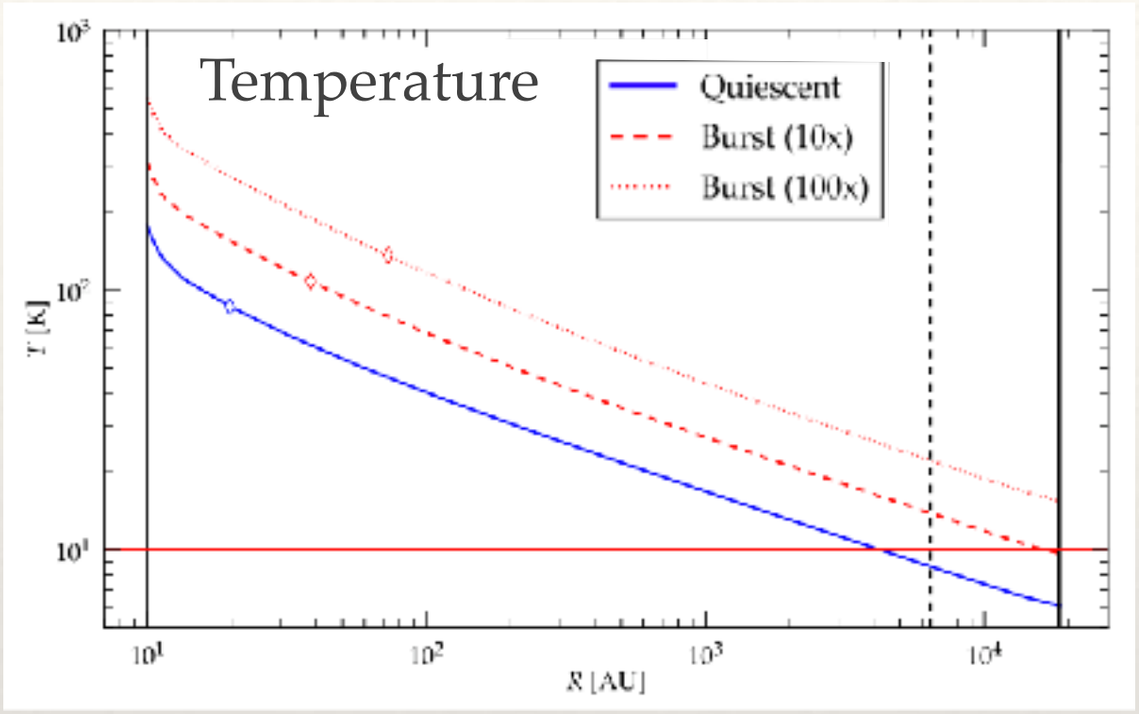
* Simple model for observed spectral energy distribution (SED) of EC 53

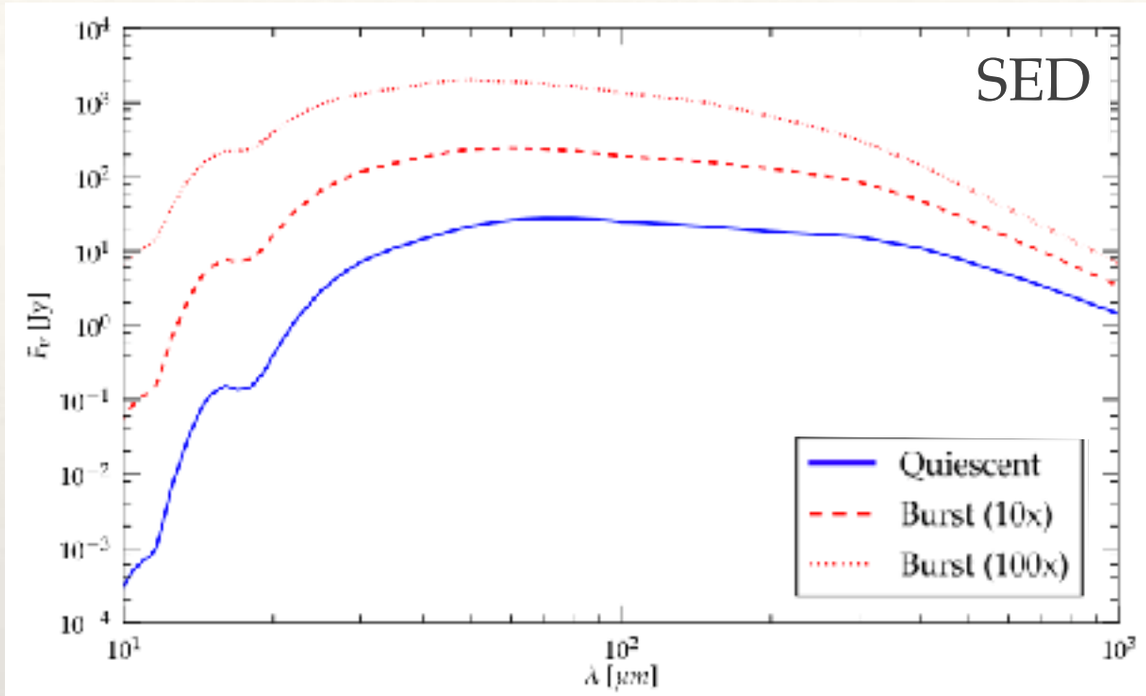


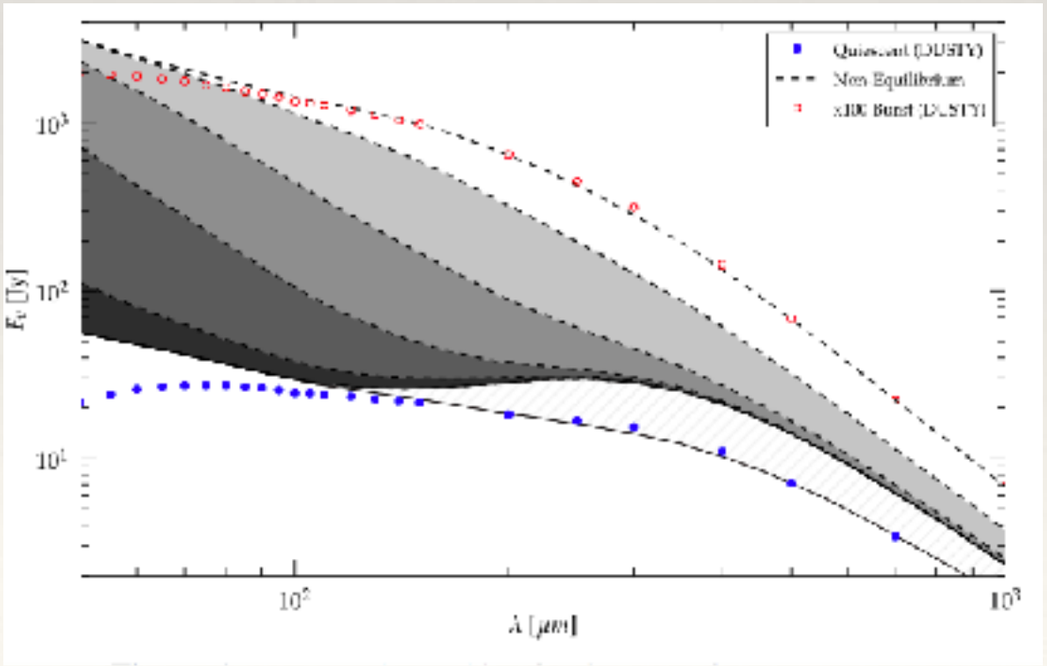

A flux enhancement by a factor of ~1.5 at 850 μm

➢ An increase of the central luminosity by a factor of ~ 4
(An increase of the envelope temperature by a factor of ~1.3)

# Spectral energy distribution



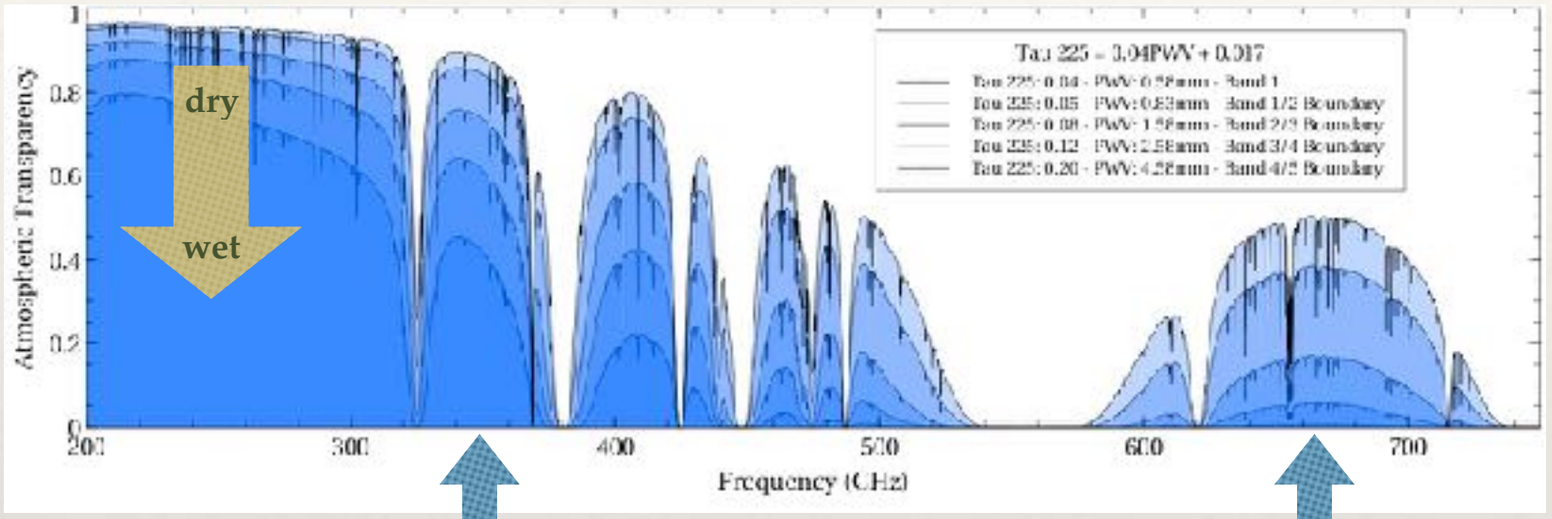

Johnstone et al. 2013

- Accretion burst change the temperature profile and spectral energy distribution at all wavelength

- The flux variation in the SED at **shorter wavelengths** is **more sensitive** to the change of luminosity of the central protostar

# JCMT atmospheric transmission

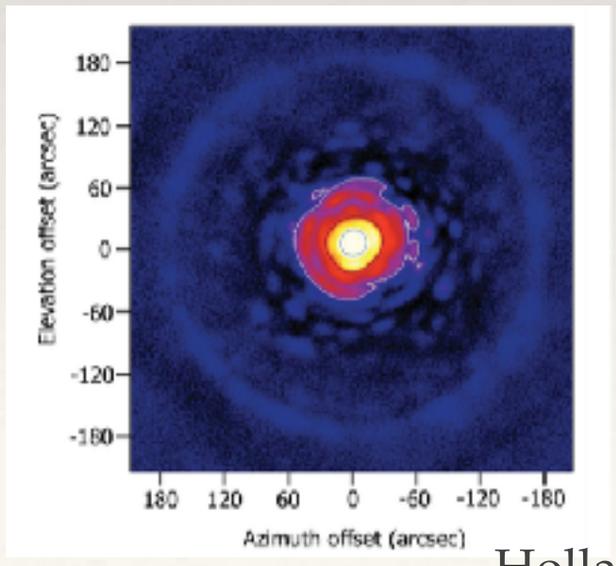
* The dependence of atmospheric transparency variation on opacity and wavelength

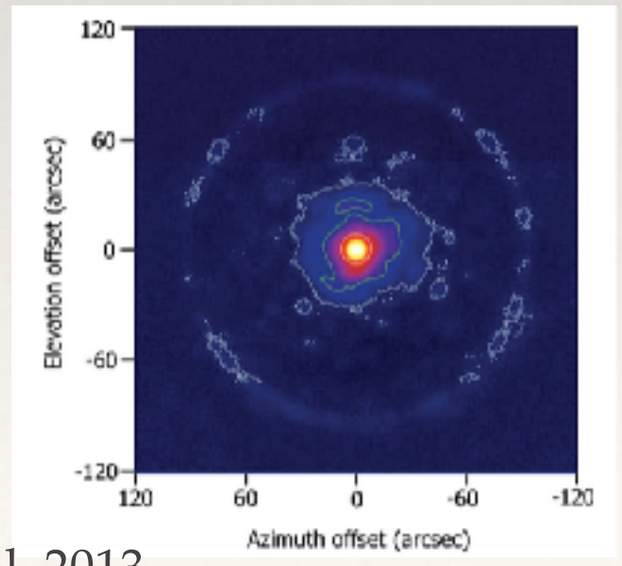



850 μm

450 μm

< Measured beam of Uranus >



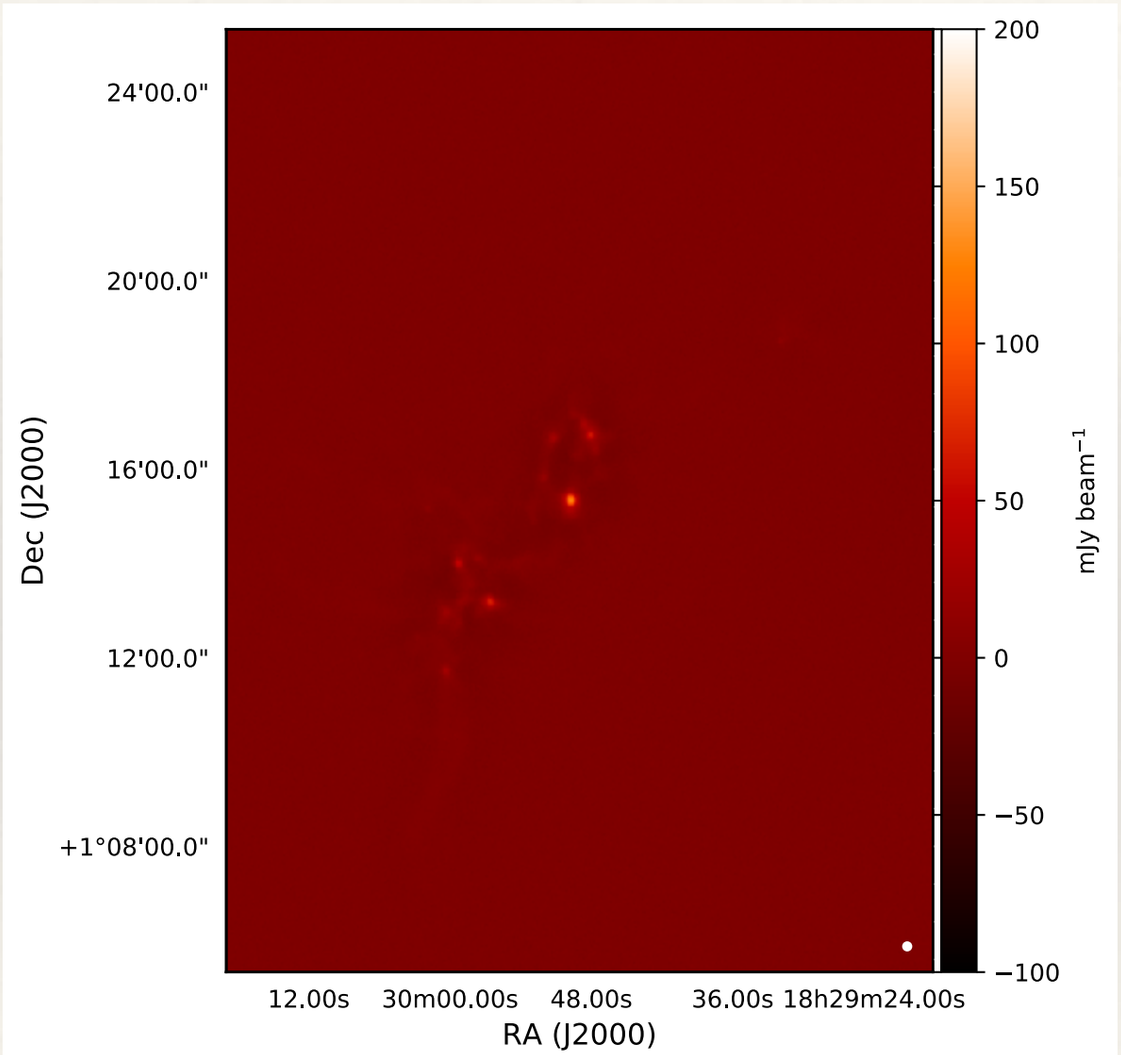

Holland et al. 2013

The 450 μm atmospheric window (severely affected by water vapor) requires much drier condition or long integration time

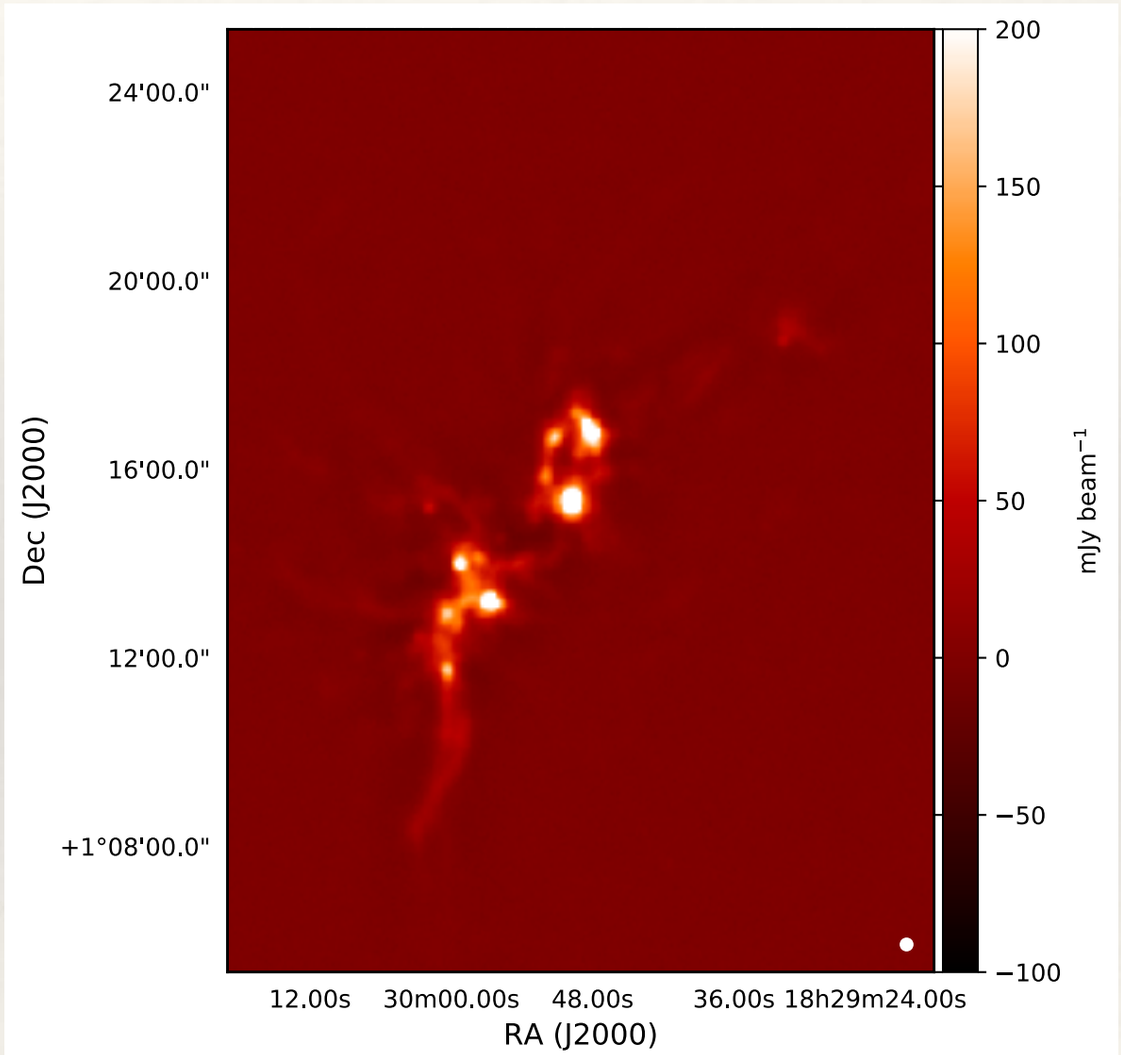
Less stable beam profile at 450 μm than 850 μm

# Signal-to-noise ratio maps

450 µm




850 µm




- significantly lower signal-to-noise ratio at 450 µm
- 450 µm maps need careful flux calibration

# Transient survey + Complementary observations

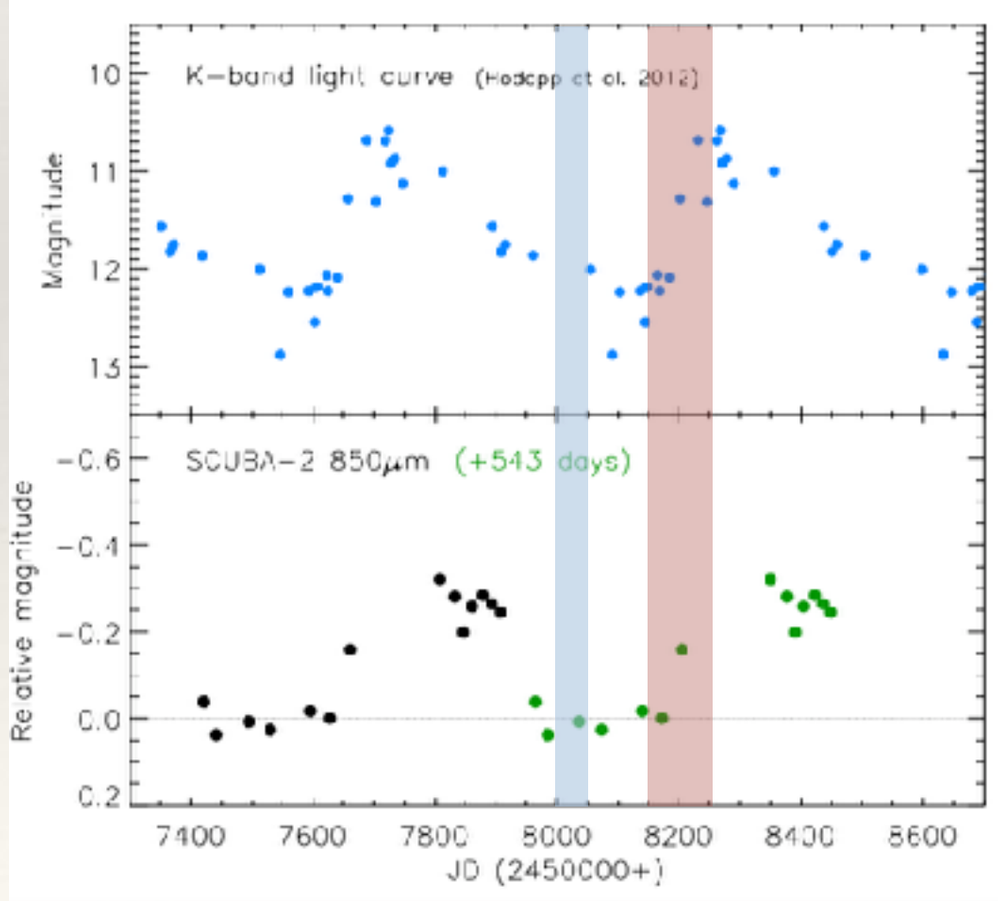
| Date (yyyy-mm-dd) | Julian day |
|---|---|
| 2016-02-02 | 2457420.72 |
| 2016-02-23 | 2457441.68 |
| 2016-04-15 | 2457493.54 |
| 2016-05-21 | 2457529.39 |
| 2016-07-22 | 2457591.44 |
| 2016-08-27 | 2457627.23 |
| 2016-09-29 | 2457660.22 |
| 2017-02-22 | 2457806.66 |
| 2017-03-20 | 2457832.58 |
| 2017-04-03 | 2457846.56 |
| 2017-04-17 | 2457860.54 |
| 2017-05-05 | 2457878.44 |
| 2017-05-19 | 2457892.63 |
| 2017-06-02 | 2457906.37 |

| Date (yyyy-mm-dd) | Julian day |
|---|---|
| 2017-06-16 | 2457920.55 |
| 2017-07-05 | 2457939.49 |
| 2017-07-21 | 2457955.42 |
| 2017-08-10 | 2457975.40 |
| 2017-08-25 | 2457990.21 |
| 2017-09-12 | 2458008.30 |
| 2017-09-24 | 2458020.26 |
| 2017-09-25 | 2458021.30 |
| 2017-09-26 | 2458022.22 |
| 2017-09-26 | 2458022.28 |
| 2017-10-17 | 2458043.23 |
| 2017-10-18 | 2458044.21 |
| 2017-10-19 | 2458045.20 |

22 Epochs from Transient survey
+ 5 Epochs from M17BP054

* Series of high-sensitivity observations of Serpens Main using JCMT/SCUBA-2

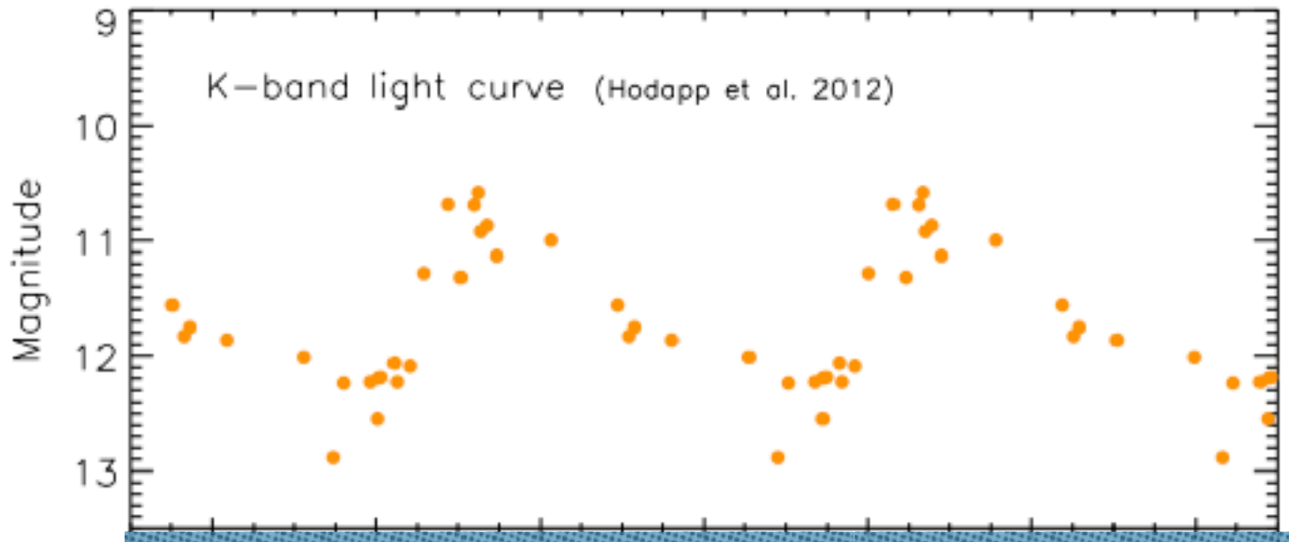
- **M17BP054 (declining phase).** ; done
- **M18AP017 (min. to max. phase)** ; soon
  (PI : Hyunju Yoo)

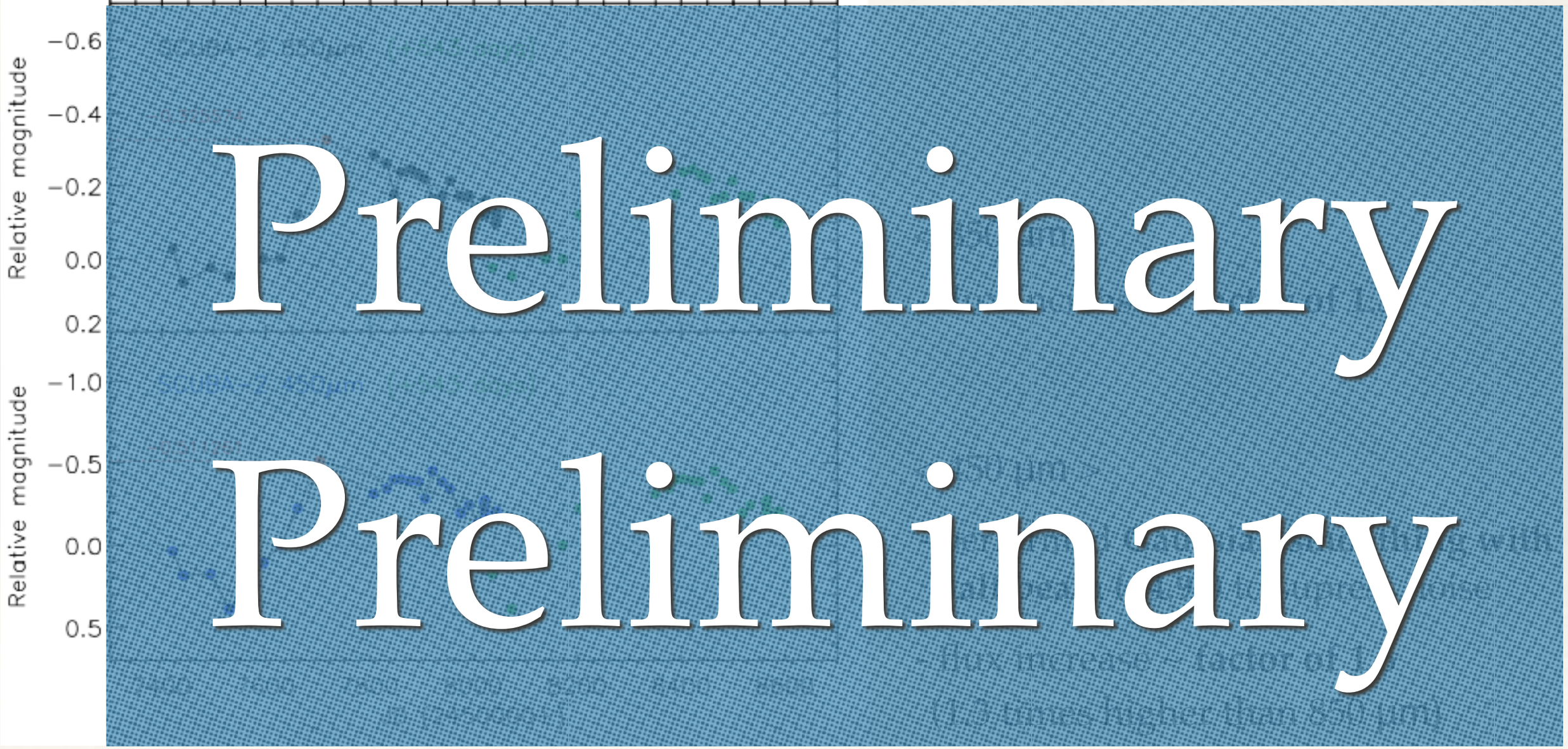


# Preliminary results

< Replicated K-band >

- △K-mag : 1.5 ~ 2



# Summary

* JCMT Transient survey aims to detect the evidence of episodic accretion from the monthly monitoring observation in sub-mm.

* We detect a new sub-mm variable source EC 53, which has been reported as a variable source in K-band with periodicity (period ~ 543 day). There is strong resemblance between light curves in K-band and 850 micron.

* We expect the increase of accretion luminosity by factor of 5.3 from simple SED model assuming flux increase by factor of 1.5 at 850 micron.

* JCMT/SCUBA-2 450 μm map shows low S/N ratio and relatively unstable beam profile than 850 μm map and the relative flux calibration is difficult due to high level of rms noise.

Preliminary