Searching for 100-yr scale variability of dust ejection from AGB stars

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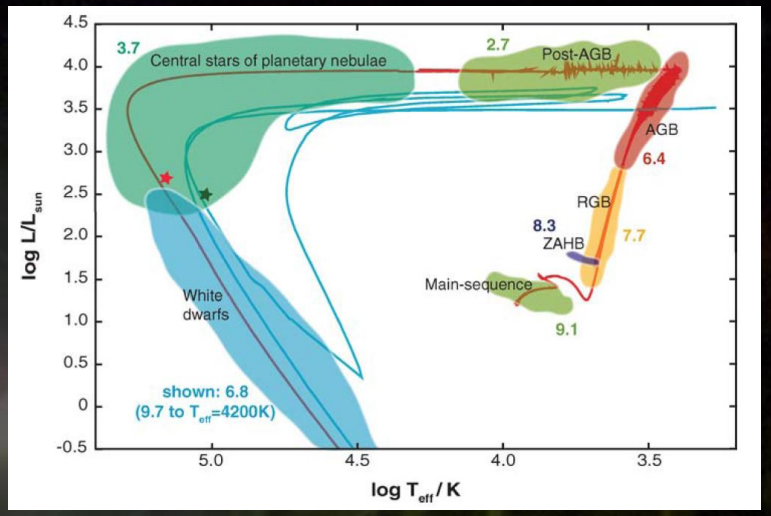
Indroduction

Mass-loss from AGB stars

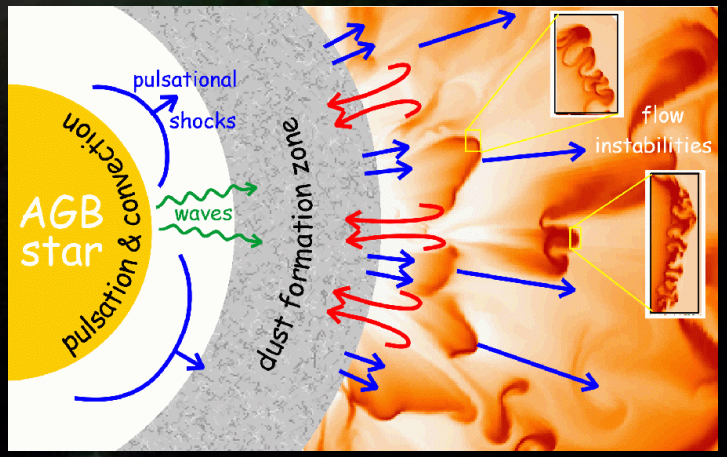
AGB (Asymptotic Giant Branch)

- Late evolutionary phase of low- and medium-mass stars (1-8 $M_\odot$)
- Long-period pulsating variable
  - Mira: $\Delta V > 5$ mag, P = 100-1000 d
  - Semi Regular (SR):
    $\Delta V < 5$ mag, P = 10-1000 d
- Dust formation and mass-loss
  - Material levitation by pulsation
  - Dust formation (Silicate/Carbon..)
  - Mass-loss by dust-driven wind

Interesting objects to understanding dust formation



Evolutionary track of $2M_\odot$ star (Herwig 2005)



Wind driving mechanism (Woitke)

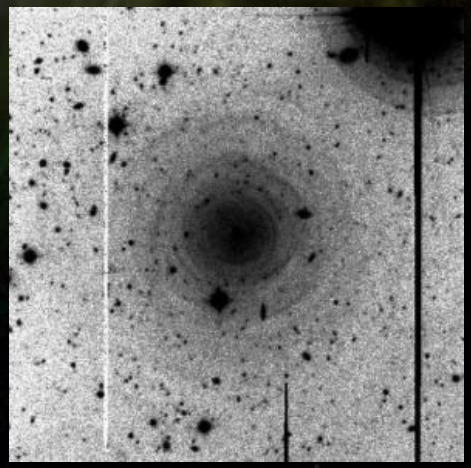
100-yr scale mass-loss variability

Mass-loss variability

- Year-scale (Pulsation related)
- 10^4-yr scale (Thermal pulse related)

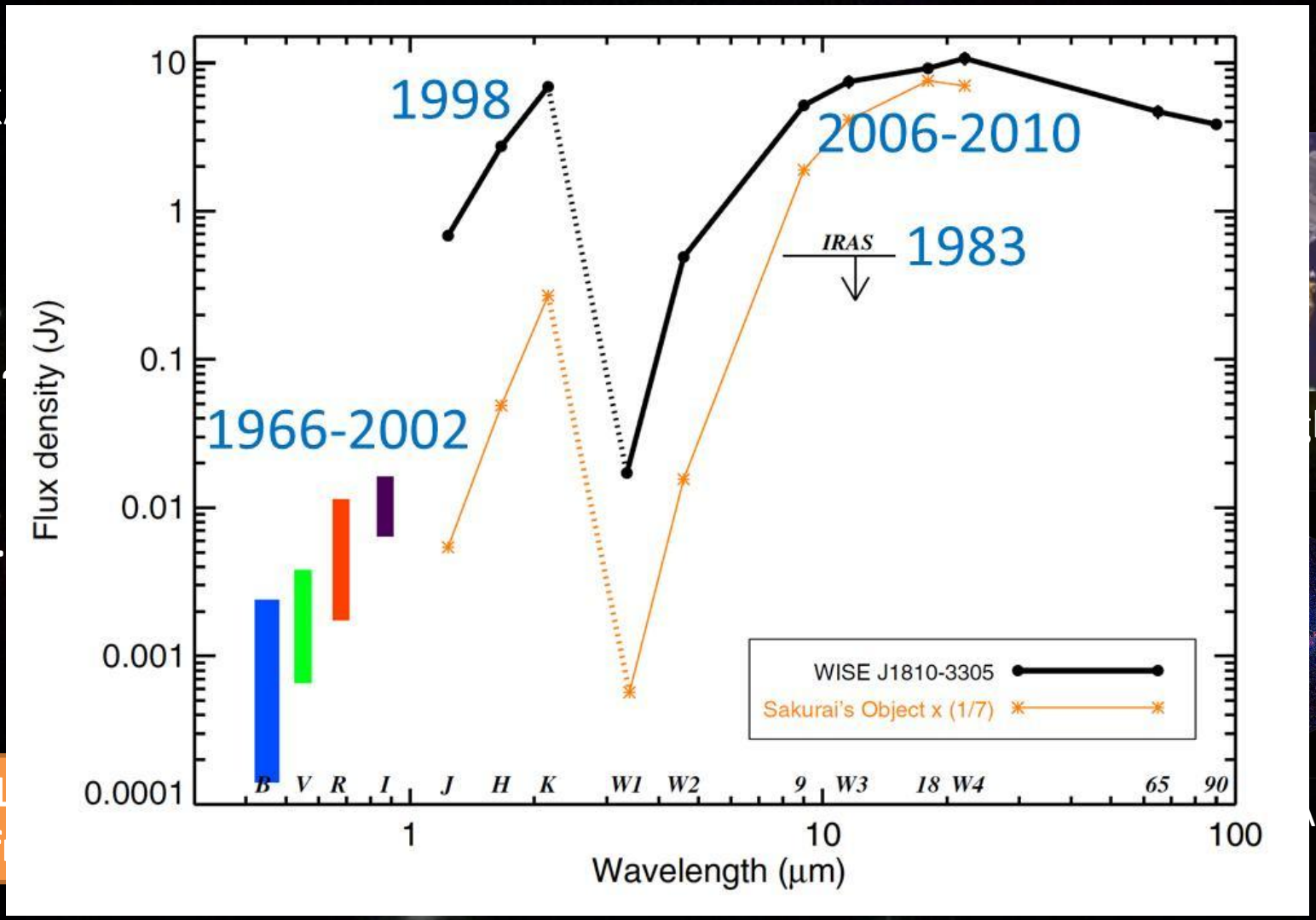
100-yr scale variability

- Some indications…
  - Egg nebula: 100-500yr (Harpaz+ 97, Sahai+ 98)
  - IRC+10216: 200-800yr (Mauron & Huggins 99)
  - Non-Mira variables: 100-yr (Marengo+ 01)
- Mechanism is unknown
  - Binary interaction?
  - Property change of star?



IRC+10216 V-band image
(Mauron & Huggins 99)

100-yr scale mass-loss variability



100-yr scale mass-loss variability

Re-activation of dust formation

- Composition difference between inactive and active dust forming state
- Chemical and Optical property of fresh dust

➔Information about dust formation/alteration

This study…

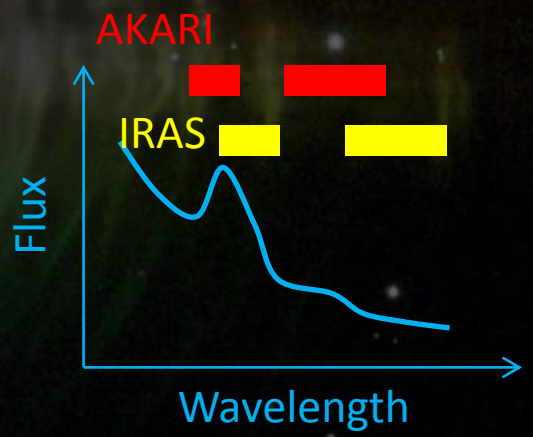
- **Search for objects with large MIR-color change from IRAS/AKARI data**
  ➔100-yr scale variability / Re-activation of dust formation
- **10-um observation of feature-less objects**
  ➔ Validate spectral change

Variability Search

Variability search

Candidates

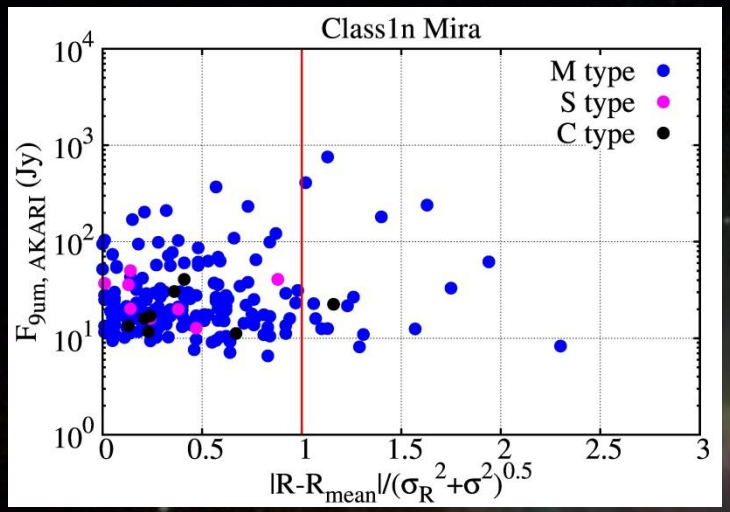
- Mira/SR variables on GCVS (Variable star catalog)
- Spectral type is known
- High-quality IRAS (12, 25um) and AKARI (9, 18um) data available
- IRAS/LRS spectrum available

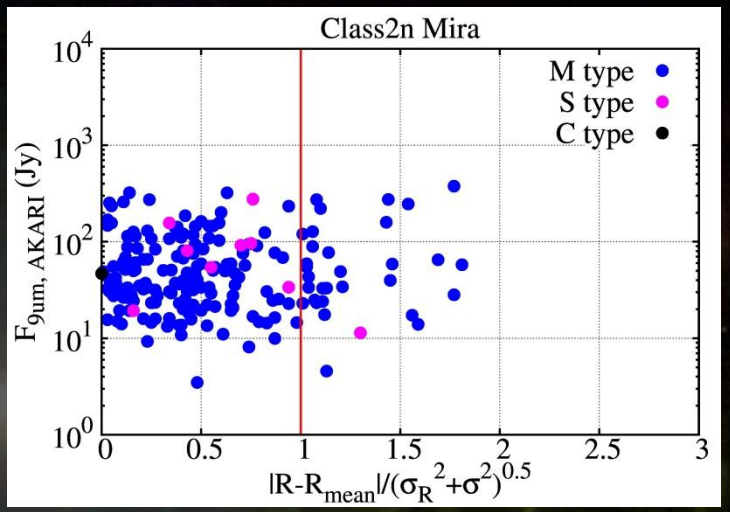


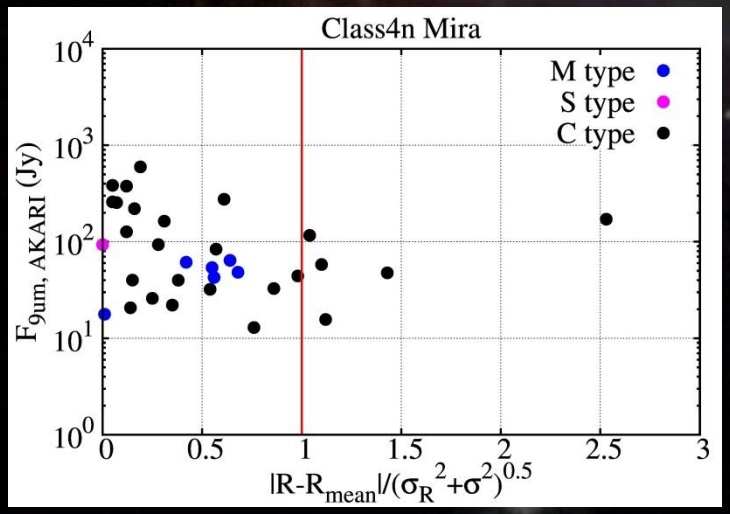
Selection

- Derive IRAS/AKARI MIR color (flux ratio)
  - IRAS: C_{IRAS}=F12/F25, AKARI: C_{AKARI}=F9/F18
- Calculate mean/stddev of color ratio for every spectral type and LRS class
  - Color ratio: R=C_{AKARI} / C_{IRAS}, Mean: R_{mean}, STDDEV: σ_R
- Examine the deviation of color ratio
  - $|R-R_{mean}| > (\sigma_R^2+\sigma^2)^{1/2}$ ➔ MIR Color change

Variability Search (Mira)

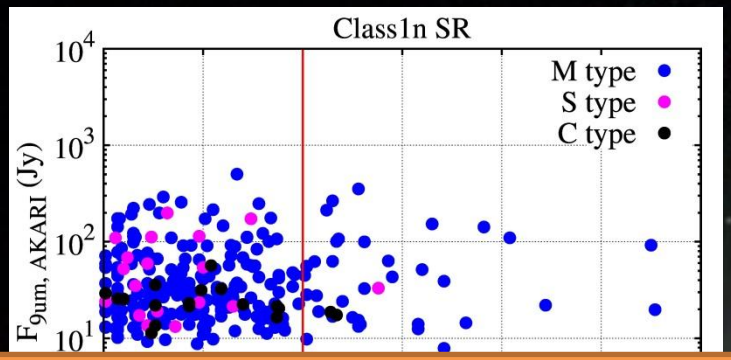


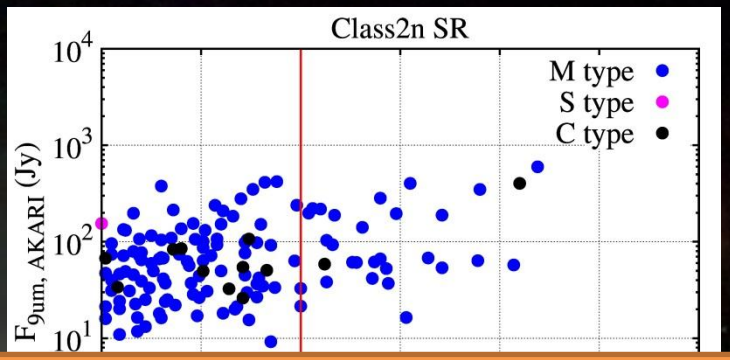




LRS Class	Spectral prop.	# of Candidates		
		M	S	C
Class0n	Others	1/16	2/4	0/3
Class1n	Blue, Featureless	16/182	1/8	0/8
Class2n	Blue, Sil. Em.	32/183	1/9	0/1
Class3n	Blue, Sil. Abs.	0/1	-	-
Class4n	Blue, 11um Feat.	0/6	0/1	5/25
Class5n	Red, Featureless	-	-	-
Class6n	Red, Sil. Em.	0/2	-	-

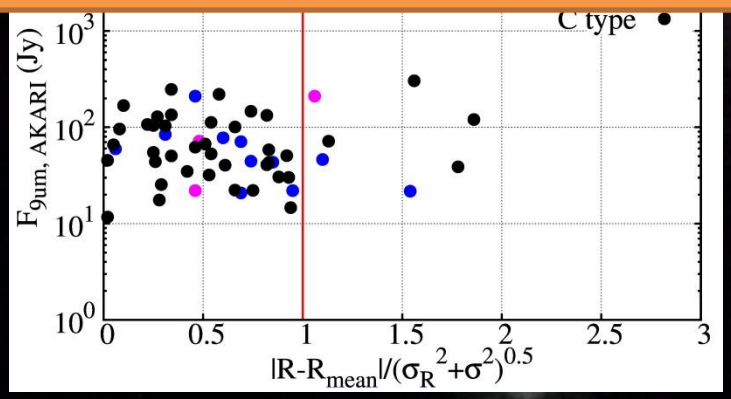
Variability Search (SR)





- **There are some objects with large color difference**
- **Class1n is easy to validate spectral change with dust feature**

➔ **Observe bright class1n candidates with miniTAO/MAX38**



Class0n	Others	1/15	0/2	0/4
Class1n	Blue, Featureless	37/243	1/18	3/18
Class2n	Blue, Sil. Em.	17/123	1/1	3/12
Class3n	Blue, Sil. Abs.	2/8	1/1	0/1
Class4n	Blue, 11um Feat.	3/11	2/3	4/40
Class5n	Red, Featureless	0/1	-	0/1
Class6n	Red, Sil. Em.	0/2	-	-

Observation with miniTAO/MAX38

miniTAO/MAX38

miniTAO telescope
- UT-led telescope (pilot for TAO)
- Diameter: 1 m
- Site: Co. Chajnantor, Atacama, Chile
  (5,640-m altitude)

  ➔Low PWV (0.38 mm @ 10%ile)

  ➔Good for IR observations

MAX38
- mid-infrared camera on miniTAO tel.
- Wavelength: 3.5—37 um
- Obs. mode: Imaging
  (N-band spectroscopy)

MAX38 on miniTAO telescope

Band name	Band center (um)	Band width (um)	Spatial resolution (arcsec)
J089	8.9	0.8	2.4
J098	9.8	0.9	2.7
J122	12.2	0.5	3.2
R187	18.7	0.9	4.9
MMF31	31.7	2.2	7.6
MMF37	37.3	2.4	8.5

Specifications of MAX38 (Asano + 12)

Observed objects

Properties

- Large MIR color difference between IRAS and AKARI era
- LRS class 1n (featureless)
- Bright (>10 Jy)

※ slightly different selection criteria were used for 2011 and 2012 observation

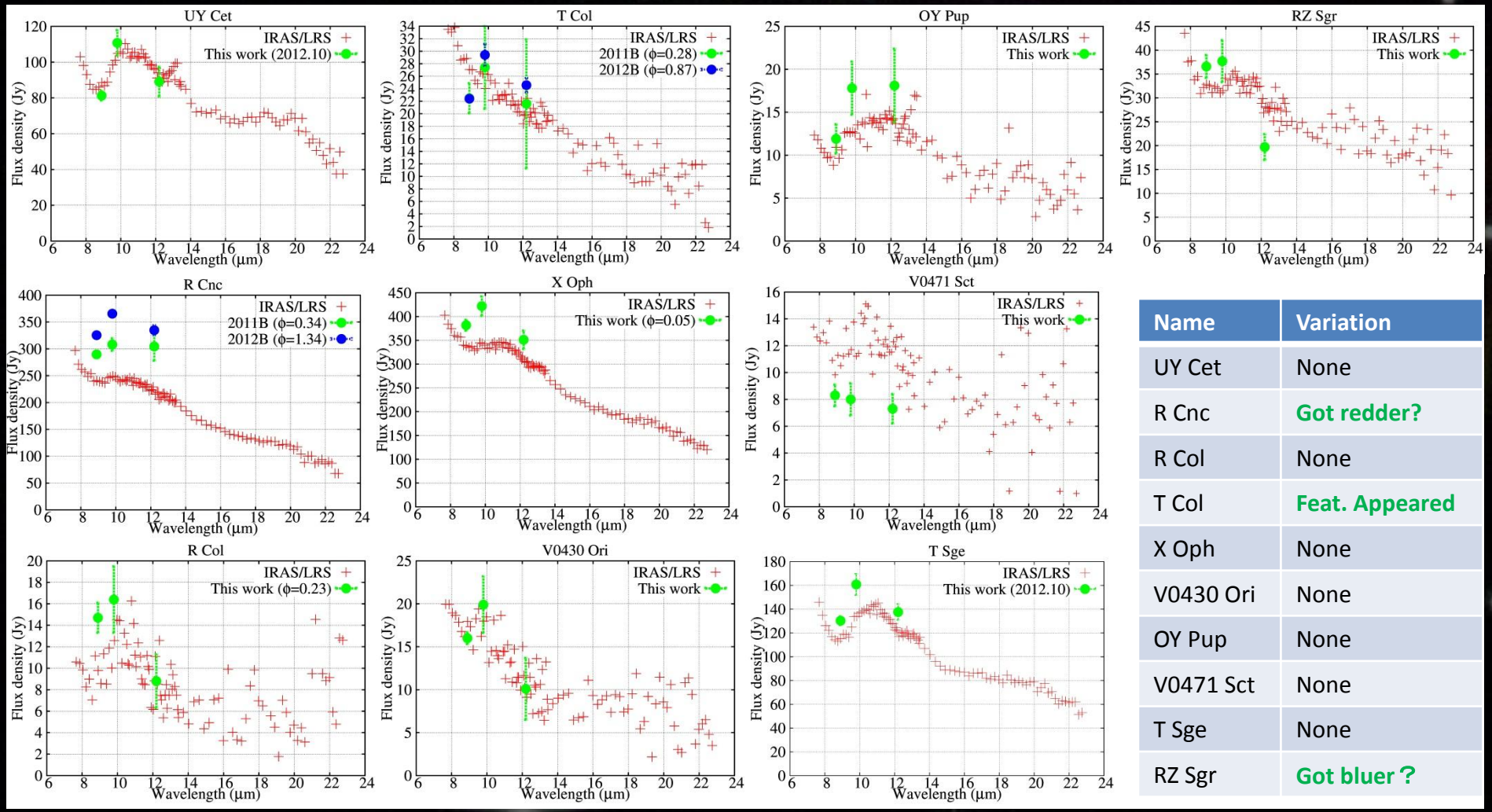
Name	Var. Type	Period (days)	Spectral type	Obs. date
UY Cet	SRb	440	M7	2012B
R Cnc	Mira	361.6	M6e-M9e	2011B 2012B
R Col	Mira	327.6	M3e-M7	2011B
T Col	Mira	225.8	M3e-M6e	2011B 2012B
V0471 Sct	Mira	-	-	2011B

Name	Var. Type	Period (days)	Spectral type	Obs. date
T Sge	SRb	165.5	M4-M6.5	2012B
RZ Sgr	SRb	223.2	S4	2011B
X Oph	Mira	328.9	M5e-M9e	2012B
V0430 Ori	SRb	104.5	M6	2011B
OY Pup	Mira	-	Me	2011B

Properties of observed objects (2011B: 2011/10-11, 2012B: 2012/11)

Results

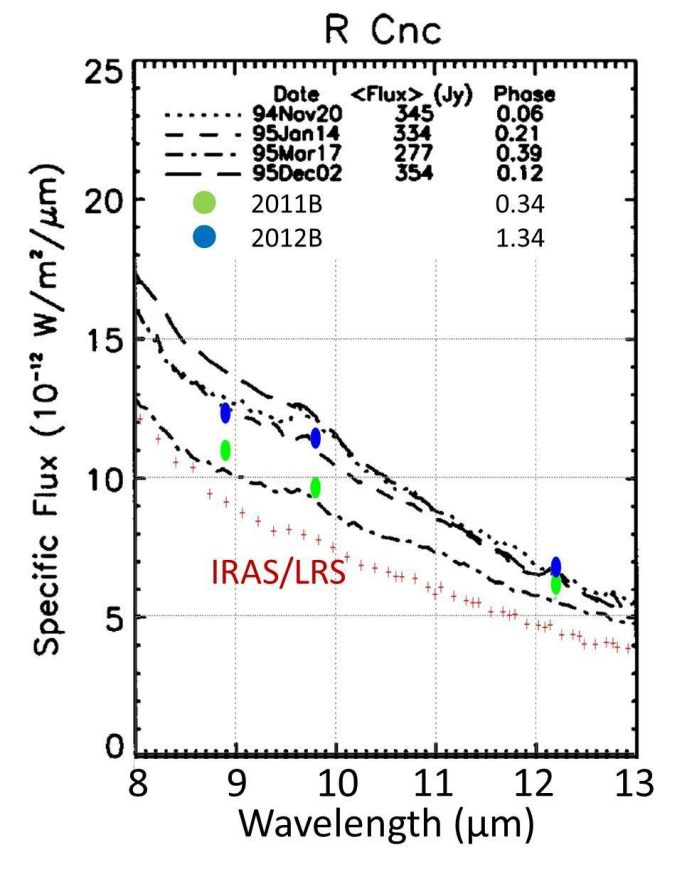
Results (preliminary)



Name	Variation
UY Cet	None
R Cnc	**Got redder?**
R Col	None
T Col	**Feat. Appeared**
X Oph	None
V0430 Ori	None
OY Pup	None
V0471 Sct	None
T Sge	None
RZ Sgr	**Got bluer？**

R Cnc spectrum

Comparison with Monnier et al. 1998

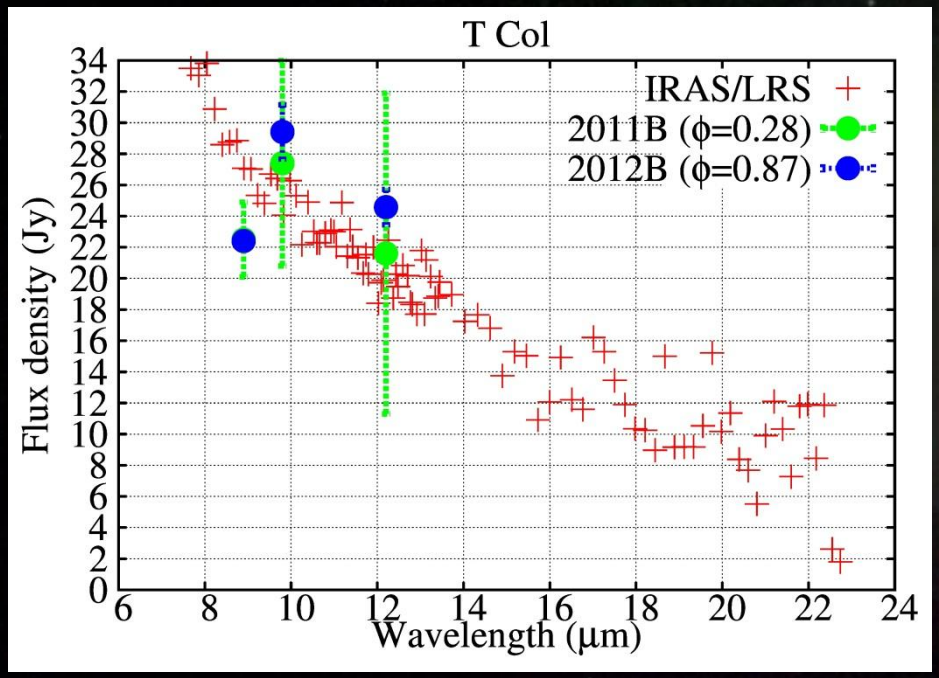


Similar to monitoring data by Monnier + 98

Slightly stronger feature than IRAS/LRS …?

➔long-term variation is not so clear

T Col spectrum



Clear difference
- IRAS/LRS
  - Smooth spectrum
- This work
  - 8.9-9.8um rise →Silicate?
  - 9.8-12.2um slow decline→Alumina?

Dust mass estimation
- 10um feature strength: ~10Jy
- Assuming hot silicate emission
  - → T=1000K, $Q_{abs}/a = 1\mu m^{-1}$, ρ=3g/cc
- Distance: 0.66kpc (Whitelock+ 08)
- → $M_{silicate} = 7\times10^{-10} M_{sol}$
- → $dM_{silicate}/dt = 7\times10^{-11} M_{sol}/yr$ (assuming Δt=10yr)
- → $dM/dt = 7\times10^{-9} M_{sol}/yr$ (assuming gas-to-dust mass ratio: 100)
- →Possible range

Silicate formation may be activated in the last 20-30 years

Summary

Summary

Mira and SR variables with large MIR color difference are extracted from IRAS and AKARI data

10 bright class1n objects are observed in 10-um band with miniTAO/MAX38

Clear(?) spectral difference from IRAS/LRS data was detected. Silicate formation may be activated in the last 20-30 years. Is this 100-yr scale variability?