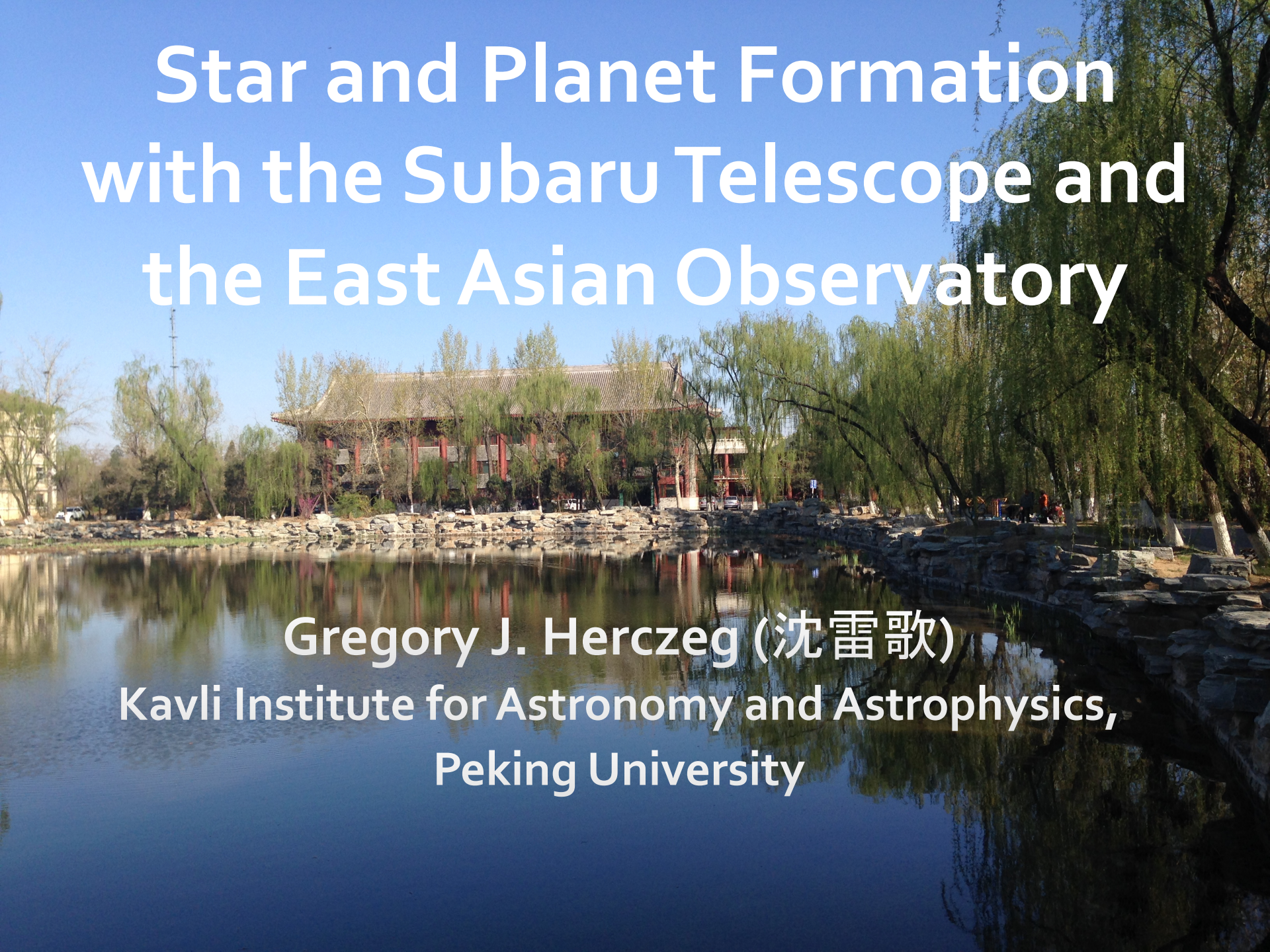
# Star and Planet Formation with the Subaru Telescope and the East Asian Observatory



Gregory J. Herczeg (沈雷歌)
Kavli Institute for Astronomy and Astrophysics,
Peking University

# EAST ASIAN OBSERVATORY

- Incorporated late 2014
- Concept: “Think Big”
- Ability to expand to larger projects, more telescope access and greater leadership


- By linking the regions, the funding can be lifted up to a level above just astronomy/ science (the ESO for Asia)

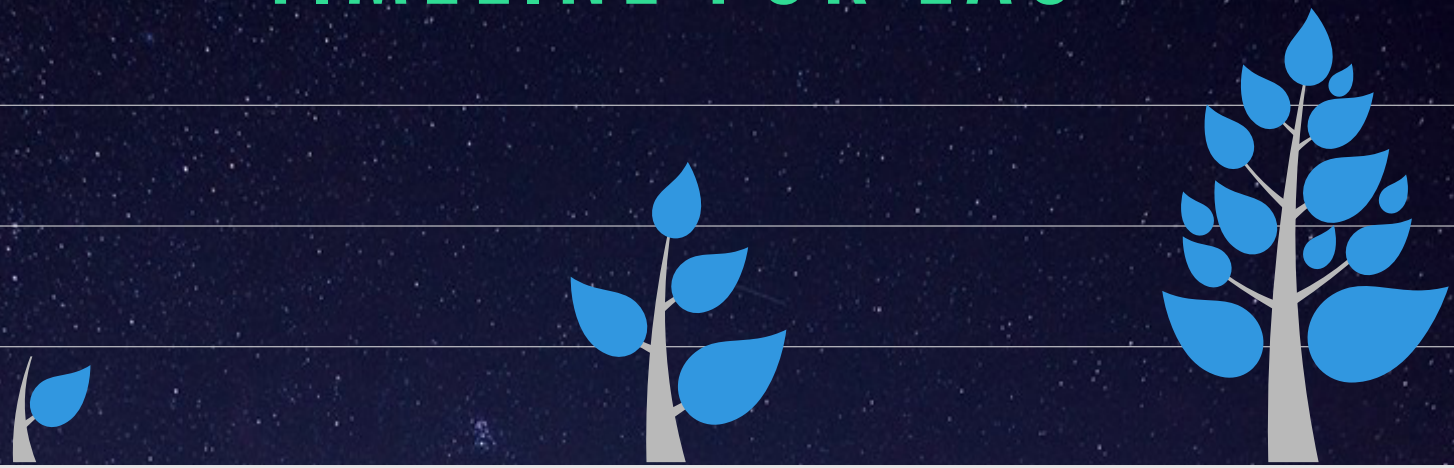


Paul Ho (Director)
Jessica Dempsey (Deputy Director)

# WHAT EAO WANTS TO DO

- Combine and focus the vast potential of the East Asian Regions
- Stronger collaborations to improve science quality and diversity
- Increase student opportunities to broaden experience
- Multi-telescope access
- Increase scope and size of instrument projects

# TIMELINE FOR EAO



**1. 2015 - 2016:**

EAO incorporated

JCMT operations assumed

JCMT Instrument upgrades begin

JCMT joins EHT

**2. 2017**

Access to 17A/17B Subaru time

Access to 17A/17B SMA time

EHT and standalone VLBI

**3. 2018...**

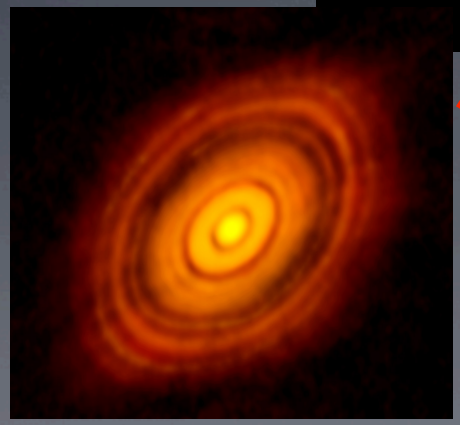
UKIRT operational partner?

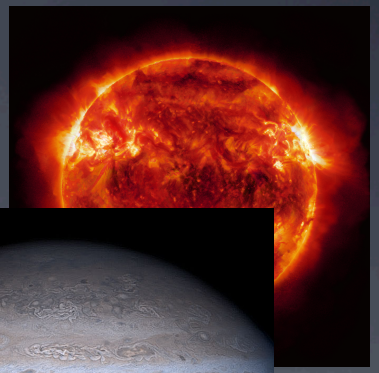
Full Partnership with Subaru?

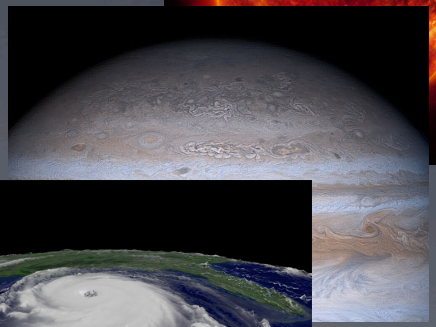
# The last astrophysical step of our origins

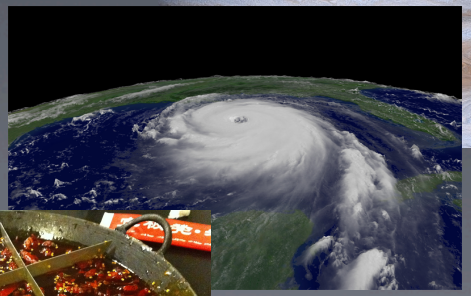
?

?

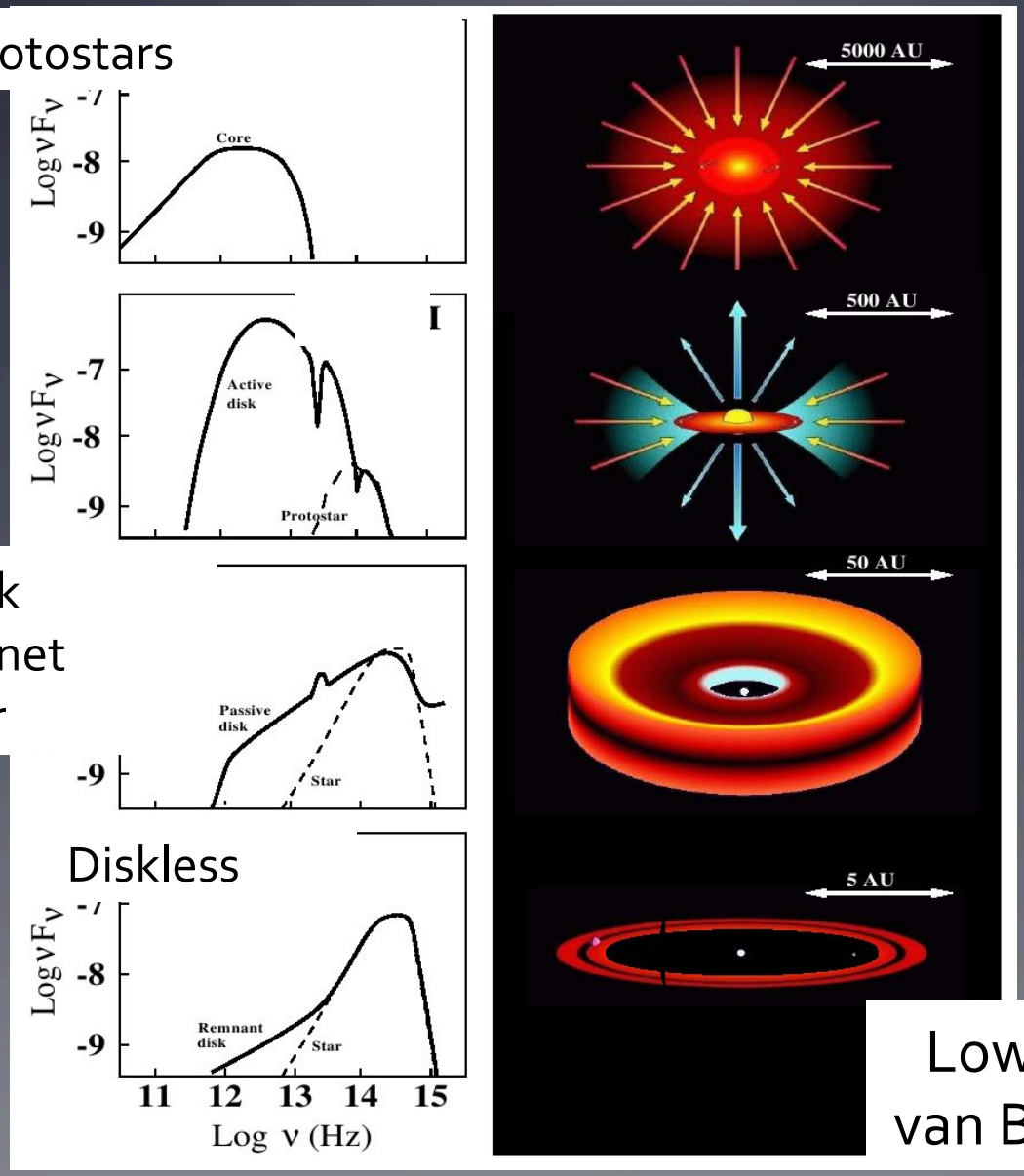








# Pre-main sequence star/disk evolution

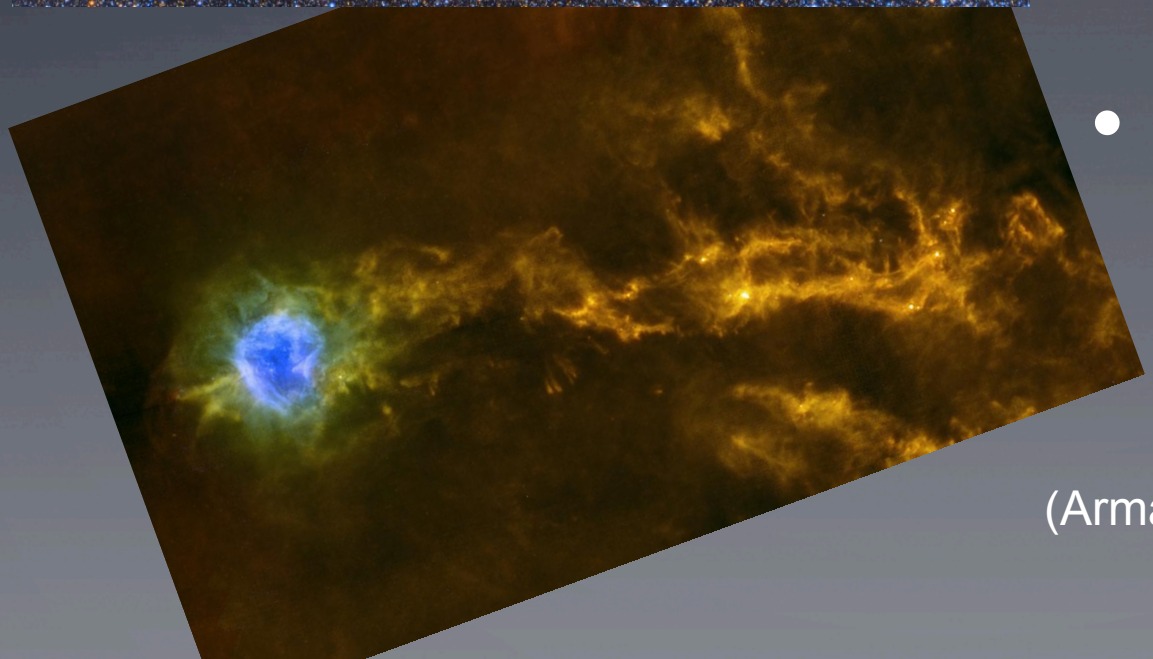



Low mass stars
van Boekel (2005)

# Cocoon Nebula

- Optical:
  - dark lanes where dust
  - Nebular H-alpha emission

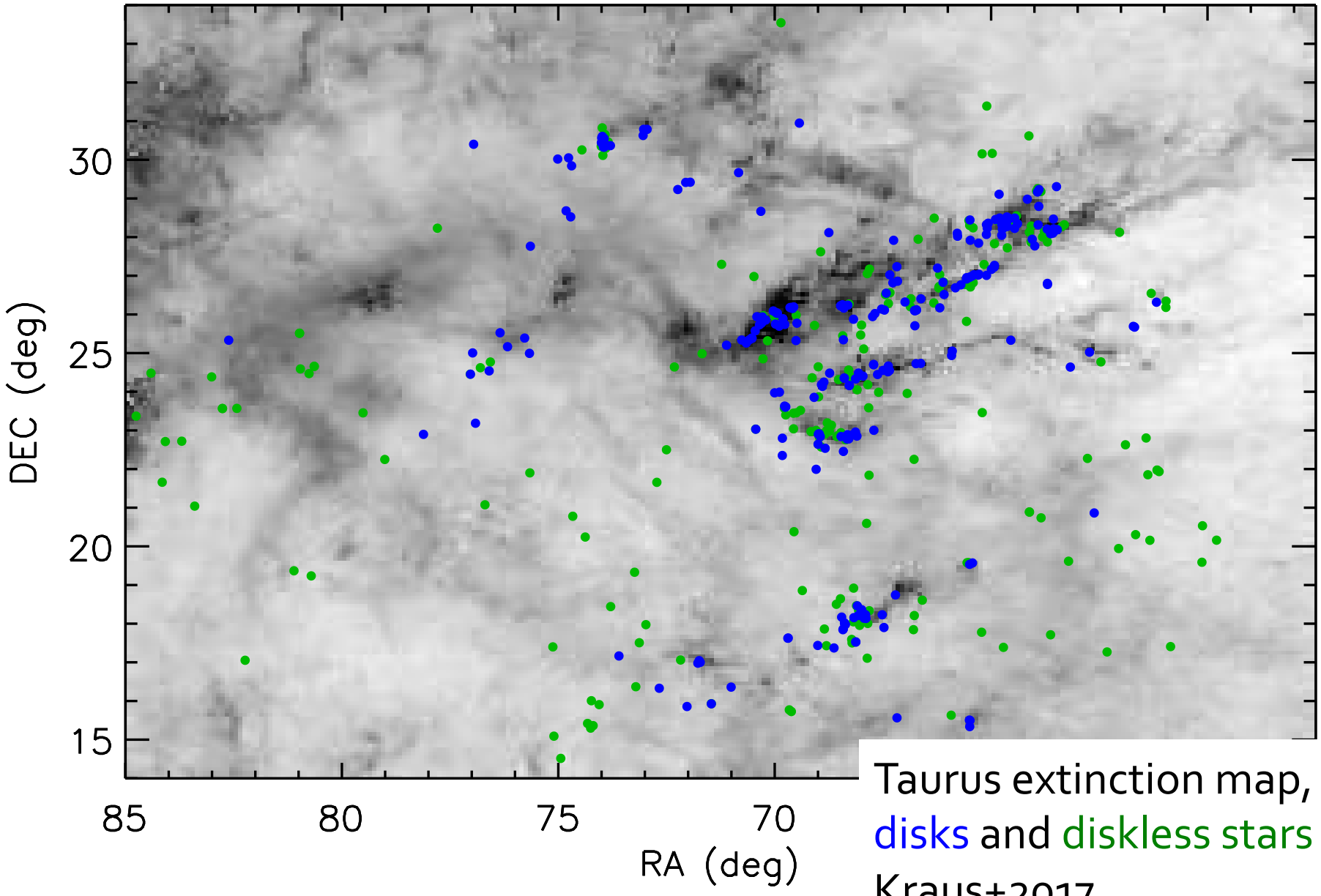
  **Recent star formation**



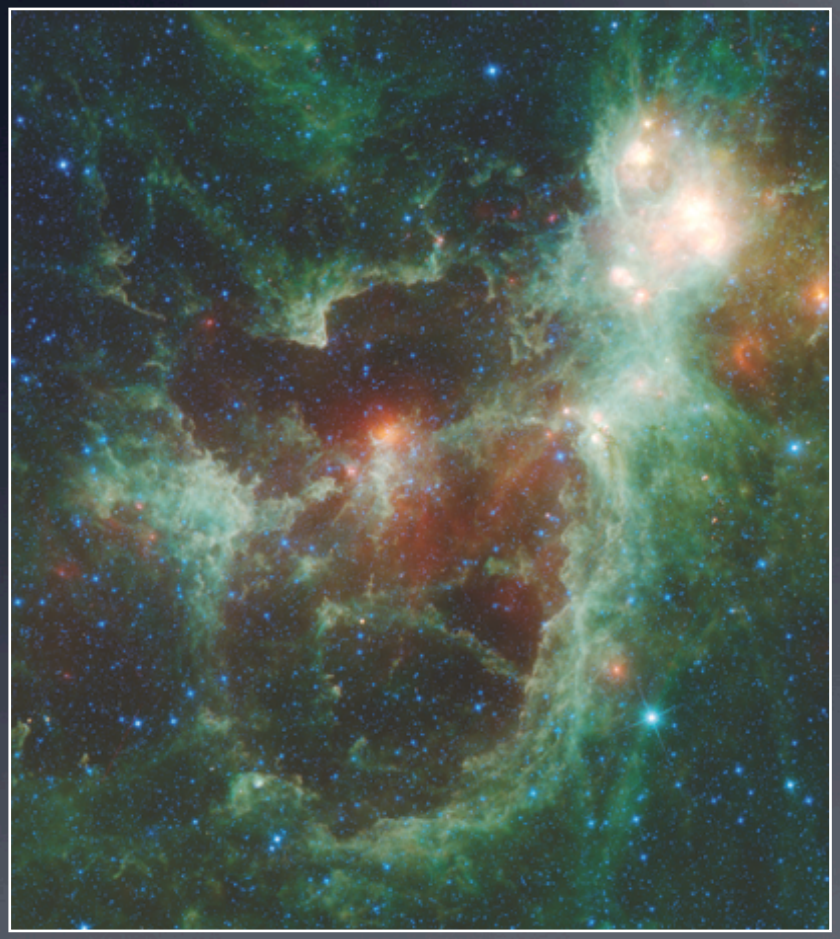
- Herschel far-IR map
  - warm dust at nebula
  - dust lanes appear bright

  **Ongoing Star Formation**

(Armazounian et al. 2011)

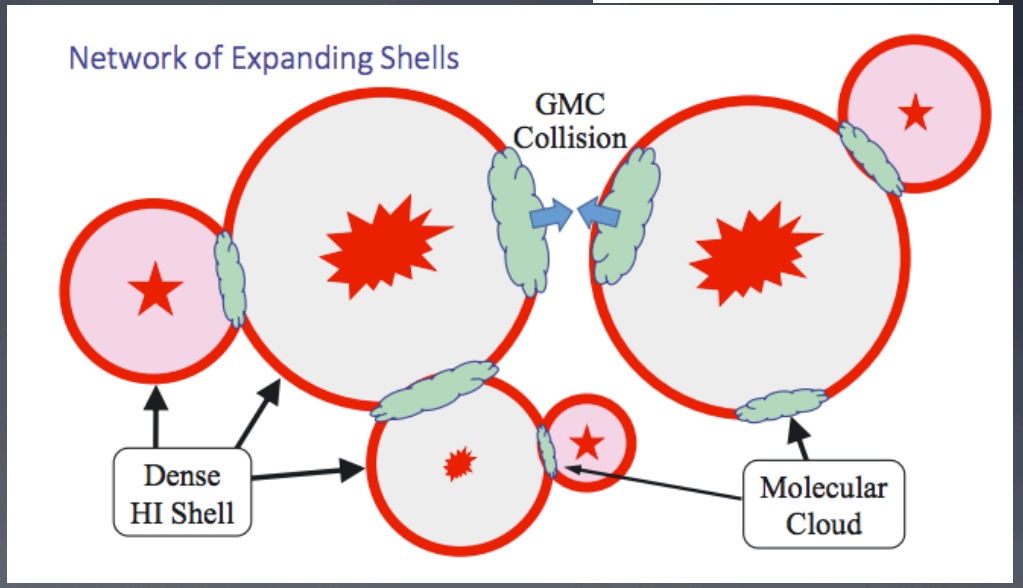



Taurus extinction map,
disks and diskless stars
Kraus+2017



# Optical/near-IR studies of star formation

Inutsuka+2015



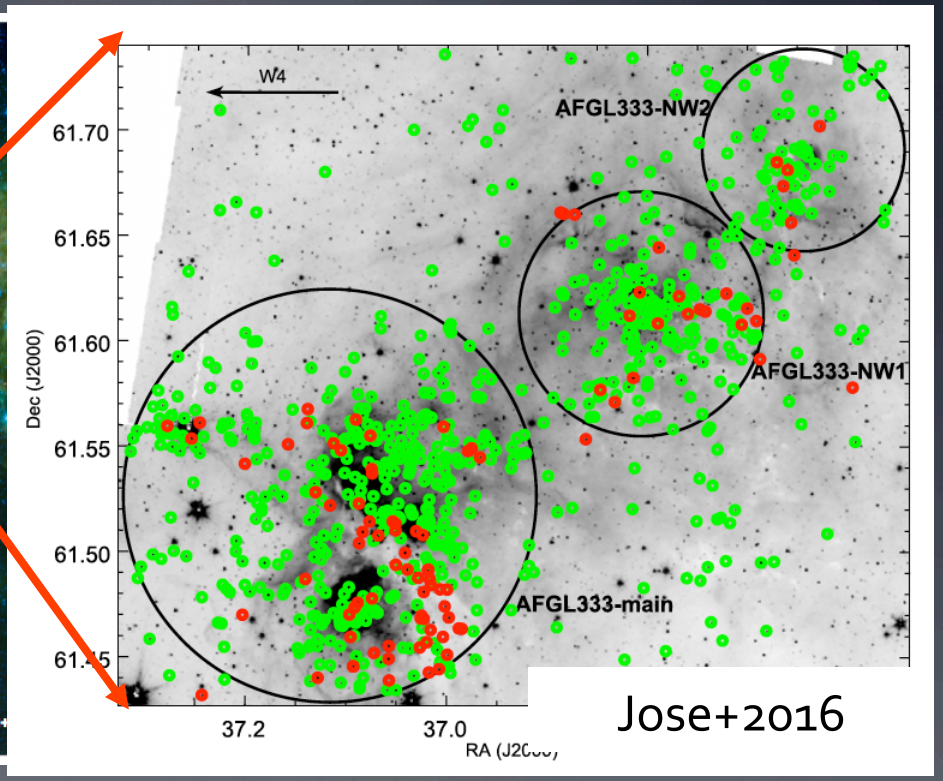

- Initial mass function
- Disks and planet formation
- Sequential star formation/triggering
- Star formation efficiency

Proposed and approved Subaru/EAO programs

Synergies with JCMT

Jessy Jose

# A triggered region in the W4 superbubble

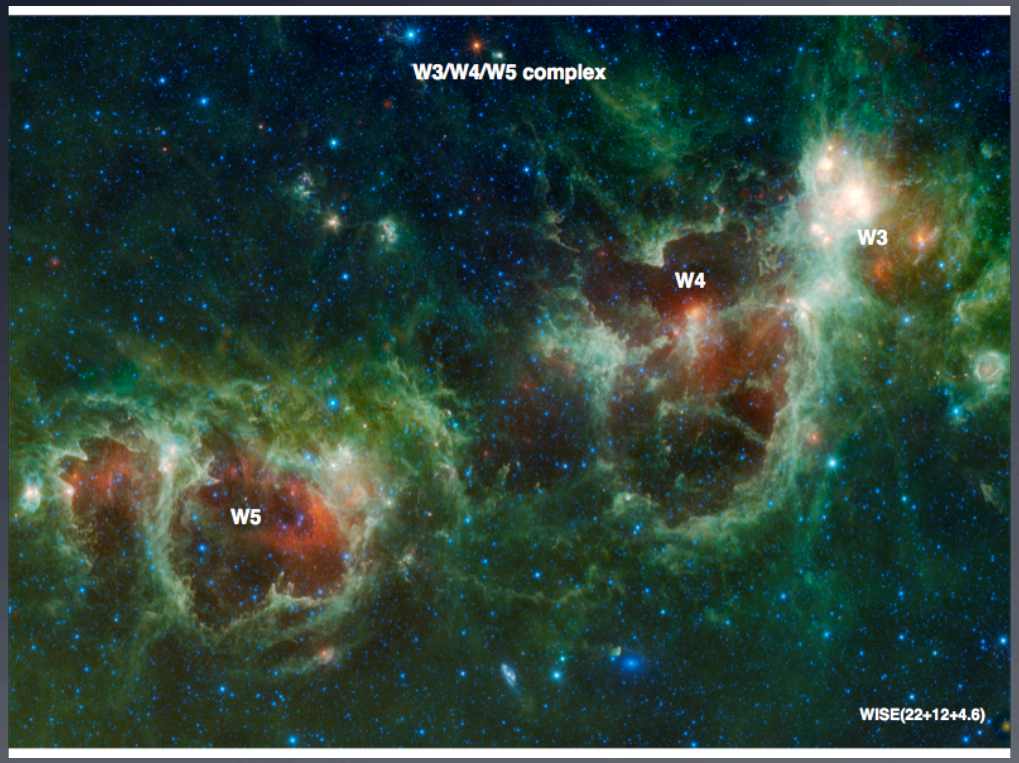



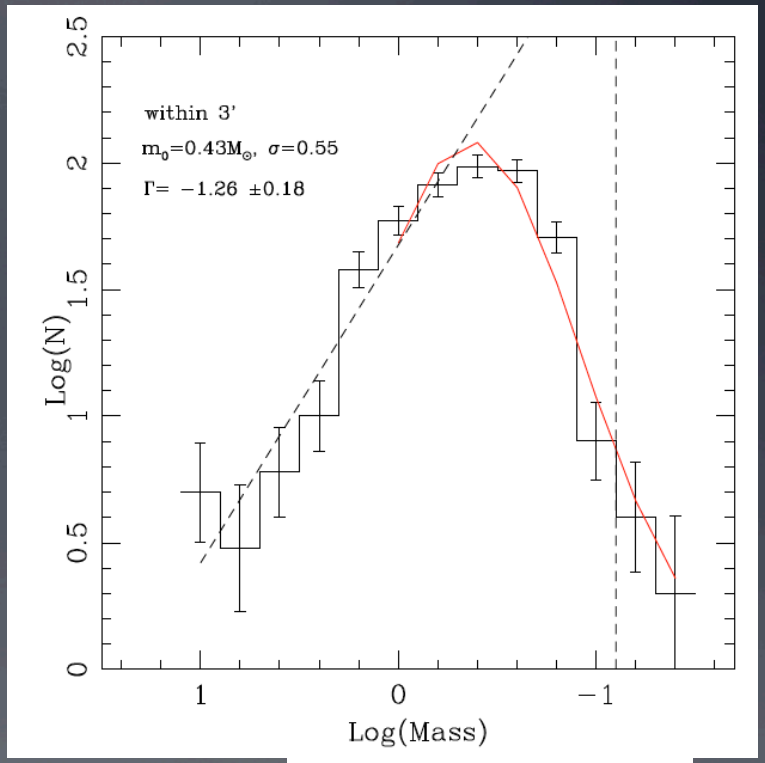

Jose+2016

- Star formation efficiency (stars/gas).....~ 5%
- Star formation rate.....~150 Msun/Myr
- Star formation rate density (ΣSFR ).....~2 $M_{sun}$ / Myr / $pc^{-2}$

Parameters typical of low-mass star formation

# A triggered region in the W4 superbubble



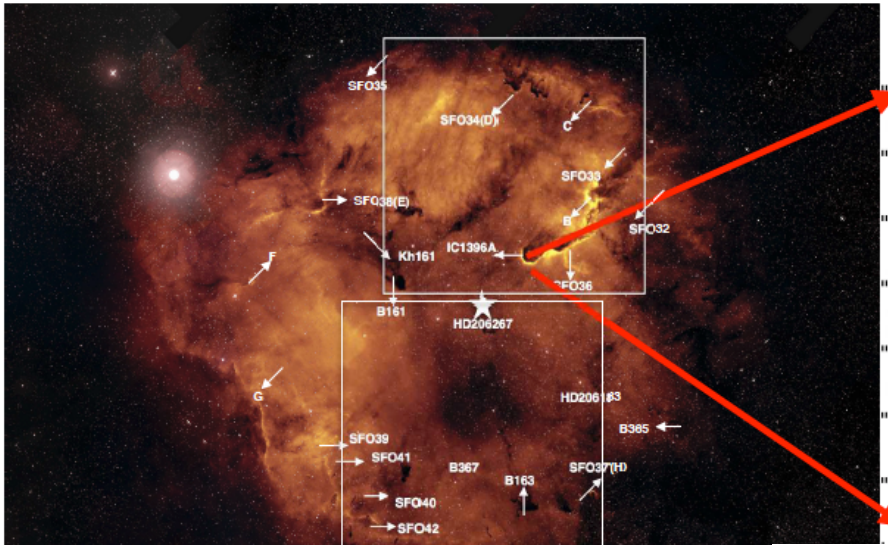



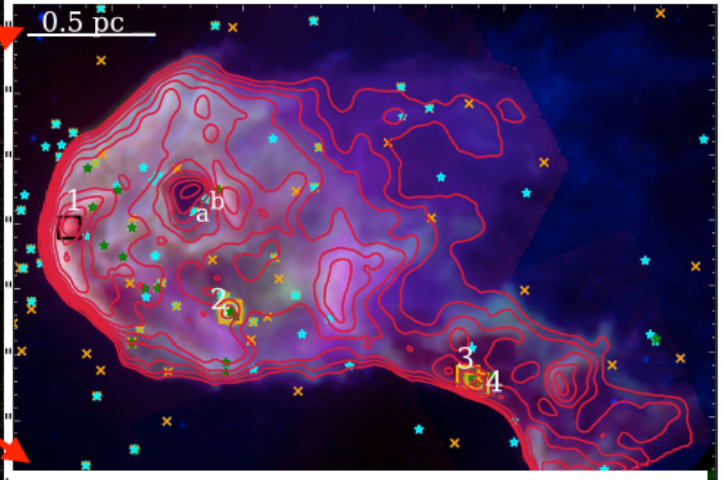

Jose+2016, 2017

IMF: similar in triggered environments and in high-mass star-forming regions?

Differences expected at very low masses
(not yet measureable)

# Example of EAO-Subaru proposal: multi-band HSC imaging of SF regions




Deeper than Pan-STARRS

Regions typically at 2-4 kpc
Look through extinction
Low-mass stars and BDs

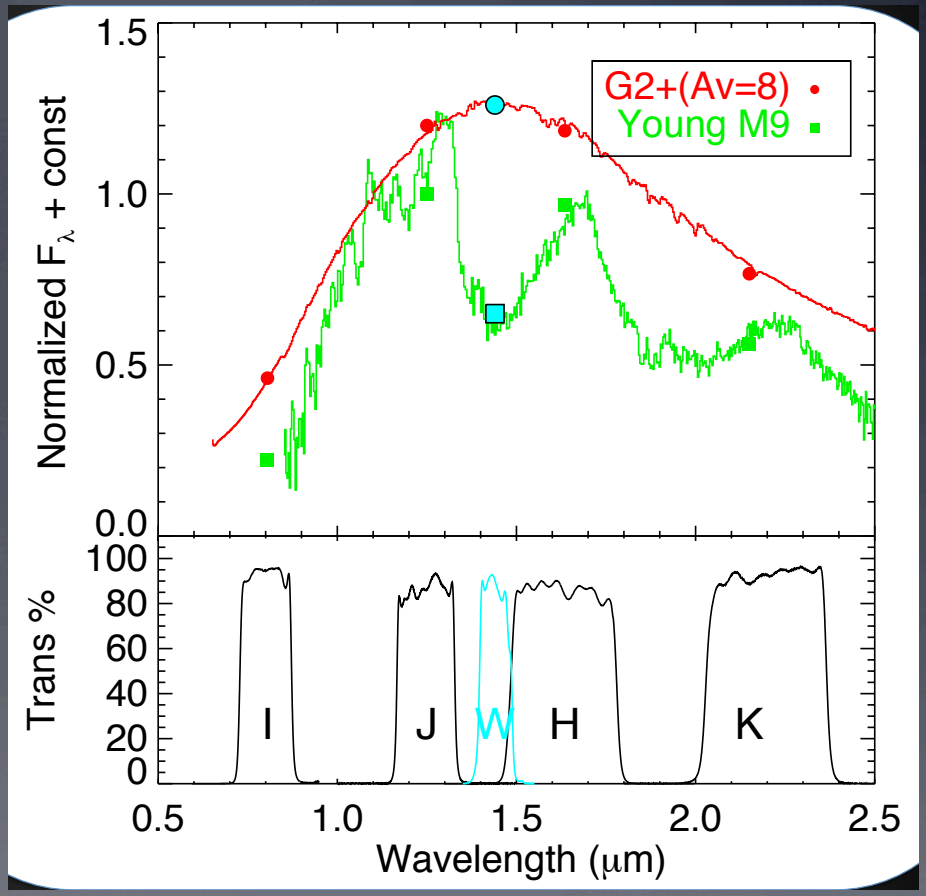
Search for variations versus mode of SF

Current Team

PI: Jessy Jose (PKU, CN)
Gregory Herczeg (PKU, CN)
Katsuo Ogura (Kokugakuin, JP)
Manash Samal (NCU, TW)
Satoko Takahashi (NAOJ, JP)
Hiro Takami (ASIAA, TW)

# Discovering the youngest free-floating planets:
## a transformative CFHT survey with the novel W(ater)-band


**Beth Biller (Edinburgh, UK)**
Loïc Albert (Montreal, CA)
Katelyn Allers (Bucknell, USA)
Étienne Artigau (Montreal, CA)
Mikael Bonnefoy (Grenoble, FR)
**Po-Shih Chiang (NCU, Taiwan)**
**Wen-Ping Chen (NCU, Taiwan)**
Niall Deacon (Hertfordshire, UK)
Philip Delorme (Grenoble, FR)
**Gregory Herczeg (KIAA/Peking, China)**
**Jessy Jose (KIAA/Peking, China)**
Michael Liu (Hawaii, USA)
**Bhavana Llalchand (NCU, Taiwan)**


CFHT contributions: Canada, France, Taiwan, China
Filter: UK

Brown dwarfs/planets: brightest when young!

# Discovering the youngest free-floating planets:
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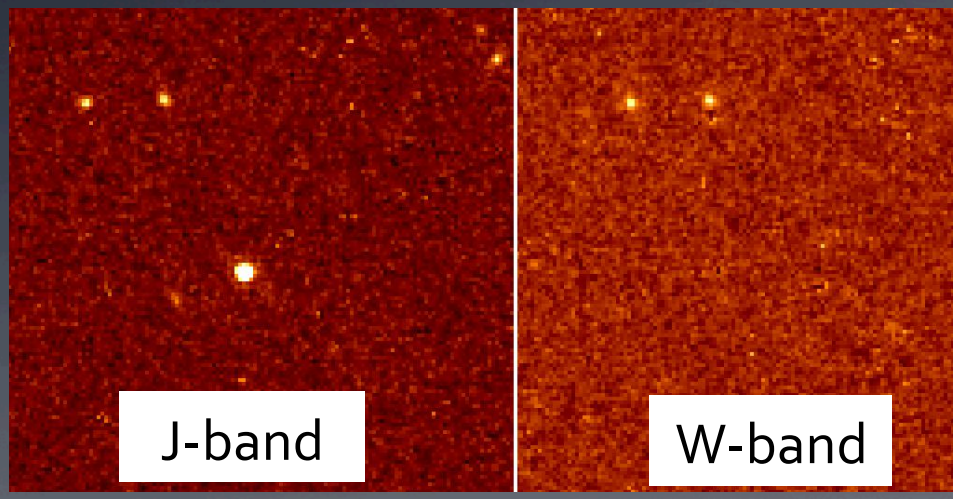
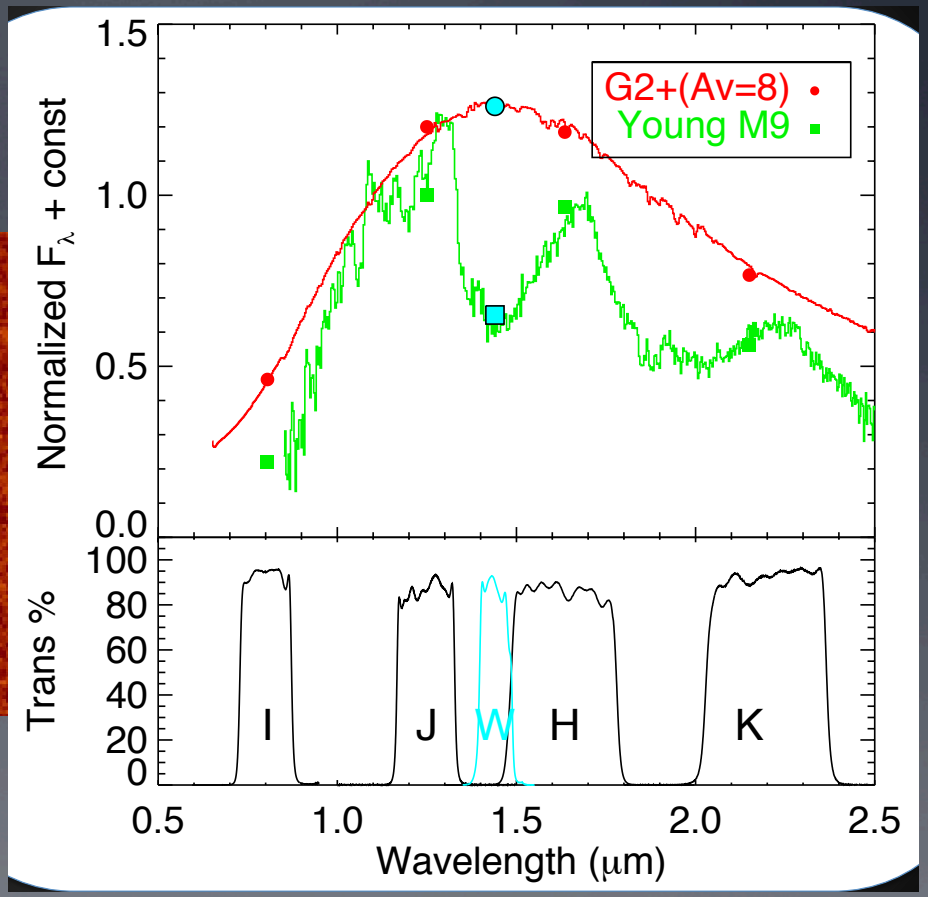
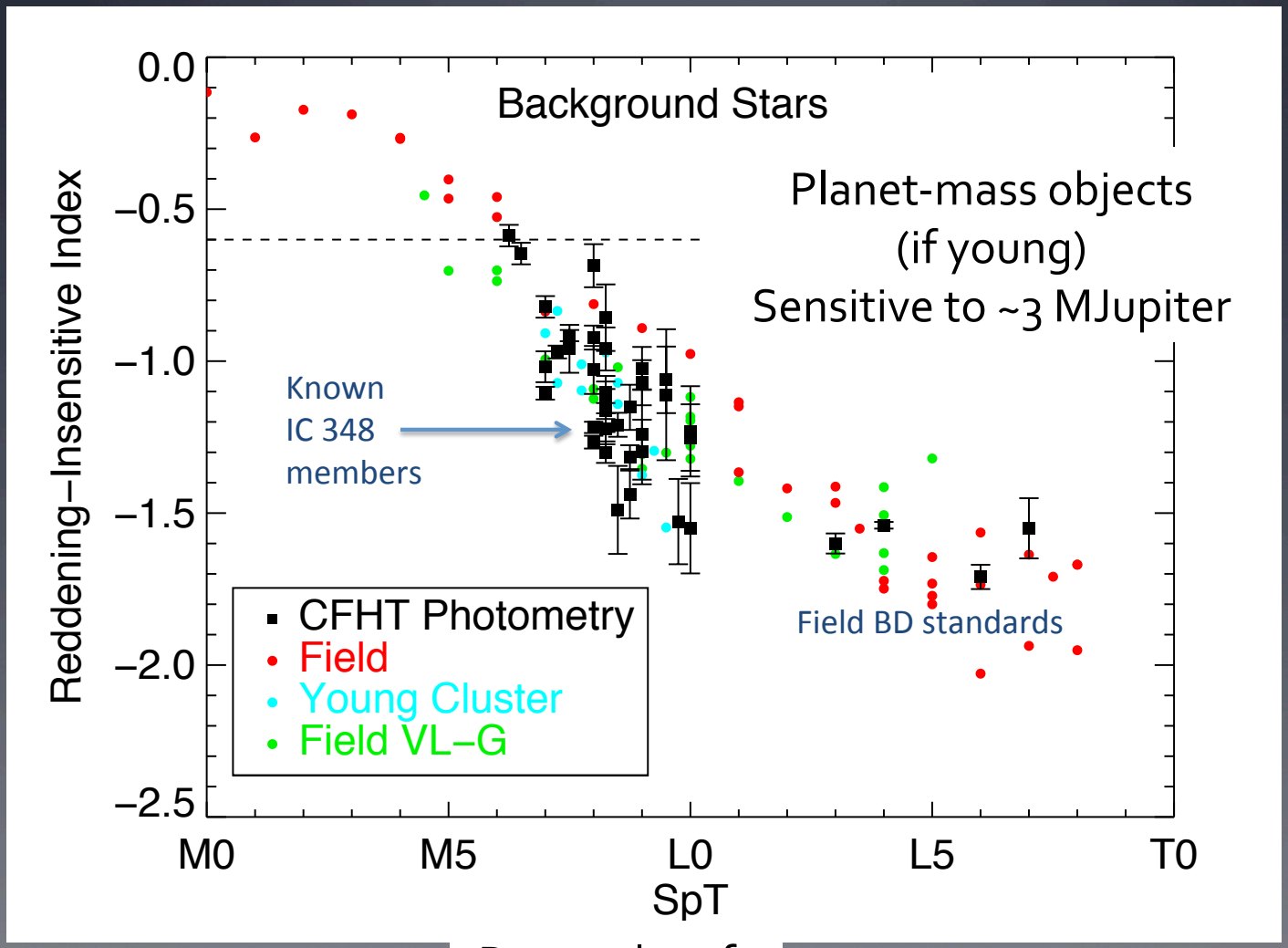



Builds on successful W-band search with UH88 (Allers & Liu 2010)
Needs Maunakea (or other dry site)

# Discovering the youngest free-floating planets:
## a transformative CFHT survey with the novel W(ater)-band



# Follow-up spectroscopic confirmation

**EAO-Subaru DDT**, PI Po-Shih Chiang (NCU-Taiwan)

Co-Is: UK, CA, FR, CN, TW, USA

1 night on IRCS through EAO
mostly weathered out

<u>Other spectroscopic facilities</u>:

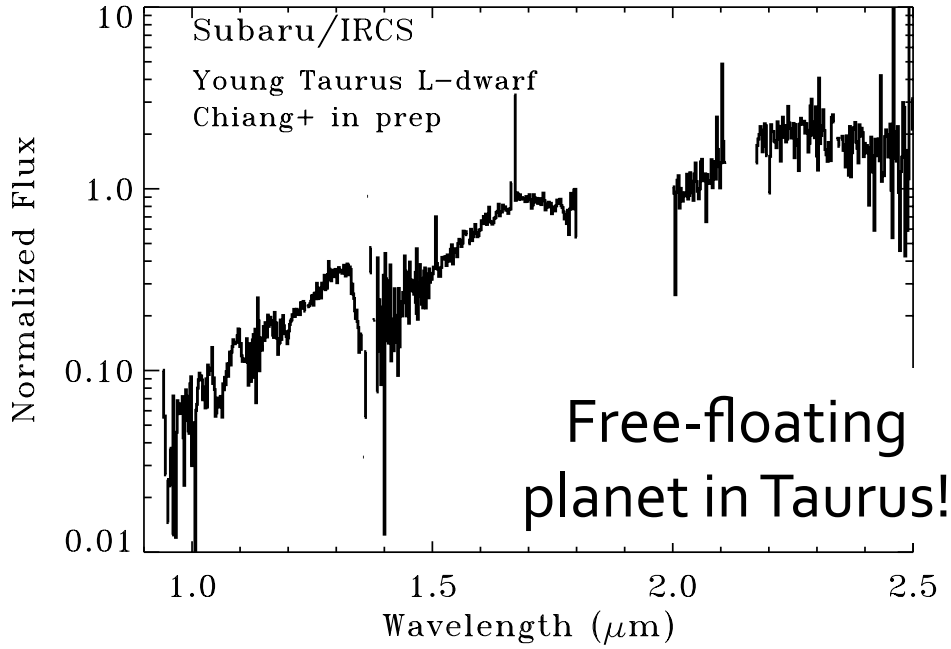
Palomar/TripleSpec

IRTF/SpeX

CTIO

Gemini

Proposals for high resolution imaging

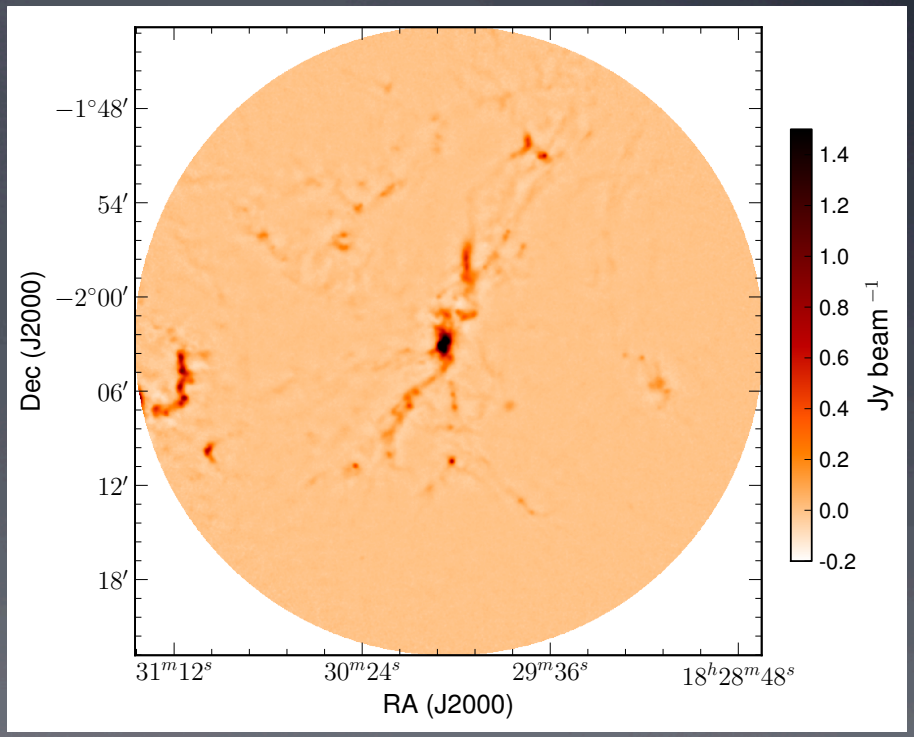



Free-floating planet in Taurus!

Free-floating planets: Complements SCExAO planet search

# The EAO-JCMT Transient search for variable protostars: how to stars gain their mass?

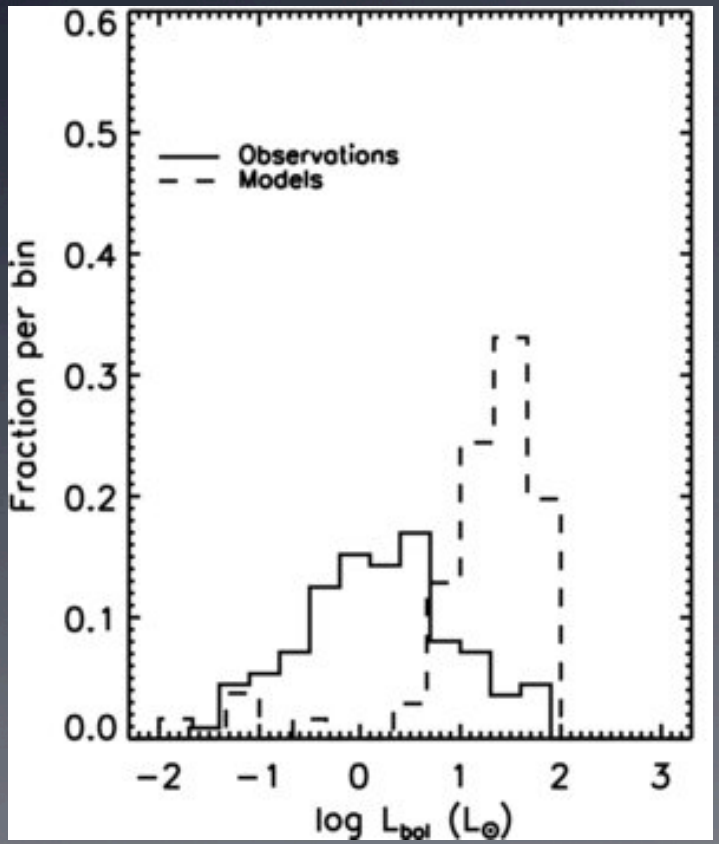
Gregory Herczeg (PI, China coordinator)
Doug Johnstone (co-PI, CA coordinator)
Jeong-Eun Lee (Korea coordinator)
Yuri Aikawa (Japan coordinator)
Geoff Bower (Hawaii coordinator)
Vivien Chen (Taiwan coordinator)
Jenny Hatchell (UK coordinator)
Steve Mairs (Victoria, CA)
Hyunju Yoo (Chungnam, Korea)
Sung-ju Kang (KASI, Korea)
Wen-Ping Chen (NCU, Taiwan)
**Plus ~60 additional team members**



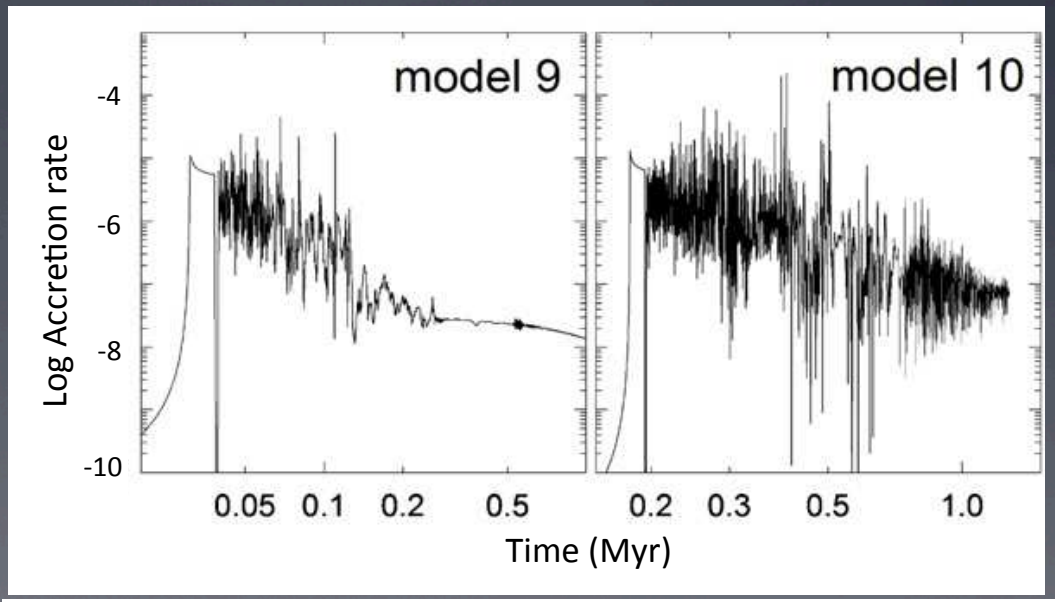

Monthy monitoring with SCUBA2 (850 micron continuum) of 8 nearby star-forming regions (30′ diameter). Large team to exploit many science goals.

**First sub-mm monitoring campaign!**

# Luminosity problem: protostars are too faint!



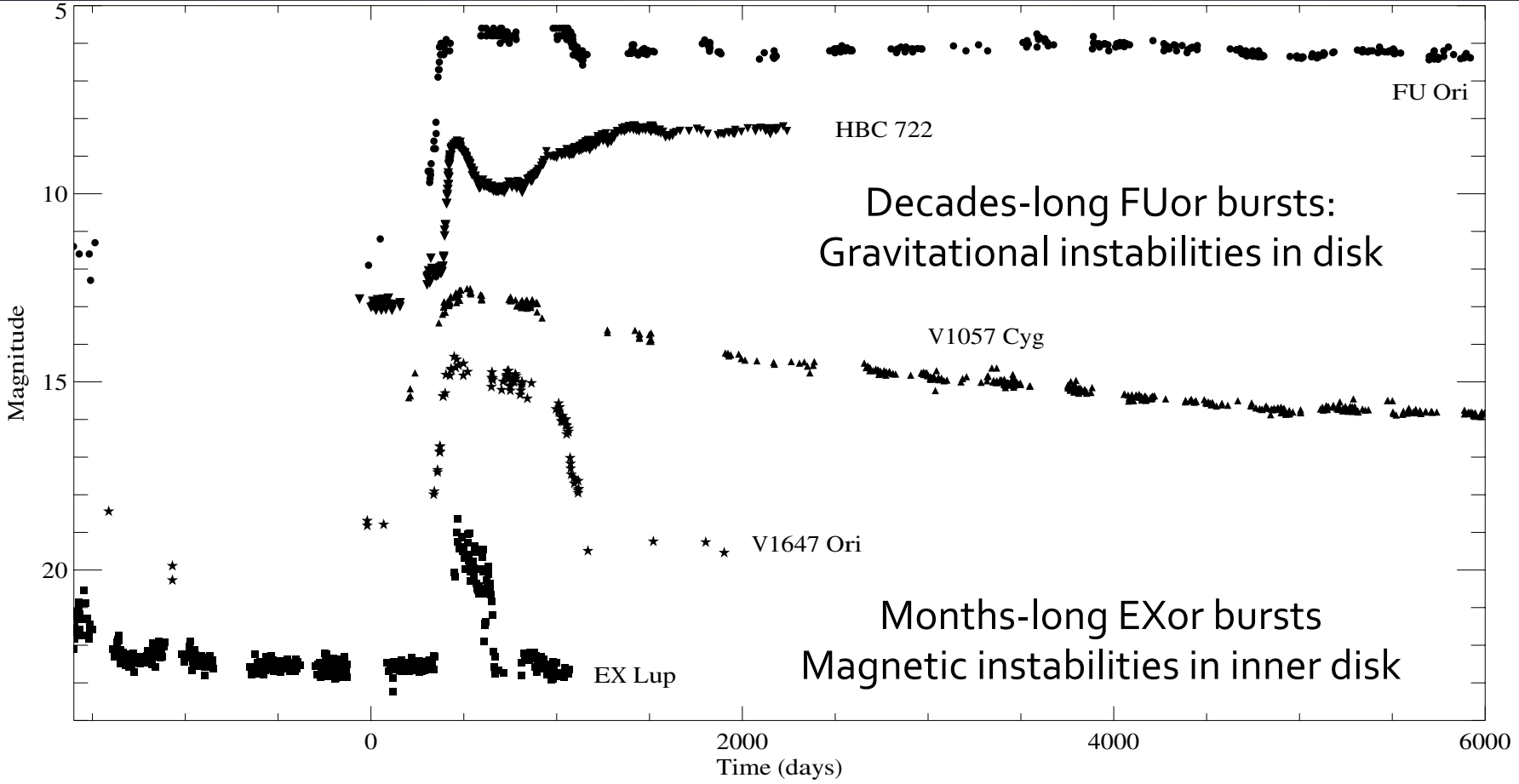

Protostars are fainter than expected (Kenyon+1990; Dunham et al. 2009)




Models from Dunham & Vorobyov (2012)

# Accretion outbursts of young stars

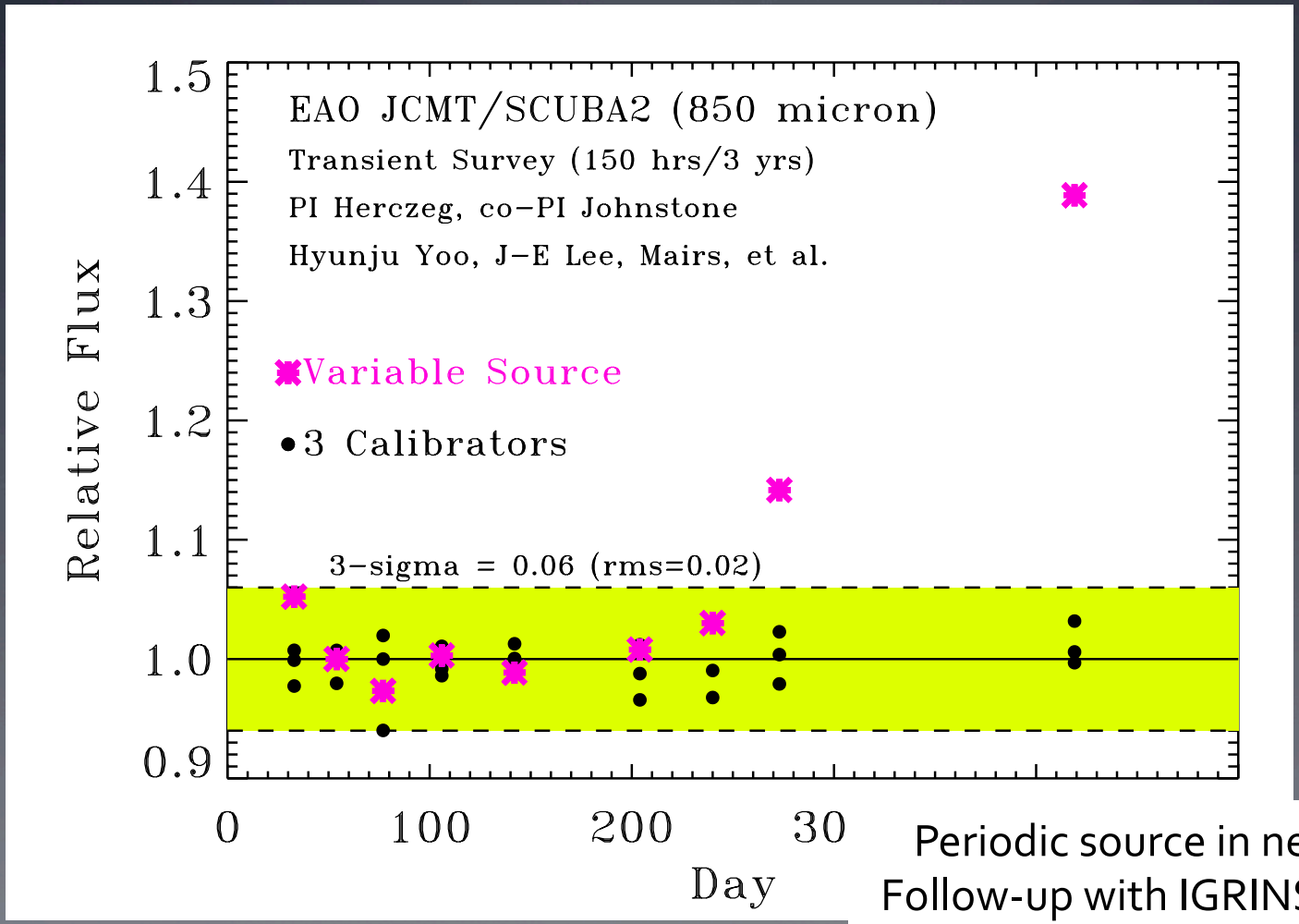
(adapted from Kospal+2011)




Youngest protostars are deeply embedded, not optically visible

# The EAO-JCMT Transient search for variable protostars: how to stars gain their mass?

(Herczeg+, Mairs+, Yoo+ in prep)




Periodic source in near-IR: Follow-up with IGRINS, other resources (Subaru?) in 2018A

# Star and Planet Formation with EAO

- Optical/near-IR: star formation histories, disk evolution
  - Characterize the very low-mass populations versus environment
  - Measure populations, ages for recent star formation history
- Confirmation/characterization of very low mass objects
  - also SCExAO!
- EAO/JCMT: active star formation
  - Transient: a novel variability survey; possible synergies with Subary

EAO-DDT, 6 nts/yr: follow-up spectroscopy, small experiments

Ambitious programs (SCExAO, IRD) would need to develop through partnerships/time (EAO/JCMT as example);

How to collaborate, build a community, and access SSP knowledge to optimize use of smaller amounts of time?