EAO/JCMT Transient Survey Update

[150 hrs: 8 star-forming fields, monthly for 3yrs]

Coordinators

Doug Johnstone (co-PI; Canada)

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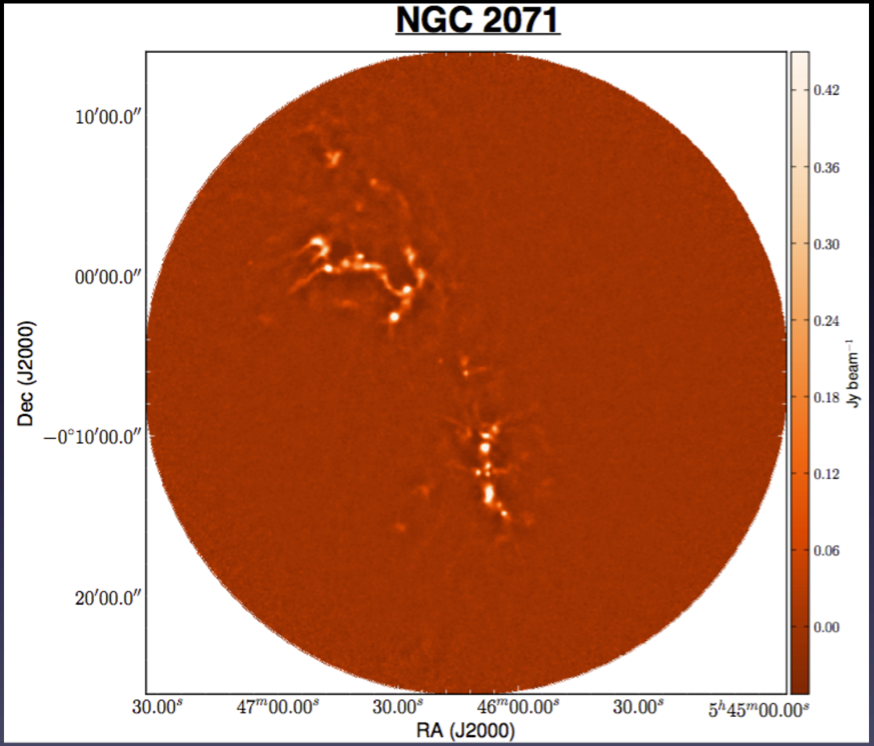
Vivien Chen (Taiwan)

Jennifer Hatchell (UK)

Jeong-Eun Lee (Korea)

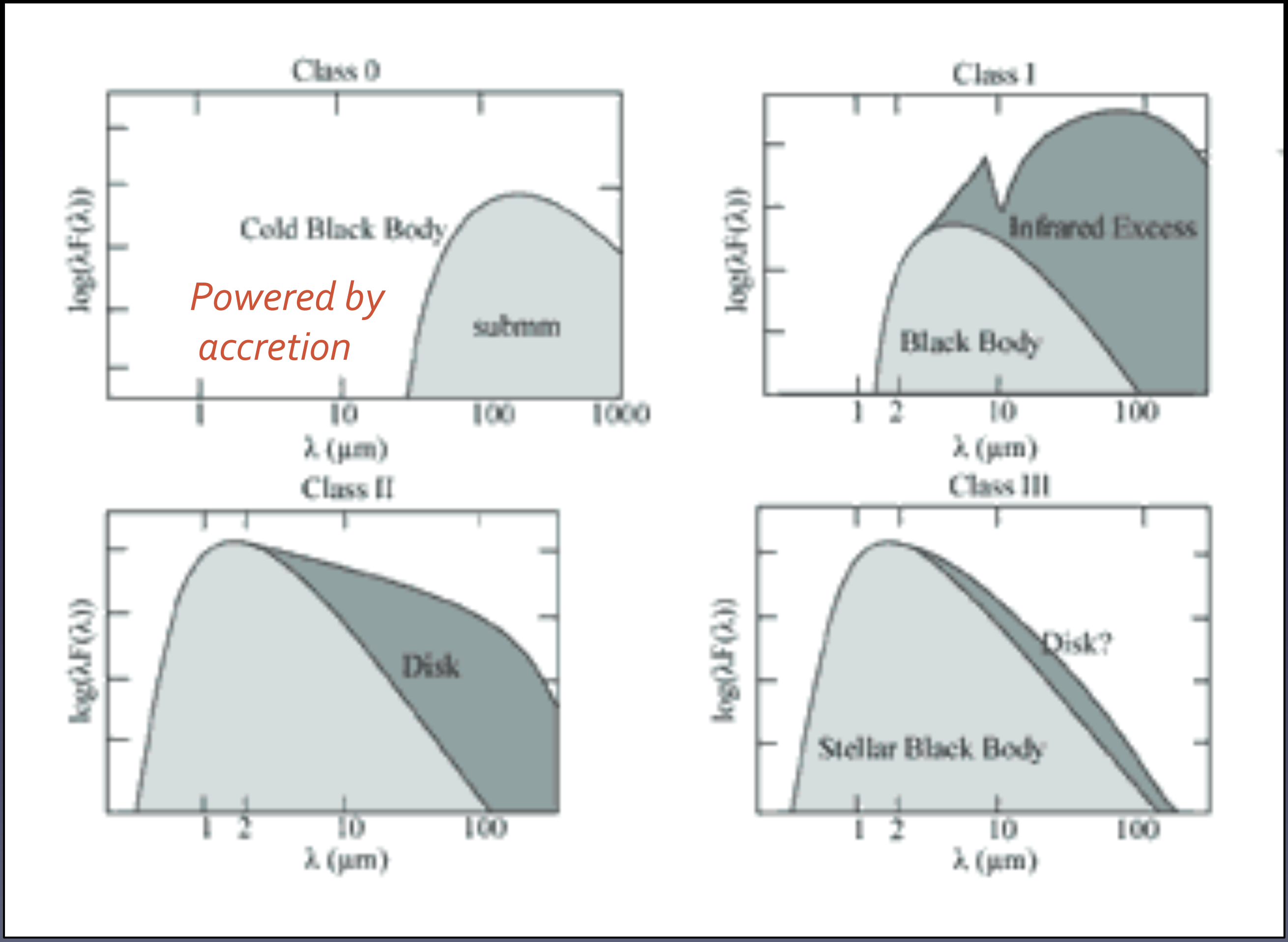


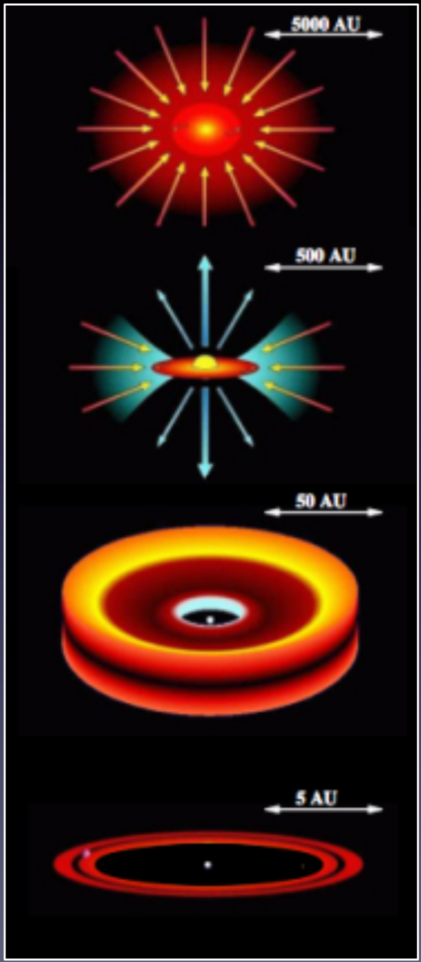
65 members (9 CA, 13 CN, 4 EAO, 3 JPN, 14 KR, 17 TW, 10 UK)

2 Independent Calibration Teams, 8 individual Region Teams

Formation of a (Proto)Star

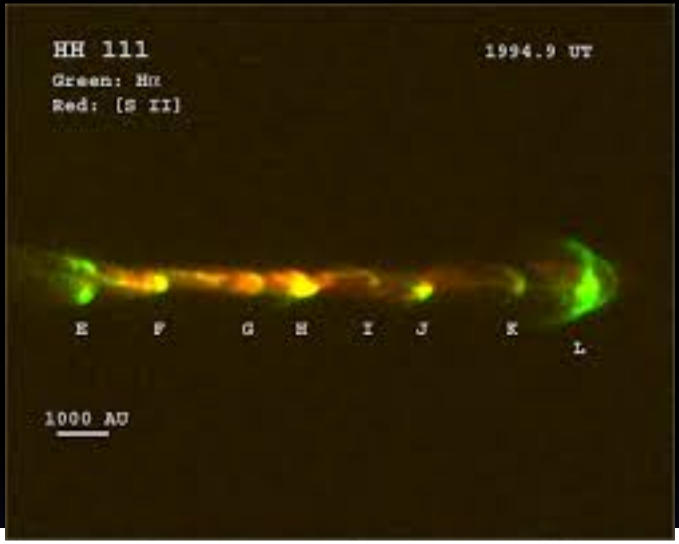
Spectral Energy Distribution Evolution



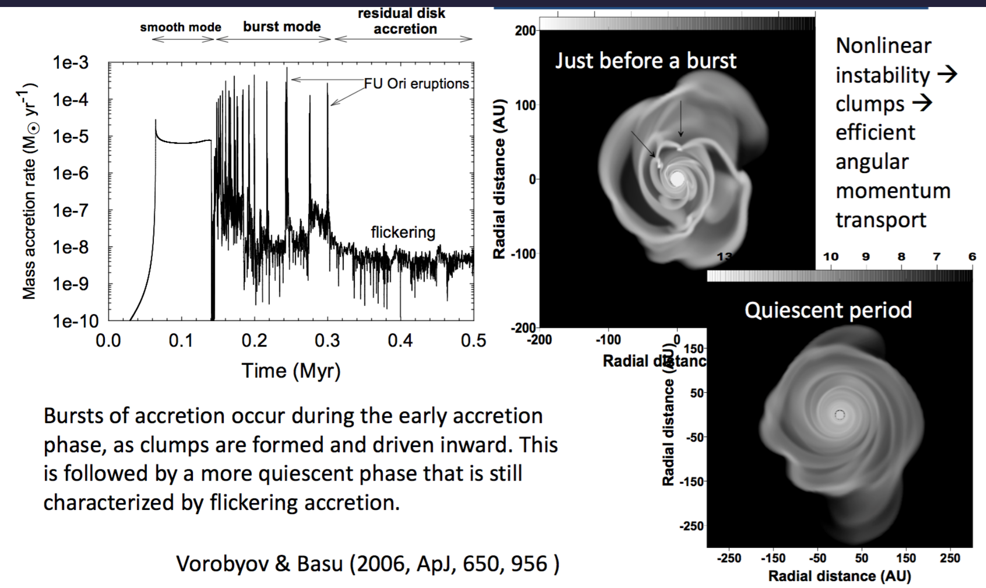


Evidence for episodic accretion

- Under-luminosity of protostars
- Repeated jet shocks
- Outbursts on more evolved protostars (FUors, EXors)
- Chemical signatures of past epochs of high luminosity
  (e.g., Kim+2011; Jorgensen+2013)
- Numerical Disk Simulations
  - So far, focus on long times…



Jet shocks in HH 111
(Reipurth 1989; Hartigan et al. 2011)

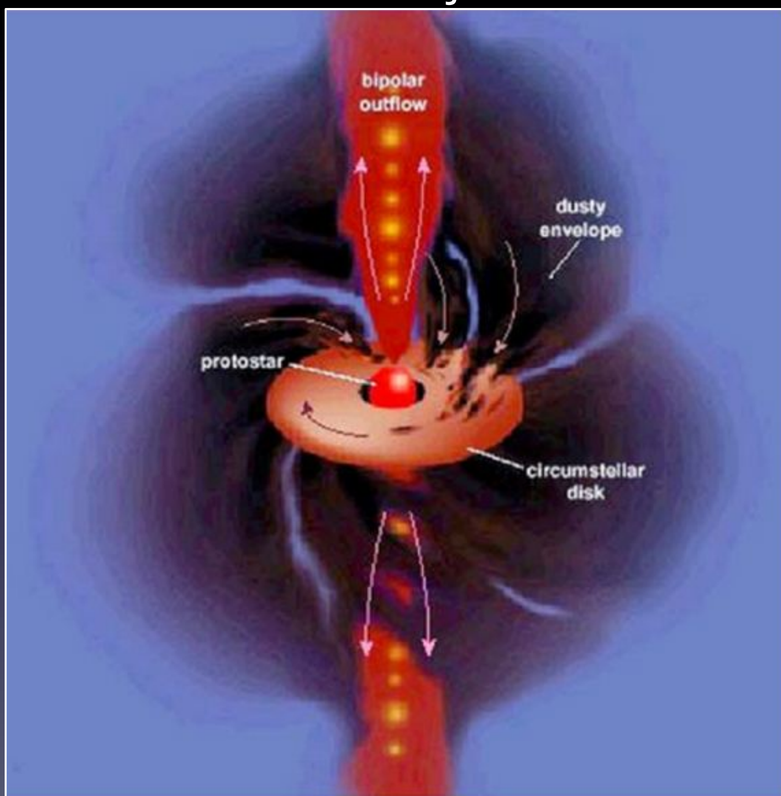


Bursts of accretion occur during the early accretion phase, as clumps are formed and driven inward. This is followed by a more quiescent phase that is still characterized by flickering accretion.

Vorobyov & Basu (2006, ApJ, 650, 956)

Importance of Disk Accretion

Cartoon of accretion/ejection

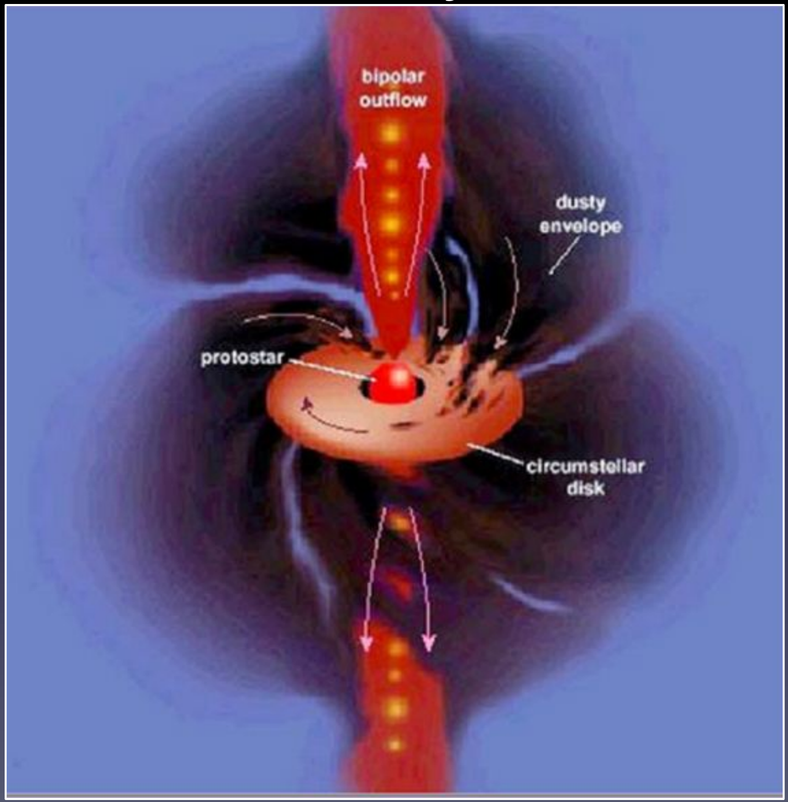


- Shu (77) SIS model considers free-fall accretion from envelope
- Accretion luminosity depends on accretion rate onto stellar surface
- Between envelope and star we expect to have a disk!
- No expectation for steady flow through the disk and onto star

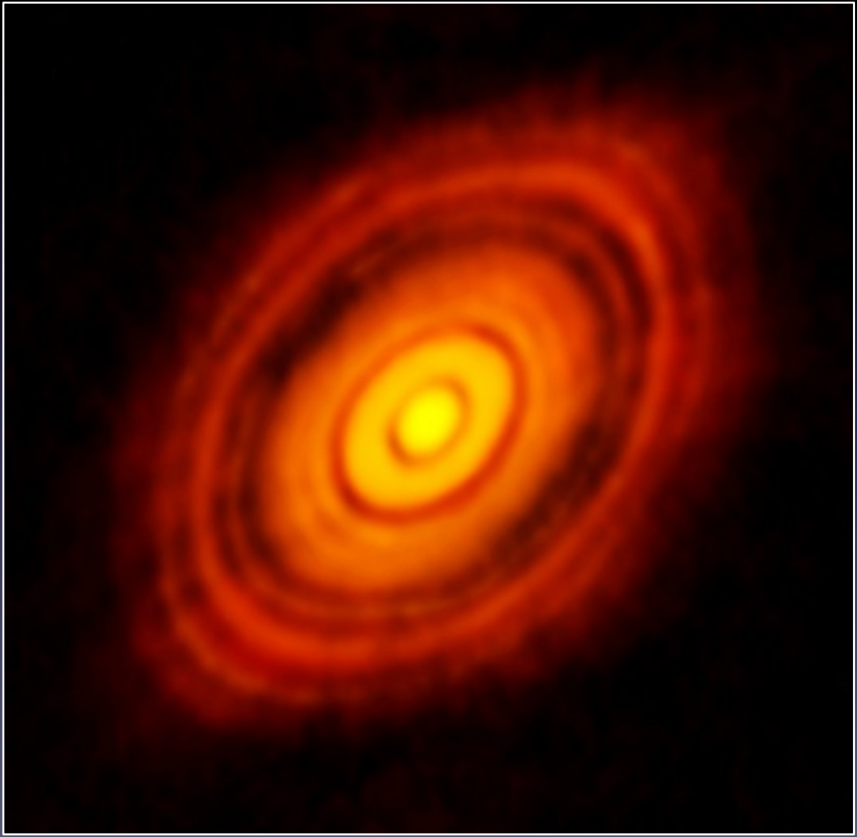
Variability related to orbital time ...

Importance of Disk Accretion

Cartoon of accretion/ejection



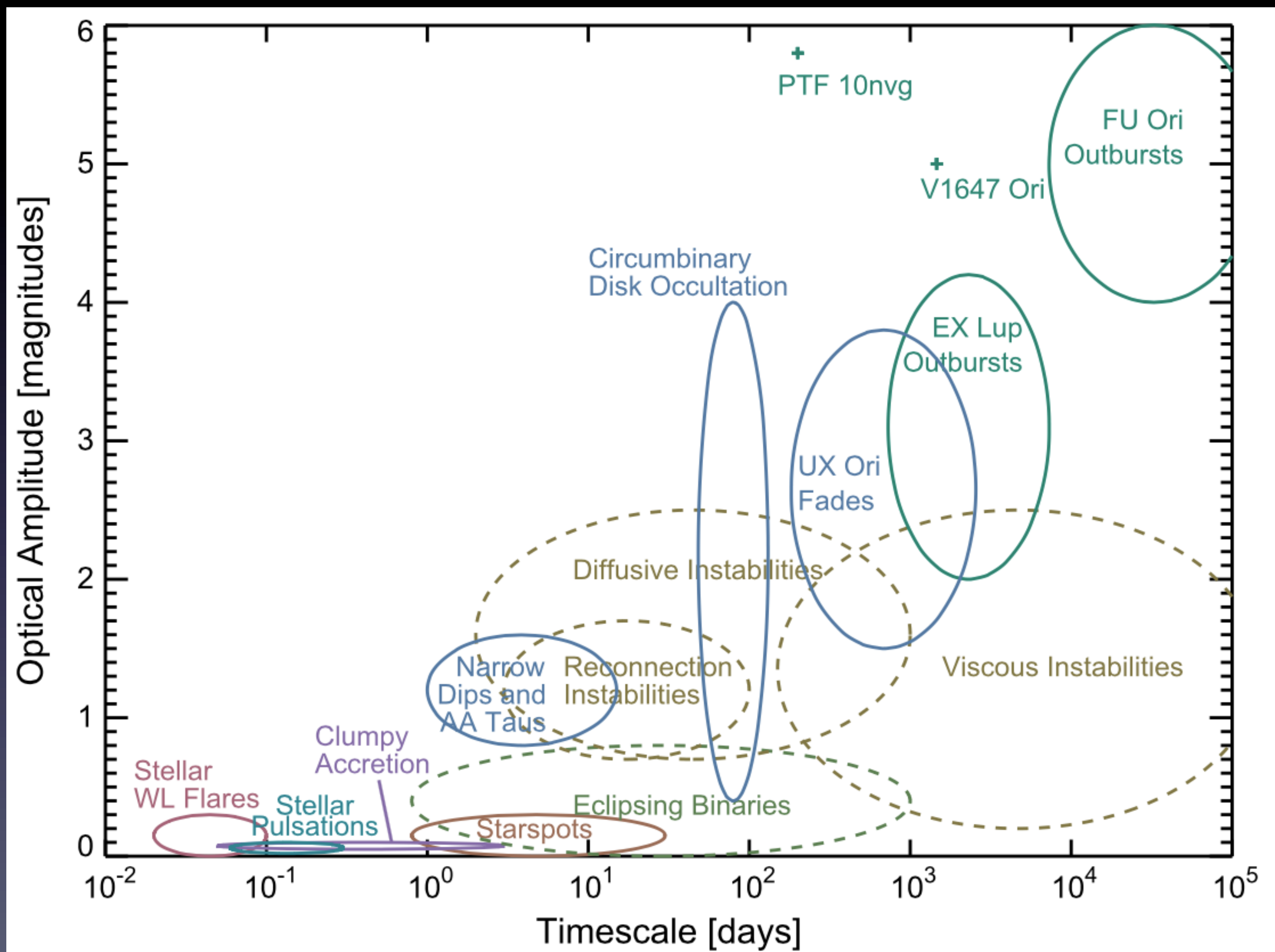
HL Tau disk observed with ALMA (rings)



Variability related to orbital time …

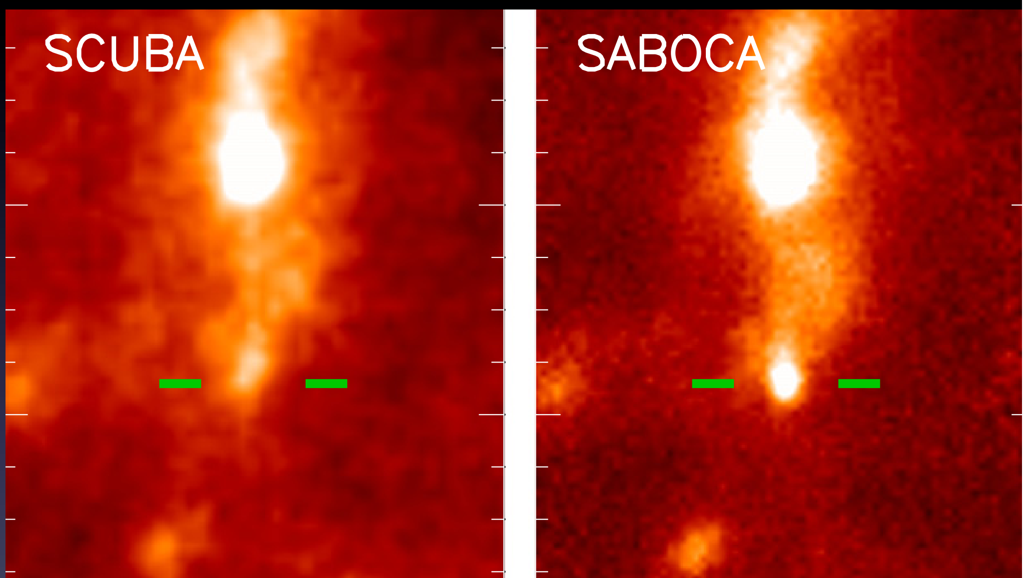
A Range of Possible Timescales

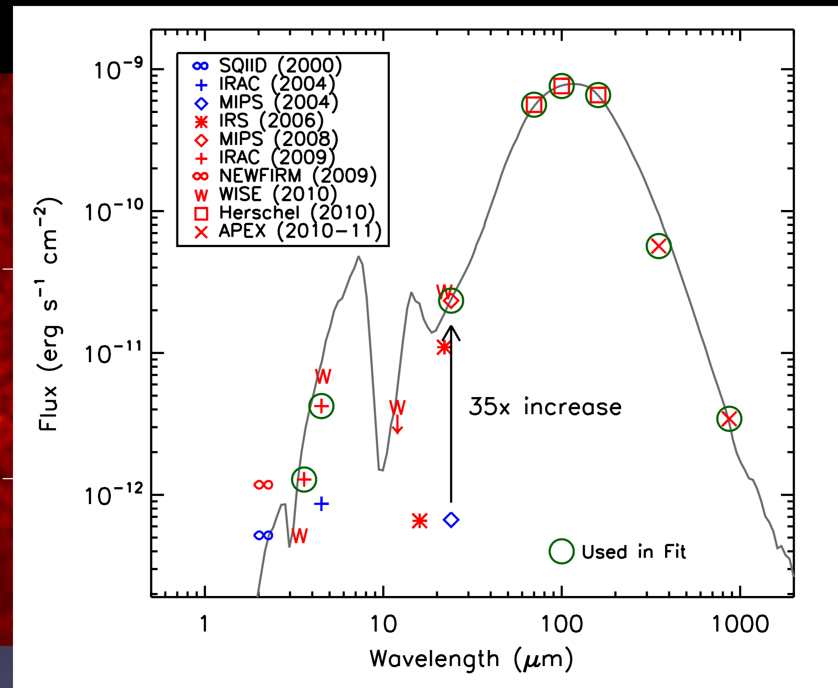
Probing both location and physical processes



Hillenbrand & Findeisen 2015

Observed Protostellar Variability
using SCUBA-2 as an envelope Calorimeter





Embedded source identified in mid-IR Spitzer;
Strong sub-mm emission post-outburst (JCMT archive)

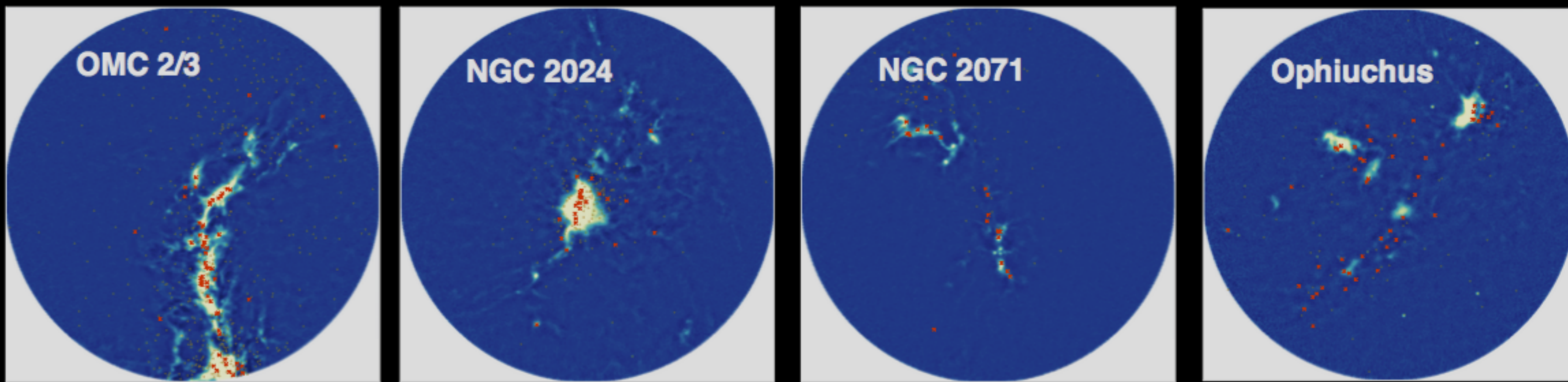
(Safron, Fischer, et al. 2015)

Transient Survey Strategy

- Eight star-forming regions observed as 30' diameter fields
- Each region observed once per month for three years
  - Just over 25% complete so far (a little behind expectations)
- Monitor for signs of variability across epochs
  - Compare also against previous GBS observations (> 5 yr baseline!)
- Co-add epochs to produce deepest sub-mm images of each region
  - Reach extragalactic confusion limit!

		SCUBA-2 peak flux/beam			Spitzer Sources		
Name	Location	> 0.2 Jy	> 0.5 Jy	> 1.0 Jy	Class 0/I	Flat	Class II
Perseus - NGC1333	032854+311652	27	9	5	31	13	57
Perseus - IC348	034418+320459	5	3	2	11	6	94
Orion A - OMC2/3	053531-050038	60	30	17	32	29	158
Orion B - NGC2024	054141-015351	21	9	5	11	12	87
Orion B - NGC2071	054613-000605	25	11	4	14	5	54
Ophiuchus	162705-243237	26	5	2	18	27	60
Serpens Main	182949+011520	14	10	7	18	10	47
Serpens South	183002-020248	20	5	2	47	30	113

EAO/JCMT Transient Survey

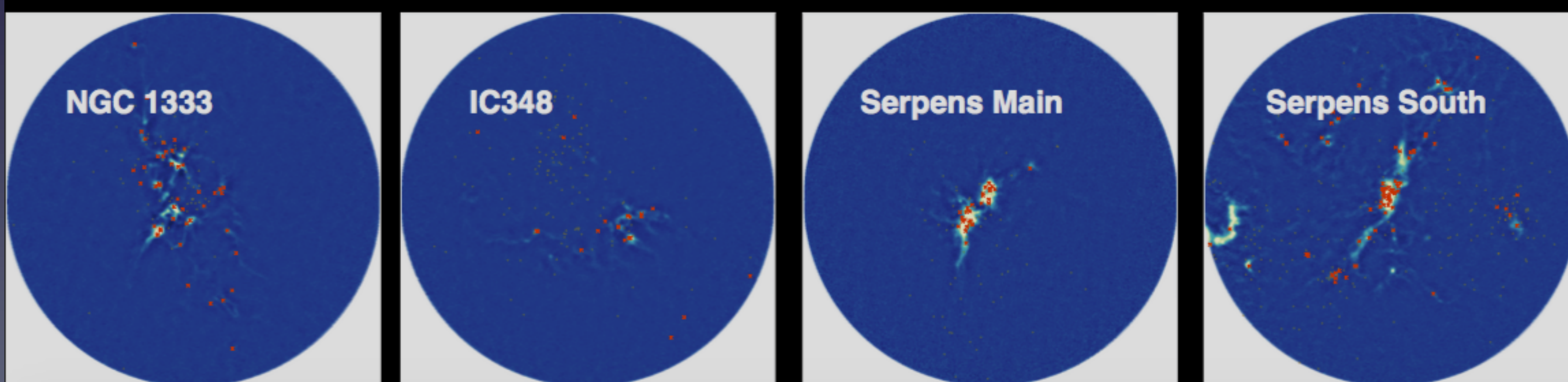


8 Regions < 500 pc (GBS)

3 Year Survey

182 Protostars, 800 Disk sources

One Month Cadence

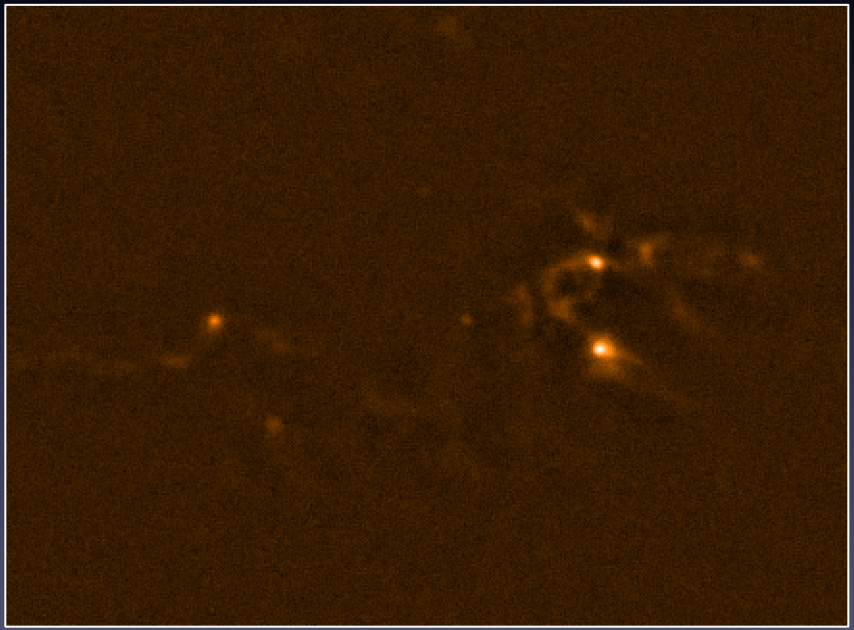


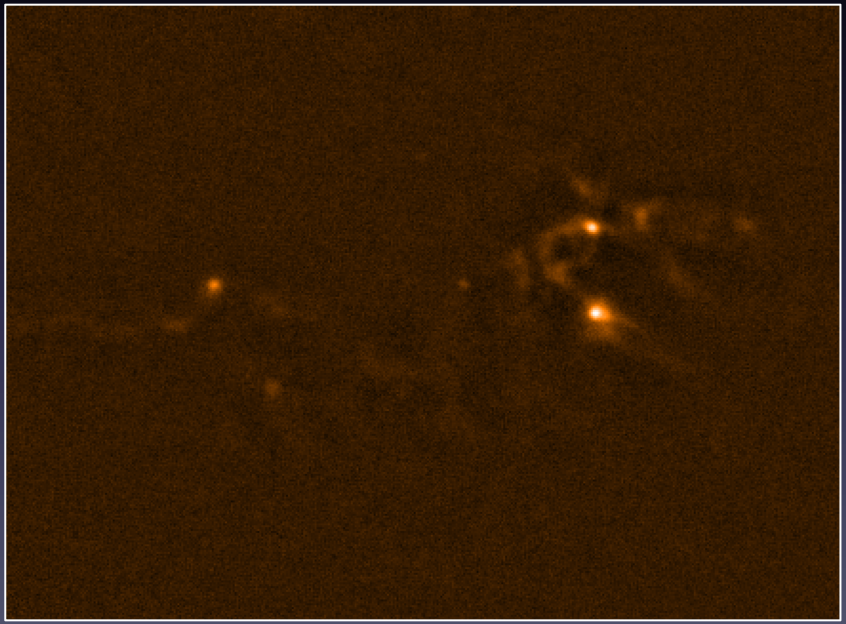
Calibration Methodology

Run Source-Finder on all epochs of the same field (PhD student- Steve Mairs).

Determine which sources are in common between observations.

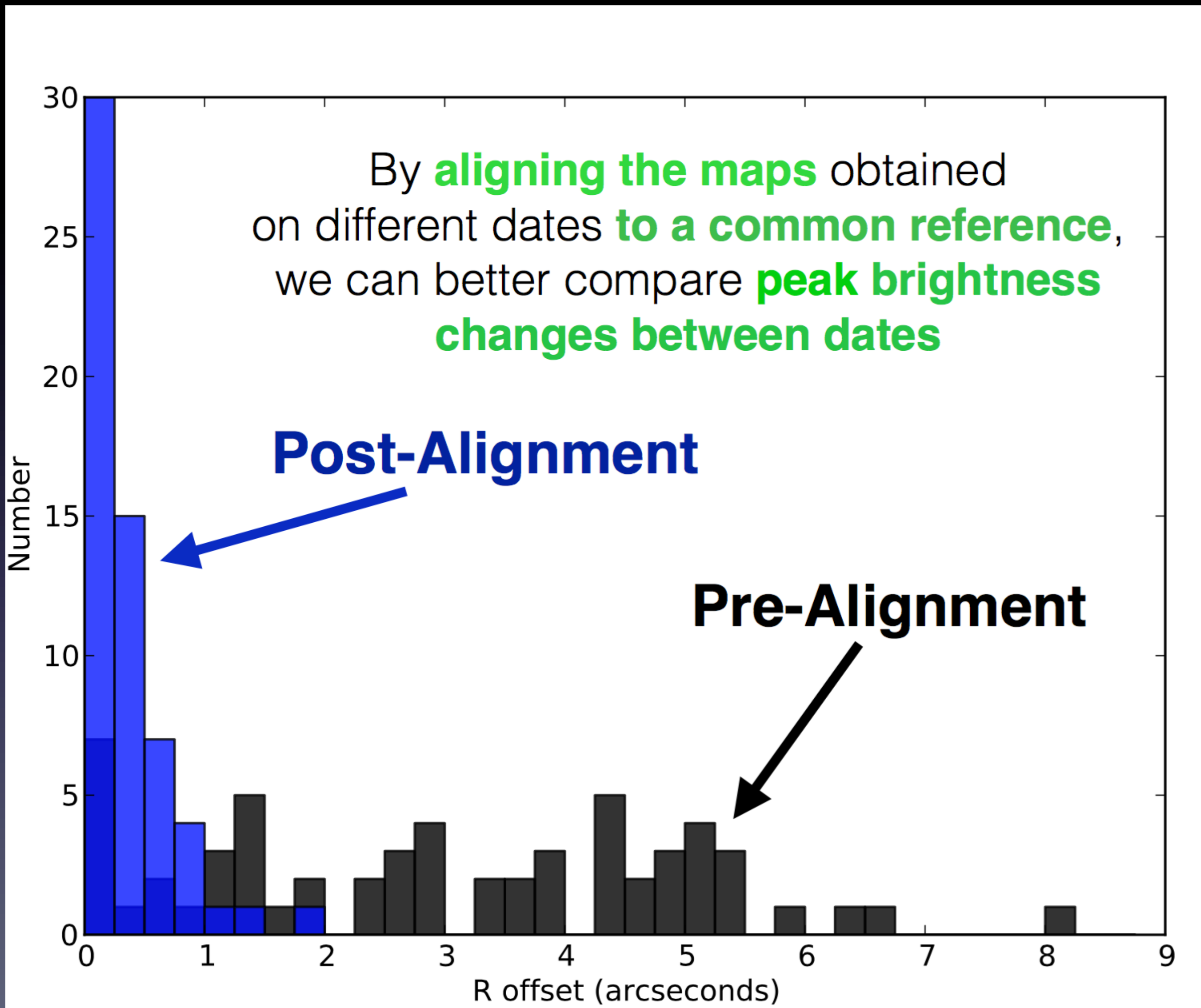
Compare clump centroids and relative brightness between observations.



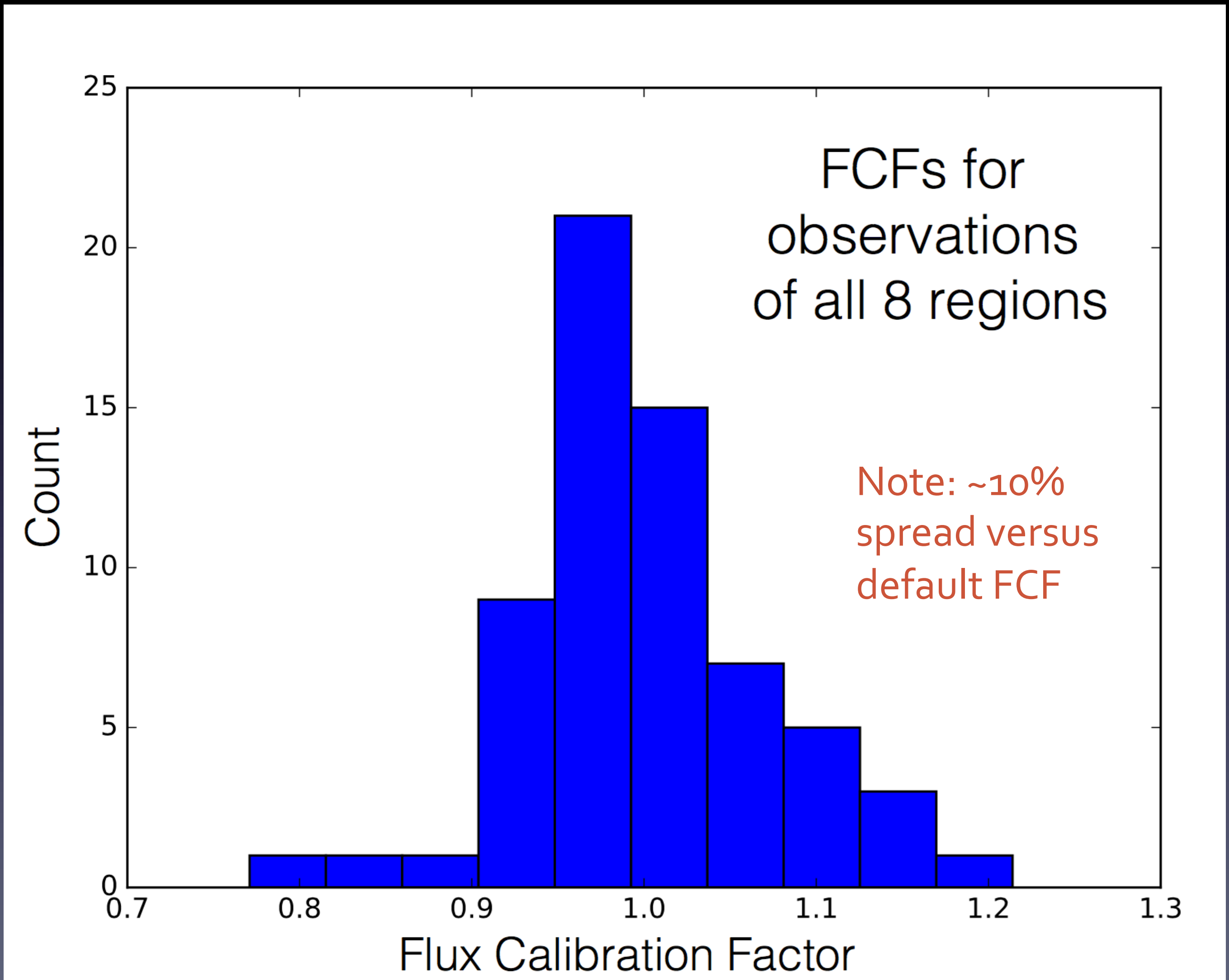


Six epochs of IC348 observed over half a year.
Left: Before residual offset calibration; Right: after applying offset.

Alignment Improvement

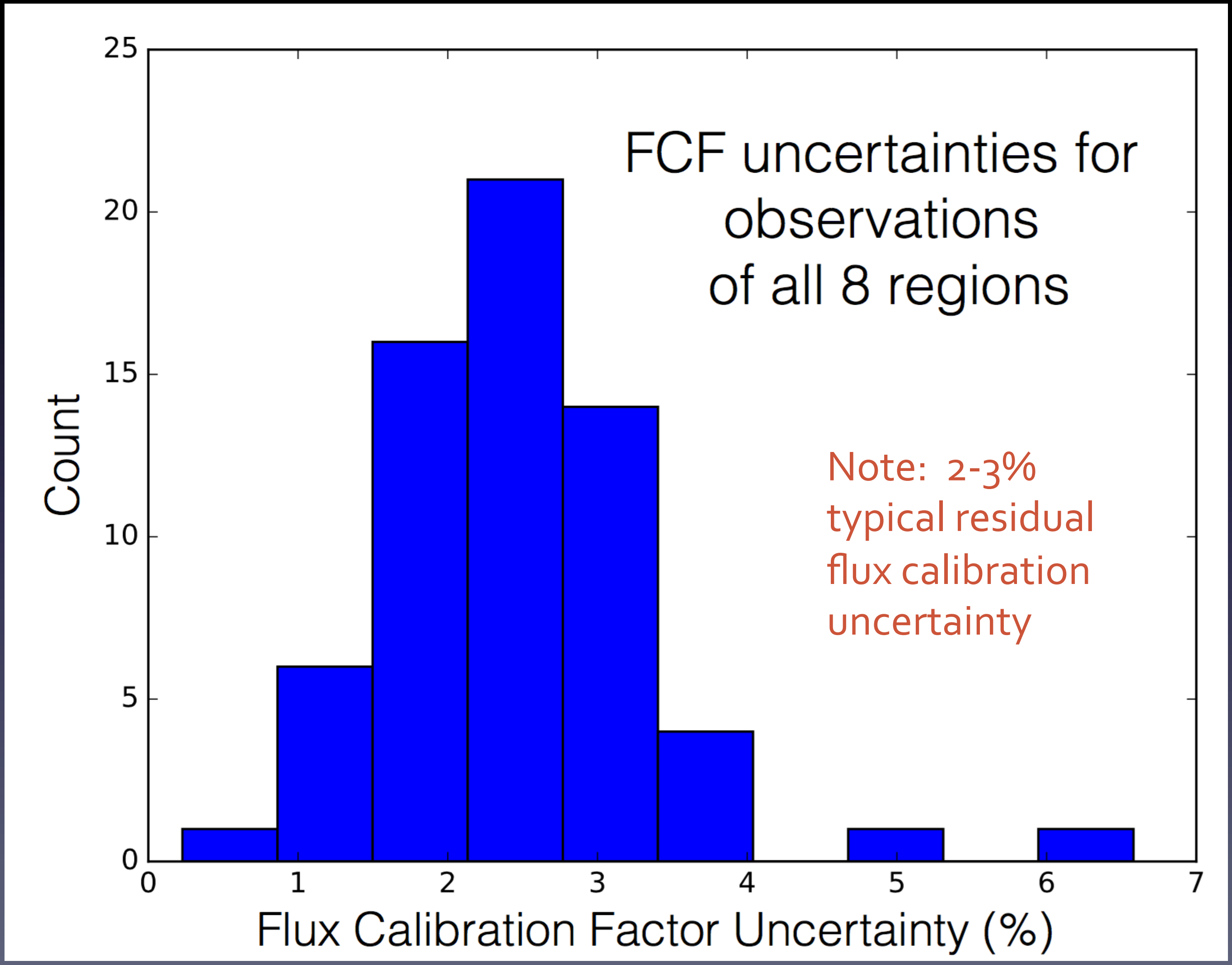


Flux Calibration Improvement
(with respect to default FCF)



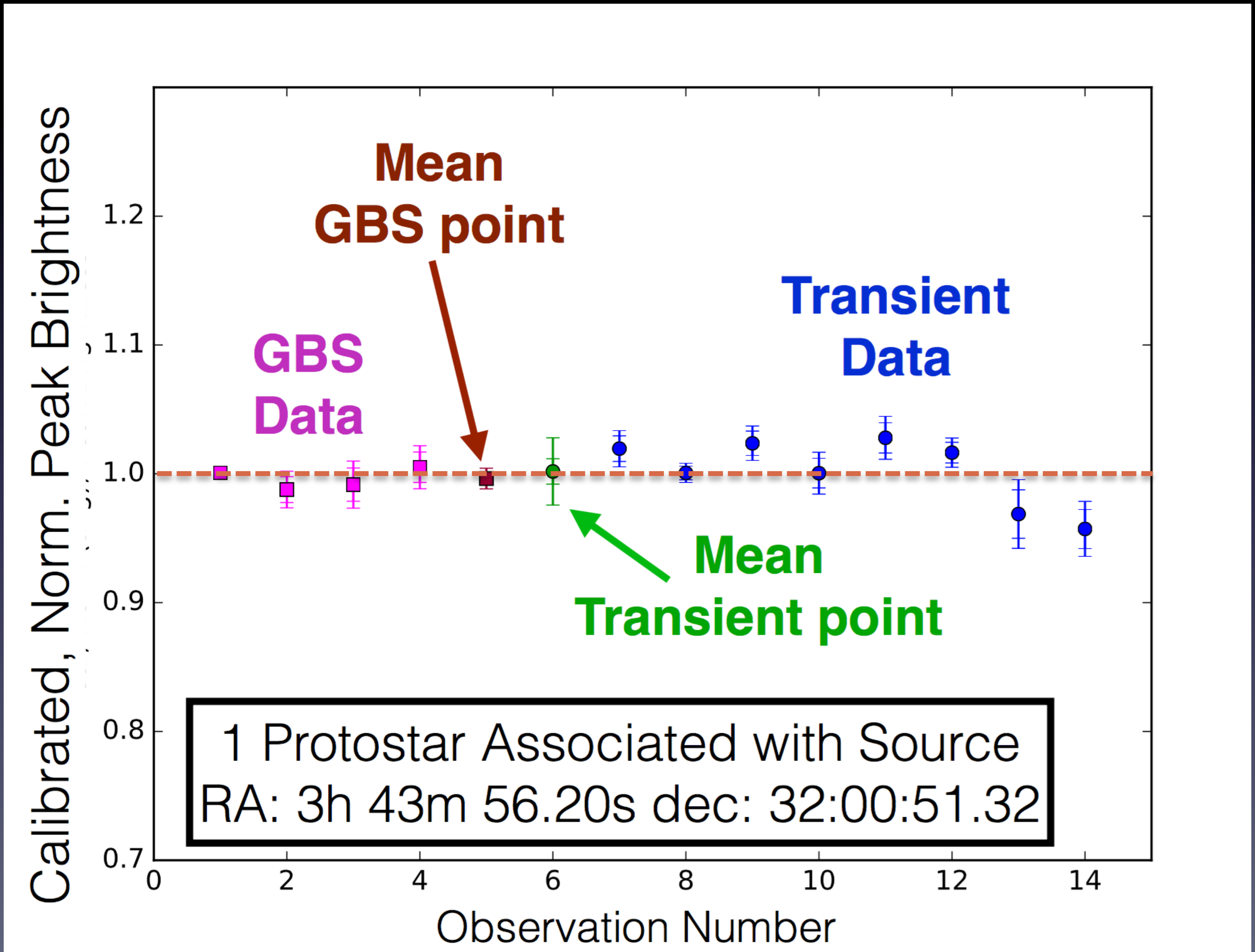
Flux Calibration Uncertainty

(residual source flux standard deviation)



Example Proto-stellar Source

12 epochs (8 Transient, 4 GBS)



First Variable Candidate!

Serpens Main: clumpfind analysis by (PhD student - Hyunju Yoo, Korea)

One Class I source has been discovered that varies by > 5 sigma.

First Year Situation

- We have an automated calibration pipeline in place (2 independent teams)
  - < 1" alignment uncertainty
  - ~ 3% relative flux calibration uncertainty
- We have 8 separate region teams looking closely at the individual epochs
  - These teams are still refining, independently, various procedures for analysis
  - One variable source has been identified, coincident with near IR periodic variable
- We have three papers in advanced draft plus two more in preparation
  - Herczeg et al. (Survey Overview), Mairs et al. (Calibration Pipeline), Mairs et al. (GBS vs. Transient), Yoo et al. (Variable Source in Serpens), Johnstone et al. (First Results from Transient Survey)
- We are ramping up ancillary analyses now that we are deeper than the GBS!
  - Studying disks, filaments, outflows, etc.
  - Following up interesting sources with other telescopes (SMA/ALMA etc)