EAO/JCMT Transient Survey Update

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

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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

Powered by accretion
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)

Mass accretion rate (M, yr^-1)

Importance of Disk Accretion

- 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!

<table>
<thead>
<tr>
<th>Name</th>
<th>Location</th>
<th>SCUBA-2 peak flux/beam</th>
<th>Spitzer Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perseus - NGC1333</td>
<td>032854+311652</td>
<td>&gt; 0.2 Jy 9 5</td>
<td>Class 0/I 31 13 57</td>
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<tr>
<td>Perseus - IC348</td>
<td>034418+320459</td>
<td>&gt; 0.5 Jy 5 2</td>
<td>Flat 11 6 94</td>
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<td>&gt; 1.0 Jy 17</td>
<td>Class II 32 29 158</td>
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<td>054141-015351</td>
<td>21 9 5</td>
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<td>Orion B - NGC2071</td>
<td>054613-000605</td>
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<td>Ophiuchus</td>
<td>162705-243237</td>
<td>26 11 2</td>
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<tr>
<td>Serpens Main</td>
<td>182949+011520</td>
<td>14 10 7</td>
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<tr>
<td>Serpens South</td>
<td>183002-020248</td>
<td>20 5 2</td>
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</table>
EAO/JCMT Transient Survey

OMC 2/3  NGC 2024  NGC 2071  Ophiuchus

8 Regions < 500 pc (GBS)  3 Year Survey
182 Protostars, 800 Disk sources  One Month Cadence

NGC 1333  IC348  Serpens Main  Serpens South
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

By aligning the maps obtained on different dates to a common reference, we can better compare peak brightness changes between dates.

Post-Alignment

Pre-Alignment
Flux Calibration Improvement
(with respect to default FCF)

Note: ~10% spread versus default FCF
Flux Calibration Uncertainty
(residual source flux standard deviation)

Note: 2-3% typical residual flux calibration uncertainty
Example Proto-stellar Source

12 epochs (8 Transient, 4 GBS)

1 Protostar Associated with Source
RA: 3h 43m 56.20s dec: 32:00:51.32
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)