Young clusters in IPHAS x IR surveys

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T Tauri objects

 young (1-10 Myr), low-mass (< 2 M☉), optically visible stars (K/M-type).

Magnetospheric

<u>Appear in clusters</u>





Context:

88% of T Tauri stars in SIMBAD are located in nearby, low-mass clusters at |b| > 5.

Questions:

Does IPHAS show T Tauri stars in high-mass clusters?

Do massive stars disrupt or trigger low-mass star formation?

Talk outline

- 1. Cluster identification
- 2. Result: IPHAS Cluster Top 5 ™
- 3. Science from IC 1396 & NGC 2264

IPHAS covers Northern Galactic Plane in r' / i' / H-alpha



IPHAS database contains ~557 million detections (r' < 21); surface density traces dust rifts (+ pointing overlap artefacts).



SELECT COUNT(*) FROM iphas WHERE r BETWEEN 13.0 AND 21.0 AND class_r = -1 AND class_i = -1 AND class_ha = -1 AND sqrt(pow(dxi_i,2)+pow(dxn_i,2)) < 0.1 AND sqrt(pow(dxi_ha,2)+pow(dxn_ha,2)) < 0.1</pre>

H-alpha emission-line objects are located above the main sequence in the IPHAS colour-colour diagram



We select candidates using a fixed cut above the main sequence, such that chromospherically active foreground dwarfs are avoided.



Result: 55 000 H-alpha emission-line candidates. Spatial distribution shows a combination of true clusters + artefacts due to weather.



(Same plot showing red objects only.)



We expect genuine clusters to show up in IR surveys as well.

SELECT *
FROM twomass_psc
WHERE ph_qual = 'AAA'
AND (j_m-h_m) BETWEEN (0.61*(h_m-k_m) + 0.5) AND (1.9*(h_m-k_m) - 0.2)

2MASS: 37 000 candidates.

Only 800 matches with IPHAS candidates due to limited depth of 2MASS :-(

UKIDSS/GPS: 1.5 million (!) candidates

SELECT * FROM reliableGpsPointSource
WHERE jAperMag3 < 20 AND jmhPnt BETWEEN (0.61*hmk_1Pnt + 0.5) AND (1.9*hmk_1Pnt - 0.25)</pre>

WISE/PDR: 100 000 candidates having [3.4]-[4.6] > 0.5

WHERE w1mpro-w2mpro > 0.5 AND w1snr>10 AND w2snr>10 AND ext_flg = 0

AKARI/IRC: 180 000 candidates having [9]-[18] > 0

Result: 1989 IPHAS candidates confirmed by one of the IR surveys; 344 of these are known by SIMBAD (mostly young stars + some Be/PN).

IPHAS => 25 clusters, distance ~0.5 to 3 kpc

Largest clusters correlate with giant HII regions.

Surprising differences in cluster centres, e.g. Rosette nebula:

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Note: additional candidates are obtained after dereddening the IPHAS database using the (r'-i') / (i'-J) diagram.

Cluster Top 5 (ranked by #IPHAS candidates)

- 1. IC 1396 (Elephant's Trunk Nebula)
- 2. Sh2-155 (Cepheus OB3)
- 3. NGC 7000 / IC 5070 (North America & Pelican Nebula)
- 4. NGC 2264 (Cone Nebula)
- 5. Sh2-190/199 (Heart & Soul Nebula)

IC 1396 IPHAS mosaic http://apod.nasa.gov/apod/ap110425.html

Elephant's trunk

O6V

2 degrees = 30 pc (d ~ 900 pc)

Tadpole globules

(Distraction: obnoxious number of ionized clouds in IPHAS resemble animals.)

2

 98°

We derive stellar parameters from (Siess et al. 2000) tracks

We derive H-alpha EW from IPHAS colour-colour diagram:

Caveat: background emission

Bad news: background subtraction may fail for objects seen in front of strong <u>spatially varying</u> nebular emission.

Good news: we find that the IPHAS pipeline flags the vast majority of these objects "extended".

Note: low-resolution spectra have the same trouble!

H-alpha luminosity correlates with UV-based accretion luminosity (data from Hartigan & Kenyon 2003, Herczeg & Hillenbrand 2008, Dahm 2008)

... and from accretion luminosity we may estimate the accretion rate

$$L_{\rm acc} \simeq \frac{GM_{\star}M}{R_{\star}} (1 - \frac{R_{\star}}{R_{\rm in}})$$

Result: stellar parameters and accretion rates for 158 candidates

Vast majority of our sample shows evidence for a circumstellar disk

2MASS

Spitzer

Many IPHAS candidates located between ionizing star and globules.

We find a gradient of increasing IR disk excess towards the Trunk

Might be explained by UV photo-evaporation?

But models & observations suggest photo-evaporation is not effective beyond ~1 pc from source (e.g. Richling & Yorke 1998; Balog et al. 2007)

We also find a gradient of increasing accretion rates and decreasing ages

This is more difficult to explain from photo-evaporation!

The spatial dispersion of objects in front of the globules suggests a true age gradient away from the O-type star

Consistent with <u>sequentially triggered star formation</u>. Detailed discussion in (Barentsen et al. 2011, MNRAS)

Accretion rates as a function of mass and age

These relationships are known to be affected by selection effects, the IPHAS method offers a handle on these

NGC 2264 = Cone Nebula

IPHAS contains reliable data for 567 known members (Sung et al. 2009),. 154 objects are found to be accreting.

Ongoing work in NGC 2264: study of the average Spitzer-based SED as a function of IPHAS-based masses and accretion rates

+ comparison with available X-ray and variability data

Conclusions

- >25 young clusters waiting to be studied in a homogeneous way
 - IPHAS/UVEX: stellar parameters & accretion rates
 - 2MASS/UKIDSS: membership & reddening
 - SPITZER/WISE/AKARI: disk properties
- Will shed light on the influence of massive stars on the formation of solar-like stars
- You want to hire a postdoc to work on this

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