INDICATE:

A novel tool to robustly study the star formation history of a cluster

Images: Flicker/ Martin Heigah

ICYBOB

Anne Buckner
University of Exeter

What Is INDICATE?

In a nutshell: A statistical spatial analysis tool that quantifies the degree of association in a cluster by deriving and assigning an index value for each and every star.

For the cluster, an evenly spaced uniform control distribution of the same density is generated across the parameter space. The mean Euclidean distance, $\bar{r}$, of every star *j* in the cluster to its 5^{th} nearest neighbour in the control is measured and the number of neighbouring stars within this radius counted, $N_{\bar{r}}$. The index is then defined as the ratio of these two numbers i.e.

$$I_{5,j} = \frac{N_{\bar{r}}}{5}$$

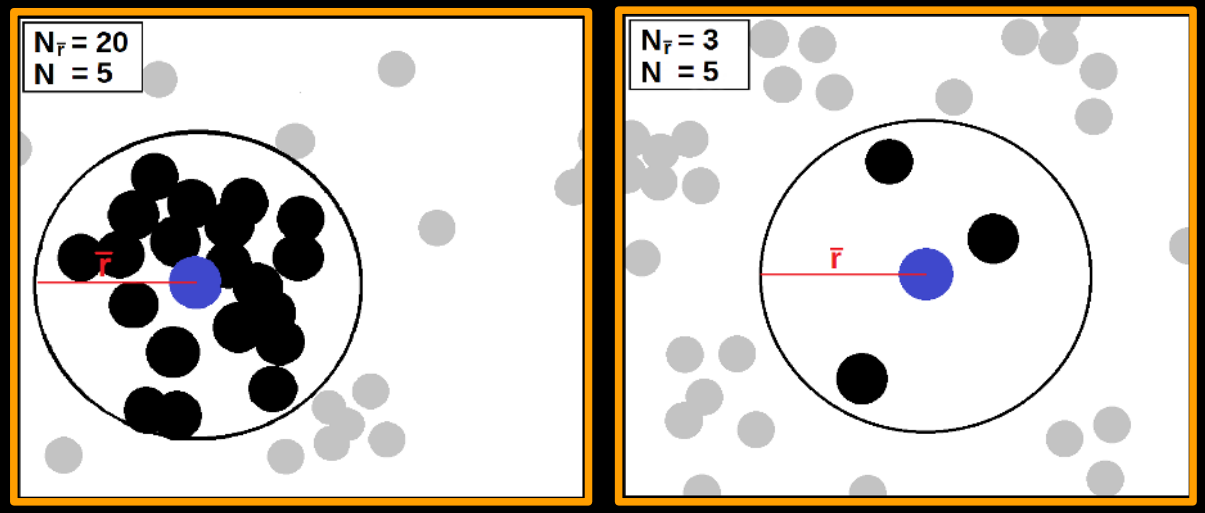
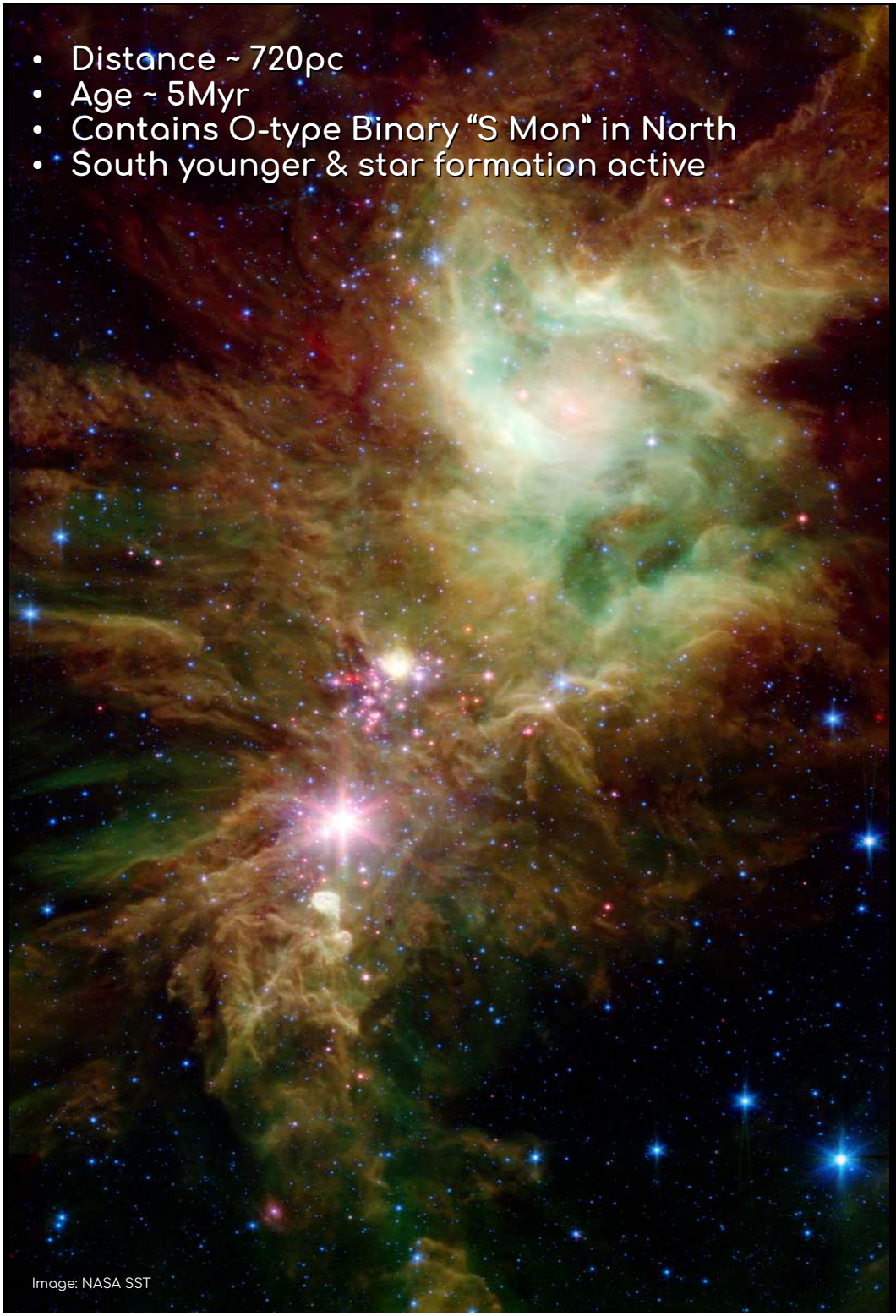


Figure 1: Diagram showing how INDICATE defines the index for a star (marked in blue). All neighbour stars within a radius of $\bar{r}$ are counted ($N_{\bar{r}}$) and compared to the number of expected stars in an evenly spaced uniform point 'control' distribution with the same number density as the cluster (N=5). The index of the star is determined as (Left:) I_5 = 20/5 = 4.0 and (Right:) I_5 = 3/5 = 0.6.

Figure from Buckner et al. (2019)

The higher the value of $I_{5,j}$ the more spatially clustered the star is.
To determine if a star is spatially clustered the index is calibrated against random distributions.

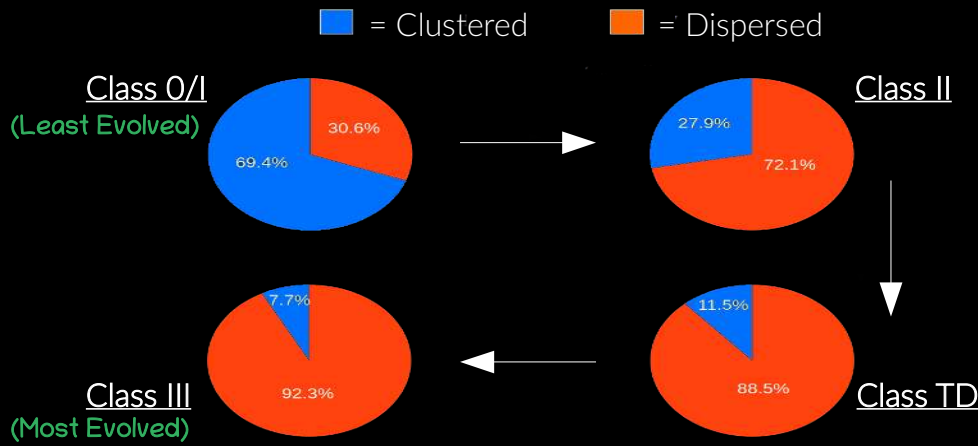
Read more: HERE.
Download INDICATE for free: HERE.

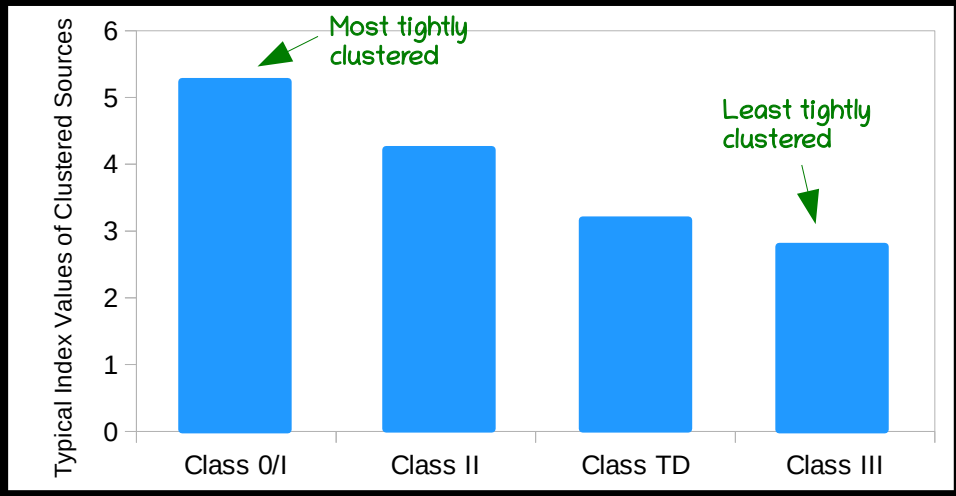


- Distance ~ 720pc
- Age ~ 5Myr
- Contains O-type Binary "S Mon" in North
- South younger & star formation active

Results with NGC2264

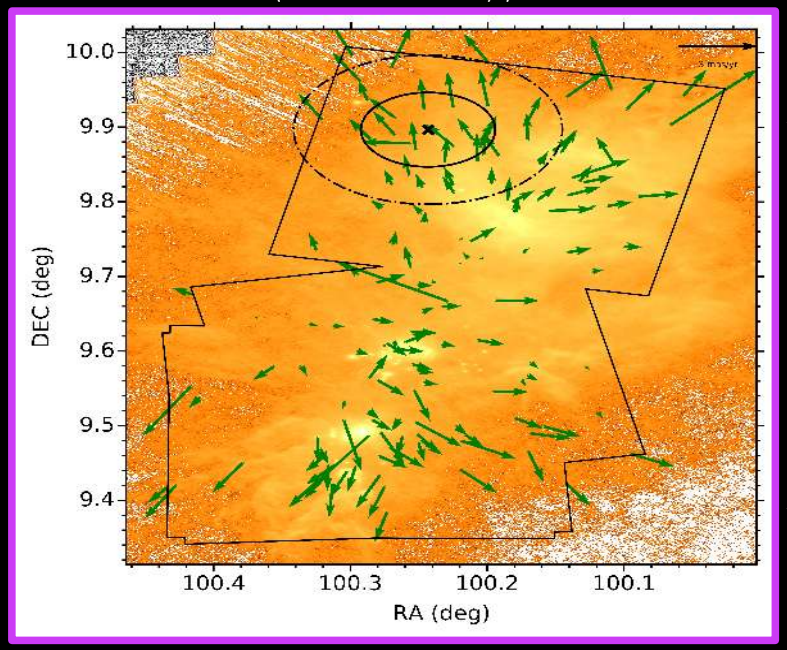
We applied INDICATE to the Young Stellar Object (YSO) members of the NGC2264 cluster. The proportion of objects clustered, and the degree of spatial concentration of these clustered objects, decreases with increasing evolutionary stage:





Comparing these results with Proper Motions from Gaia.....

Class II's
(median: 1.009 mas/yr)

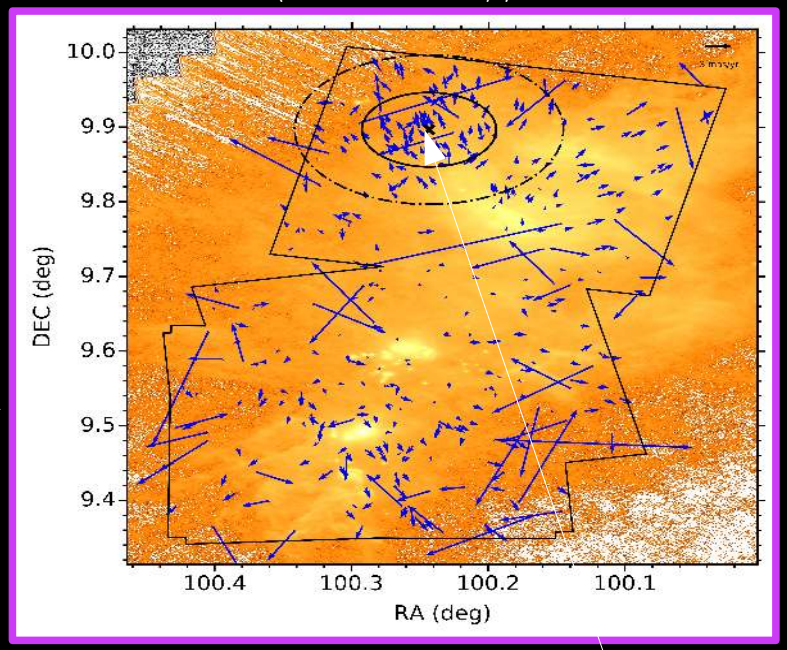


Outward motion in older northern region

Motions dispersed and randomised in south

Motions consistent with the properties of known structure in south

Class III's
(median: 1.192 mas/yr)



Both figures from Buckner et al.(2020)

S Mon
CIII behave like CII spatially & kinematically within 0.1° (dashed circle) but particularly within 0.05° (solid circle)

...suggests that:

- dynamical evolution is responsible for the present YSO distributions
- prolonged star formation has been occurring sequentially in the cluster
- stellar feedback from S Mon is causing neighbour YSOs within 0.05° to appear as more evolved sources

Read more about our results HERE.

Got questions?
Email: a.buckner@exeter.ac.uk