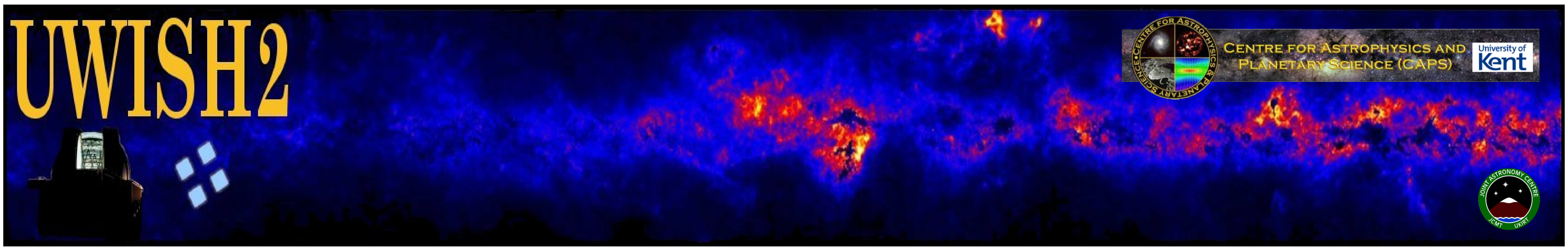

UKIRT WIDEFIELD INFRARED SURVEY FOR H2

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Abstract: The UKIRT Widefield Infrared Survey for H2 (UWISH2, Froebrich et al. 2011) is an unbiased, narrow band, inner Galactic Plane survey in the H2 1-0S(1) emission line at 2.122μm using WFCAM. It is completed and covers an area of about 180 square degrees (7°<l<65° & -1.5°<b<+1.5°) with a per pixel integration time of 720sec. The typical seeing in our data is 0.7arcsec, the point source detection limit is K=18mag and the surface brightness limit is 1E-19Wm-2arcsec-2. The survey includes well known massive star forming regions (e.g. W33, W51), supernova remnants (e.g. W31, W44) and a number of molecular clouds within 1kpc. Here we present our data analysis methods as well as the results of the investigations of 20% of the total survey area - the Serpens and Aquila region of the Galactic Plane.

Outflow and driving source detection:

We have determined H2-K difference images in order to remove continuum features, utilising the K-band data from the UKIDSS Galactic Plane Survey (GPS, Lucas et al. 2008). These were then manually inspected for Molecular Hydrogen emission line Objects (MHO). All detected features are double checked in colour composite images. Potential Planetary Nebulae (PN), Supernova Remnants (SNR) as well as fluorescently excited edges of molecular clouds, HII regions and areas around young embedded clusters with massive stars are excluded.

Potential outflow driving sources for each detected MHO are identified via a variety of Young Stellar Object (YSO) candidate lists. These include the catalogue of intrinsically red objects in Glimpse (Churchwell et al. 2009) from Robitaille et al. (2008), detections in the AKARI/IRC mid-infrared all-sky survey bright source catalogue (Ishihara et al. 2010; Yamamura et al. 2009), detections in the IRAS Point and Faint Source Catalogue (Moshir 1989, 1991) and detections in the Bolocam Galactic Plane Survey (Aguirre et al. 2011), which all cover our entire survey field. Additionally we used K-band excess sources identified from JHK detected objects in the UKIDSS GPS, as well as K-band variable sources identified in the H2-K difference images as potential driving source candidates. In cases where non of the above mentioned catalogues allowed us to find a potential source for an H2 feature, we additionally searched the SIMBAD database for other indicators of YSO outflow sources, such as masers and (sub)-mm sources.

Distance calculation and outflow/source properties:

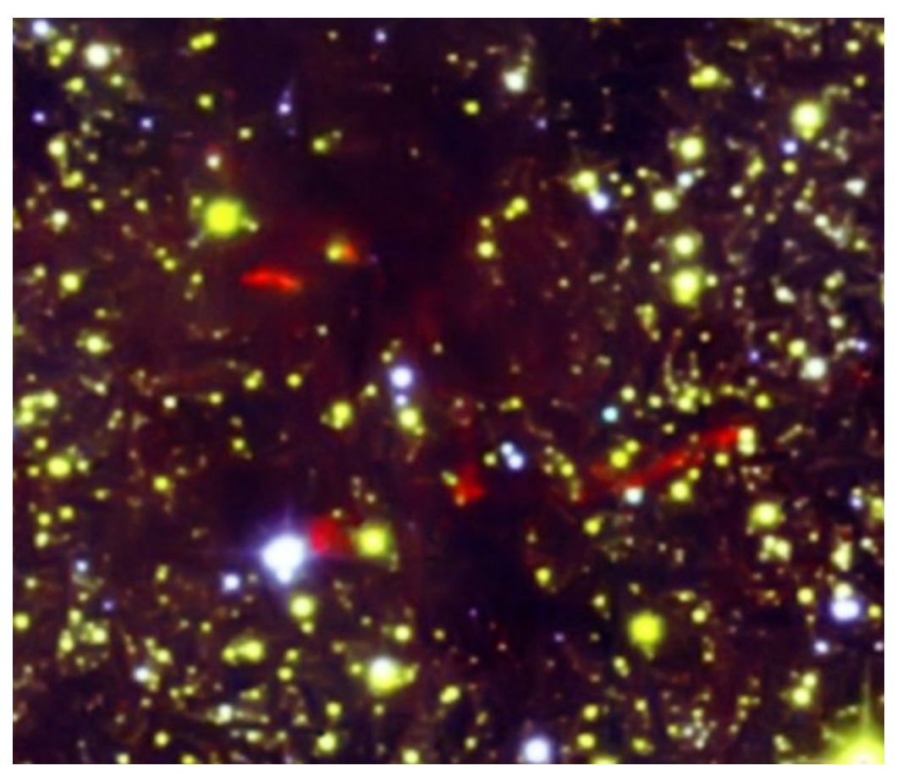
The distance calculation to all our MHOs is based on foreground star counts in the associated parental dark clouds utilising UKIDSS GPS data. These foreground stars are identified in histograms of J-K colours of stellar objects projected against the darkest parts of the clouds. We then compare the observed density of blue foreground stars to predictions from the Besancon Galaxy Model (Robin et al. 2003). For calibration purposes we use RMS sources with known distances in the survey area from Urquhart et al. (2008). This method recovers the intrinsic scatter of the calibration objects and is thus accurate to within at least 25%.

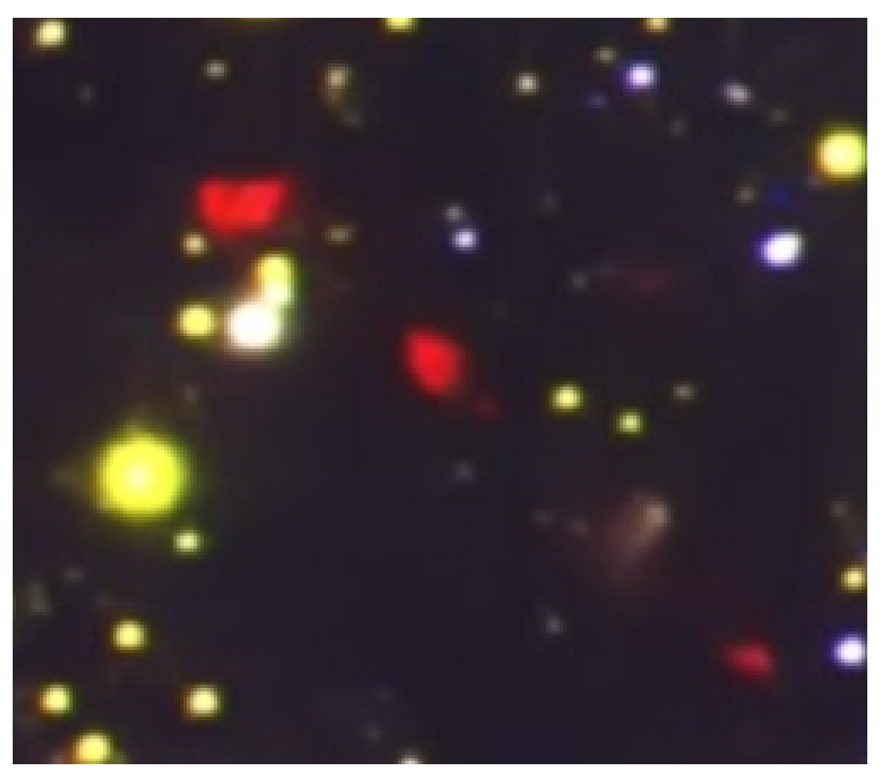
Photometry is performed in the H2 images to obtain fluxes and luminosities. Based on the distance calibration and extinction measurements from Rowles & Froebrich (2009) we obtain statistically corrected outflow luminosity distributions. Length measurements of outflows with source candidates allow us further to generate a length distribution.

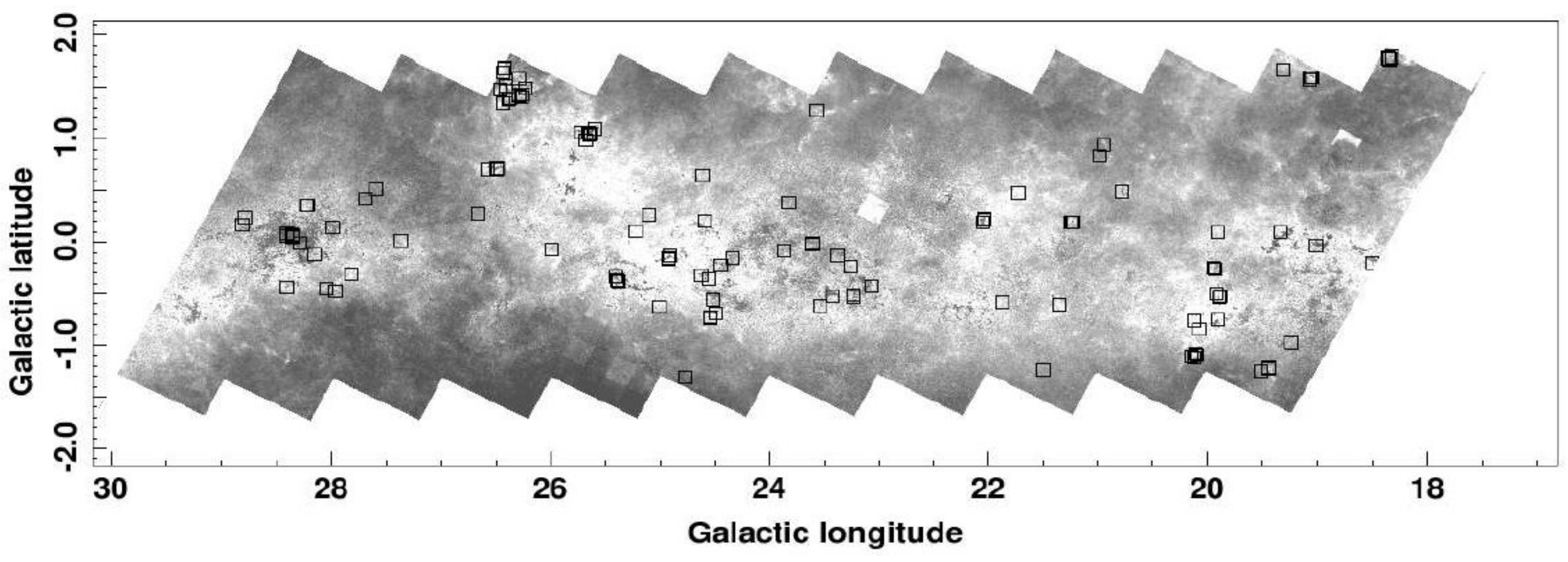
We generate Spectral Energy Distributions (SED) based on NIR JHK photometry and Spitzer IRAC data for all driving source candidates. These are then fitted via the online SED fitting tool from Robitaille to obtain source properties such as masses, accretion rates and ages. We also determine these properties for all YSO candidates from the list of Robitaille et al. (2008) in the dark clouds with detected outflows. The properties of the outflow driving sources and non driving sources are then compared to investigate differences and/or similarities.

General Distribution of the Jets and Outflows

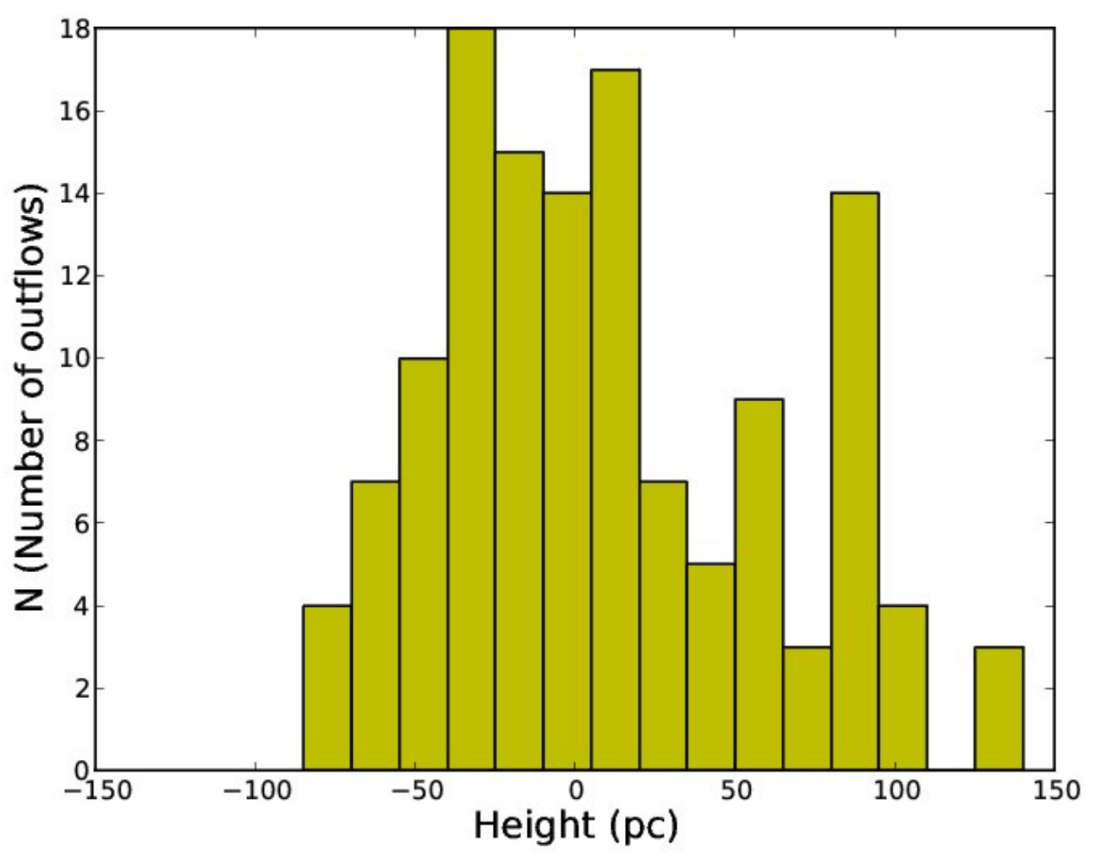
Our analysis of the Serpens and Aqulia region of the Galactic Plane has uncovered 131 jets and outflows from YSOs. This is a 15 fold increase in the total number of known MHOs in this area. However, the total 1-0S(1) flux has only been increased by a factor of two, indicating that the known outflows dominate the bright end of the flux distribution. We are able to assign potential source candidates to about half the objects. Typically, the flows are clustered in groups of 3 – 5 objects, within a radius of 5 pc. These groups are separated on average by about half a degree, and 2/3rd of the entire survey area is devoid of outflows.
The distances of our flows range from about 3kpc to 5kpc. There is a peak in the distance distribution at 3.5kpc, indicating the presence of a spiral arm. We estimate the completeness limit of our sample as 1E-3Lo at 5kpc. This is an HH211 like object behind 1mag of K-band extinction. The scale height of the outflows is 30pc. This is the same as young massive OB stars and much smaller than typical young clusters.

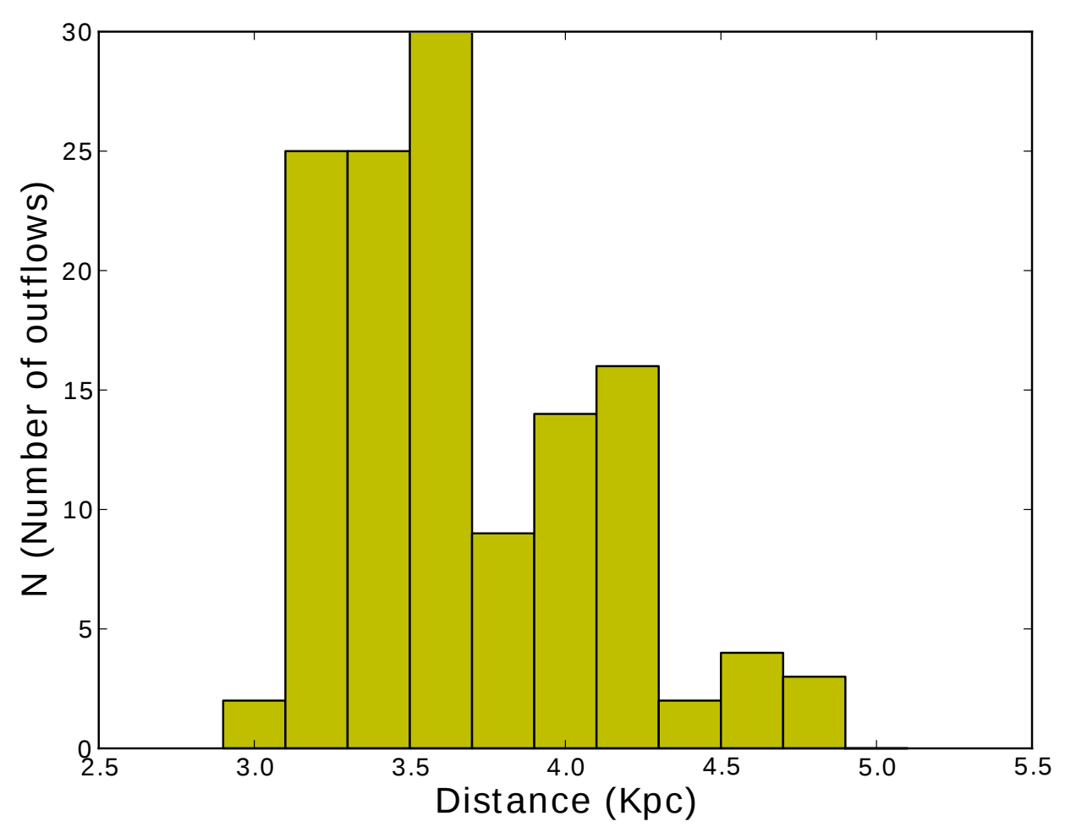






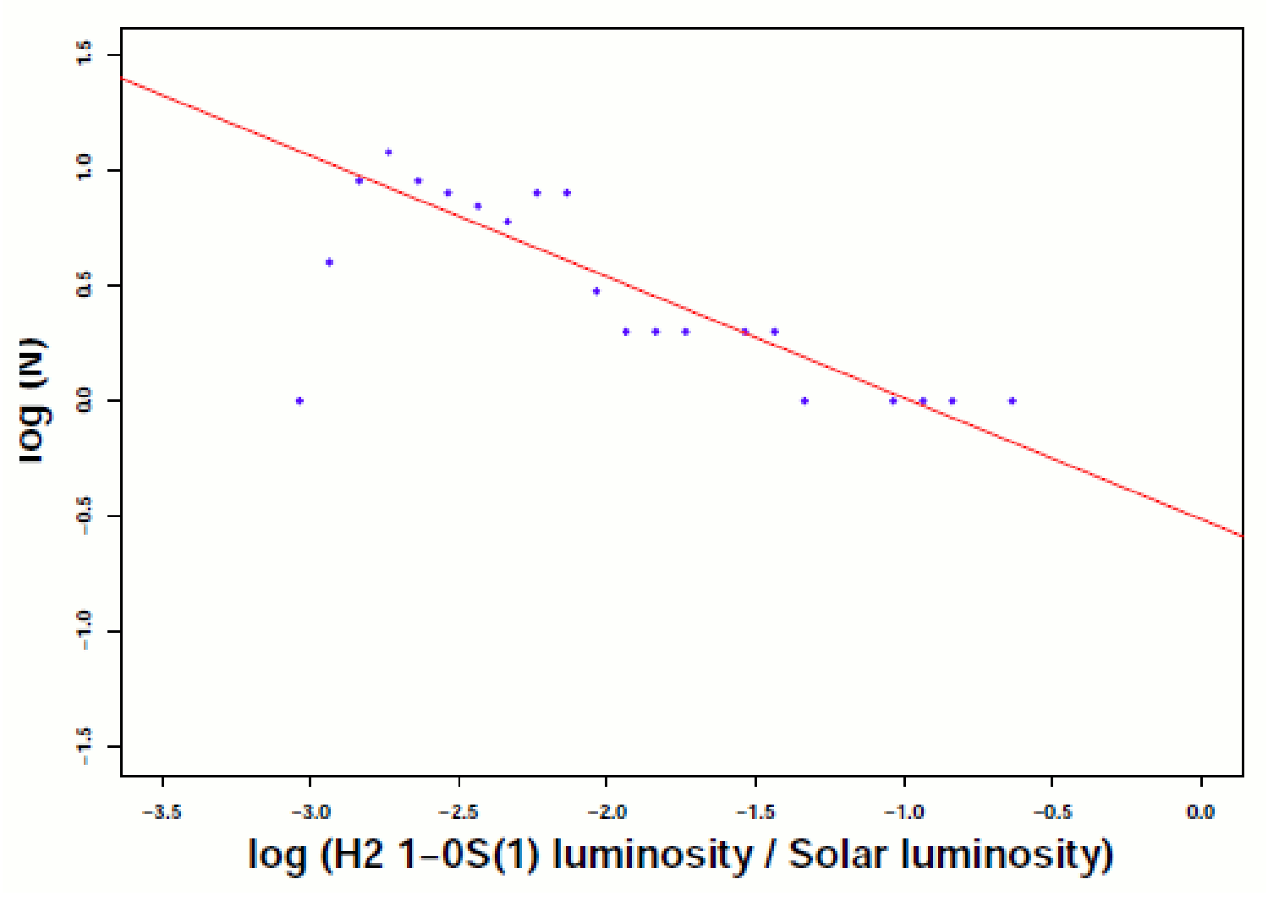
Top: Spatial distribution of MHOs identified in our survey area (black squares) over plotted on a relative extinction map (grey scale image) based on near infrared colour excess in GPS data. A clear clustering and association with dark clouds is evident.





Bottom left: Histogram of the height with respect to the Galactic Plane of our outflows. The scale height is about 30pc, similar to young massive stars.

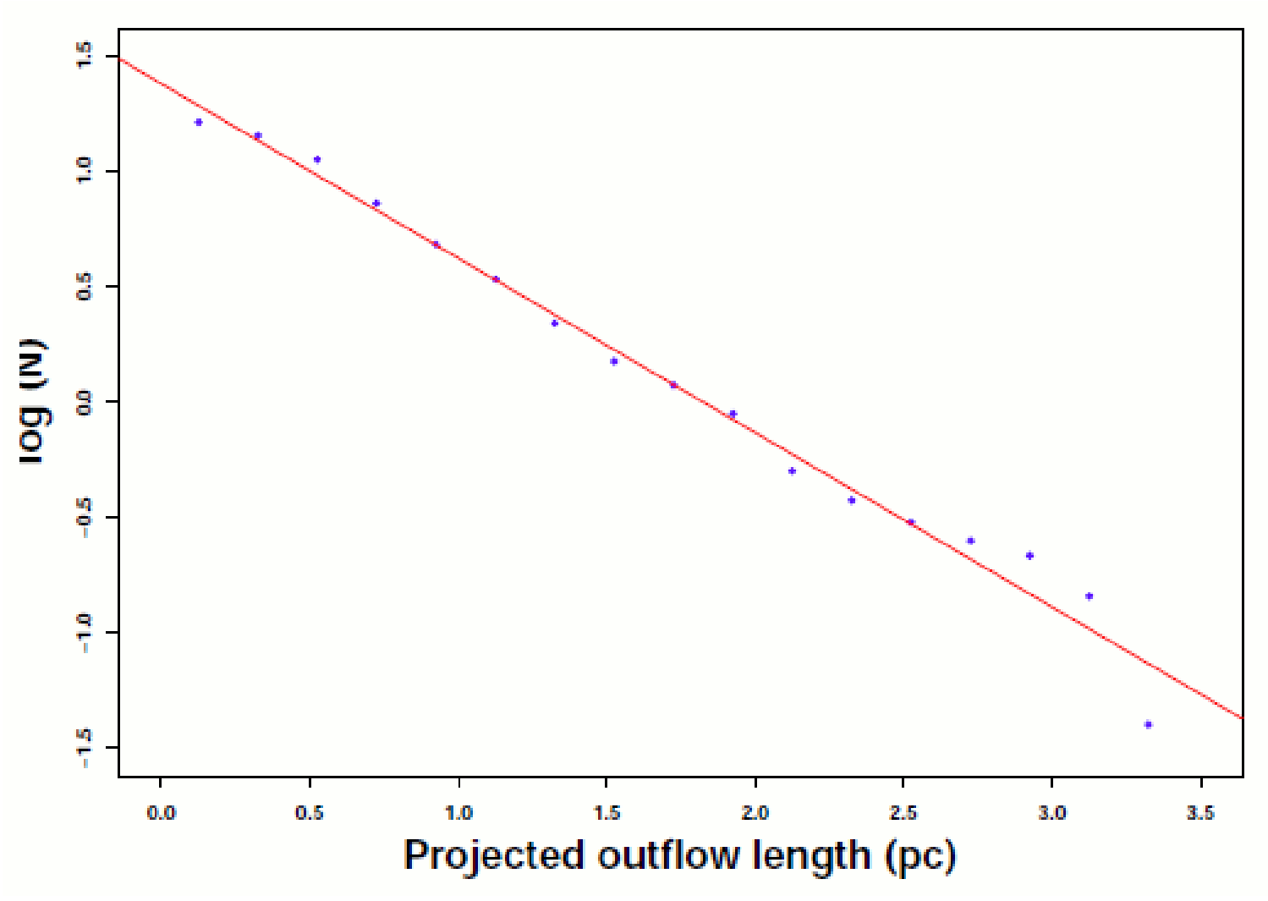
Bottom Right: Distance histogram of the jets. A clear peak at 3.5kpc indicates the presence of a spiral arm along this sight line.

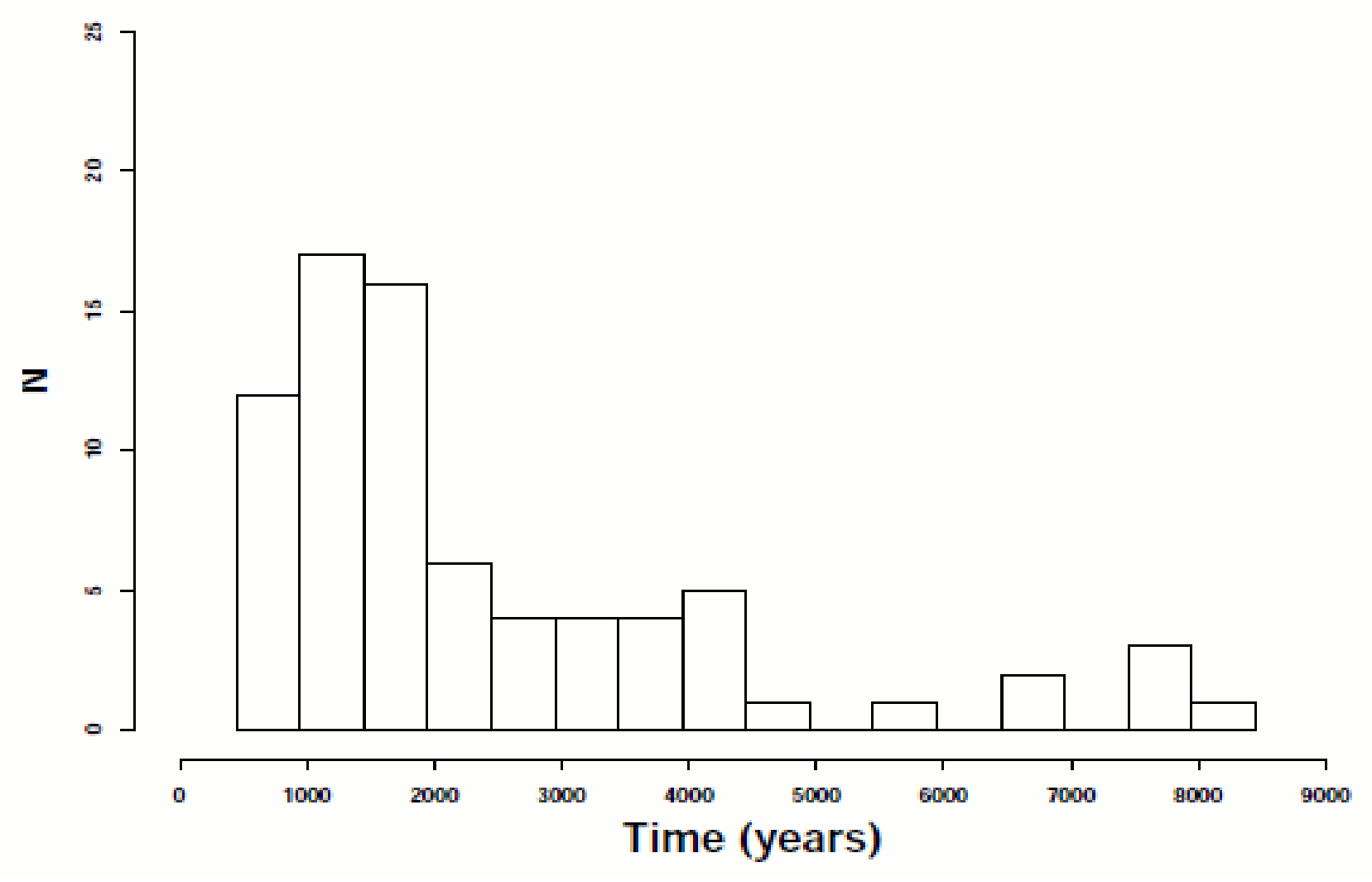


Top Left: Distribution of the 1-0S(1) luminosities of our outflows. The fitted power law slope (about -0.5 to -0.7) is dependent on the histogram bin size due to the small number of objects.

Bottom Left: Statistically corrected distribution of the projected lengths of our outflows. Note that the distribution resembles an exponential and not a power law.

Bottom Right: Time difference between the emission of successive H2 knots calculated based on the projected separation and an average speed of 80 km/s.





Statistical Properties of the Jets and Outflows

The total 1-0S(1) molecular hydrogen luminosities of the outflows range from 0.001 to 0.1Lo. Their number distribution clearly resembles a powerlaw. The powerlaw index ranges from -1.5 to -1.7, depending on the histogram bin size. If we statistically correct the luminosity distribution for the distance uncertainties as well as extinction the powerlaw index decreases to -1.9+-0.1. This value is slightly steeper than the value for outflows in Orion discovered by Stanke et al. (2002). Based on assumptions about the relation of mass accretion and ejection rates, the total luminosities of the outflows indicate a star formation rate in the Milky Way of more than 0.4 solar masses per year. Furthermore, the energy and momentum input is not sufficient to sustain the observed turbulence even locally in the densest parts of the parental molecular clouds.
If we correct the projected lengths of our outflows for random inclination angles, one quarter of them is of parsec scale. The distribution of lengths follows an exponential and not a powerlaw. To simulate this observed distribution we require typical velocities of 40-130km/s and dynamical lifetimes of 4-20 thousand years. This is at least an order of magnitude lower than estimates for protostellar lifetimes, which are typically a few 1E5 yrs (Hatchell et al. 2007). Furthermore, low inclination objects are rare in our sample.
We also measure typical 'gaps' between groups of emission knots in the outflows. Based on the typical velocities estimated from the length distribution, the largest gaps correspond to the dynamical jet lifetime. The most common gap, however, is of the order of 1000years. According to the burst mode of star formation models from e.g. Vorobyov & Basu (2006) the creation of the H2 knots is hence linked to low level fluctuations of the mass accretion rate and not FU-Ori type events. Their duty cycle seems more in agreement with the total jet lifetime, which might suggest these outburst as trigger (or stopping point or both) of a jet ejection phase. However, better constraints of the FU-Ori duty cycle and mechanism as well as more detailed models are required to draw any further conclusions.
The SEDs of the jet driving sources and other YSO candidates in the same clouds reveal significant differences in their properties. The driving sources are on average about half the age and possess a twice as high mass accretion rate compared to the non-driving sources.

For more detailed results see Ioannidis & Froebrich 2012a,b,c.

This poster is also available online at the project webpages:
http://astro.kent.ac.uk/uwish2

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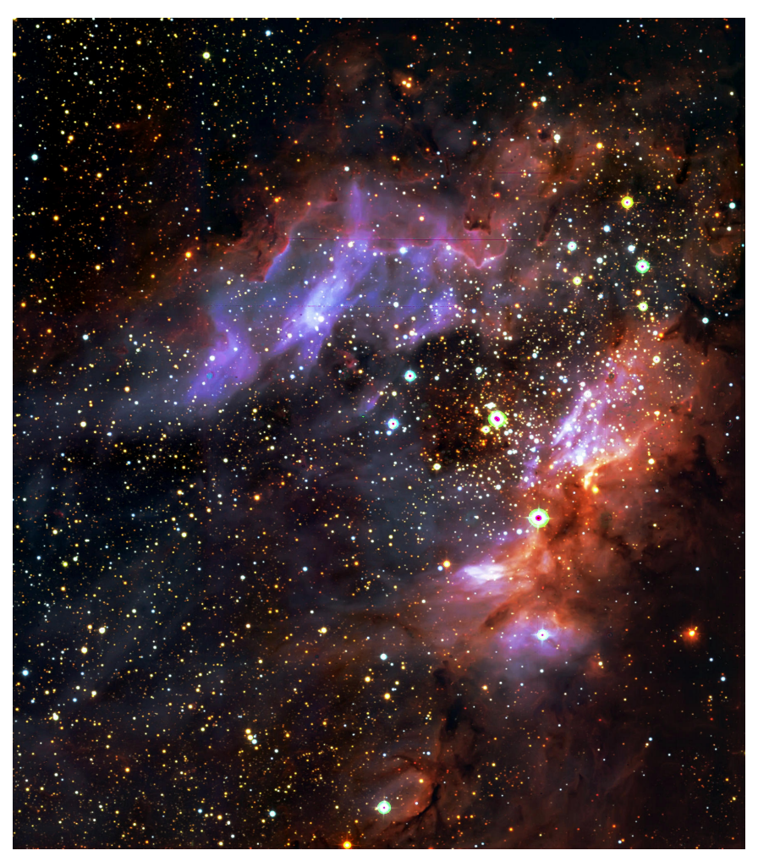

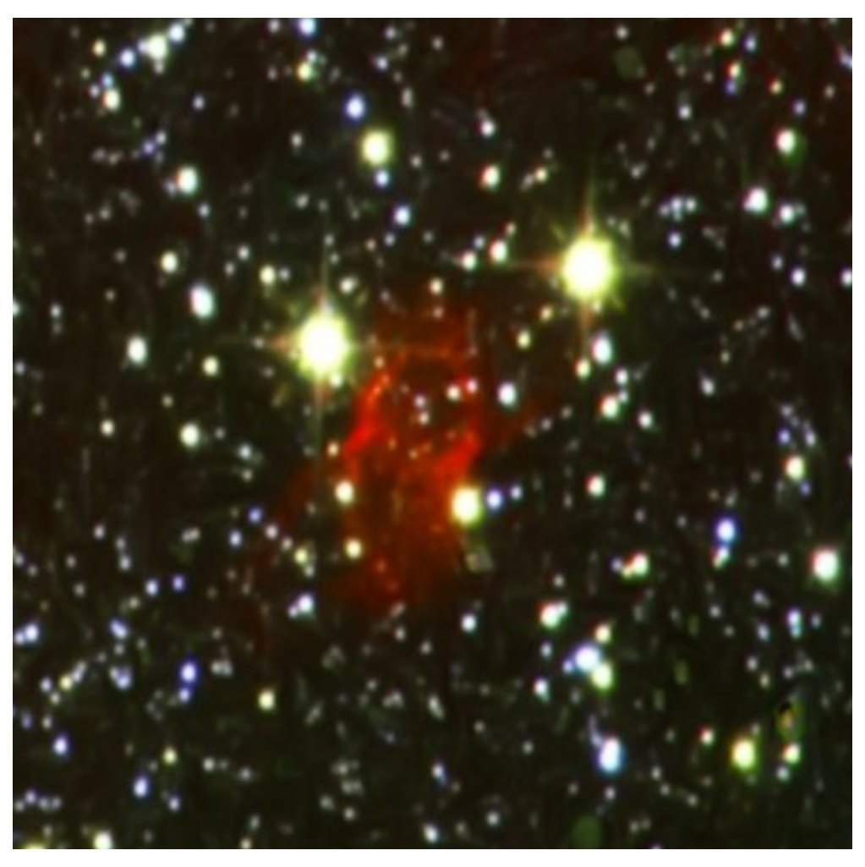

References:

Aguirre et al., 2011, ApJS, 192, 4; Churchwell et al., 2009, PASP, 121, 213; Froebrich et al., 2001, MNRAS, 413, 480; Hatchell et al., 2007, A&A, 468, 1009; Ioannidis & Froebrich, 2012a, MNRAS,421, 3257; Ioannidis & Froebrich, 2012b, MNRAS, in press, astro-ph/1206.5095; Ioannidis & Froebrich, 2012c, MNRAS, in preparation; Ishihara et al., 2010, A&A, 514, 1; Lucas et al., 2008, MNRAS, 391, 136; Moshir, 1991, JBIS, 44, 495; Robin et al., 2003, A&A, 409, 523; Robitaille et al., 2008, AJ, 136, 2413; Stanke et al., 2002, A&A, 392, 239; Urquhart et al., 2008, A&A, 487, 253; Yamamura et al., 2009, AIPC, 1158, 169;

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