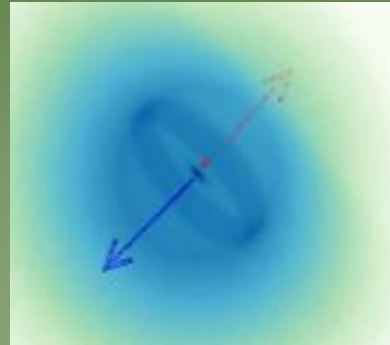


Mid-infrared studies of Massive Young Stellar Objects

René Oudmaijer (Leeds, UK)



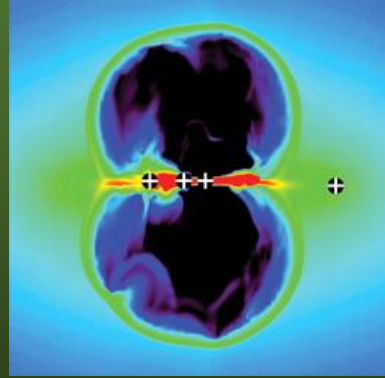
Outline

- Massive Young Stellar Objects & the RMS survey
- Exploitation phase: examples follow-on observations
- The E-ELT & METIS prospects



Massive Young Stellar Objects

- Luminous ($>10^4 L_{\odot}$) IR source
- Bipolar molecular outflow
- Compact, ionised wind, $v \sim 100$ km/s
- Well-studied MYSOs number in the tens
- Serendipitously found and nearby
→ not necessarily representative



Krumholz et al. 2009

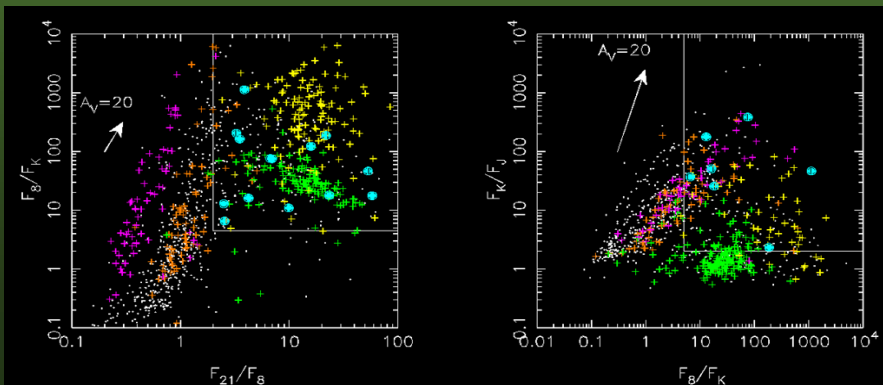
Questions:

- How do they form?
- Accretion (disk) properties?
- Outflow and envelope properties?

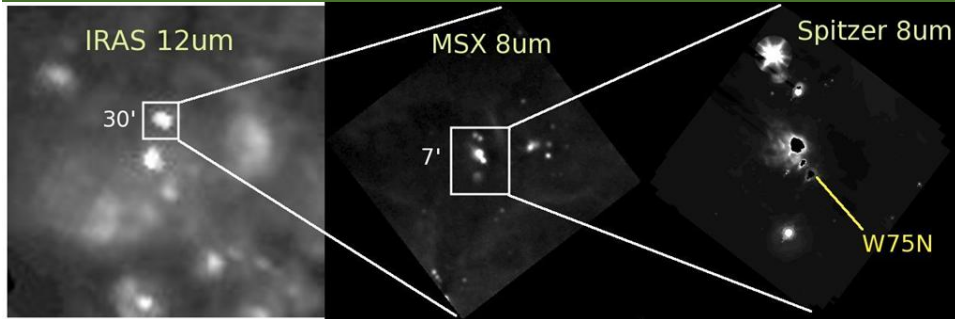
The Red MSX Source (RMS) Survey

In order to obtain a representative and well paratmerized sample of MYSOs, 2000 candidates were colour-selected from MSX catalogue (Lumsden et al 2002)

- Massive YSOs + UCHII regions + PN + C stars + OH/IR stars

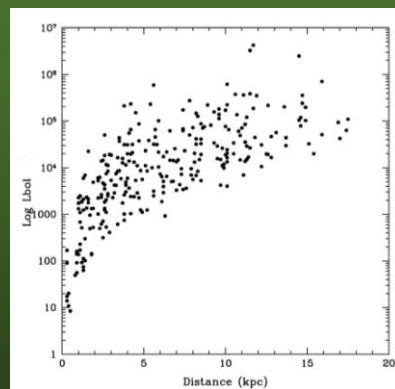
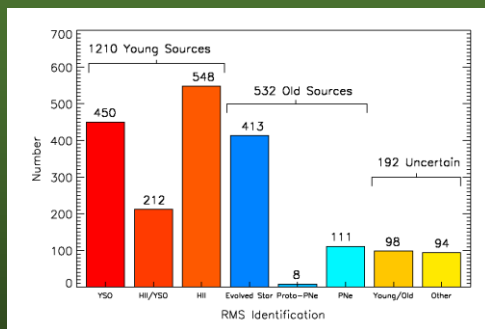


RMS survey



Sample selection required radio, MIR snapshot imaging, mm, NIR lo-res spectroscopy. Final sample 500 MYSOs (Hoare et al 2005; Urquhart et al 2011; etc)

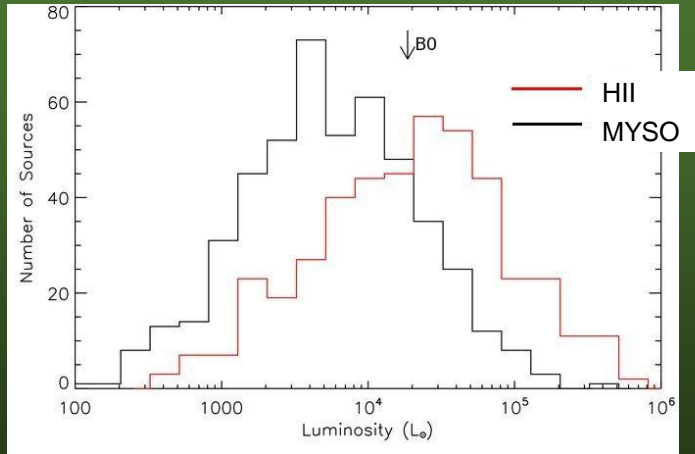
Source Identification



Sample definition complete.
<http://www.ast.leeds.ac.uk/RMS>

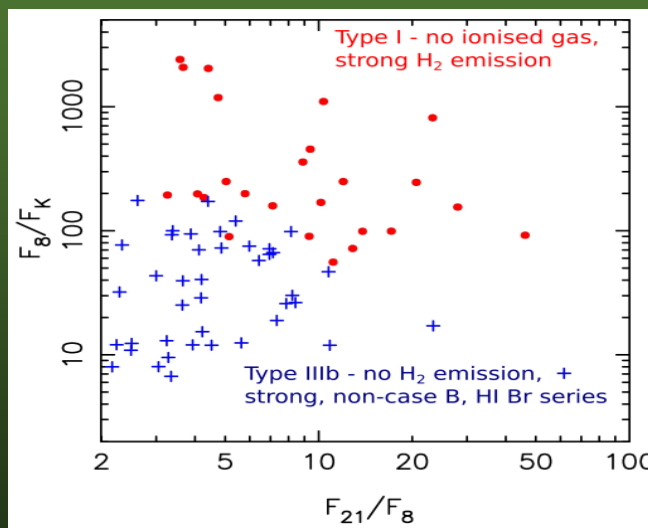
Sample is Galaxy wide

Luminosity Function



See also Mottram et al. 2011 ApJL

Lo-res NIR Spectroscopy : Evidence for an Evolutionary Sequence

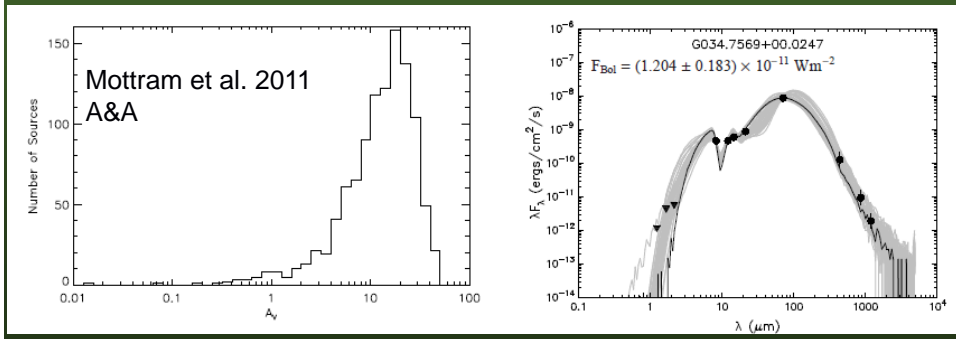


Cooper et al
2013, in prep

Properties relevant for this talk:

Optically in visible, NIR faint (for hi-res), MIR bright

Distance typically few kpc



Designed to map in the CSM as function of distance to central star.

Spectroscopy

Spectro-astrometry

Interferometry

Integral Field Spectroscopy

Imaging

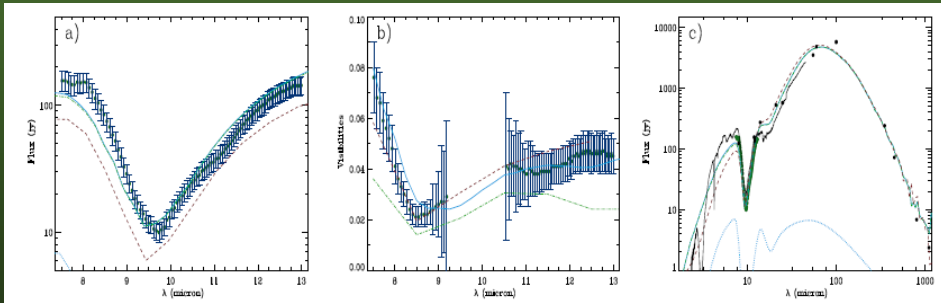
Some examples given below



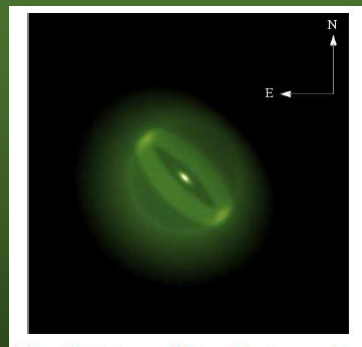
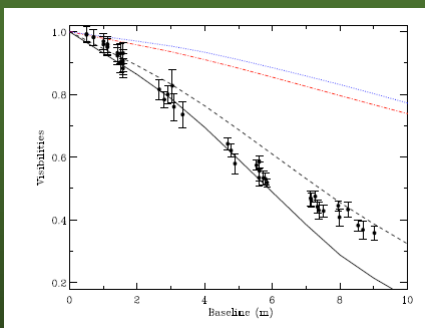
Figure: Gemini

CRL 2136, de Wit et al., 2011, A&AL – 42m baseline (!)

Axi-symmetric dust radiative transfer code Whitney et al. 2002



Simultaneous fitting SED and spatial information

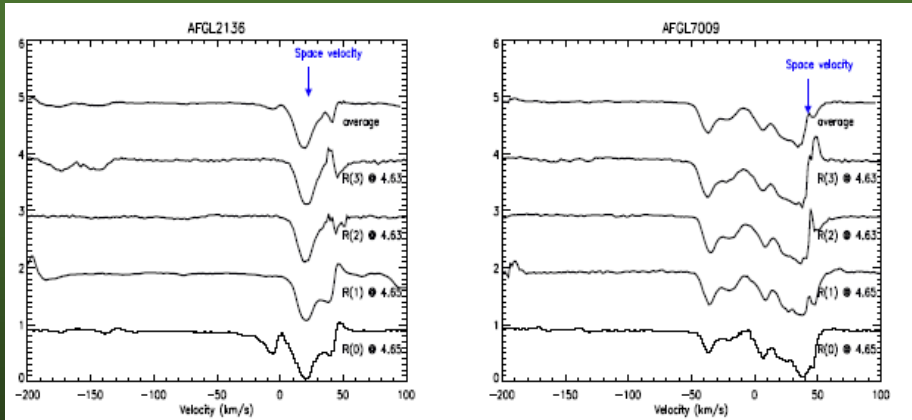


Envelope well characterized

Compact source in center – bloated star or accretion disk

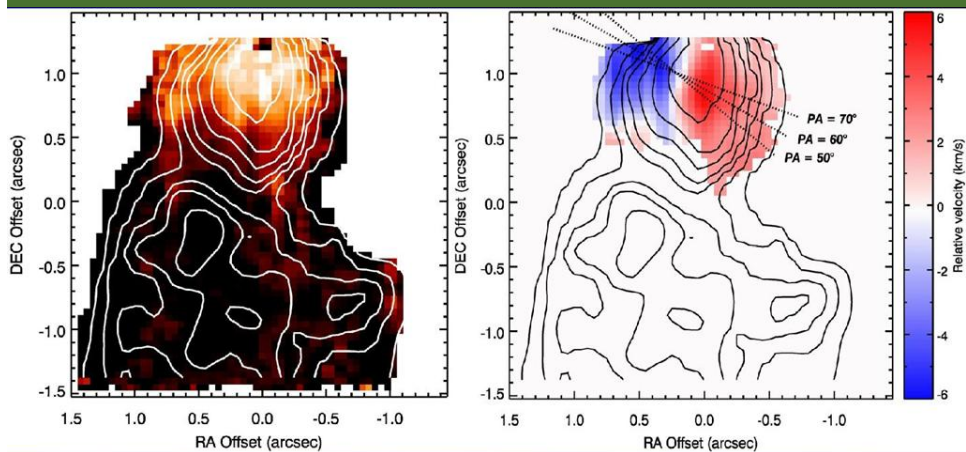
Morale : need spatial information (few MYSOs observed)

Outflows & Feedback, Cool gas



CO 4.6 μm spectroscopy, Murakawa et al 2013, in prep

IFU data of a MYSO: cool gas in a torus: Dynamical mass determination



Integrated CO absorption

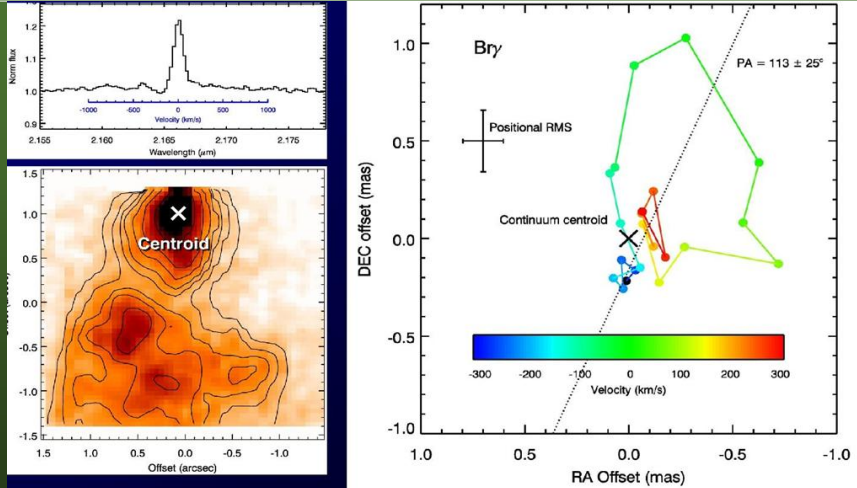
Radial velocity map

(Davies et al. 2010)

Probing at very small scales: Prospects for spectro-astrometry



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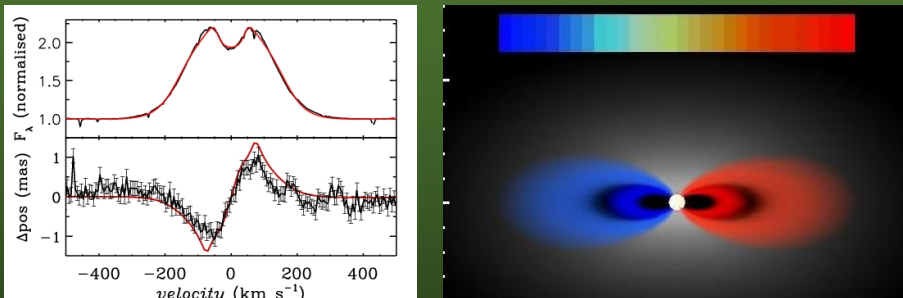


mas precision traces of Bry in IFU data – tracing the first base of a bi-polar flow in a massive young star (Davies et al. 2010)

Prospects for spectro-astrometry



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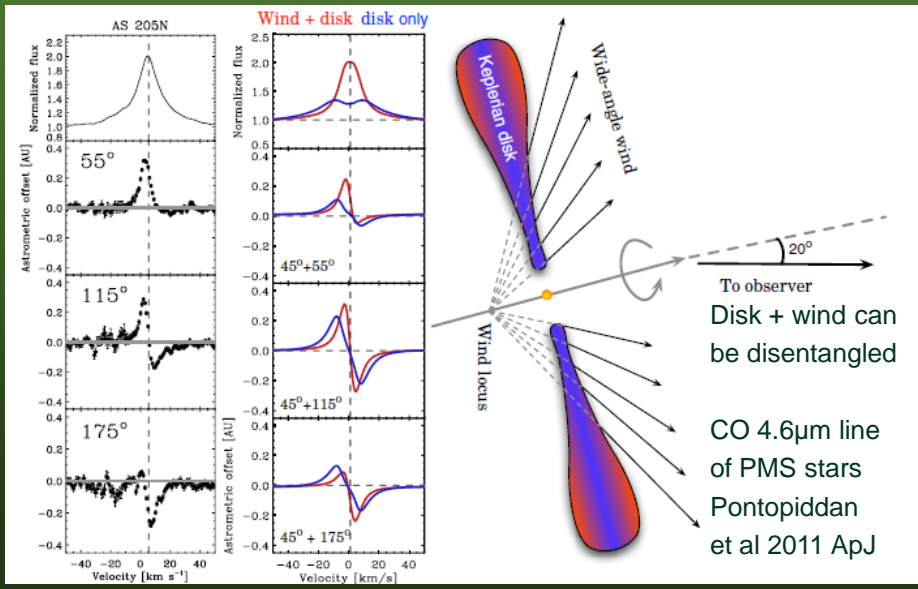


Sub-mas precision traces of H α in Be stars, fit by 3D non-LTE models \rightarrow disk parameters (UVES, Wheelwright et al. 2012, MNRAS Let; Oudmaijer et al 2012) METIS Bra observations to be applied to MYSOs

Probing at very small scales: Prospects for spectro-astrometry



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Discussion

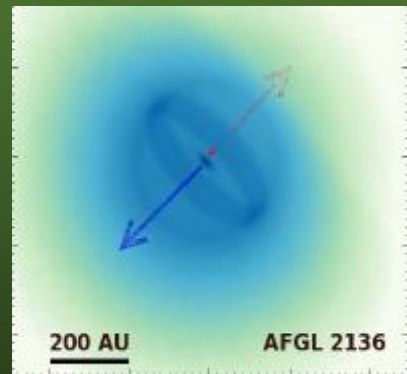


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Studies so far:

Limited to the brightest objects

Often limited to individual objects



- Imaging – high resolution → full parametrization envelope
- IFU – spectral line imaging → Outflow and disk properties
- Spectro-astrometry → Disk and accretion parameters
- (Polarization – B-fields)

Possible for bulk sample, allowing proper studies as function
age, mass, location – final census of Massive Star
Formation on the horizon