Outflow and Accretion in Massive Star Forming Regions

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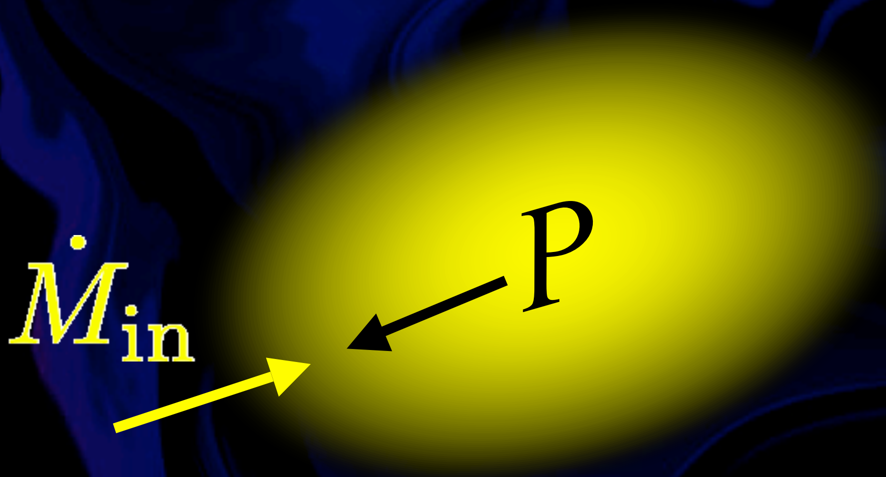
Outline

- Motivation for this Study
- Survey of Massive Star Forming Regions
  - Klaassen & Wilson 2007 (ApJ 663, 1092)
- High Resolution Observations of ^{12}CO
  - Klaassen, Wilson, Keto & Zhang, in prep.
- Higher Resolution Continuum Images
  - Klaassen & Wilson, in prep.
- Future work: 3D Radiative Transfer Models for Comparing with Observations
  - Klaassen, Keto & Wilson, in prep.

Accretion past the formation of an HII region

Let's assume HMSF occurs similarly to LMSF

Once a star reaches ~8 $M_\odot$ it burns hot enough for its stellar winds to ionize its surroundings, and the hot ionized gas pushes outwards to maintain the pressure balance



How can accretion continue despite such strong outward pressures?

Two Accretion Models

Once an HII region has formed, accretion can be:

Ionized

accretion continues in an ionized form through the HII region, and onto the massive star

Halted

accretion is very rapid before the HII region forms, and stops when the radiation pressure begins to push outwards

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G10.6-0.4

Keto & Wood (2006)

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G5.89-0.39

Klaassen et al. (2006)

Two Accretion Models

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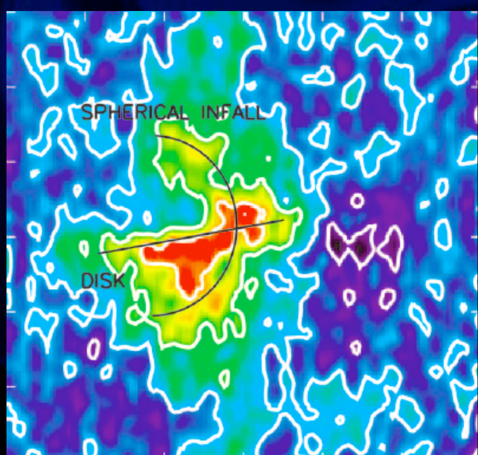
Ionized

Offset



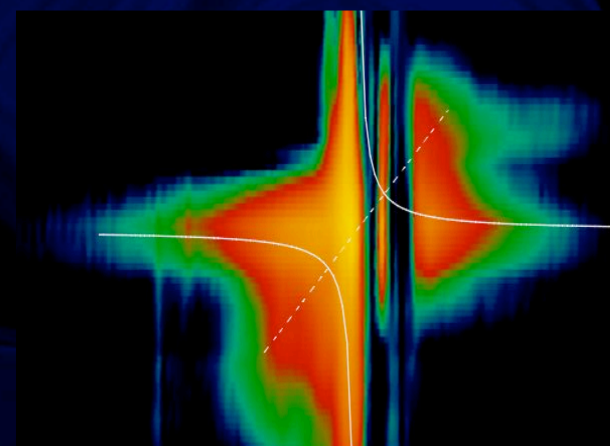
Velocity

G10.6-0.4

Keto & Wood (2006)

Halted

Offset



Velocity

G5.89-0.39

Klaassen et al. (2006)

Two Accretion Models

Ionized

Halted

Both models have observational support, but are based on in depth analysis of individual regions

G10.6-0.4

G5.89-0.39

Keto & Wood (2006)

Klaassen et al. (2006)

Initial Survey

Both models have observational support, but are based on in depth analysis of individual regions

Is there a simple observational test to see whether accretion has stopped without mapping and simulating every massive star forming region?

And what is the critical spatial resolution required to make definitive statements about the outflow powering source?

Klaassen & Wilson, 2007

JCMT Survey

Single pointing observations in SiO and HCO^+ of 23 MSFRs with UCHII regions & outflows

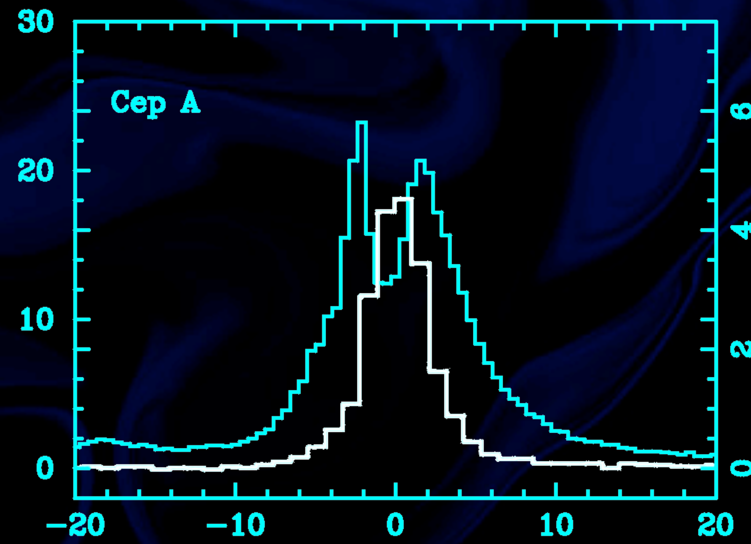
14 sources detected in SiO

(ongoing outflow)

SiO is shock enhanced, and depletes again in ~10^4 yr

8 sources have double peaked HCO+

(ongoing infall)



Klaassen & Wilson, 2007

JCMT Survey

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6 sources overlap

Approximately half of the sources with outflow have ongoing infall
(active accretion)

JCMT Survey

- With single pointings in molecular gas, we can not see ionized accretion
  - although it's possible that it is present
- The central star for the sources without an infall signature may have finished accreting
  - G5.89 is in this group

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A low resolution study is a good place to start

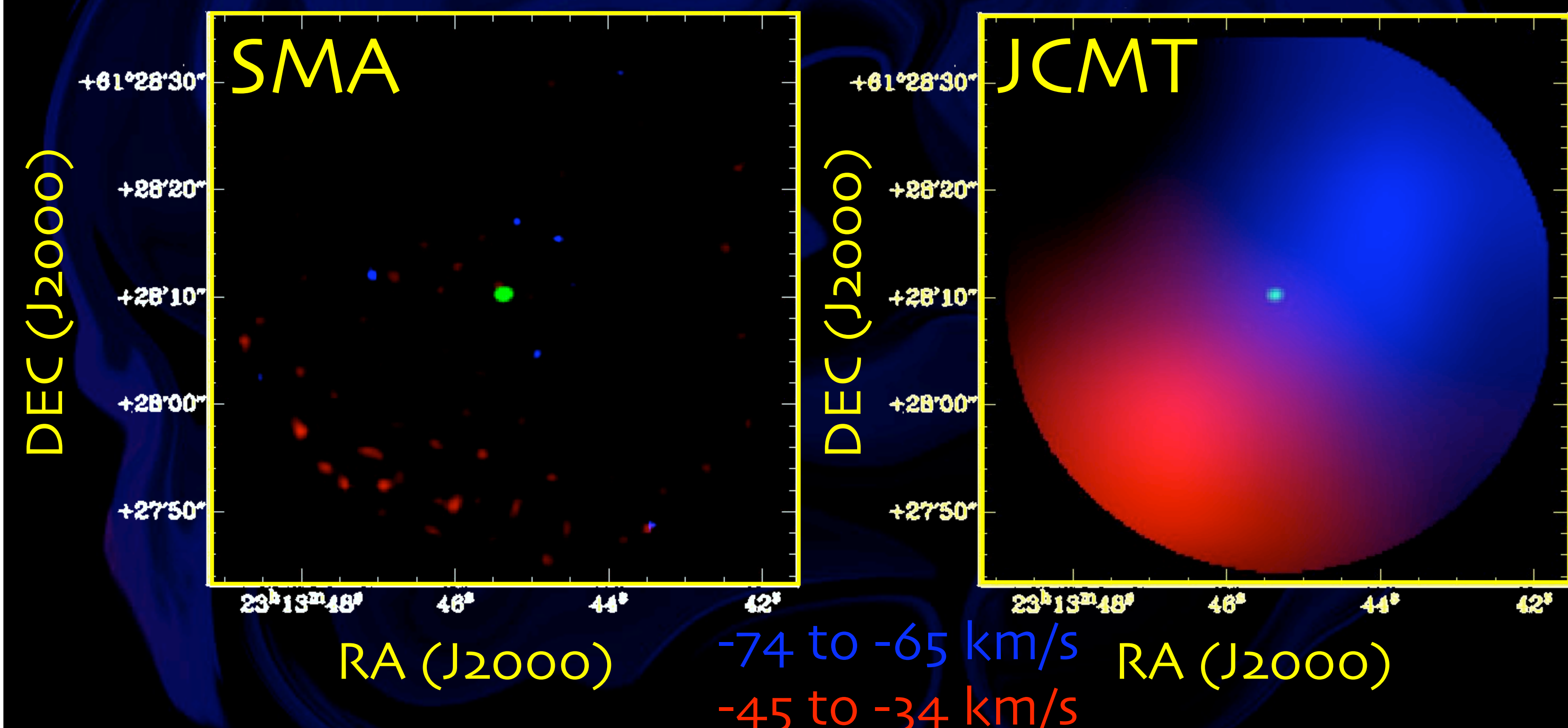
(just not to finish!)

Klaassen et al. in prep

High Resolution Imaging

Low resolution observations cannot give details on small scale structures

NGC 7538 IRS1



High Resolution Imaging

- An interferometer can only see structures on scales proportional to its longest and shortest baselines
- A single dish telescope can only resolve structures larger than its primary beam

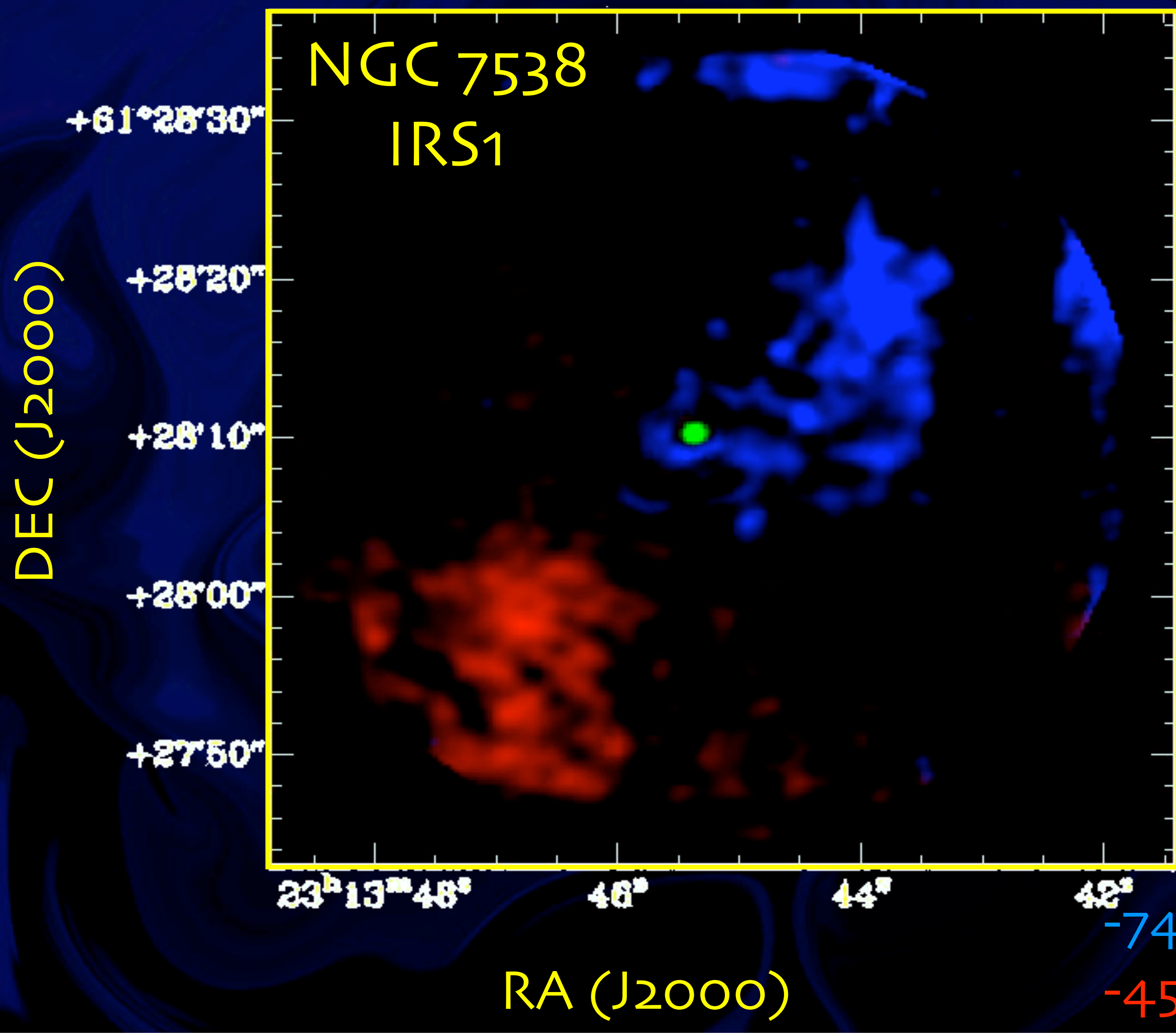
$$\theta = 1.22\frac{\lambda}{D}$$

Datasets can be combined using packages such as MIRIAD

We used the non-linear image combining method (MOSMEM)

Klaassen et al. in prep

High Resolution Imaging

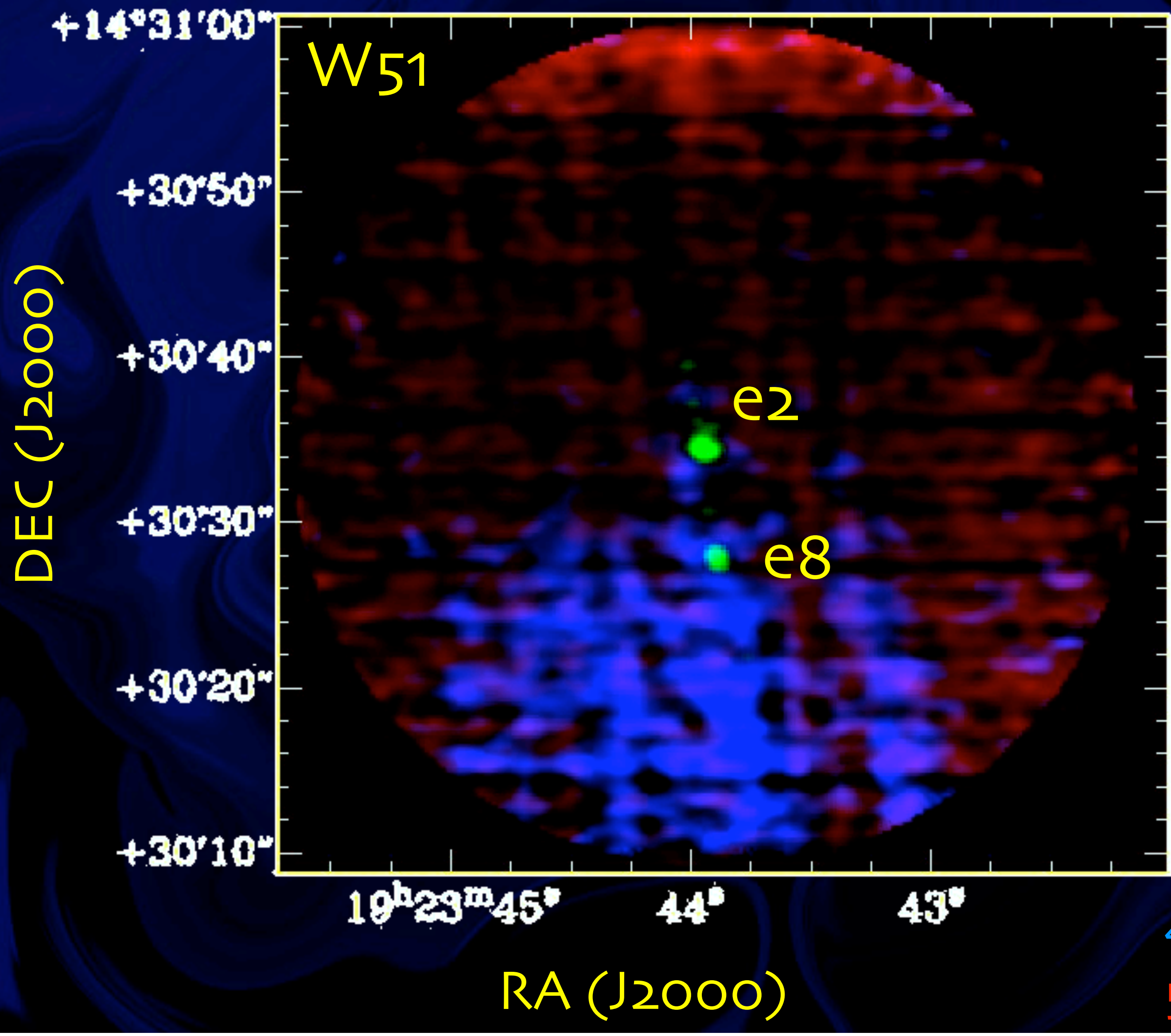


-74 to -65 km/s

-45 to -34 km/s

Klaassen et al. in prep

High Resolution Imaging



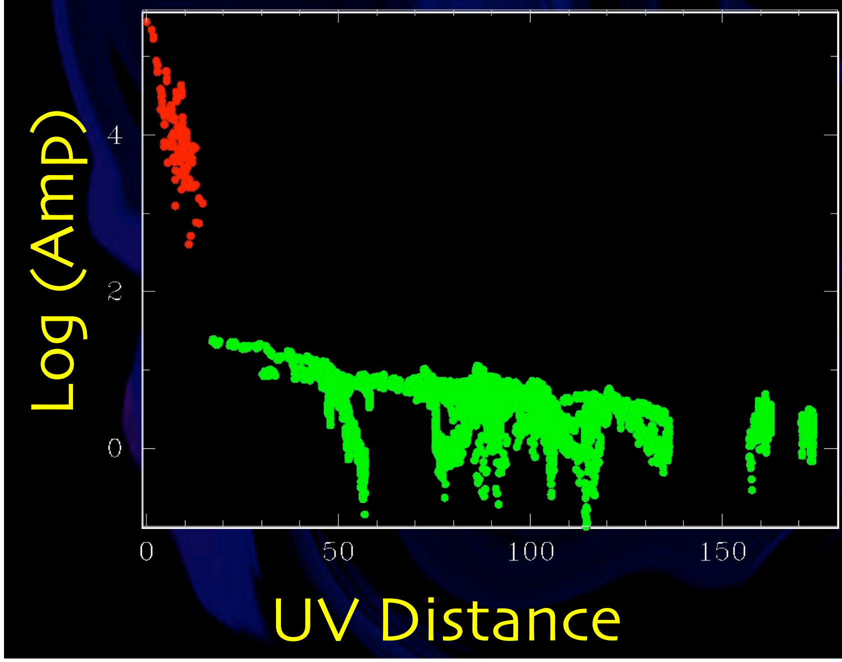
46 - 50 km/s

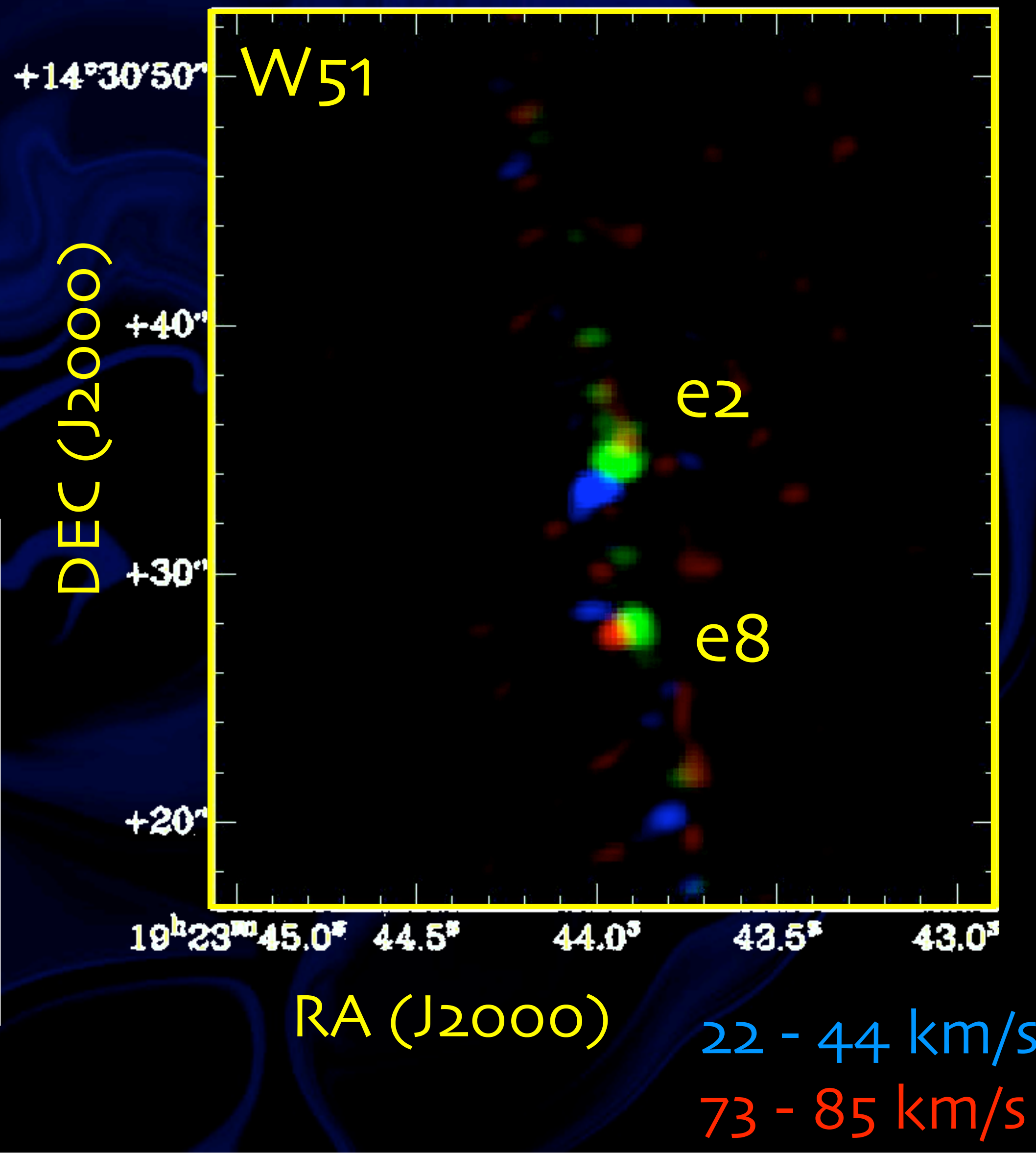
59 - 63 km/s

Klaassen et al. in prep

High Resolution Imaging

There is no overlapping UV coverage between our SMA and JCMT datasets





Klaassen et al. in prep

Outflow Kinematics

	G10.6	G28.2	NGC 7538 IRS 1	W51e2 LV	W51e2 HV
Mass ($M_\odot$)					
Blue	42.3	6.8	10.8	483	3.3
Red	36.5	1.6	2.9	1057	3.81
Momentum ($M_\odot$ km s^{-1})					
Blue	205	3.5	226	1290	26
Red	99	14	113	2624	34
Energy (x 10^{42} J)					
Blue	46	0.07	48	215	26
Red	12	5.4	45	407	38

Higher Resolution Imaging

Arcsecond resolution imaging at the average distances to massive star forming regions is not quite good enough for our purposes,

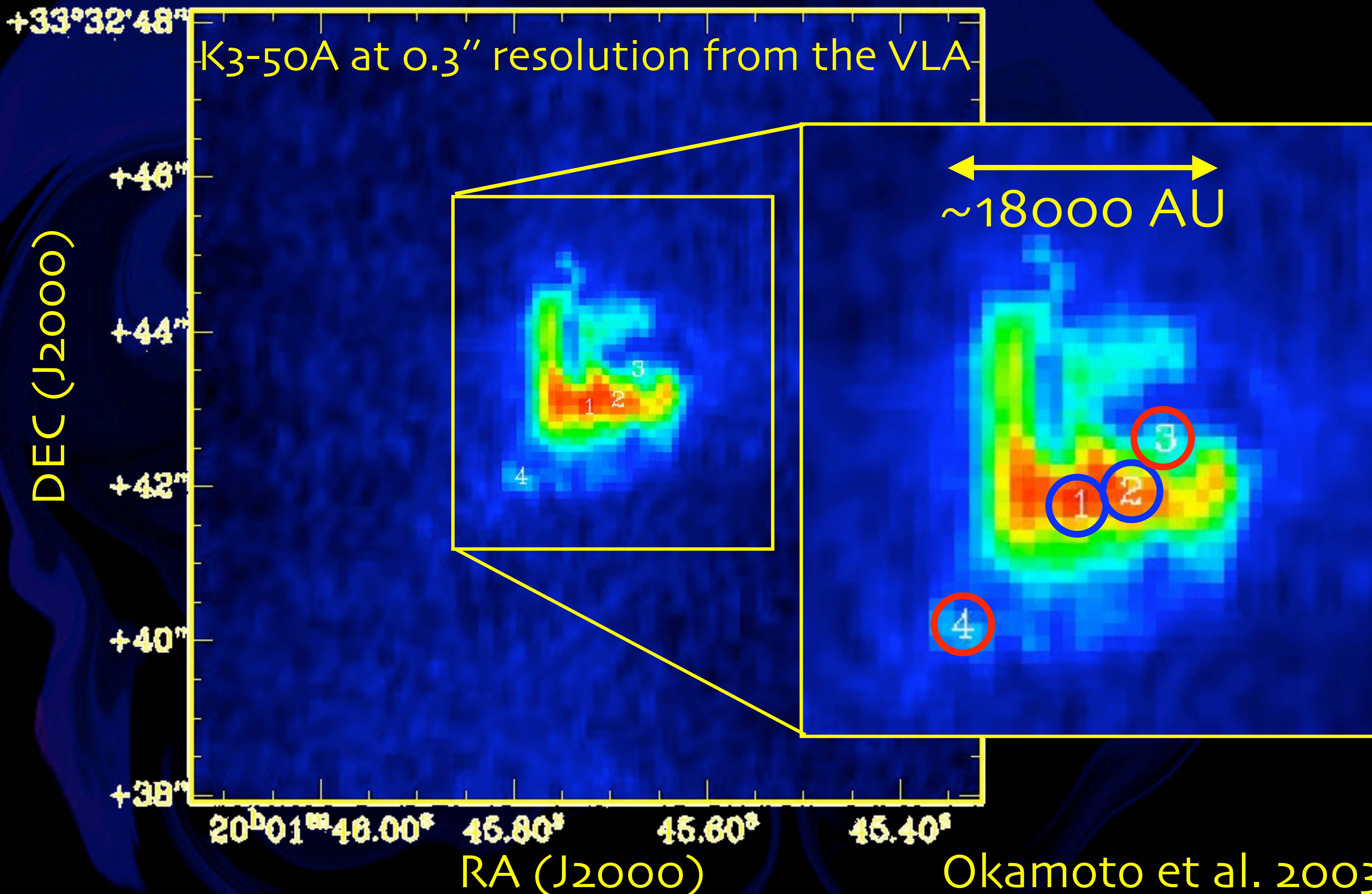
@ 5.6 kpc, $1'' \simeq 0.027$ pc

not if we want to have more than one beam on a possible accretion disk.

Klaassen & Wilson 2007, Thompson et al. 2006, Shirley et al. 2003, Plume et al. 1992

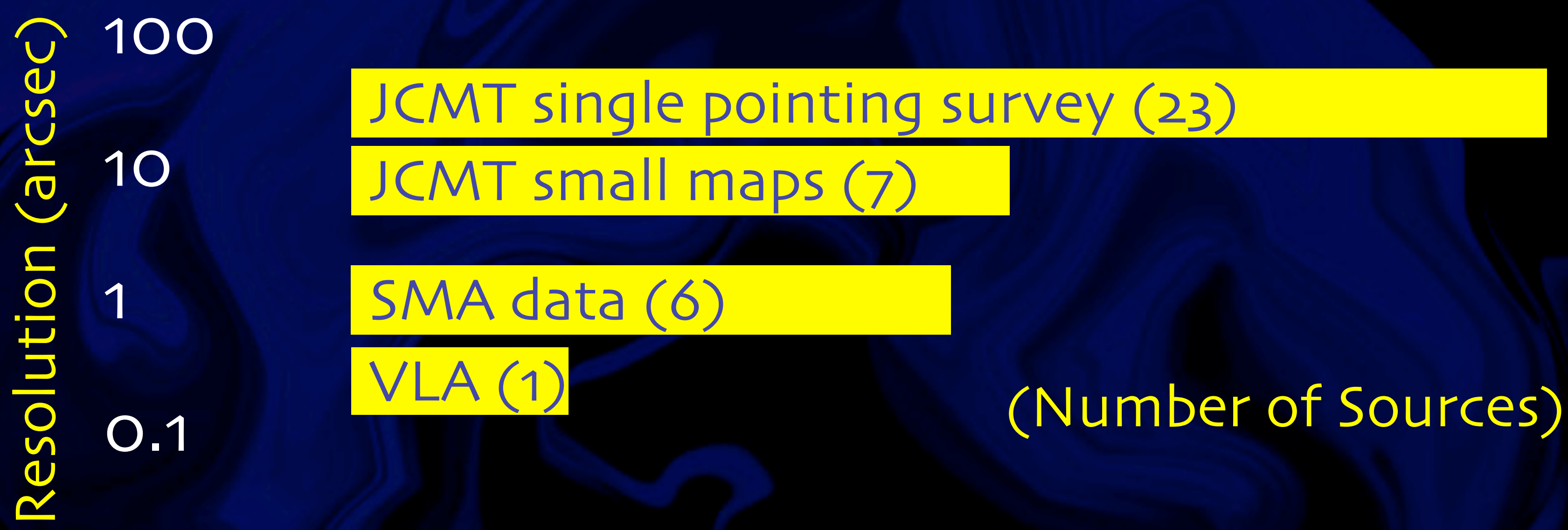
Klaassen & Wilson, in prep

Higher Resolution Imaging

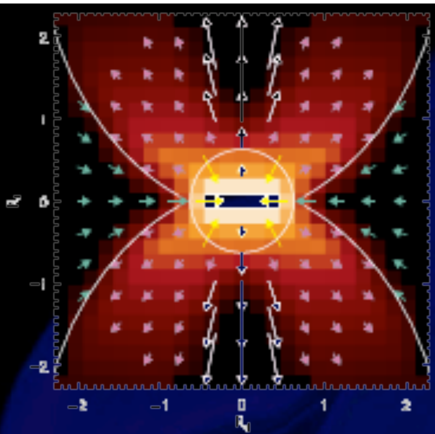


Okamoto et al. 2003

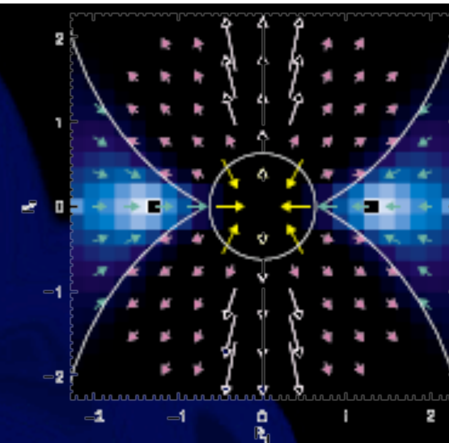
How Far Do We Need to Go?



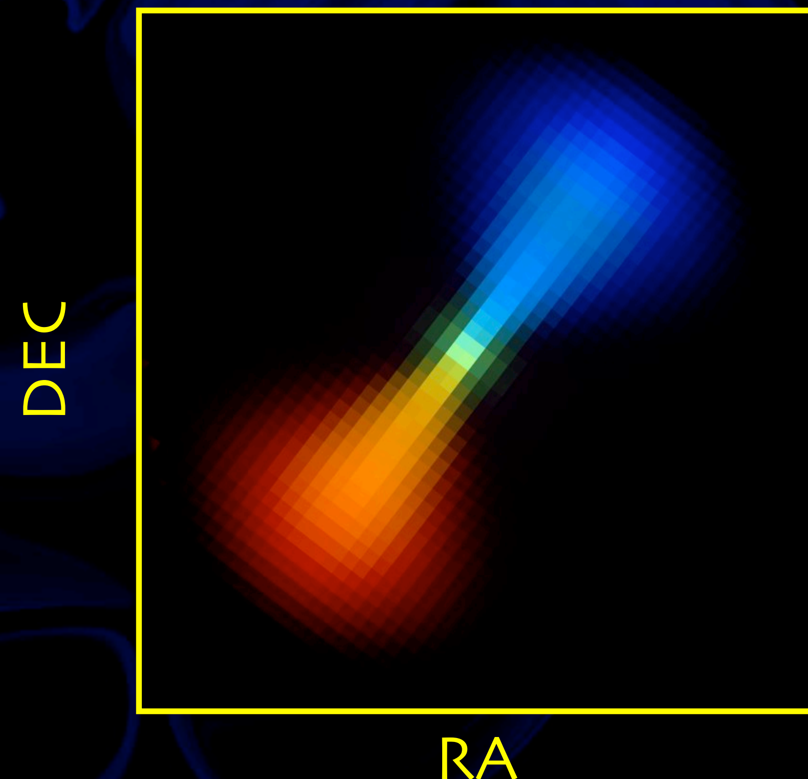
In order to compare our observations to theoretical models, we need to simulate how these models manifest on observable scales (in both ionized and molecular gas)



Future Work: Modelling



- Create radiative transfer models of these regions to distinguish between:
  - Disk/X wind outflows
  - Champagne Flows
  - Stellar winds



- Compare to Observations

Keto (2006),
Klaassen, Keto & Wilson, in prep.

Conclusions

- We have obtained a sizeable dataset on a number of HMSFRs
  - which we are finishing up the analysis of
- We will be able to compare these observations to outflow generation models
  - to try to constrain how the outflows are powered
- We can use our (ionized and molecular) gas kinematics to probe the various structures in HMSFRs (infall, outflow, rotation & accretion)
  - and to see what the critical size scales are.