# Aaron Rizzuto

GSPS Dec-2014

# A Bit About Me

- Undergrad at University of Sydney
  Physics + Maths

Famous USyd Jacaranda

- PhD at Macquarie University,
  with Mike Ireland

Finished Sep 20th

Started here on Oct 1st as Adam Kraus' postdoc

MacWarrior

Also in Sydney

# A Bit About Me

I work on star/planet formation by studying populations of PMS stars (Mainly Sco-Cen 5-20 Myr).

- Finding young Sco-Cen stars with various methods
- Multiplicity statistics with Interferometry
- Disk frequency and evolution
- Spectro-astrometry
- Lots of Bayesian stats.

# Random Things About Australia

Kangaroos and Emus
can't walk backwards

And so they are the national animals.

# Random Things About Australia

- Have some on the most poisonous spiders

But….No deaths from spiders since 1979

# Random Things About Australia

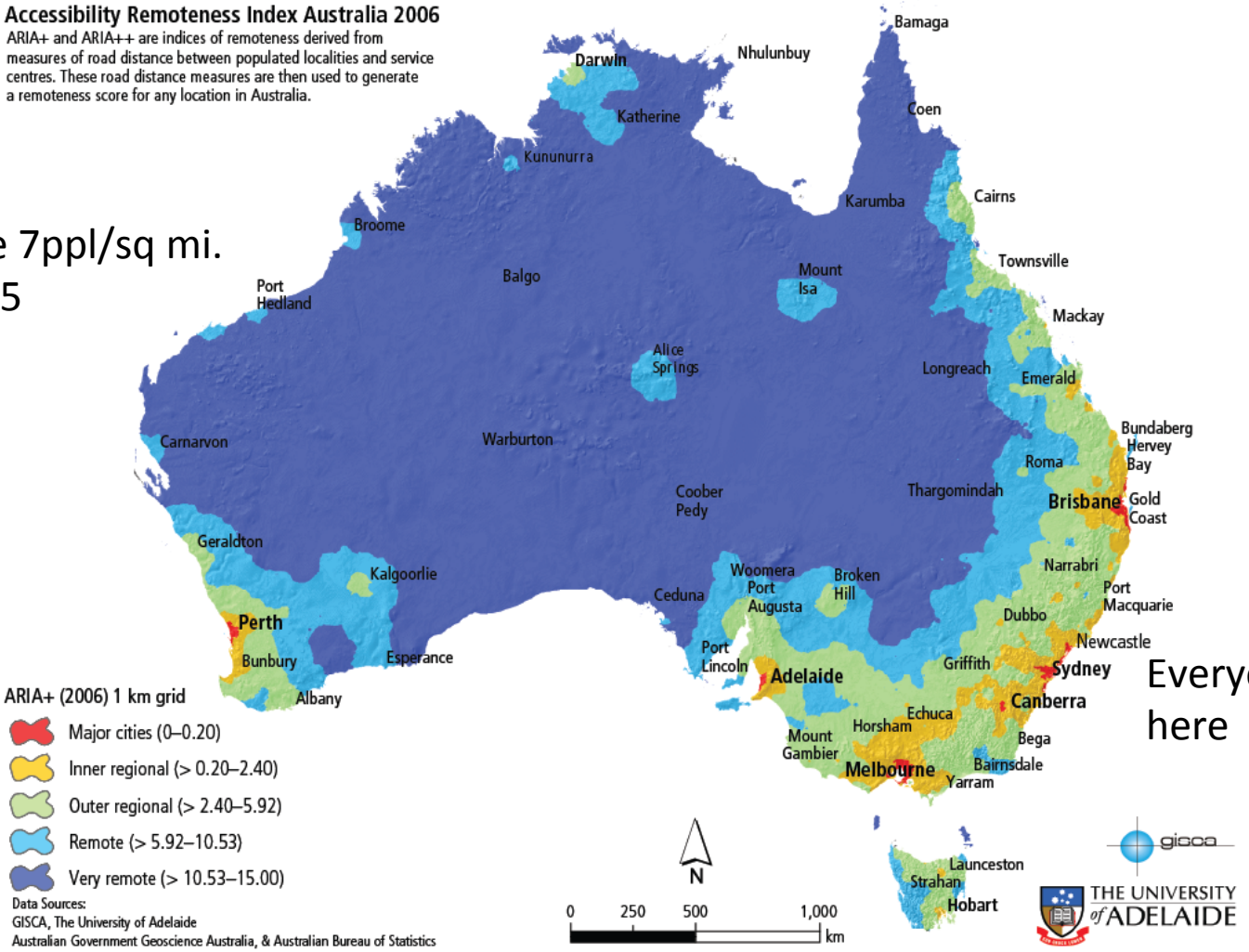
No Guns!

Government bought them all

# Random Things About Australia

The Middle isn't very nice

Average 7ppl/sq mi.
USA = 85




Everyone lives here

# Random Things About Australia

- Largest population of feral camels (750,000)

# Random Things About Australia

Bob Hawke:

Prime Minister (1983-91)

Was in Guinness Book Or Records for speed drinking.

# Random Things About Australia

We really do say “Mate”

It’s supposed to mean friend, but usually used when talking to people you don’t know.

Don’t call a Texas bus driver mate

# Astronomy In Australia

Lots of Radio (which I know very little about), including SKA soon
Most jobs are radio-related, but you might have to live in Perth

One main optical site Siding Spring Observatory with a few telescopes:
AAT, ANU 2.3m,  UKST, etc….
Lots of great instrumentation people at places like the AAO.

# Astronomy In Australia

## A Bit Less intense

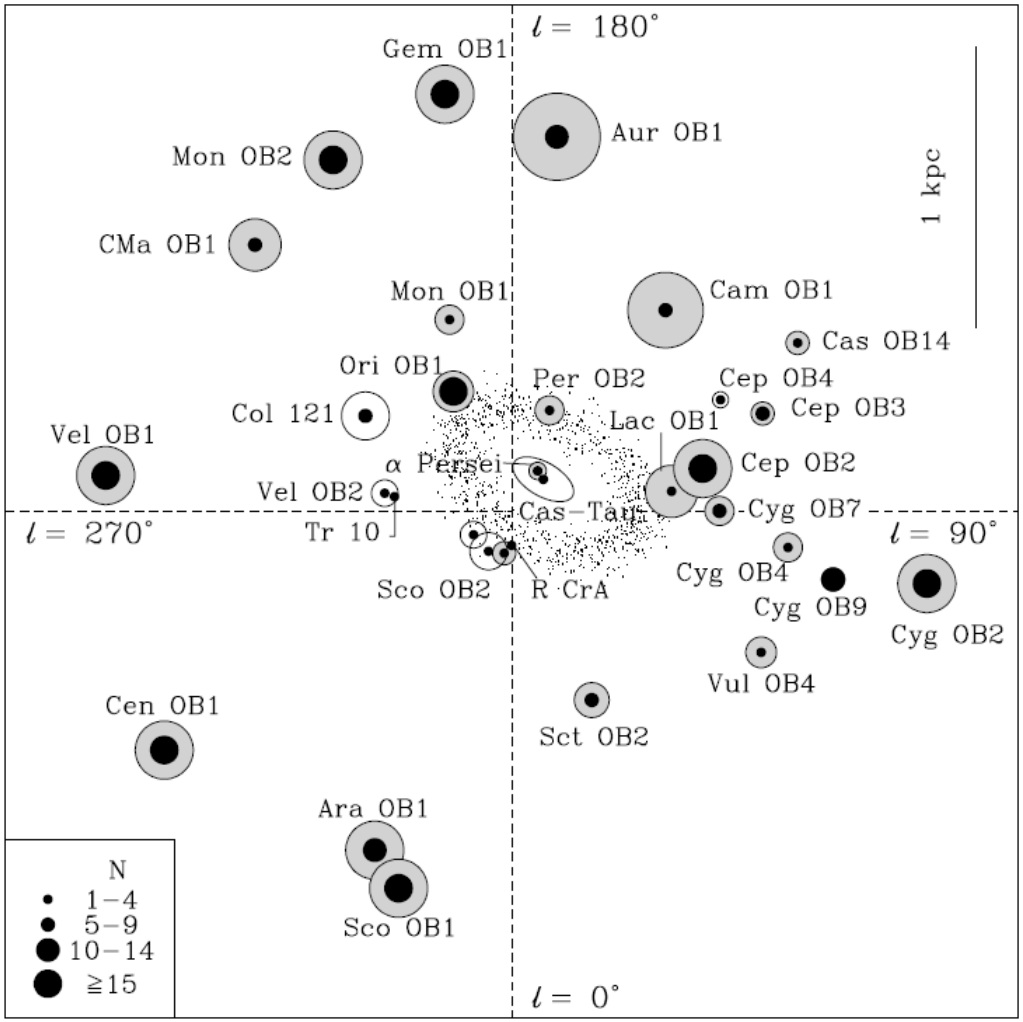
- No Emails about 80 hour work weeks
- PhD's are a bit shorter (but that might change) and you don't have to do anything for funding.
- No-one AstroPh snipes
- Less people work on Saturday (or at least less answer emails)
- But less jobs!

SCIENCE!

# OB Associations

- Young, loose, unbound “Associations” containing O and B-type stars, which all share a similar origin.
- Quite sparse, 1-10pc between B-type stars. Hence they are dispersed quite quickly.
- Members share similar motions through space. This has become the basis for identifying which stars are part of a given association (where good kinematics are available).
- Important because they provide a sample of stars which have just formed prior to interactions which may alter primordial characteristics, e.g. Multiplicity, IMF.
- There are many of these association in our neighborhood, suggesting that they are an important part of the stars formation picture.

# OB Associations



# The Sco-Cen Association

- Nearest OB association and region of recent star formation to the sun (~130 pc). It contains ~150 B-type stars (Rizzuto 2011) and is predicted to contain 1000's of low-mass pre-main-sequence stars. Membership is incomplete past early G-type stars.

- Covers a very large swath of the southern winter sky, covering thousands of square degrees. Many well known visible stars are part of the association (e.g. Southern Cross and Pointers).

- Historically Sco-Cen been divided into three subgroups with different ages (5-20Myr) and kinematics, and potentially different star formation history.

# Low-Mass Stars

- Most of the K, M-type members are not known. Expected that there are ~10000 stars in Sco-Cen.

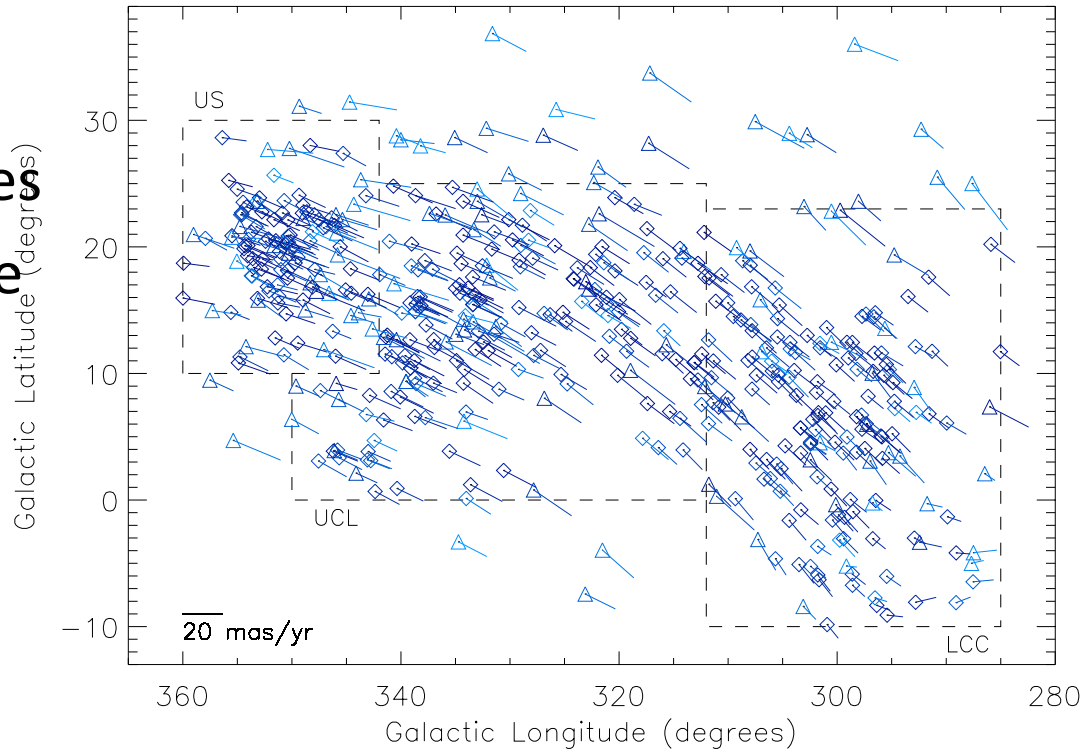
- Finding them requires

e.g. spectroscopy to see

Youth indicators like

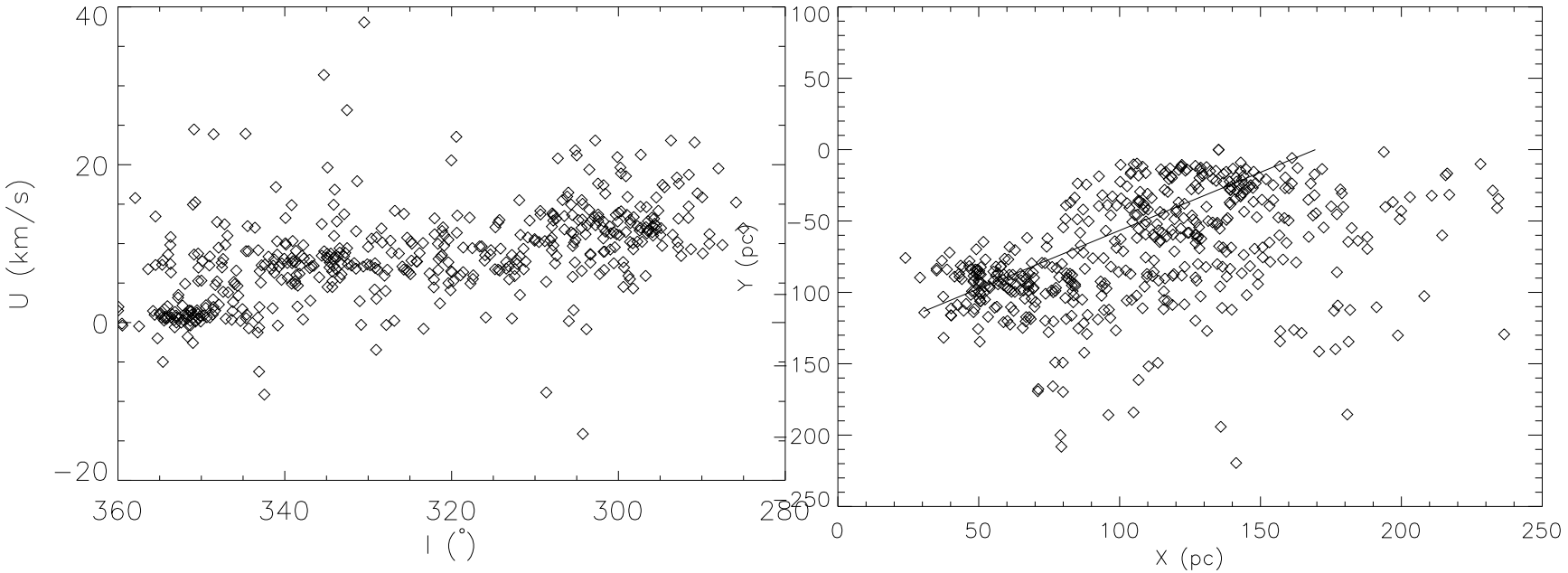
Lithium + H-alpha

→1000's of targets



# Low-Mass Stars

Use smarter selections to choose the targets:




We know the group velocities, distance and position on sky. Also have estimate of velocity dispersion.

# Bayesian Selection

- Idea: Optimally use available position, distance and velocity information to decide if a stars is part of Sco-Cen. We have to decide between two mutually exclusive models

Model Likelihood ratio:

$$R = \frac{P(M_g / D)}{P(M_f / D)}$$

$M_f$ Refers to the field model

$M_g$ Refers to the association or "group" model

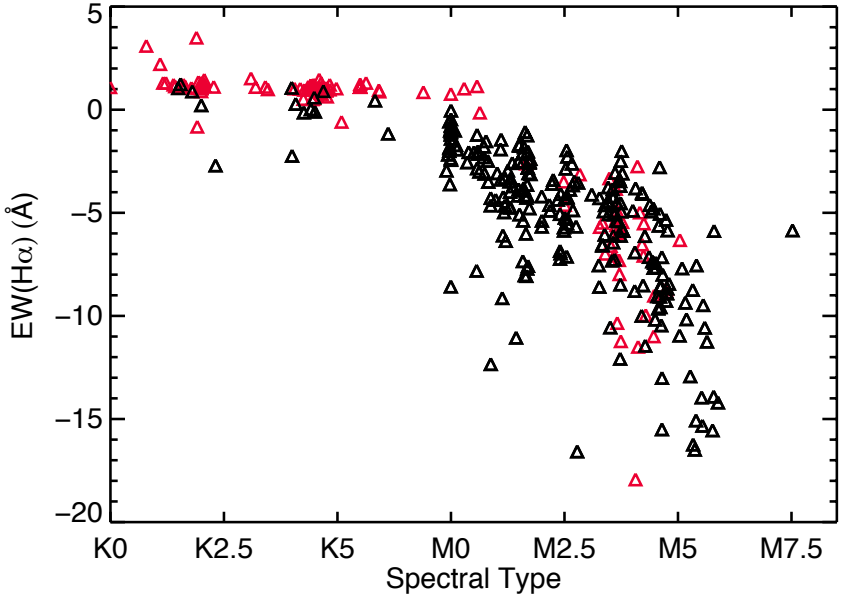
Not useful until rewritten with Bayes' Theorem:

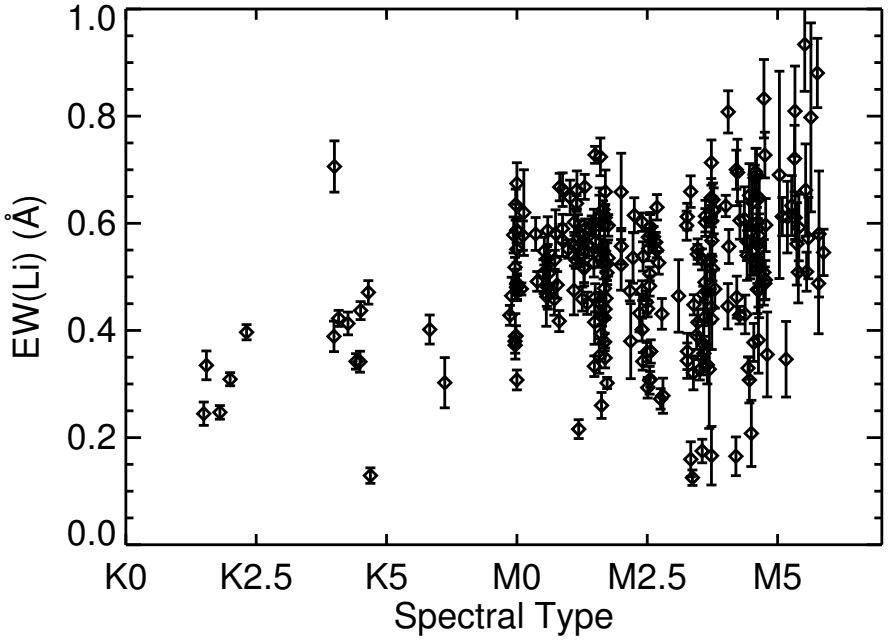
$$P(M / D) = \frac{P(D / M)P(M)}{P(D)} \quad \Rightarrow R = \frac{P(M_g)P(D / M_g)}{P(M_f)P(D / M_f)} = \frac{P(M_g)}{P(M_f)} K$$

$$M_{g,f} = \{l, b, r, \mu_{//}, \mu_{\perp}, v_r, m_i\}$$

Use this to prioritise targets and throw away obvious non-members

# New Low Mass PMS stars

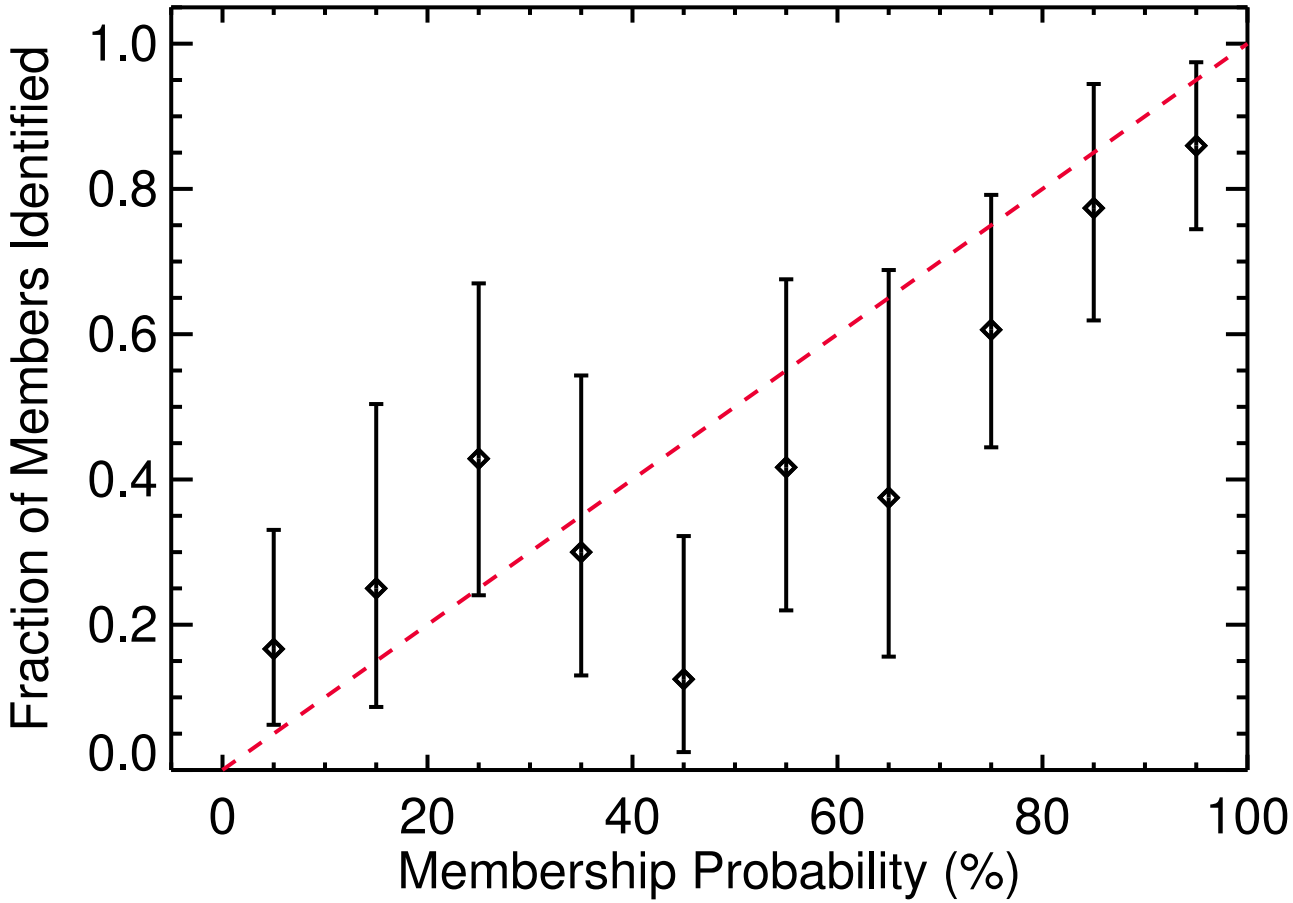


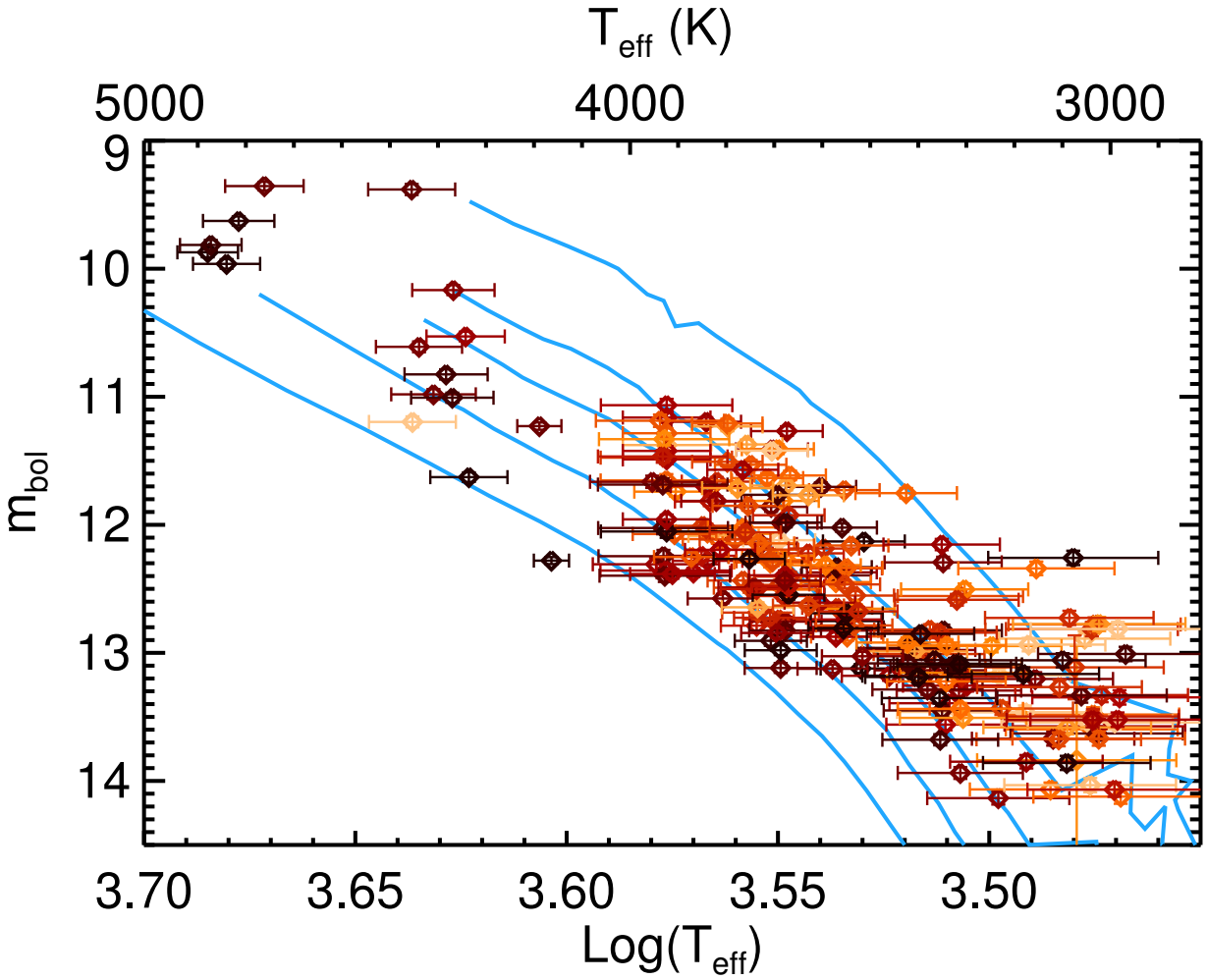

Found 236 new PMS K/M-type Upper-Scorpius Stars!

# Efficiency?

60-70% of observed stars were young!



# How Old Are They?




Got BCj and T_eff from spectral types + young stars temperature calibration (Pecaut et al., 2013)

# Other Evidence

1. Existence of Early B-type stars that are very young ~5Myr (Tau-Sco, Del-Sco, w-Sco)
2. Existence of clearly evolved B-type stars. i.e. ~10Myr
3. F-type stars appear to be ~13Myr based on HR-diagram. Explainable as two populations using an IMF and a spectral type range.
4. Orbits of K/M binaries suggest some old stars and other young stars

# Young Upper-Sco

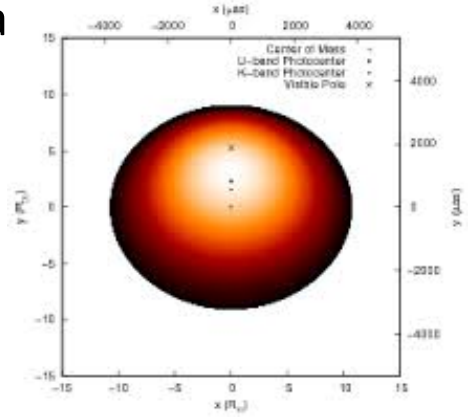
- B-Type Stars

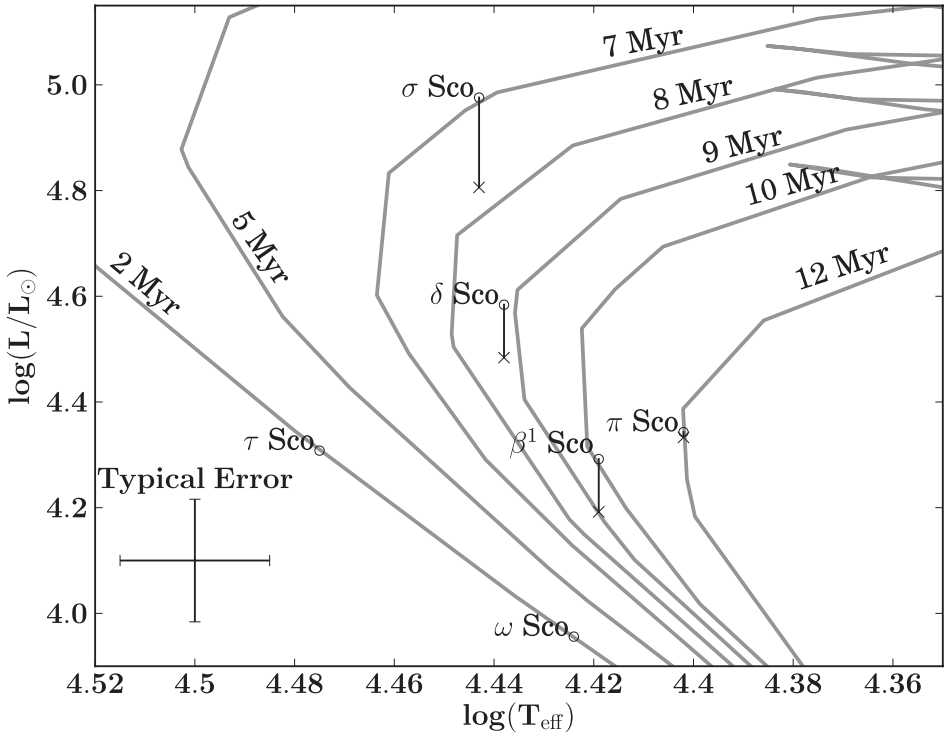
<u>Young Stars (<10Myr)</u>

Tau-Sco

Omega-Sco

Delta






(Pecaut et al., 2012)

# F-Type Stars Seem Old

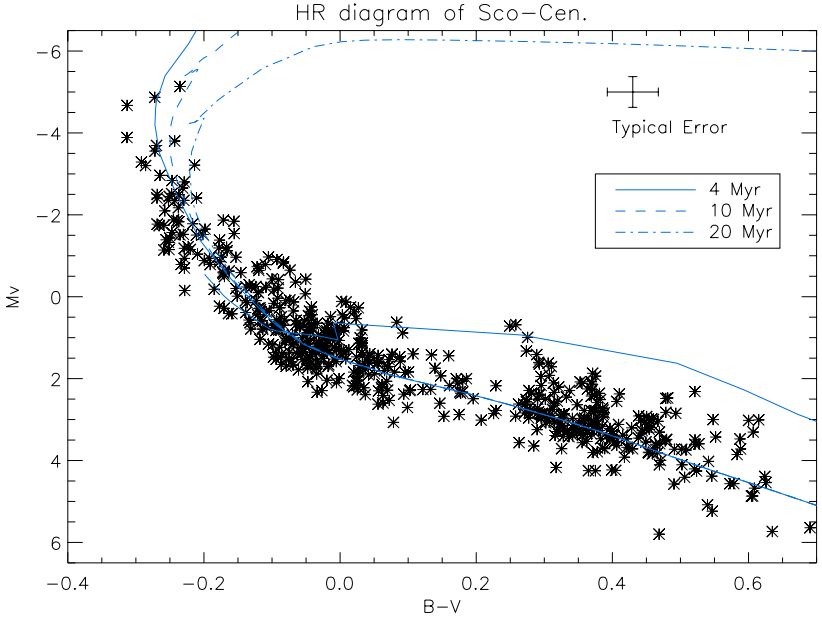
Imagine two populations (5 and 15 Myr) in 3.78<T_eff<3.85 and look at some models (Dartmouth)

These are significantly different mass ranges in the two populations:

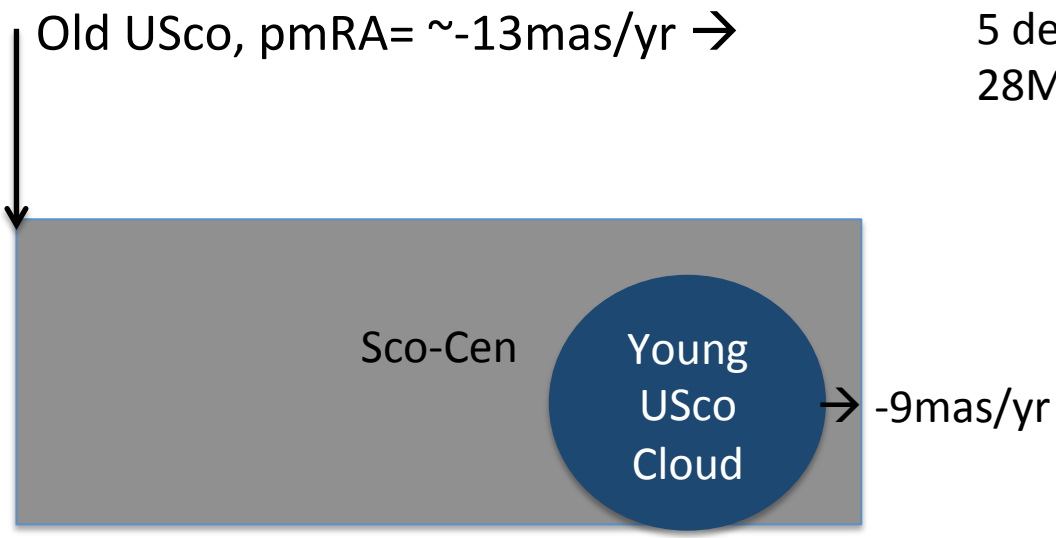
5Myr : 1.87 – 2.02Msun

15Myr: 1.23 – 1.54Msun

With e.g. A Kroupa IMF, this means there will be 20 times more of the older stars!



# Formation Scenario?




5 deg (10pc) on sky over 5Myr
28Msun star dies in 6.3Myr

# Thanks For Listening!