The dynamics of OB associations

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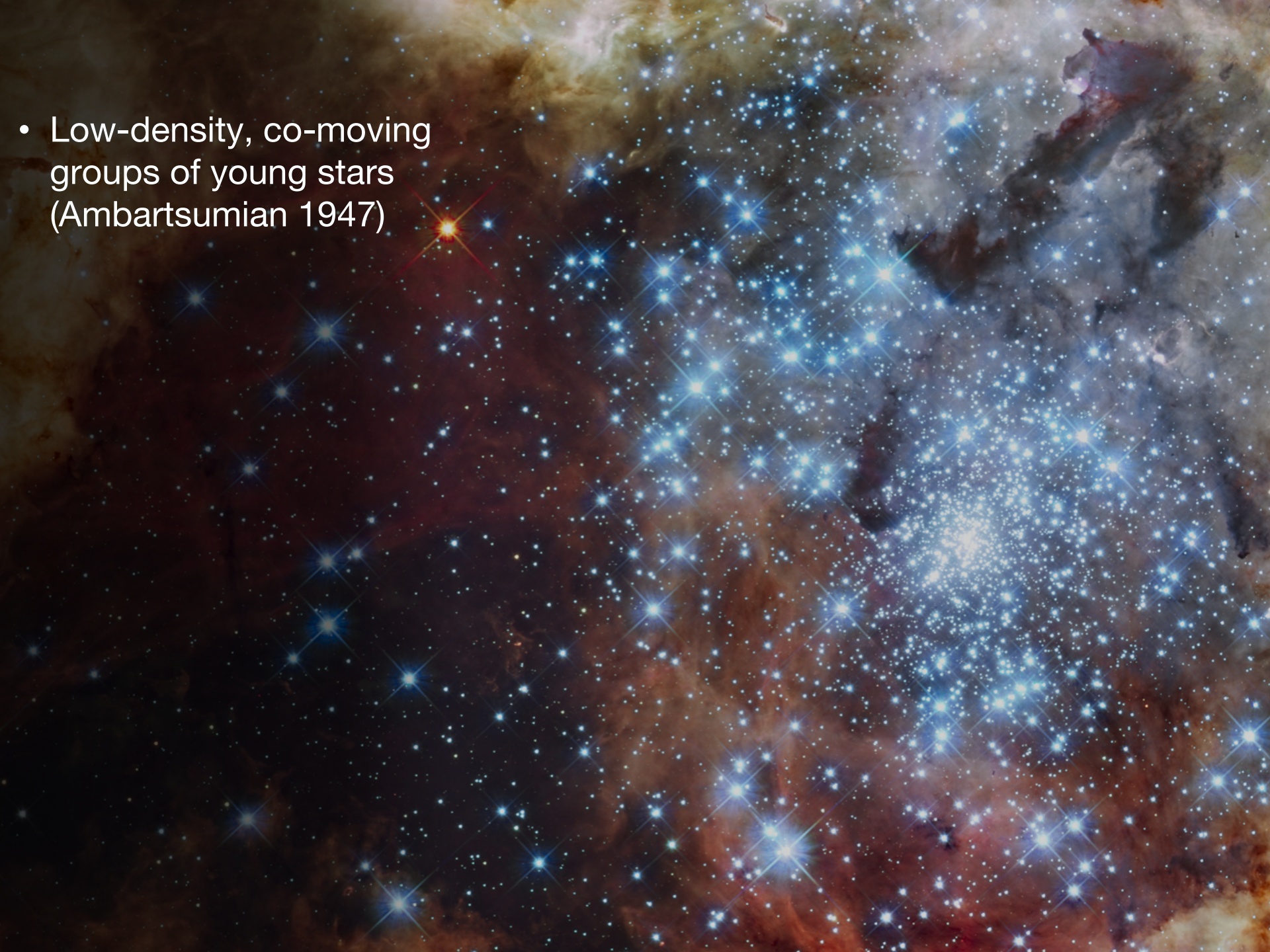
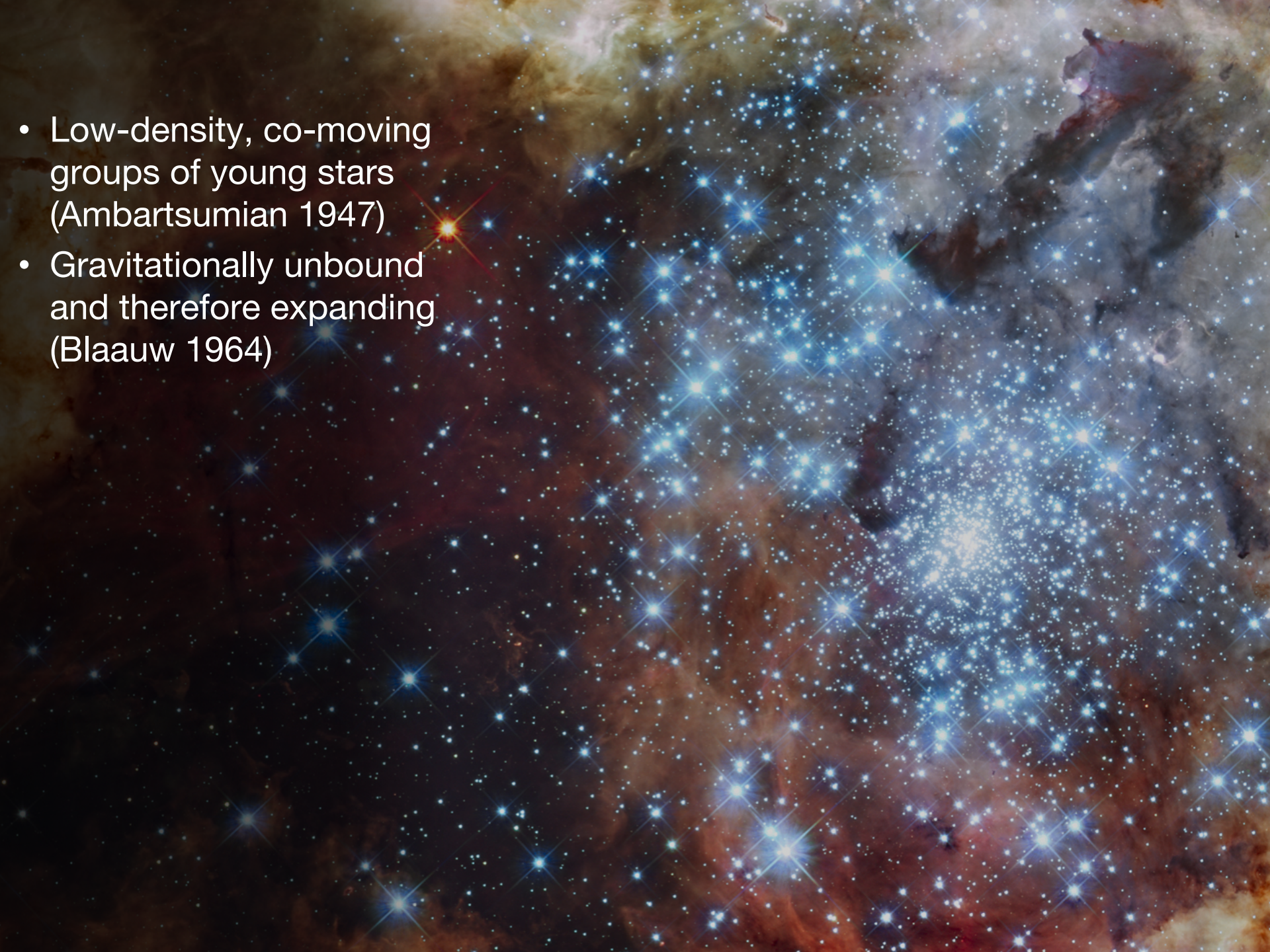
With thanks to…
Herve Bouy, Eric Mamajek, Richard Parker, Janet Drew, Jeremy Drake, Rob Jeffries, Simon Goodwin, Emmanuel Bertin, David Barrado, Jean-Charles Cuillandre & Luis Manuel Sarro



- Low-density, co-moving groups of young stars (Ambartsumian 1947)



- Low-density, co-moving groups of young stars (Ambartsumian 1947)
- Gravitationally unbound and therefore expanding (Blaauw 1964)

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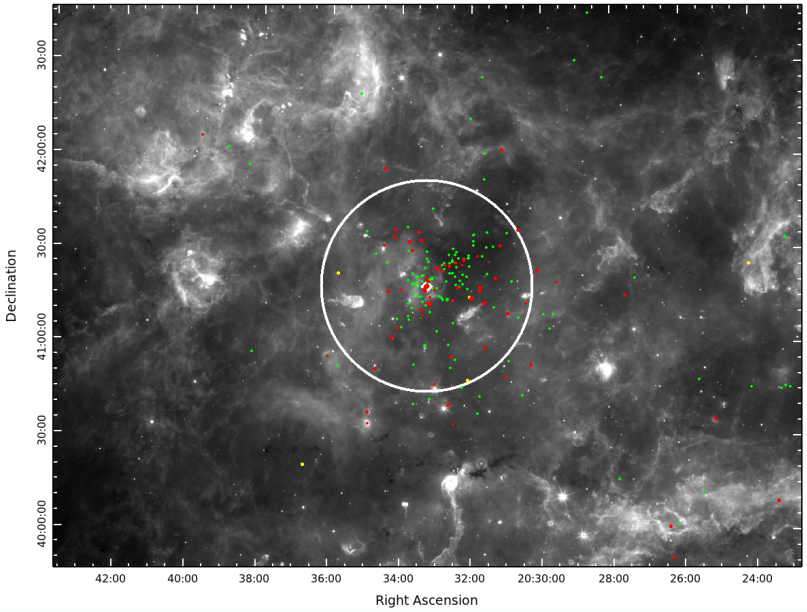
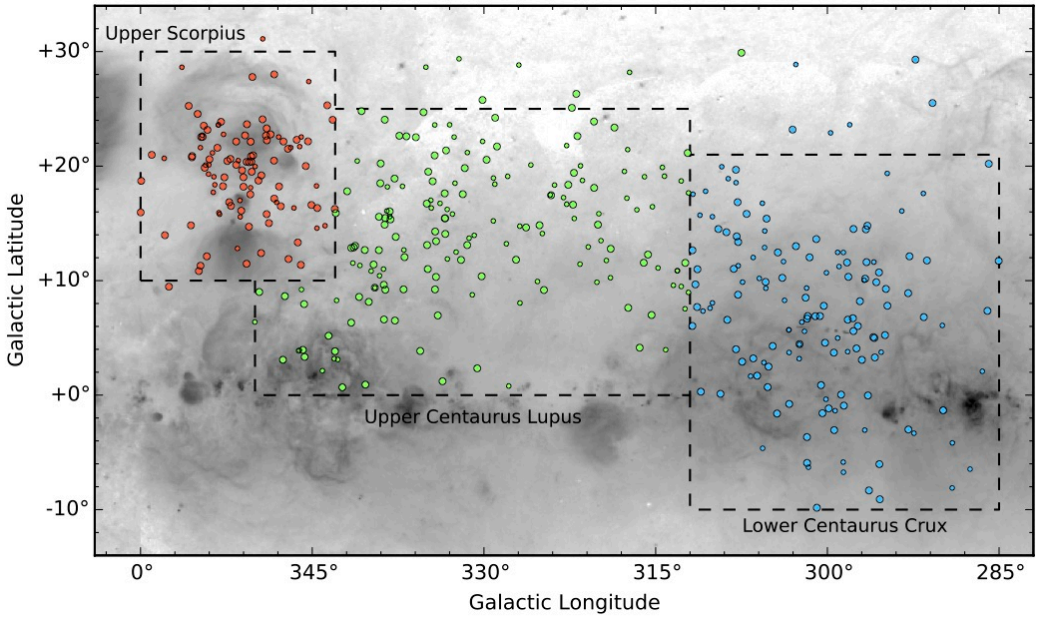
- Thought to be the expanded remnants of star clusters disrupted by residual gas expulsion

  (e.g., Hills 1980, Lada & Lada 2003, Baumgardt & Kroupa 2007)

Testing the origins of OB associations





Cygnus OB2

Pre-Gaia ground-based astrometry

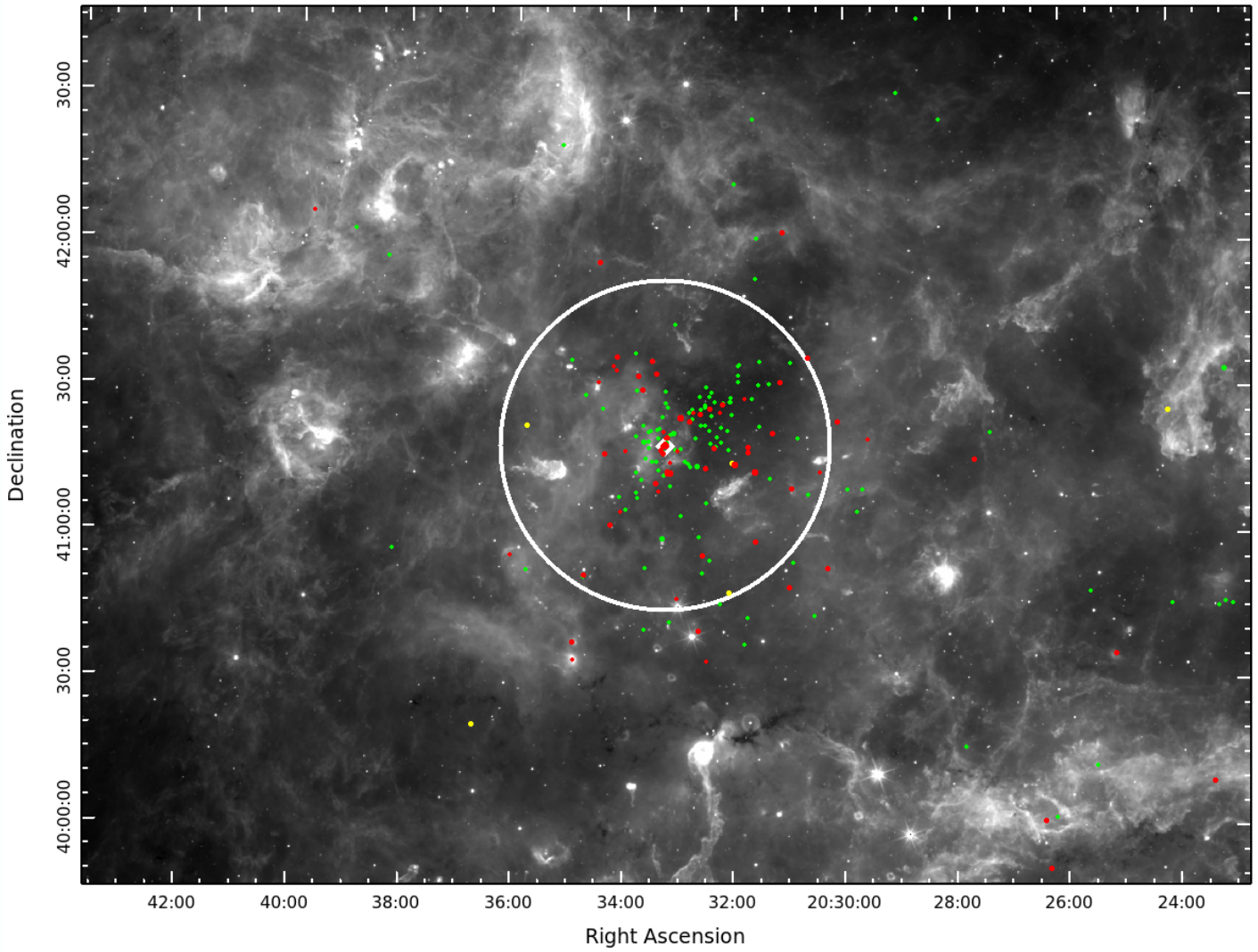
Scorpius-Centaurus

Gaia DR1 astrometry

Cygnus OB2 association

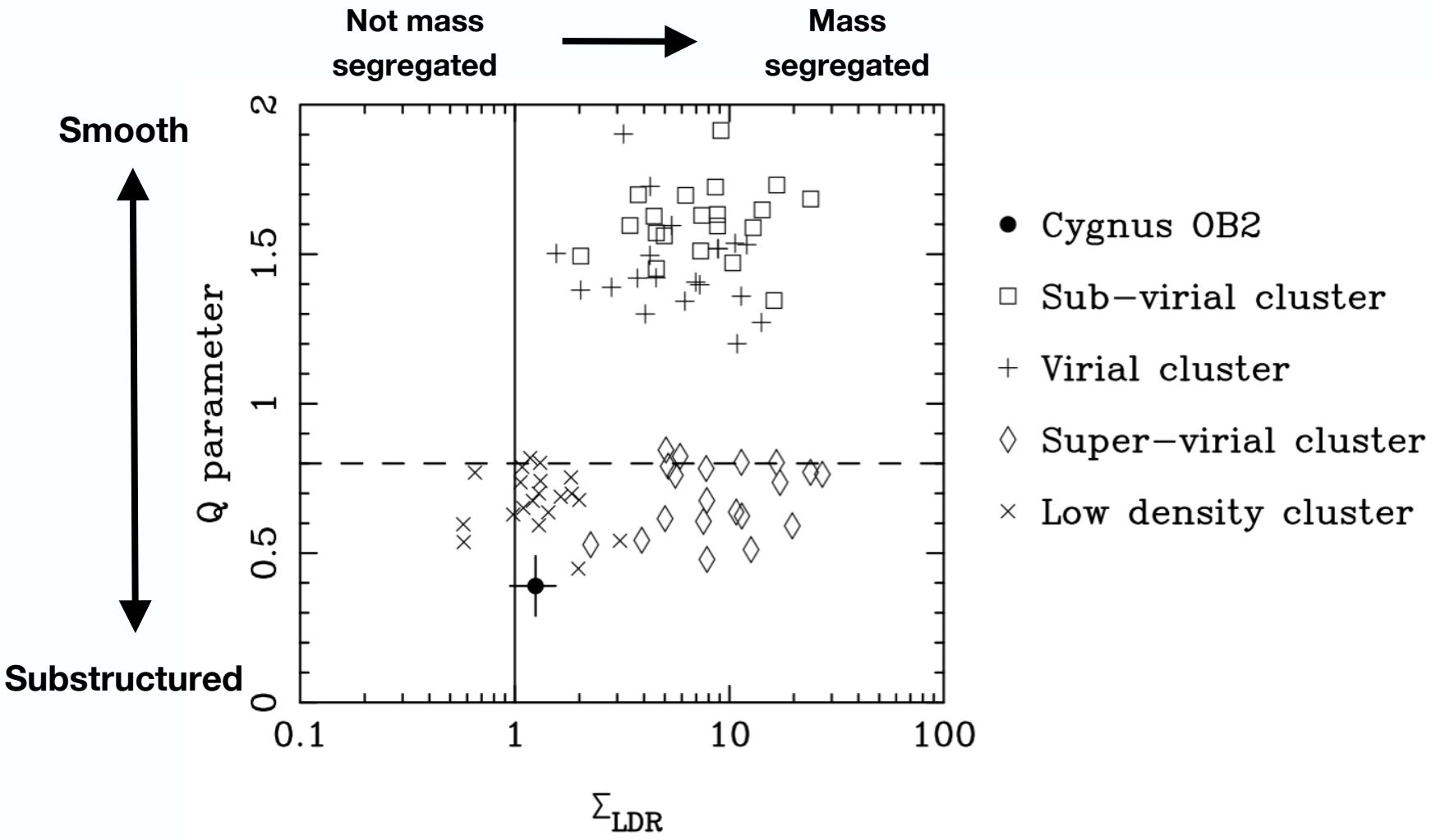
- Total mass ~ (2-4) × 10^4 $M_\odot$ (Wright+ 2010)
- ~ 65 O stars, up to 100 $M_\odot$
- Age ~ 5 Myr (Drew+ 2008, Wright+ 2010)

Using X-ray selected sample of members (Wright & Drake 2009, Wright et al. 2010)



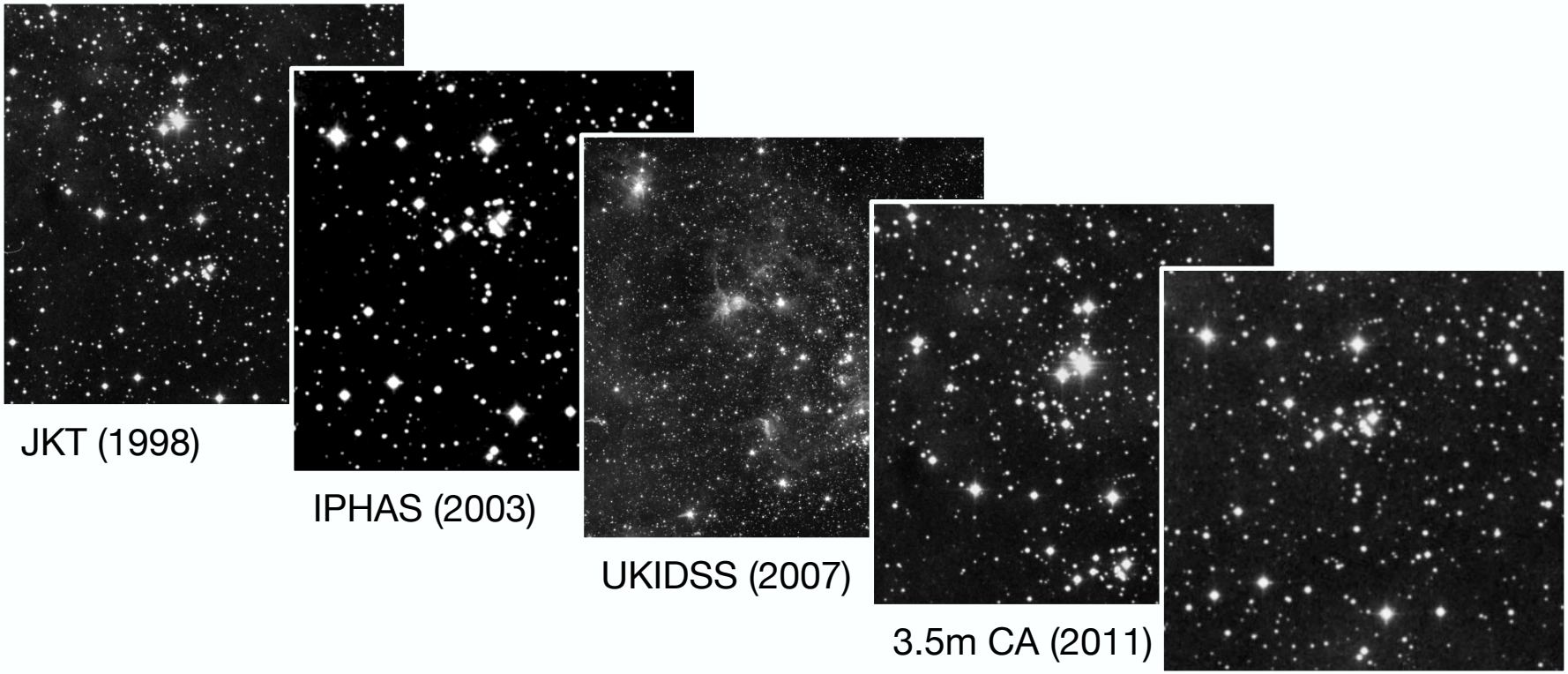
WISE 12um image of Cygnus X showing distribution of massive stars (Wright+ 2015)

Substructure in Cygnus OB2



Wright+ 2014

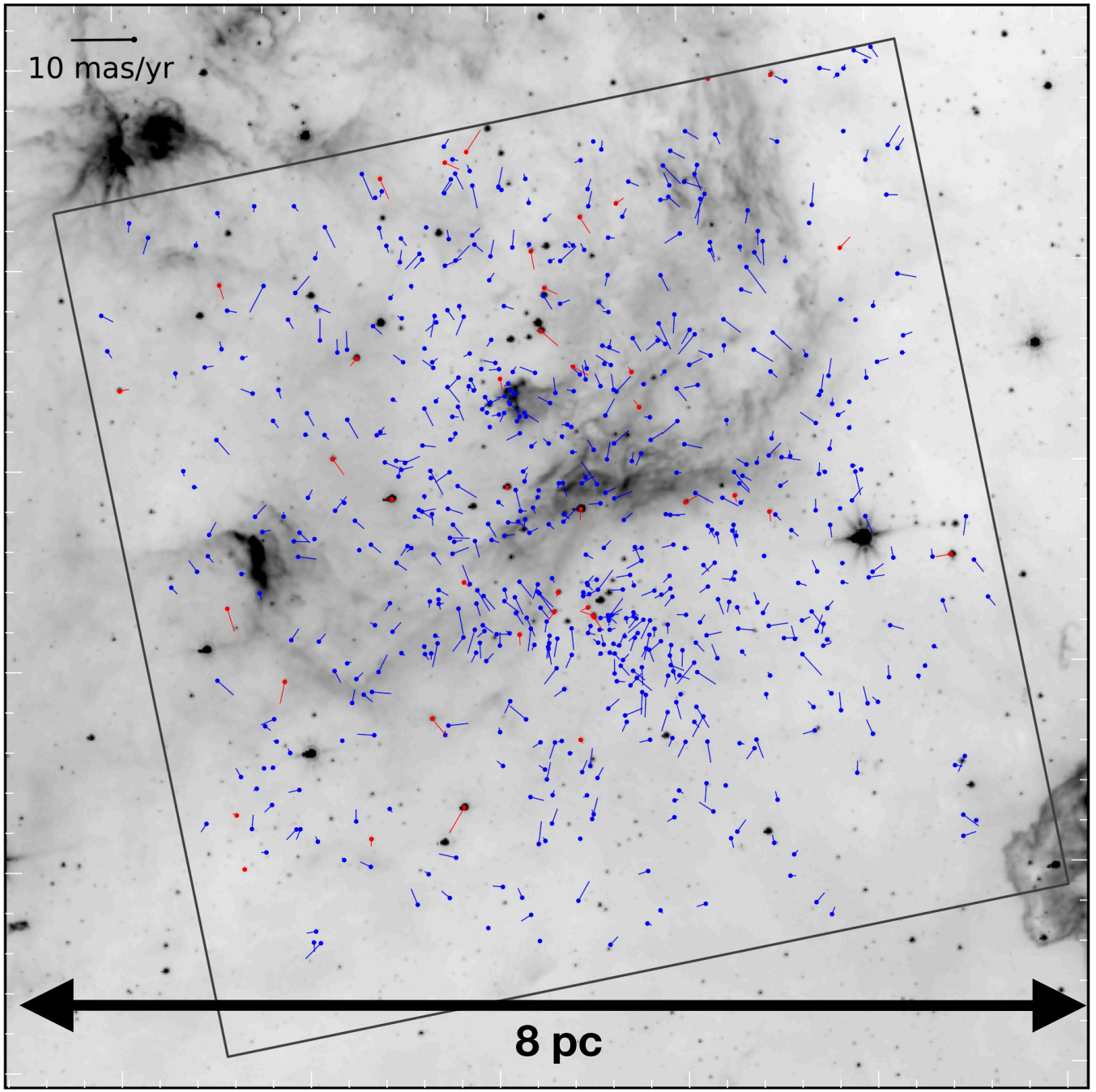
Proper Motions from Wide Field Imaging



15 year baseline => PMs with sub-mas/yr precision

Proper Motions

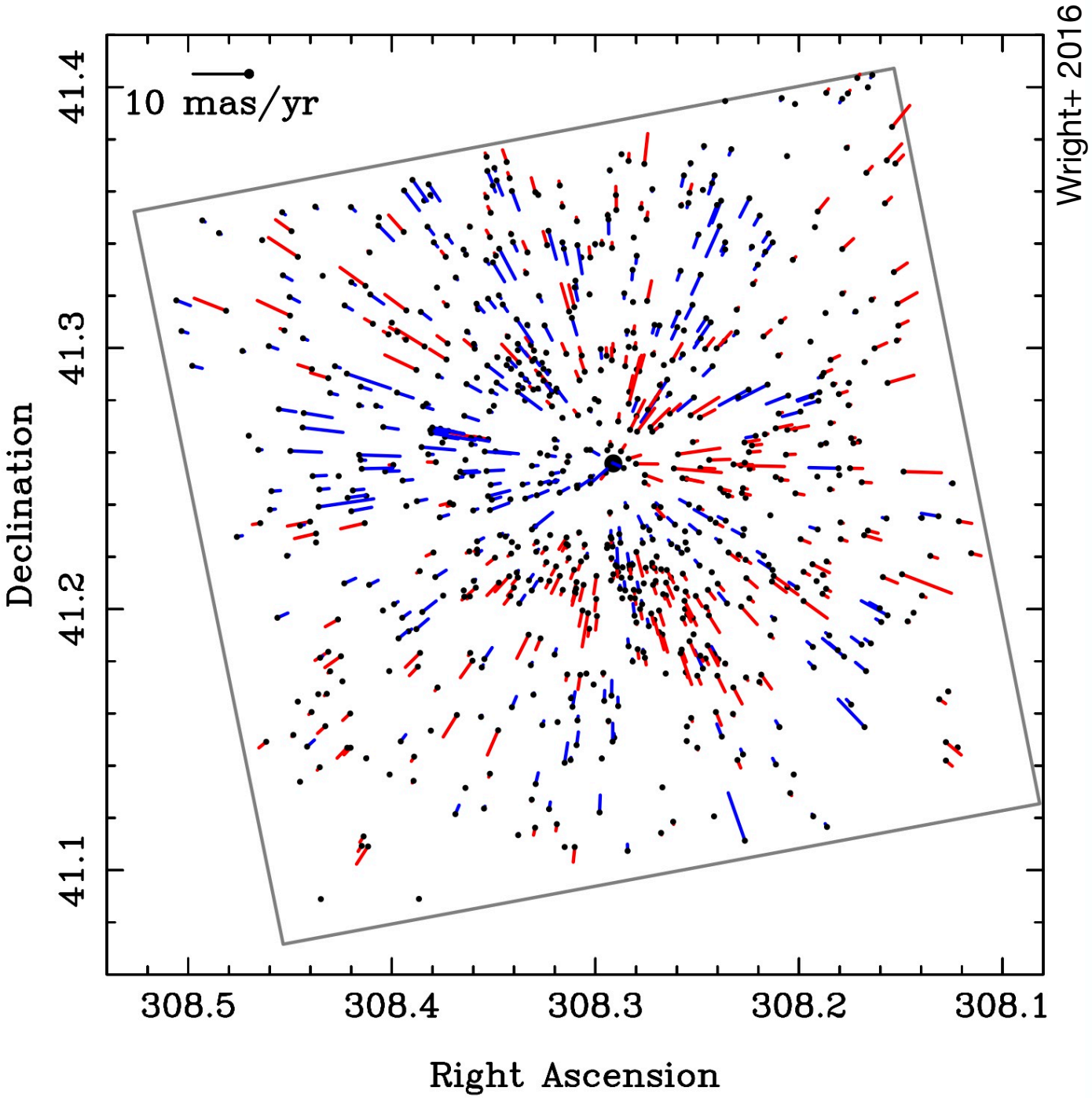
- 748 members of Cyg OB2 shown
- O stars in red



Wright+ 2016

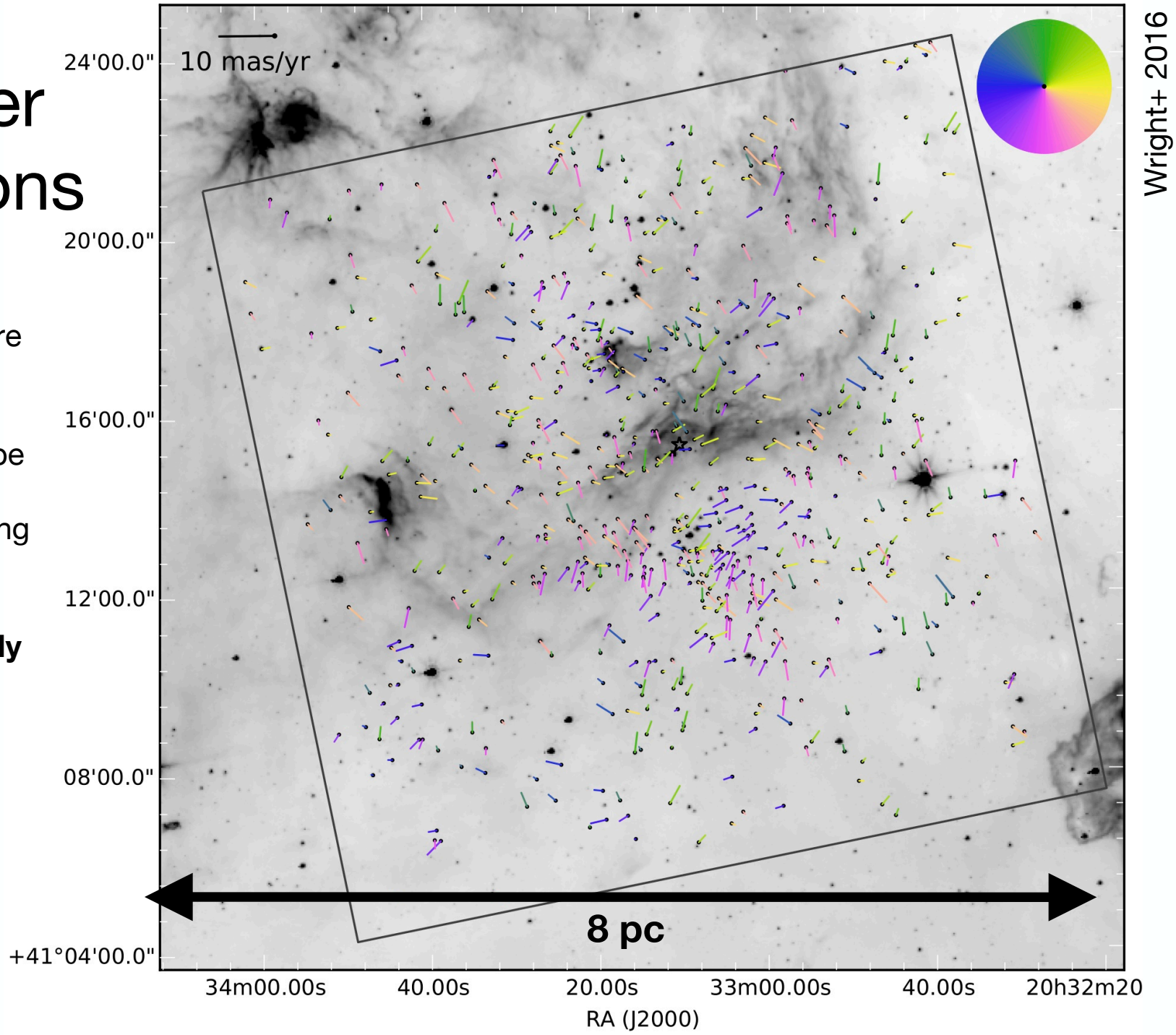
Proper Motions

- Radial component of PMs divided between:
  - Expansion (red), 50% of KE
  - Contraction (blue), 50% of KE
- No cohesive expansion motion -> not an expanded star cluster
- Cluster disruption mechanisms (e.g., residual gas expulsion) not been at work

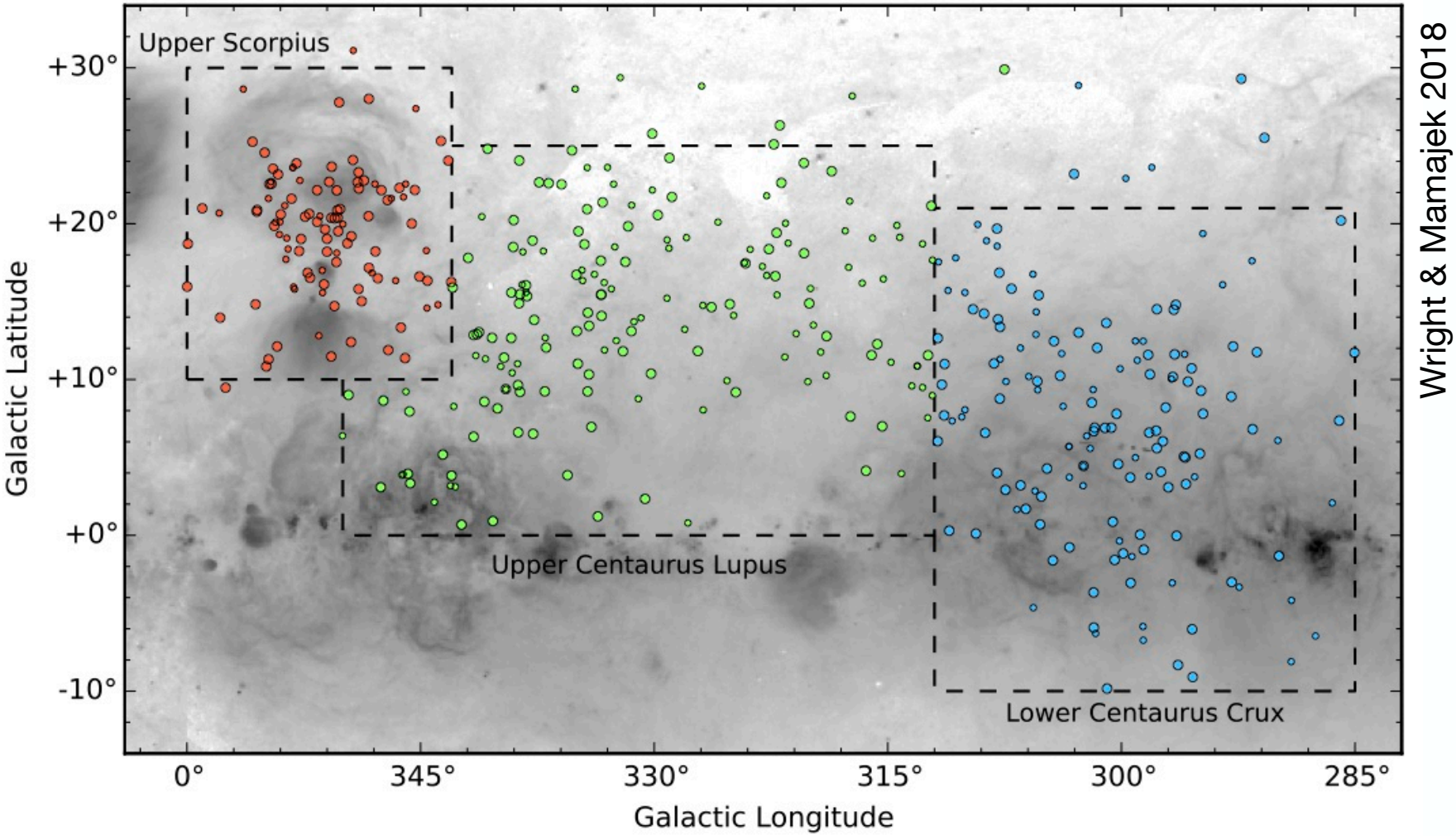


Proper Motions

- Significant kinematic substructure
- Moving groups appear to be bound and possibly long lived
- **Not dynamically mixed**



Scorpius-Centaurus OB association



- Nearest OB association to the Sun (d ~ 100-150 pc)
- Age ~ 10-20 Myrs (Pecaut & Mamajek 2016)
- Mass ~ 4000 $M_{\odot}$ (Mamajek+ 2002, Preibisch & Mamajek 2008)

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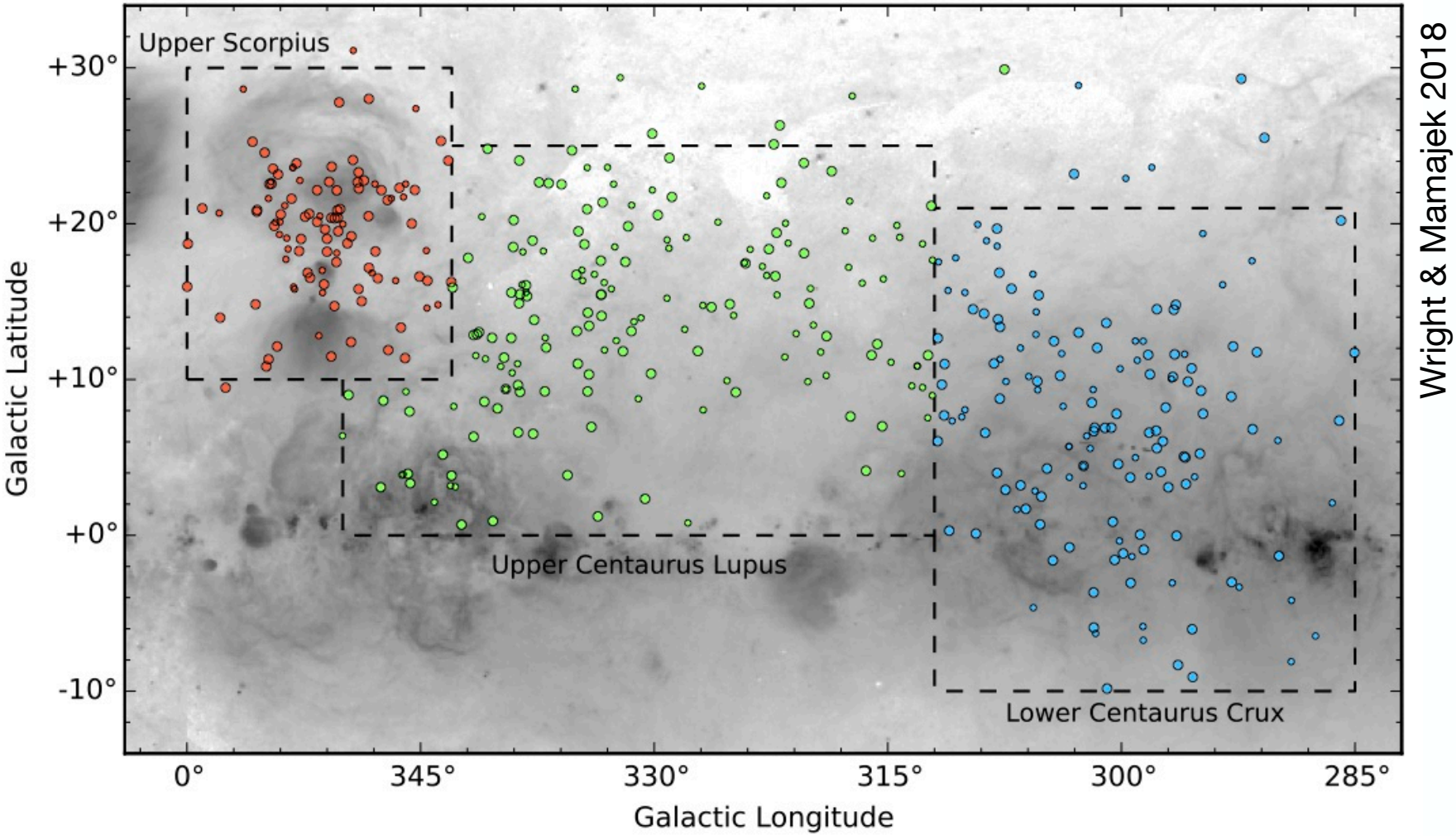
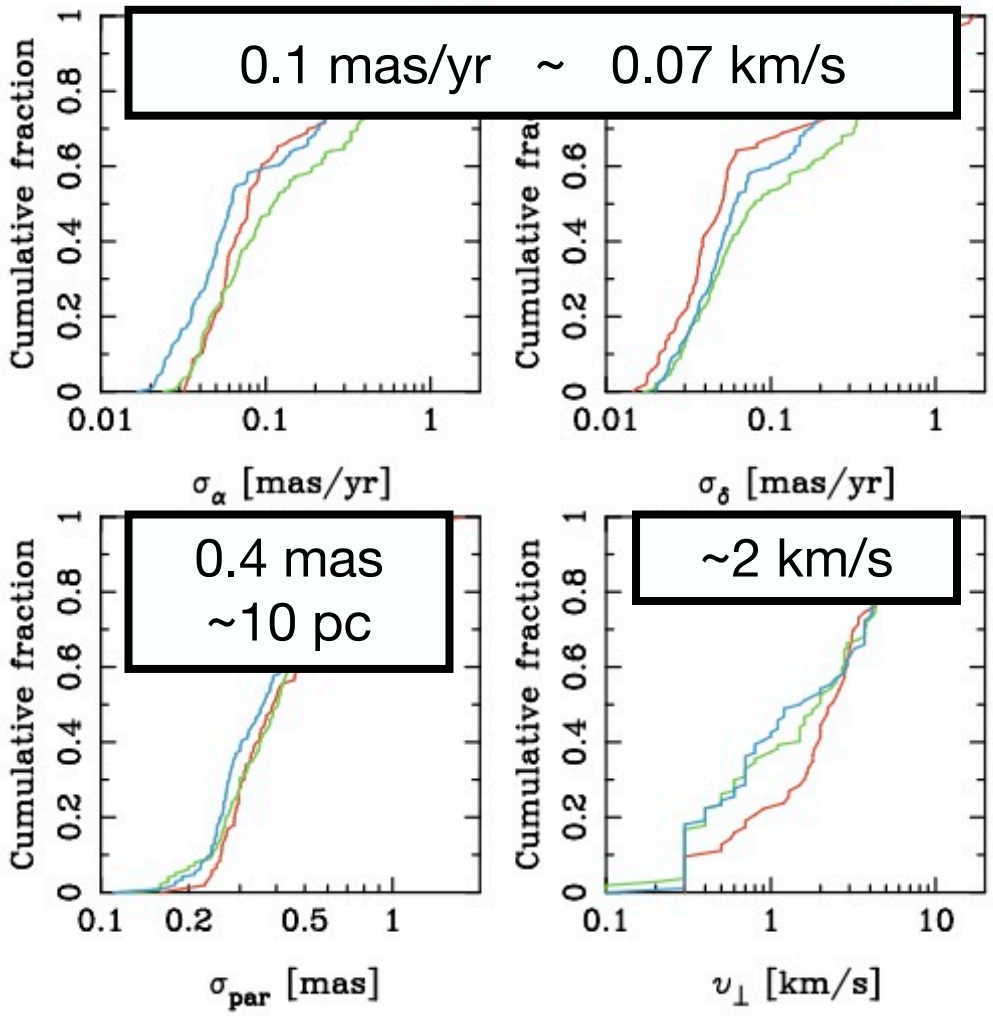
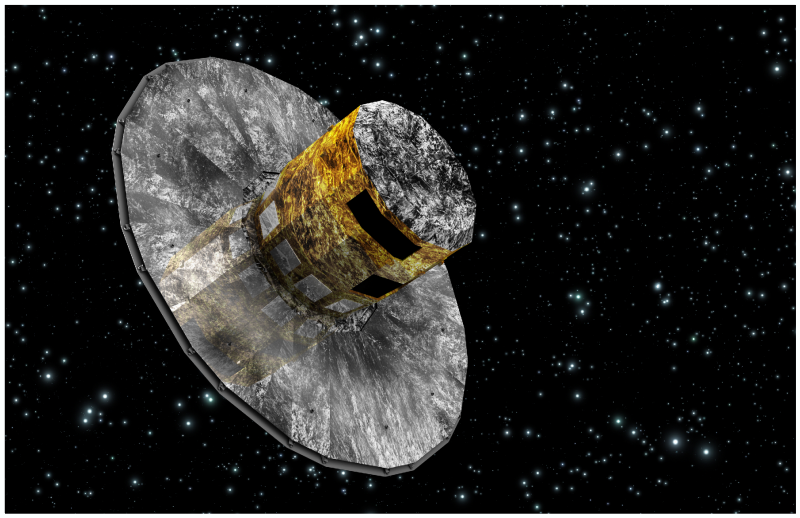


- Approx. ~500 OBA Hipparcos members identified by de Zeeuw+ (1999)
- Using revised Hipparcos members list of 433 stars from Rizzuto+ (2011)
- Majority have vastly improved proper motions in Gaia DR1

Scorpius-Centaurus OB association



Wright & Mamajek 2018



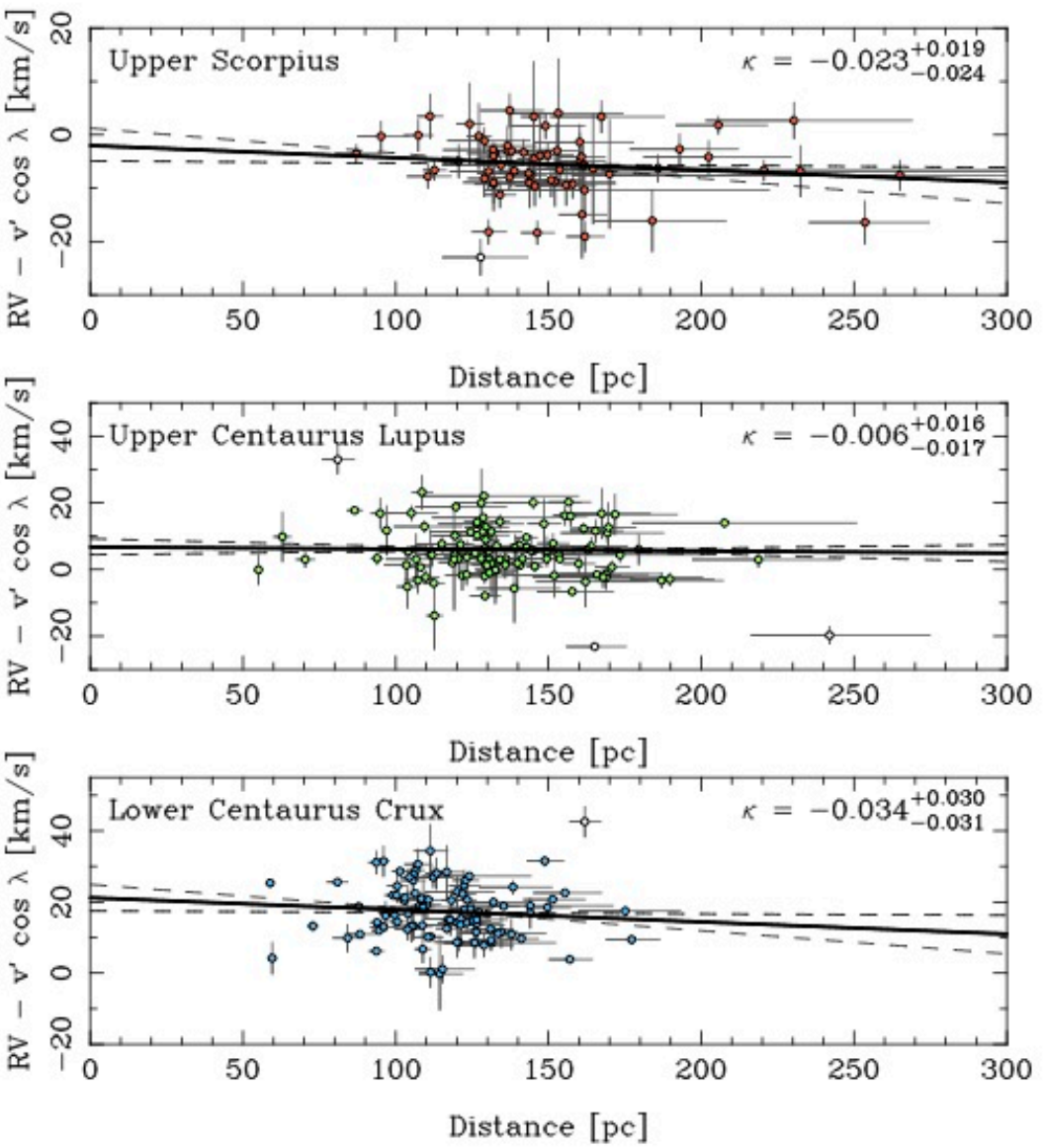
- 258/433 (60%) stars have Gaia DR1 astrometry (Gaia Collaboration+ 2016a,b)
- RVs available for 273/433 (63%) stars (Gontcharov 2006, Kharchenko+ 2007, Chen+ 2011, Dahm+ 2012)

How are the associations expanding?

Radial streaming of nearby groups leads to *virtual expansion*, so not simple to assess expansion.

Other methods:

- Blaauw's (1964) linear expansion model



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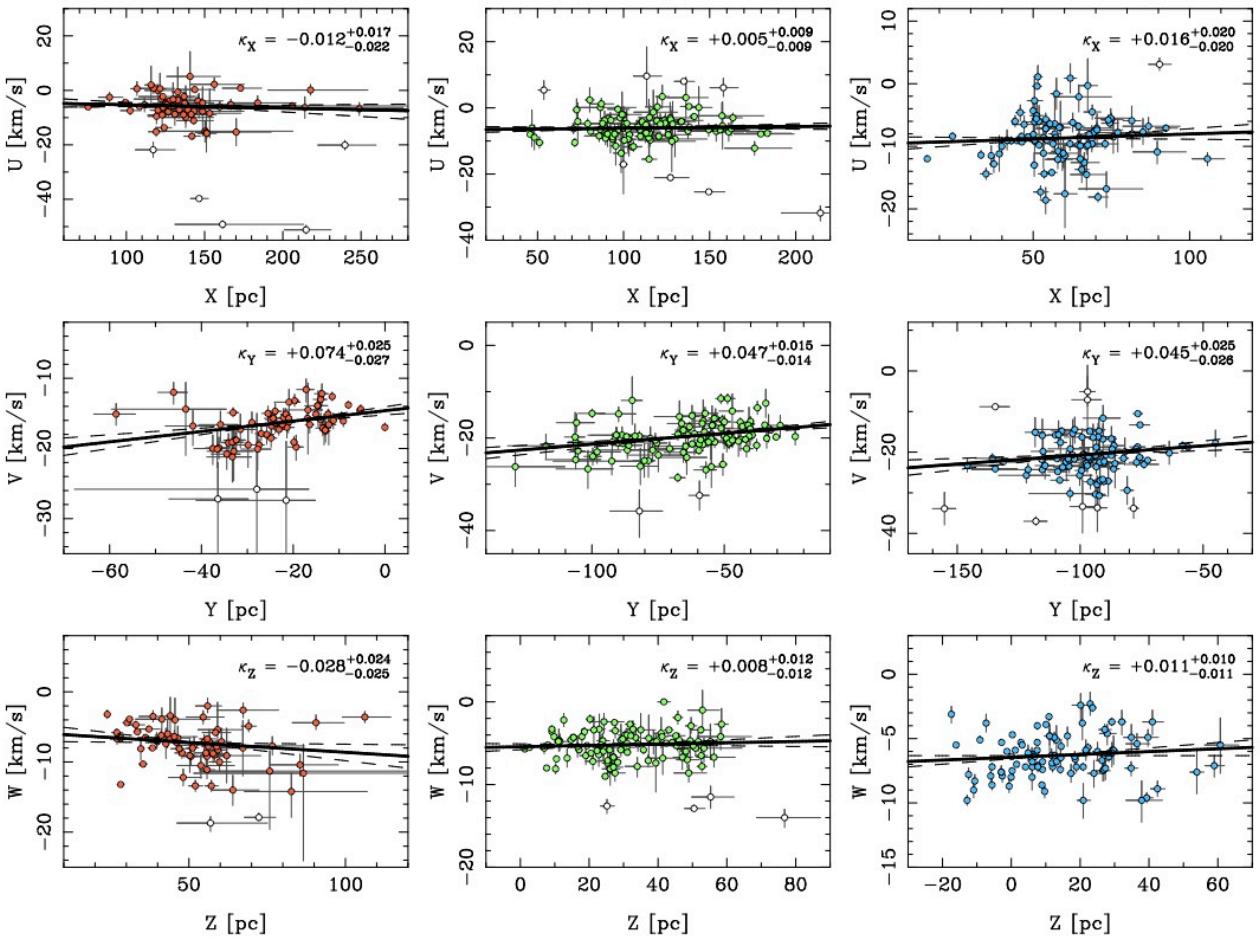

Wright & Mamajek 2018

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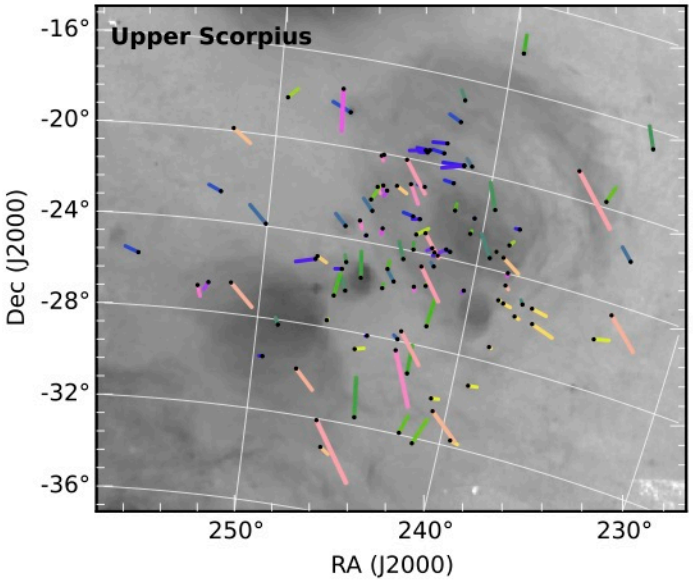
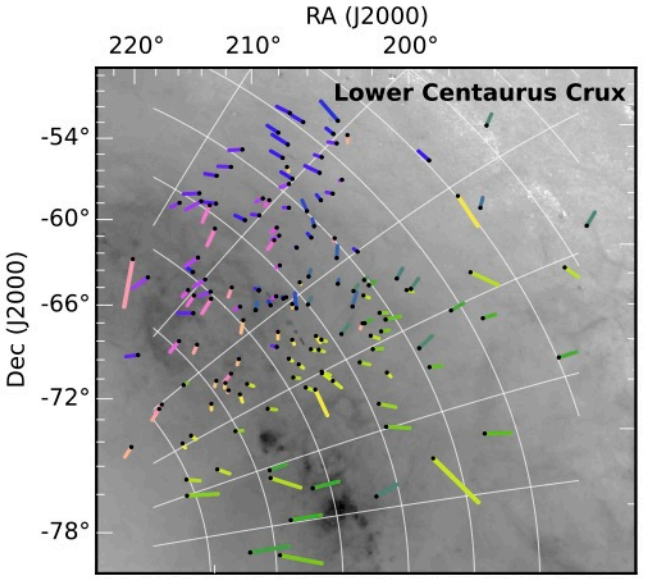
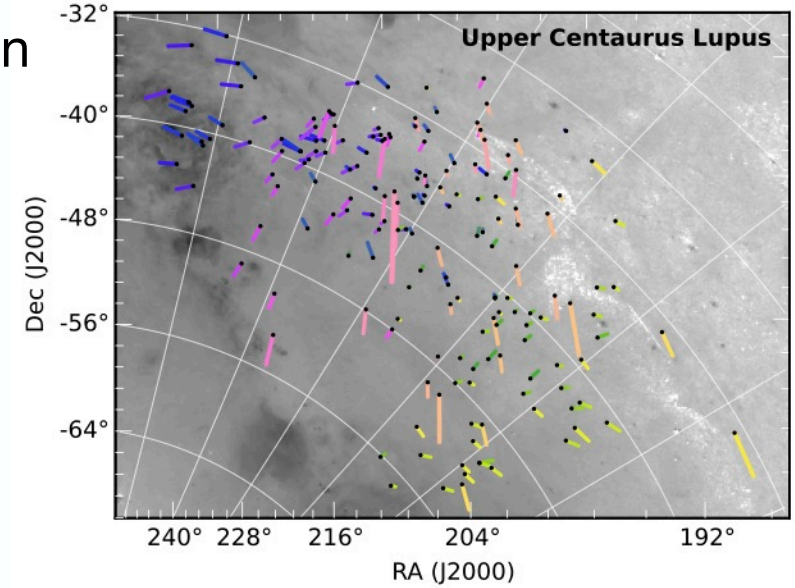
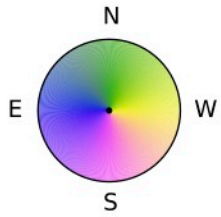
Other methods:

- Blaauw's (1964) linear expansion model
- 3D linear expansion tests
- Corrected proper motion vector maps





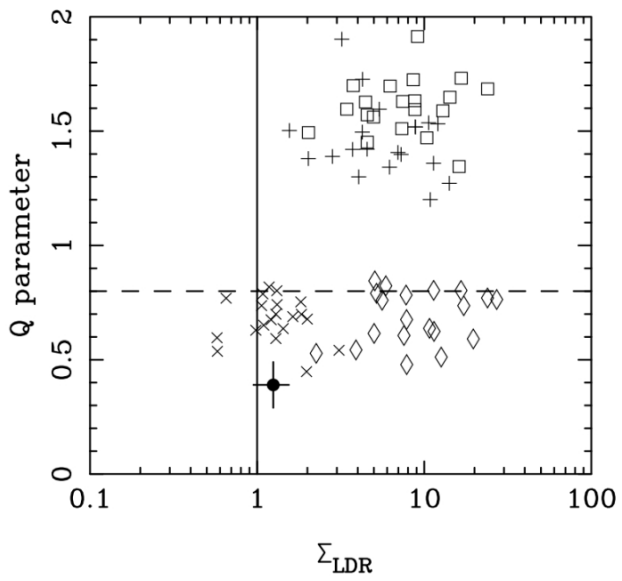


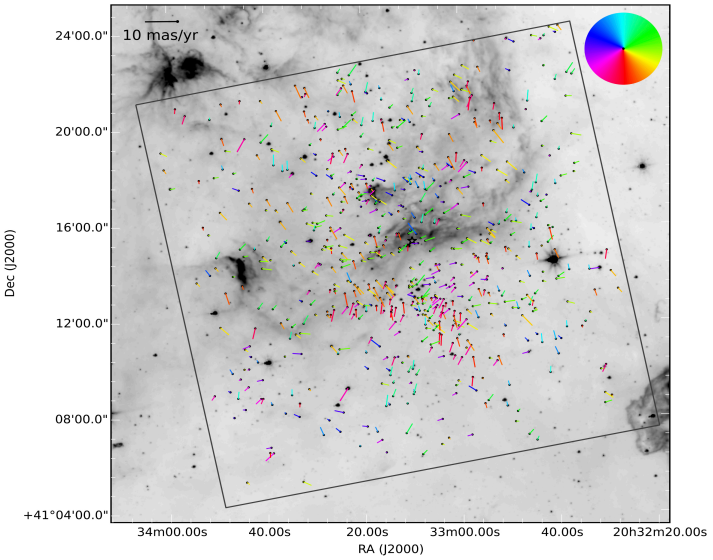


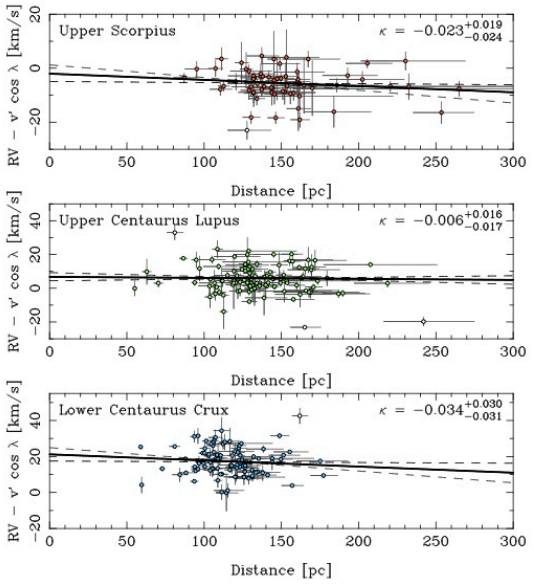
Proper motion vector colour (in RA/Dec)

Wright & Mamajek 2018

Conclusions



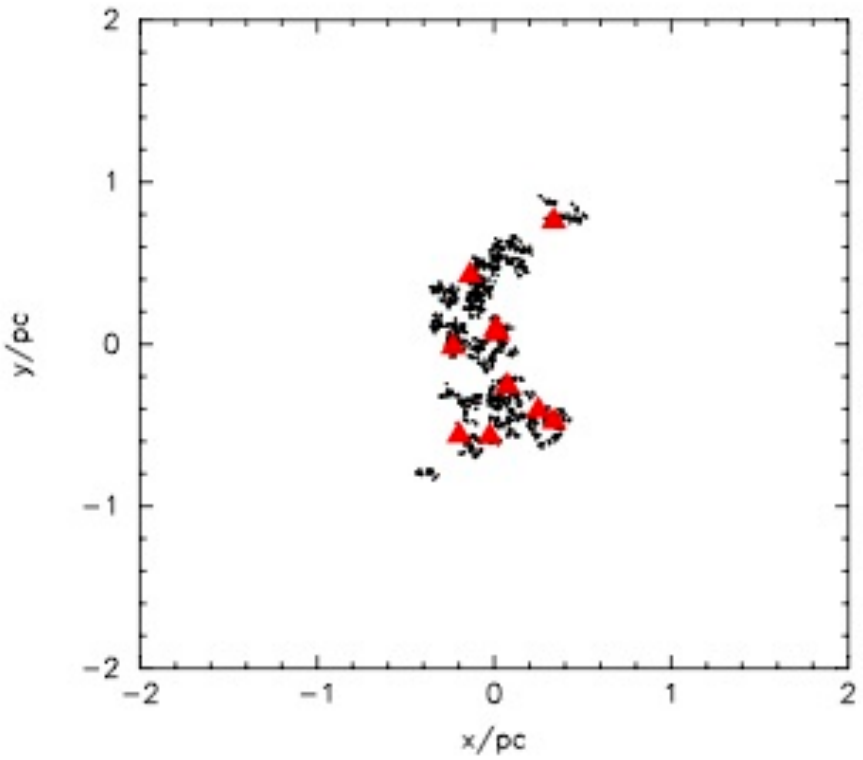


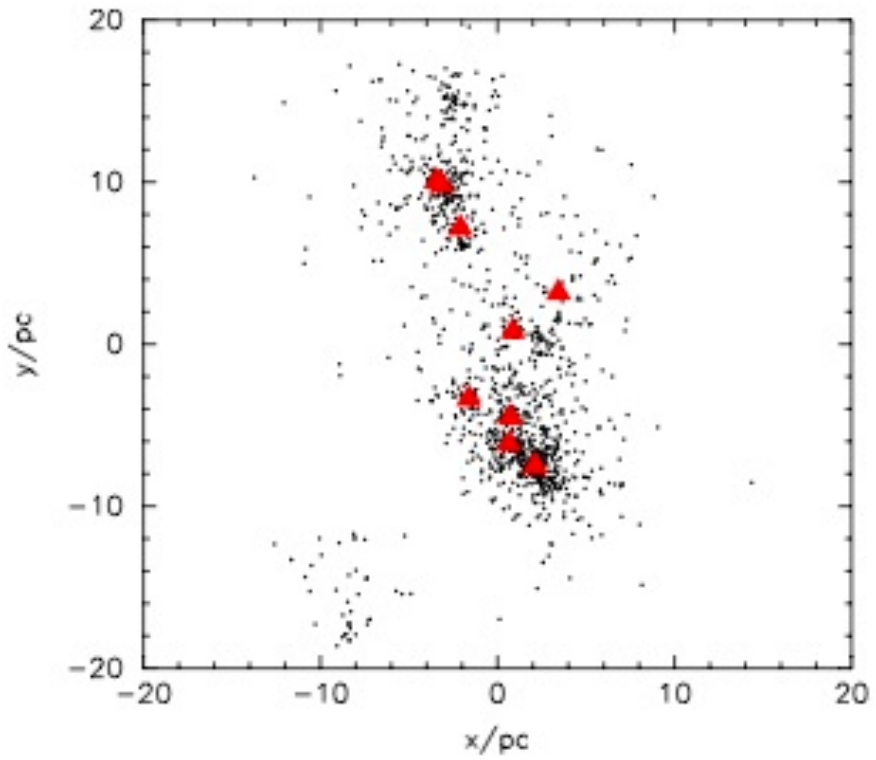


- OB associations long thought to be the expanded remnants of star clusters.
- We find that while OB associations are expanding, they are not expanding from compact initial conditions, but from extended and substructured distributions. This implies:
  - Massive stars in Cyg OB2 **did not form in dense clusters**
  - Residual gas expulsion is **not responsible for dispersing young clusters**
  - Planetary / binary systems in the associations **not born in dense clusters**
  - Associations **not comparable to individual star clusters**

Thank you for listening

Simulating Cluster Evolution





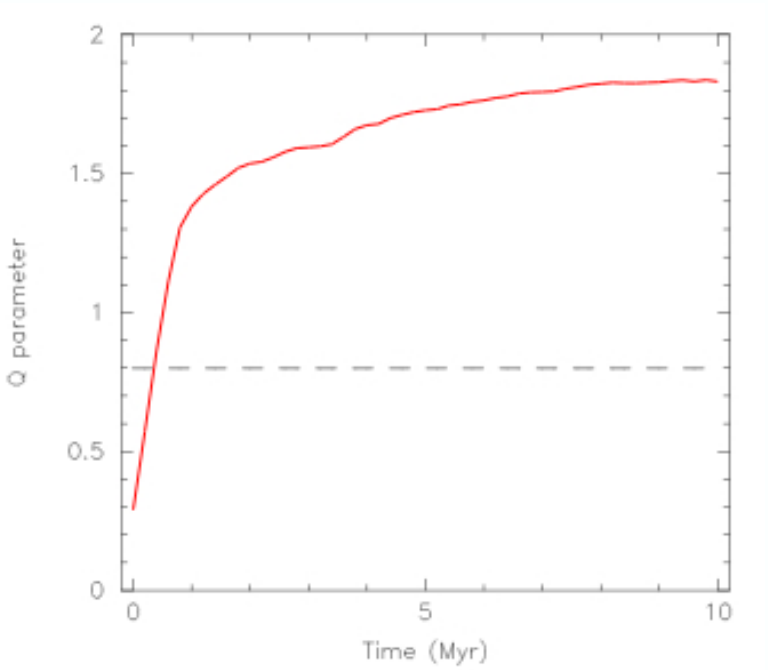
Parker, Wright et al. 2014

Parker & Wright 2016

Simulating Cluster Evolution

- Example: Evolution of the Q parameter (Cartwright & Whitworth 2004) to trace cluster substructure

Sub-virial

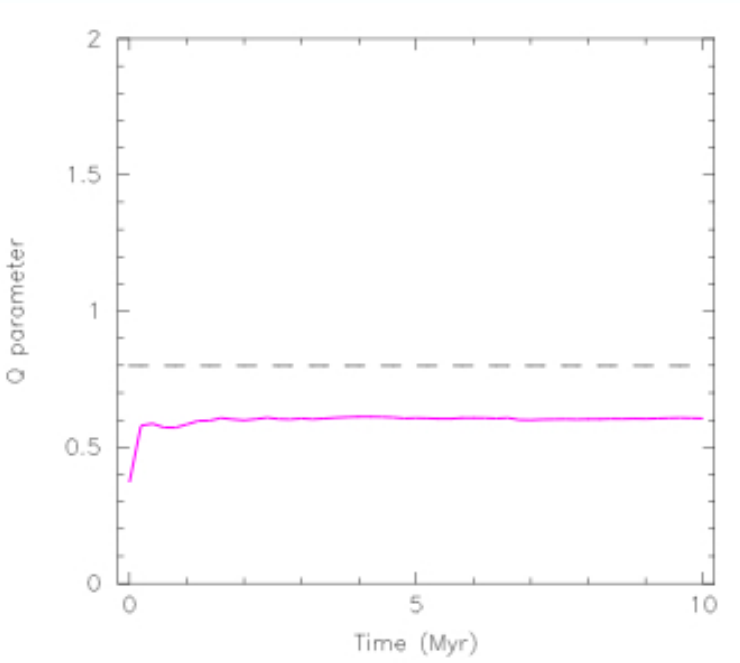


Smooth

Q

Structured

Super-virial



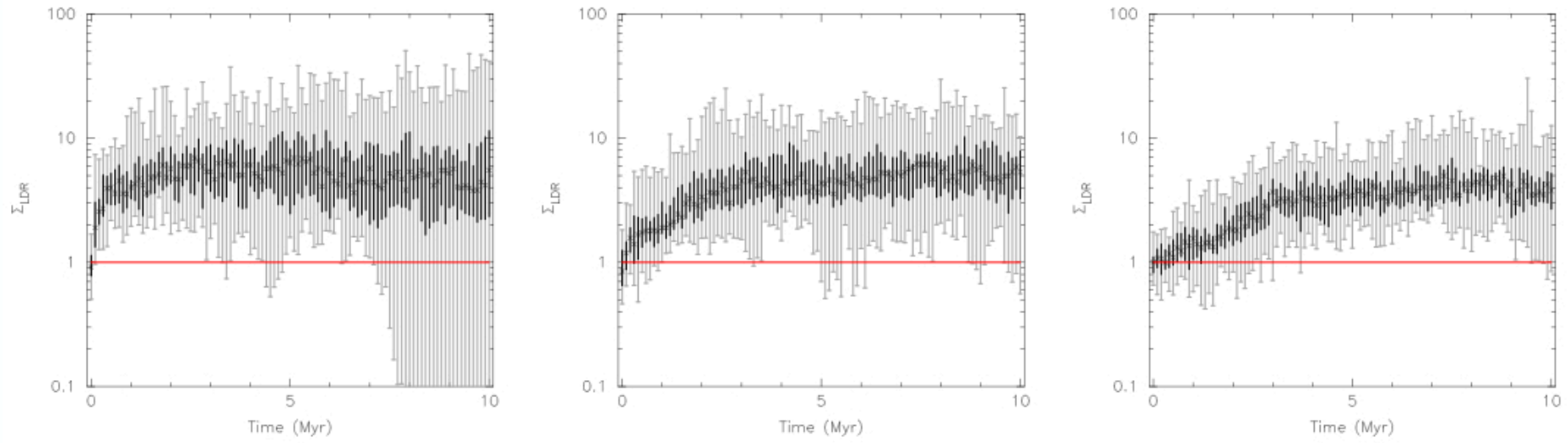
Parker, Wright et al. 2014

Simulating Cluster Evolution

- Example: Evolution of Σ_{LDR} (local surface density ratio) to trace local mass segregation

Sub-virial

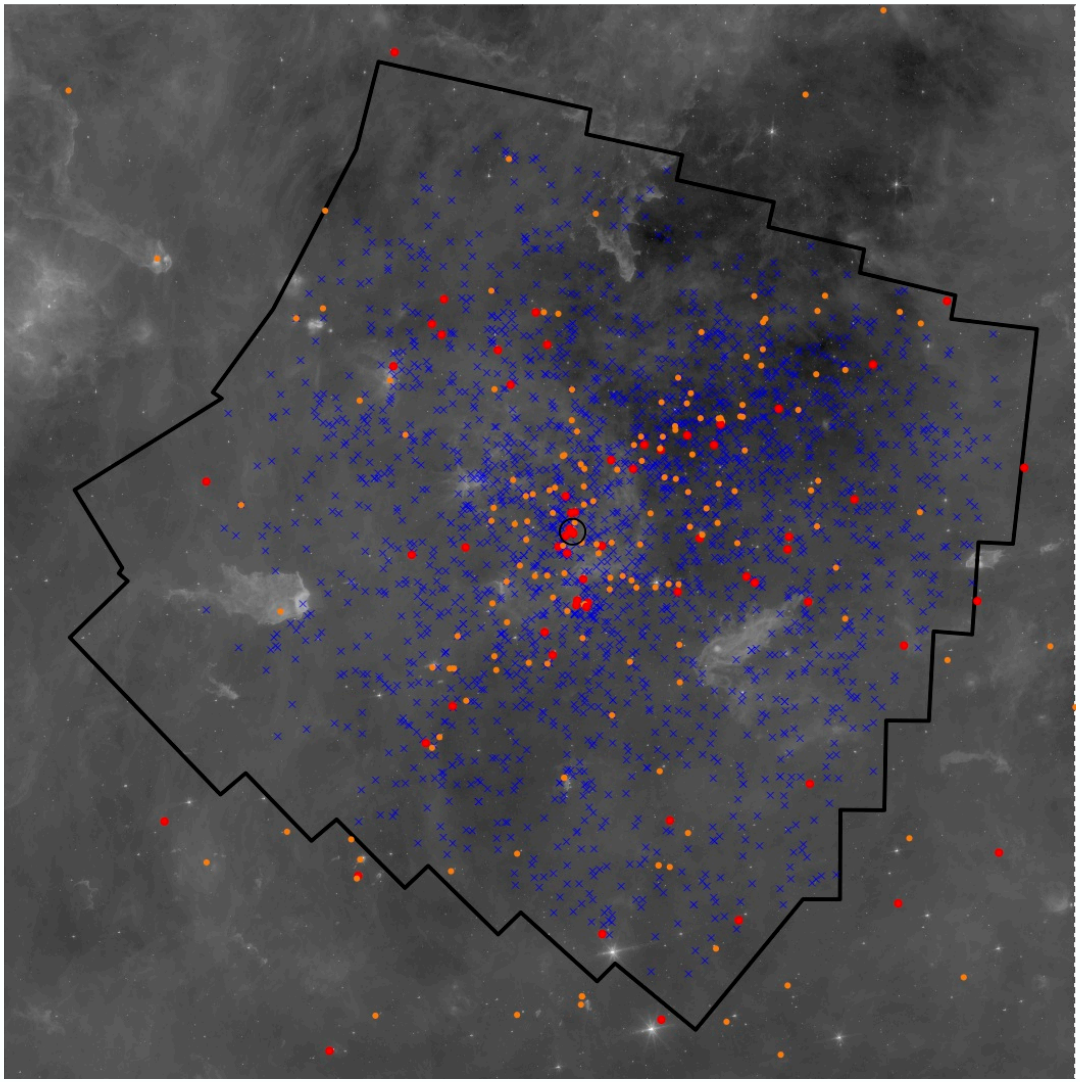
Substructured **Intermediate** **Uniform sphere**



Parker, Wright et al. 2014, see also Allison+ 2009 and Parker+ 2016

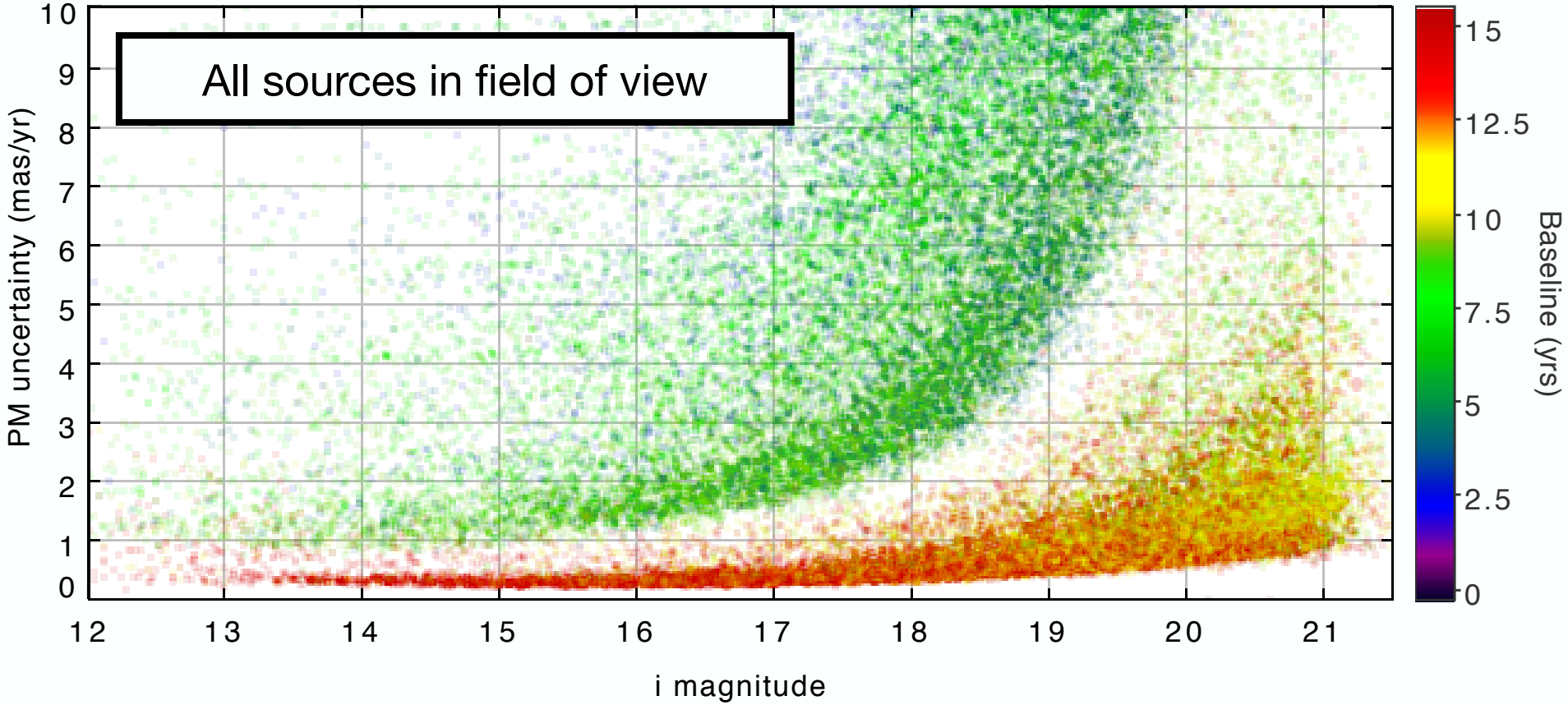
Cygnus OB2 Kinematic Survey

- 3D kinematics: radial velocities and proper motions
- ~4000 X-ray and spectroscopic targets
- RVs from 12-night MMT/Hectospec survey
- PMs from multi-epoch, long-baseline archival images



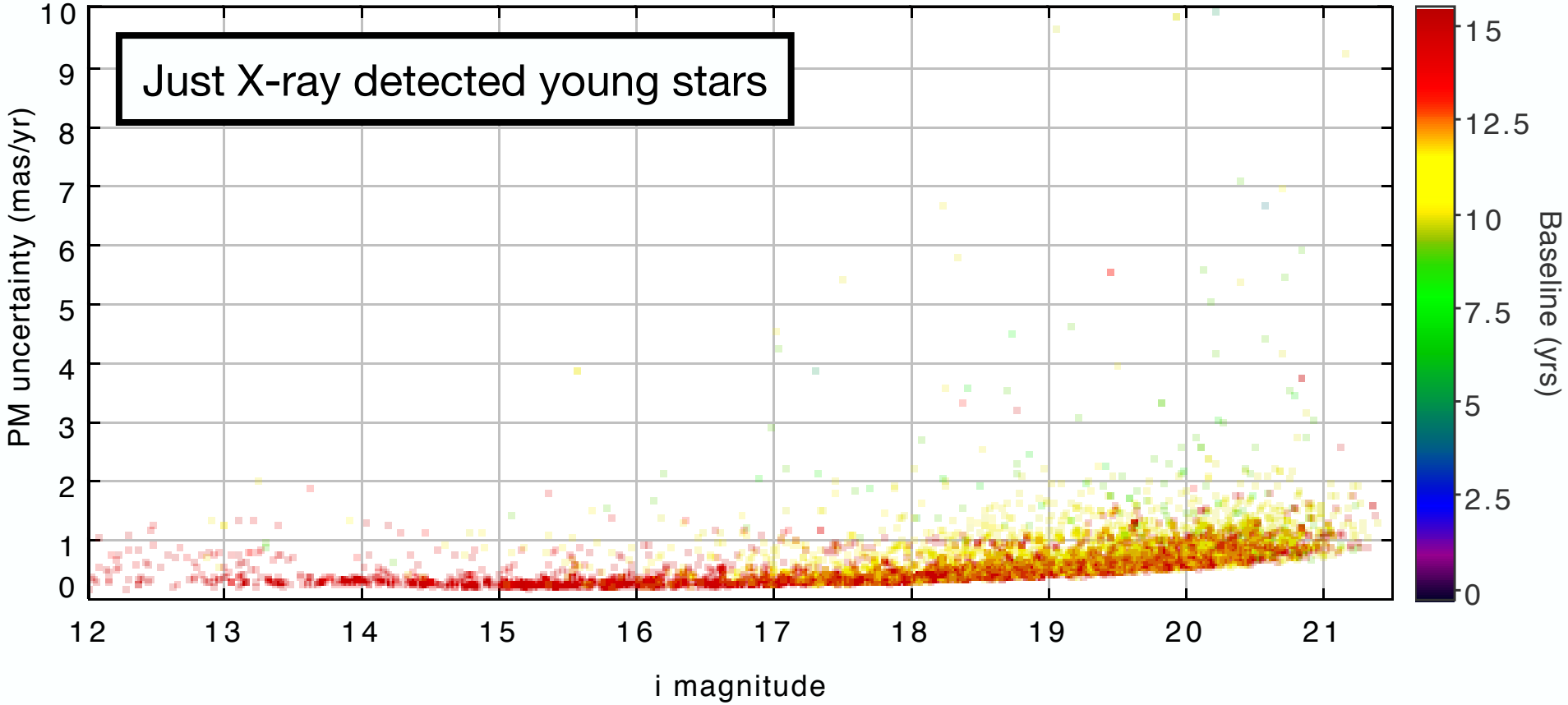
Wright et al. *in prep*

Kinematic Survey: Proper Motions



Wright+ 2016

Kinematic Survey: Proper Motions



Wright+ 2016

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Other methods:

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- 3D linear expansion tests
- Tracing back stellar motions