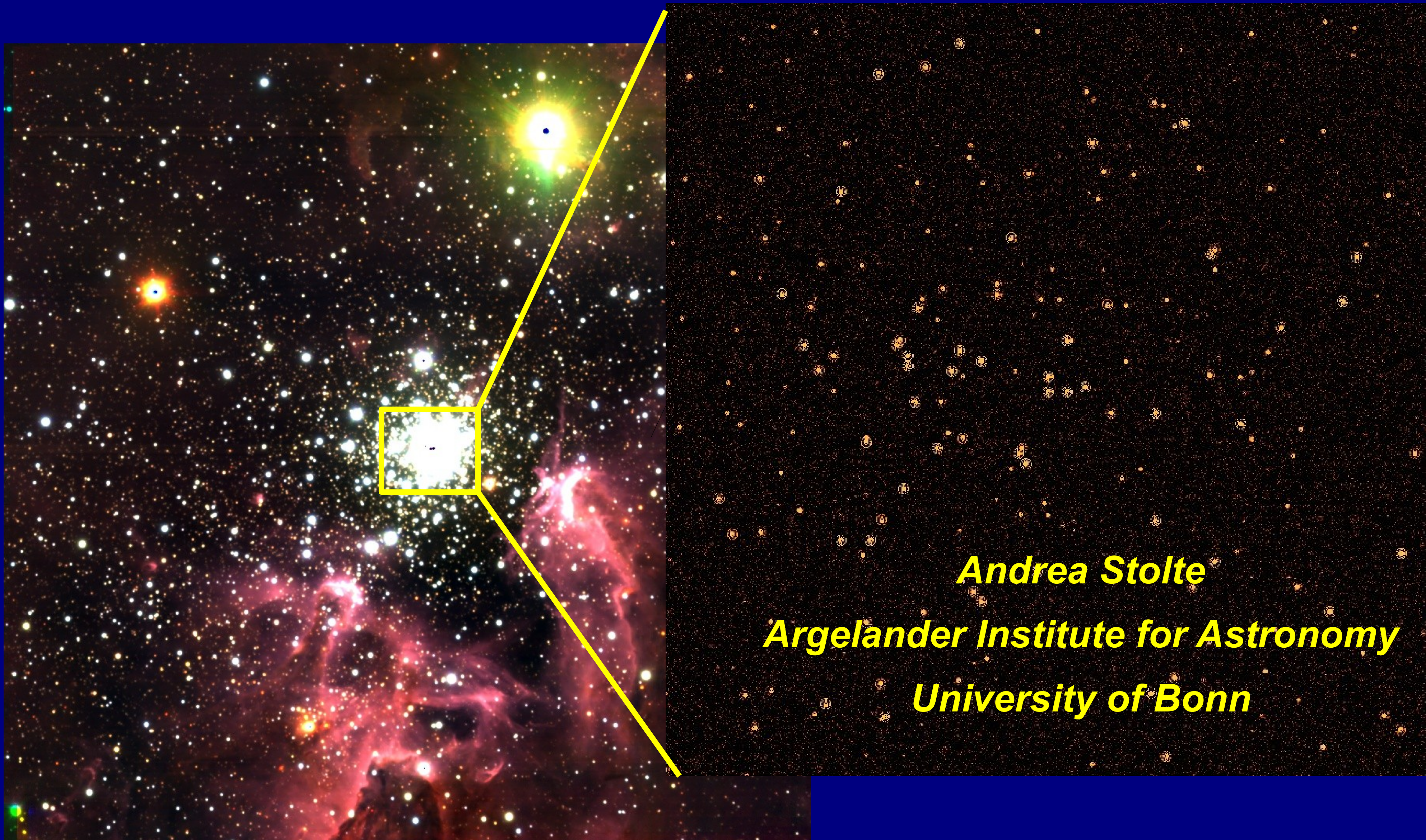
Simulating E-ELT starburst cluster observations with METIS



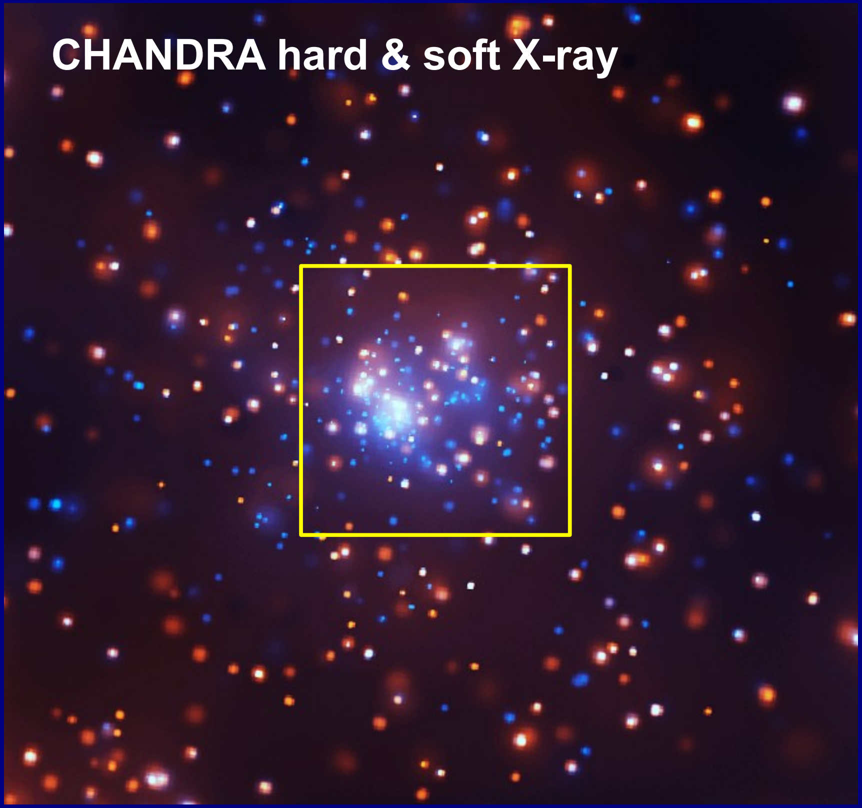
Andrea Stolte

Argelander Institute for Astronomy

University of Bonn

METIS – uniqueness of the mid-IR in starburst clusters

Bik et al. 2012



NASA/CXC/Penn State/L.Townsley et al.

Penetrating the dust & reducing patchy extinction variations in the mid-IR.

METIS – uniqueness of the mid-IR in star-forming regions

NASA/JPL/A. Marston (ESTEC)

Penetrating the dust & detecting the embedded population.

METIS – uniqueness of the mid-IR in star-forming regions

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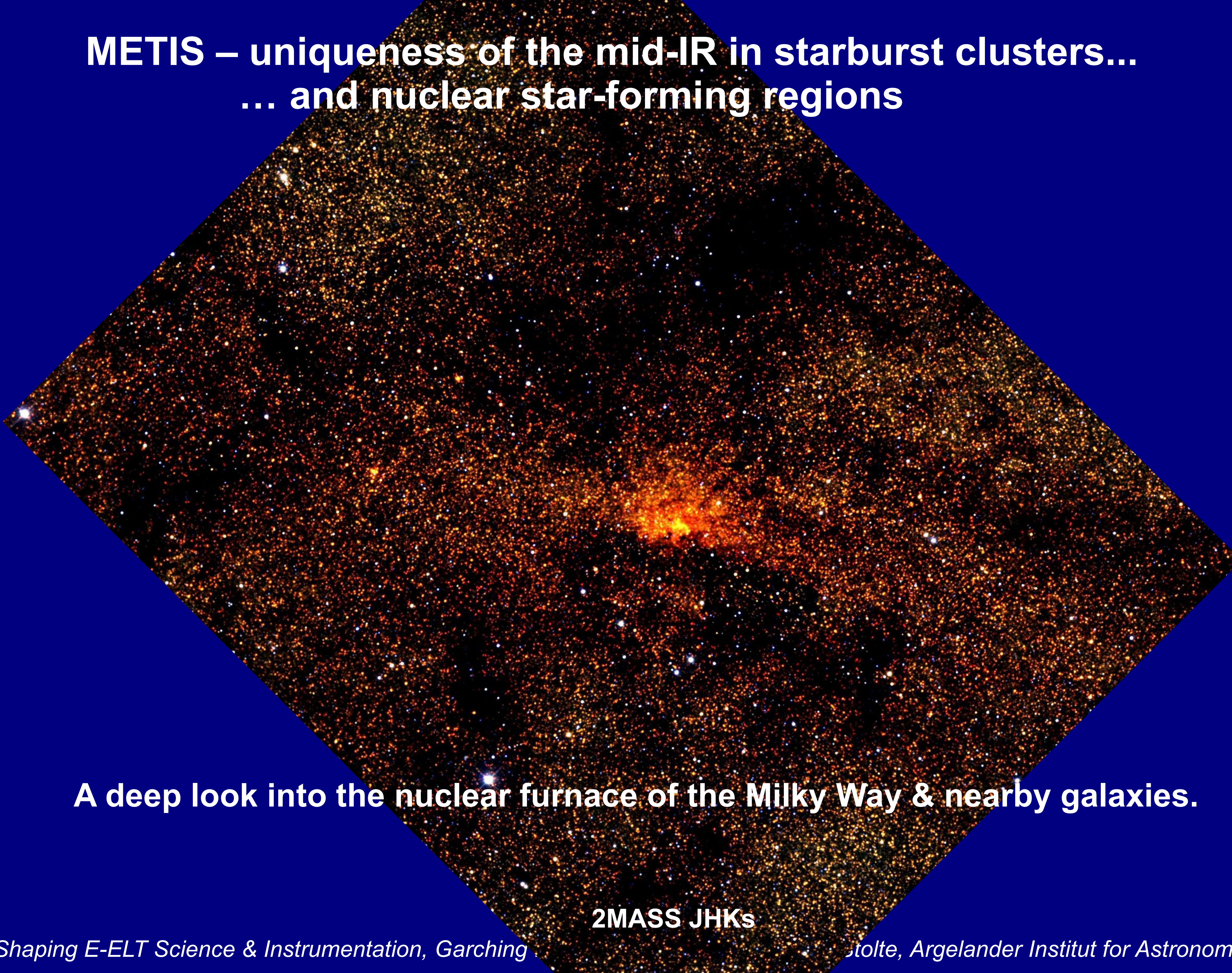
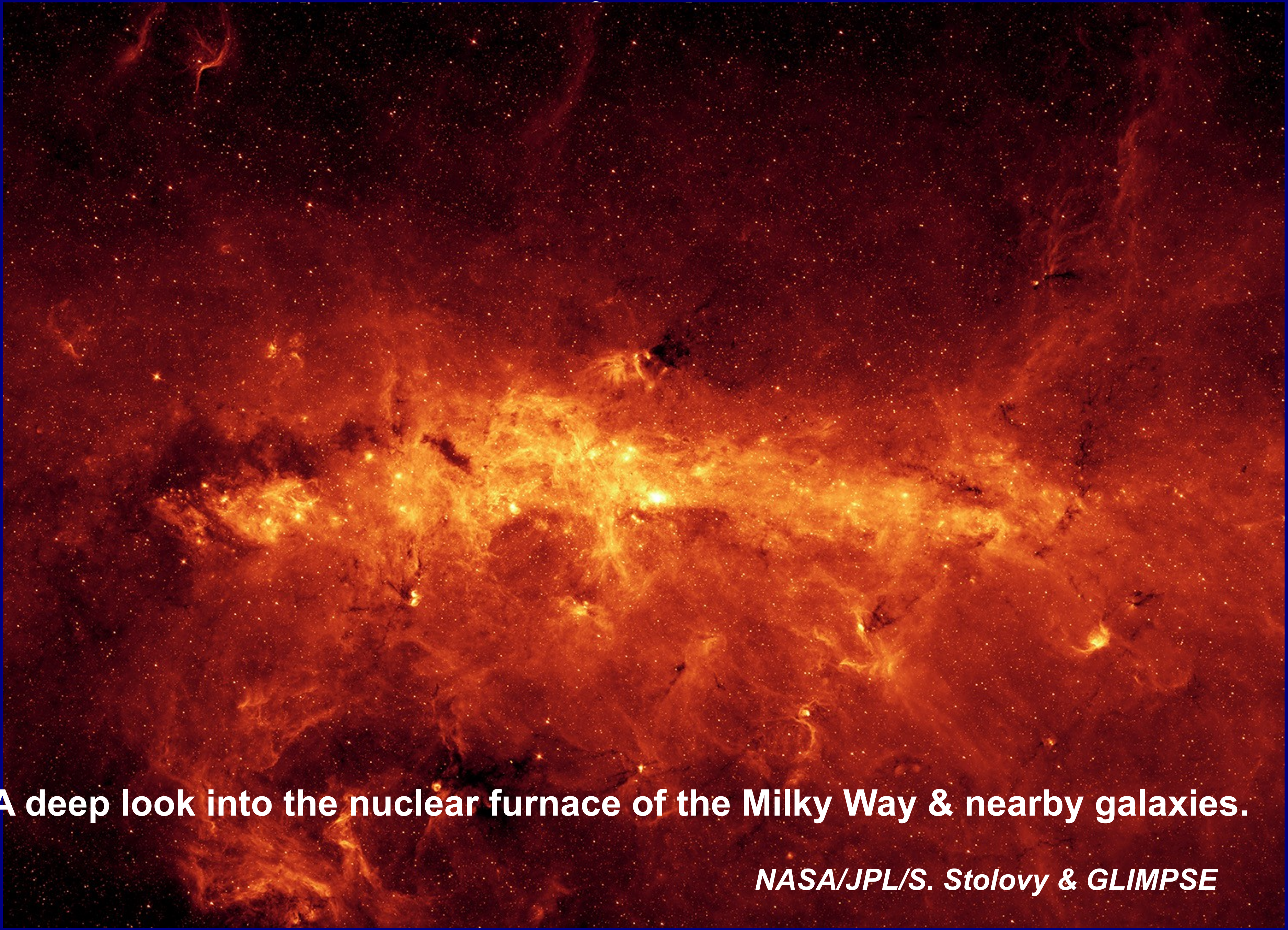
METIS – uniqueness of the mid-IR in starburst clusters...
… and nuclear star-forming regions



A deep look into the nuclear furnace of the Milky Way & nearby galaxies.

METIS – uniqueness of the mid-IR in starburst clusters...



METIS – uniqueness of the mid-IR in starburst clusters...
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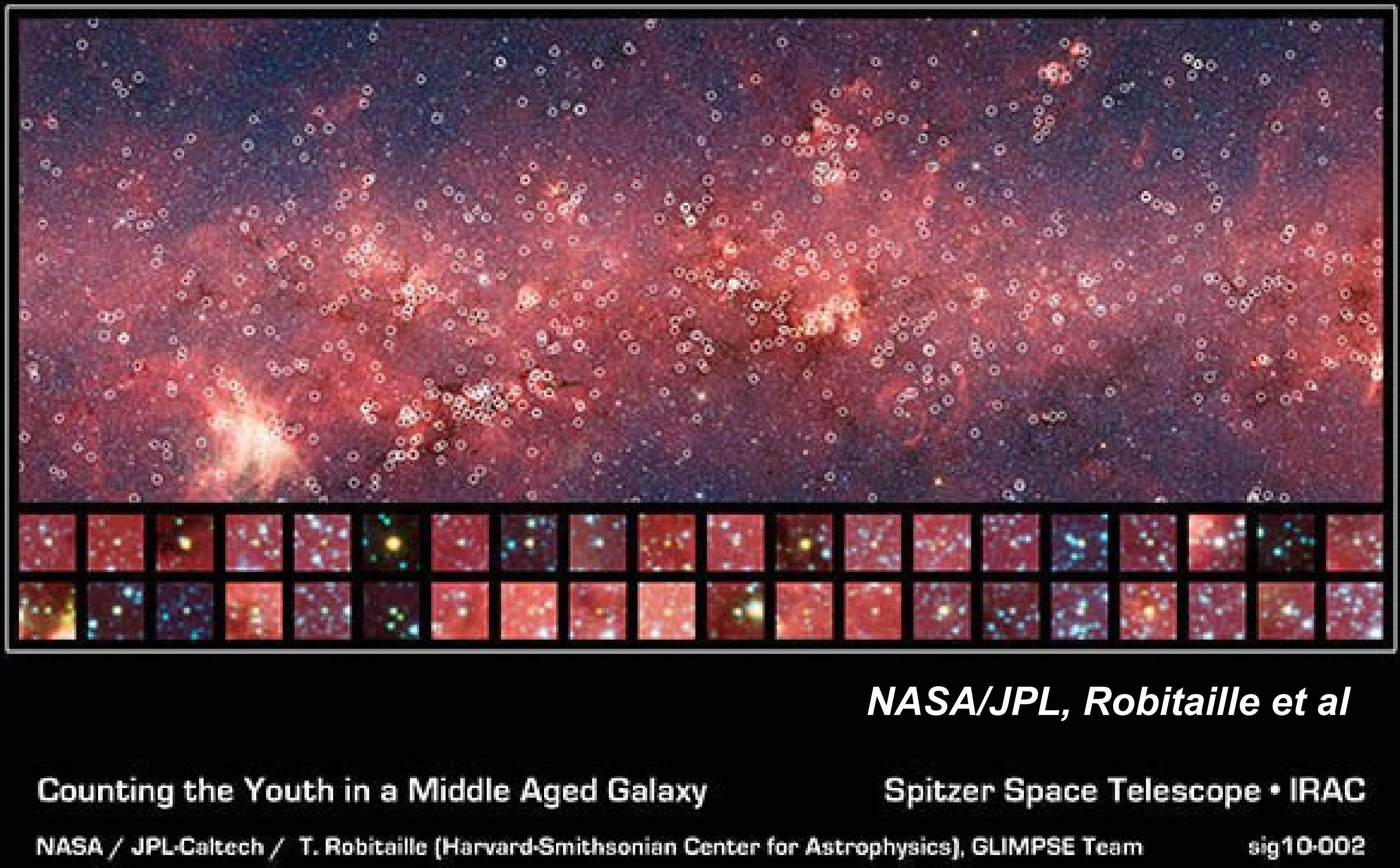
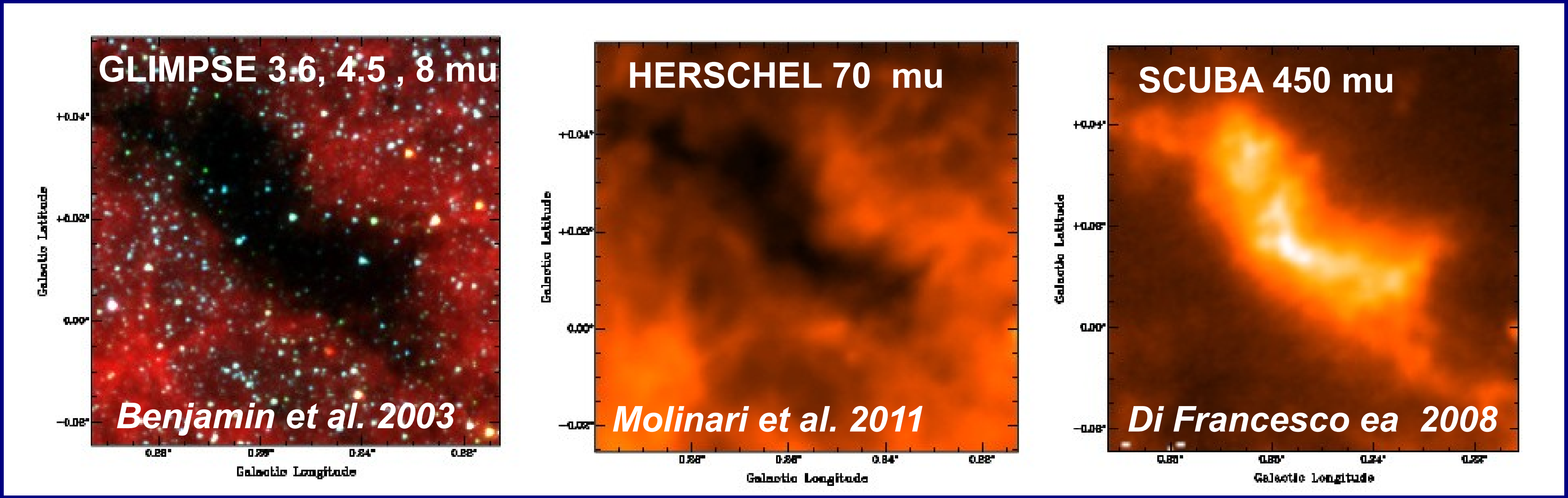


NASA/JPL, Robitaille et al

Understanding the nuclear star formation process...

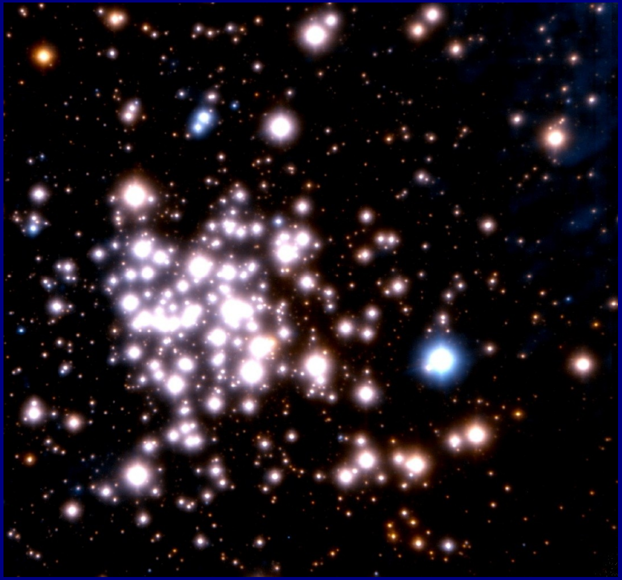
METIS – bridging forming & formed clusters

"A Molecular Cloud Progenitor of an Arches-like Cluster"



Longmore et al. 2012

How do we get from here...



….to here?

METIS – bridging forming & formed clusters

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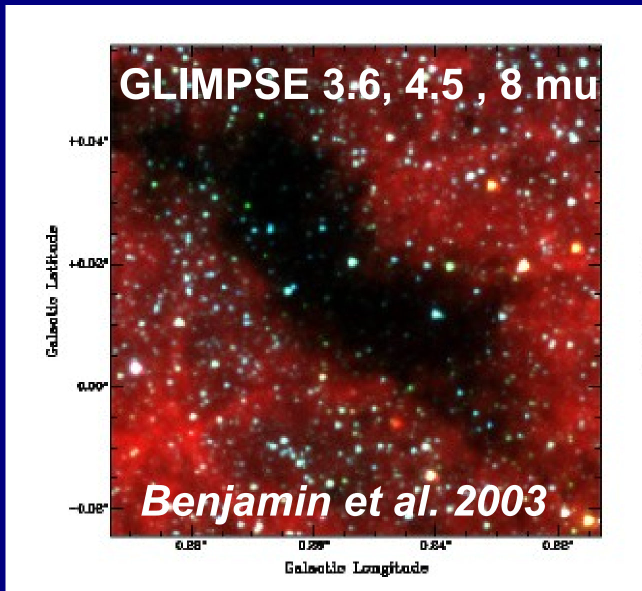
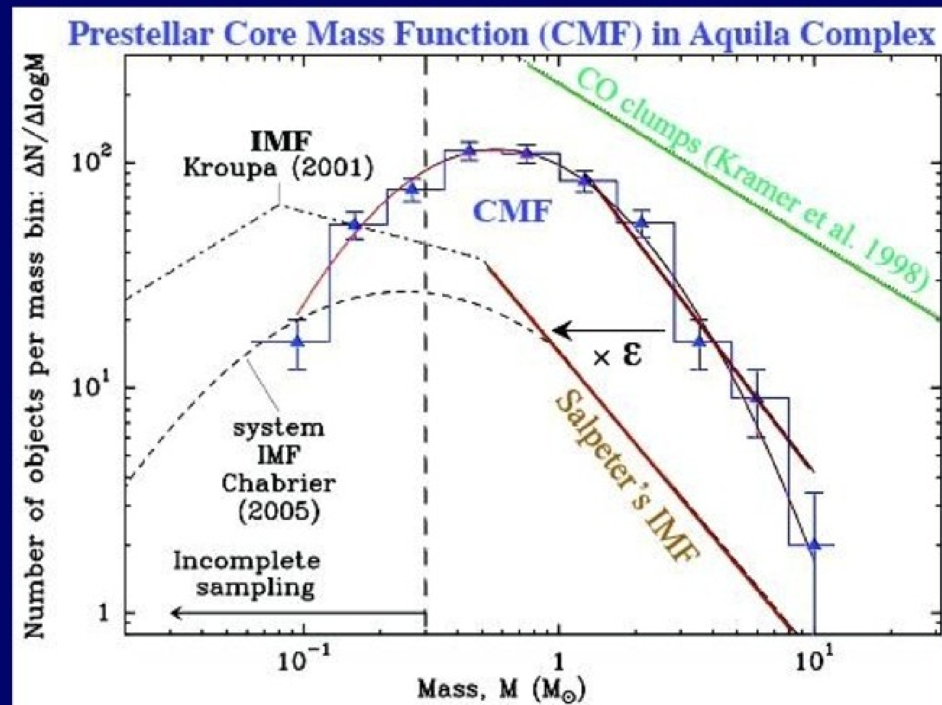




typical ε ~ 0.3 = 30% of mass in cores ends up in stars

Andre et al 2010

How do we get from here..

….to here?

Courtesy D. Ward-Thompson

Simulating E-ELT starburst cluster observations with METIS
Motivation

The idea:

* Understand E-ELT & METIS performance in what we call a
Crowding limited field today

* Define the new science questions that can be uniquely addressed

* Define the distance scale

* Answer questions such as:

- What can be done with METIS that could not be done before?

- Which sensitivity do we ideally need, which do we realistically get?

- What do we gain in the mid-infrared regime?

→ METIS simulator developped in Leiden: B. Brandl, E. Schmalzl, J. Meissner

The METIS starburst cluster science case

Science Goals

* ***3D view***: proper motion of individual cluster members → Ric Davies

* ***densely packed***: resolving the most compact clusters in nearby galaxies

  → Bernhard Brandl

* ***deep & young***: deeply embedded clusters forming from dense cores

* ***faint & cool***: free-floating low-mass objects (planets?) &
  variations in the substellar IMF

  → Ignas Snellen
  → Wolfgang Brandner

Star cluster simulations – Technical Assumptions

METIS & E-ELT

Pixel scale: 6.4 mas/pix

Filter characteristics: Lprime (3.8 micron, bandwidth 0.65 micron)

Telescope effective M1 area: 976.29 m^2

Zeropoint = 25.0 (arbitrary)

Sky level & noise

Sky noise Paranal Lprime = 3.0 mag/arcsec^2 ***pessimistic?!***

Sky flux = 6×10^8 photons/s/arcsec^2 ~ 3×10^4 counts/s/6.4 mas pix^2

Poissson noise added to sky

All other noise sources (PSF/stellar photon noise) ignored

Star cluster simulations – Technical Assumptions

METIS PSF

Simulated with METIS PSF simulator

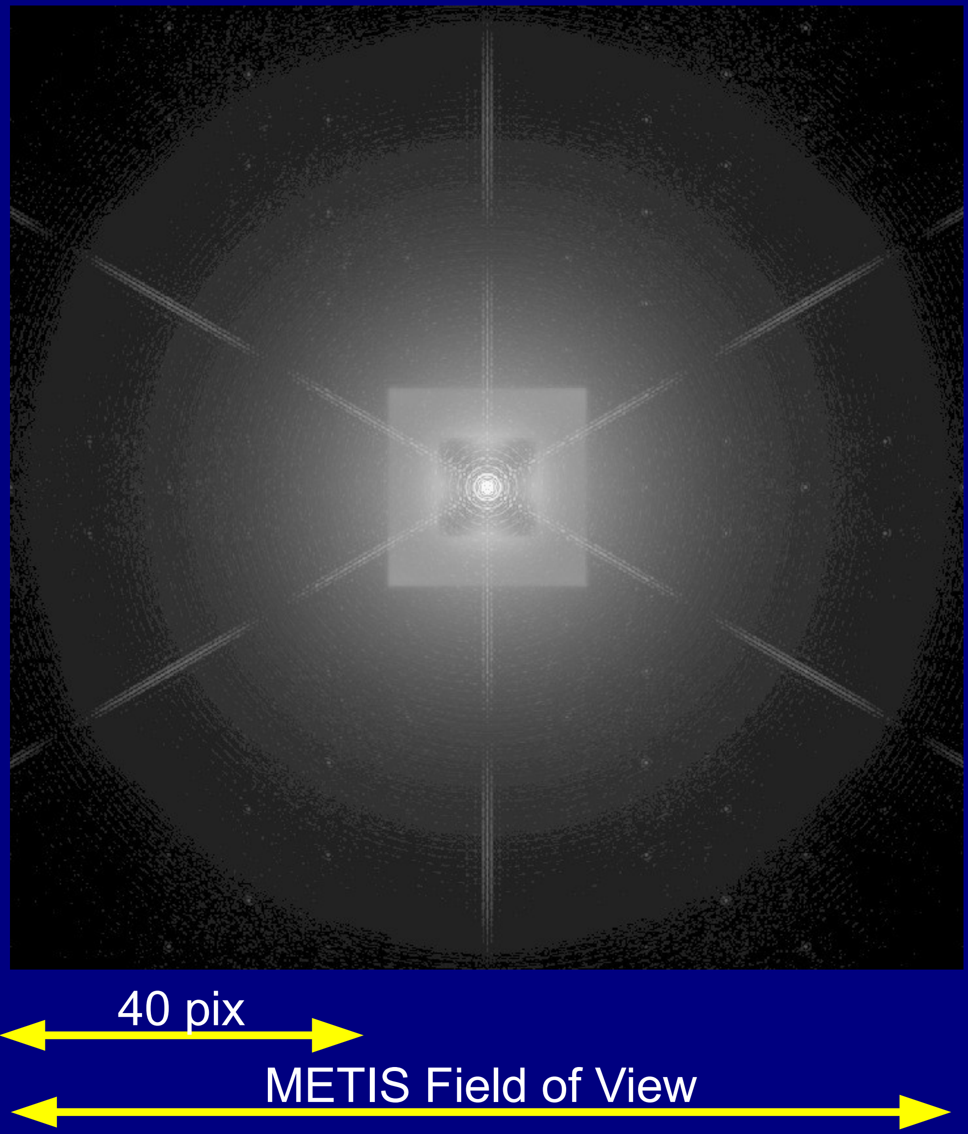
→ Remko Stuik, Stefan Hippler

Central peak plus 1st Airy ring

63% of total flux

Stellar flux scaled to the peak value

4.4% of total flux



Star cluster simulations – Technical Assumptions

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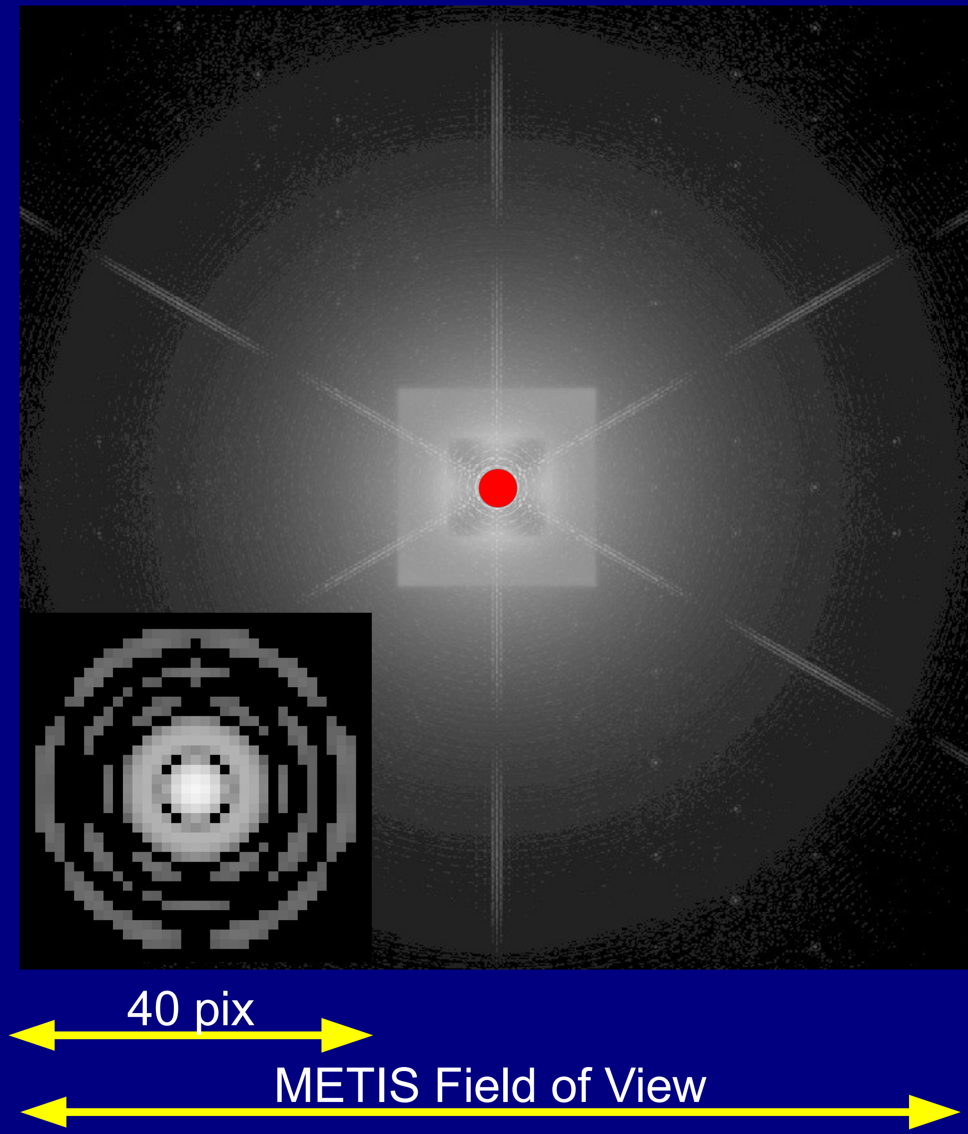


Star cluster simulations – Science Assumptions

NGC 3603 – compact cluster template

- resolved starburst cluster
  in the Milky Way

- realistic “mixed age” population

- current limit: L < 15 mag

- numerous data sets:

  ISAAC, NACO, HST/WFPC2

Star cluster simulations – Science Assumptions

NGC 3603 – what we need:

- current limit: L < 15 mag

→ many cluster stars missing

Faint & pre-main sequence:

- filled in K-L colour by populating a 2 Myr isochrone

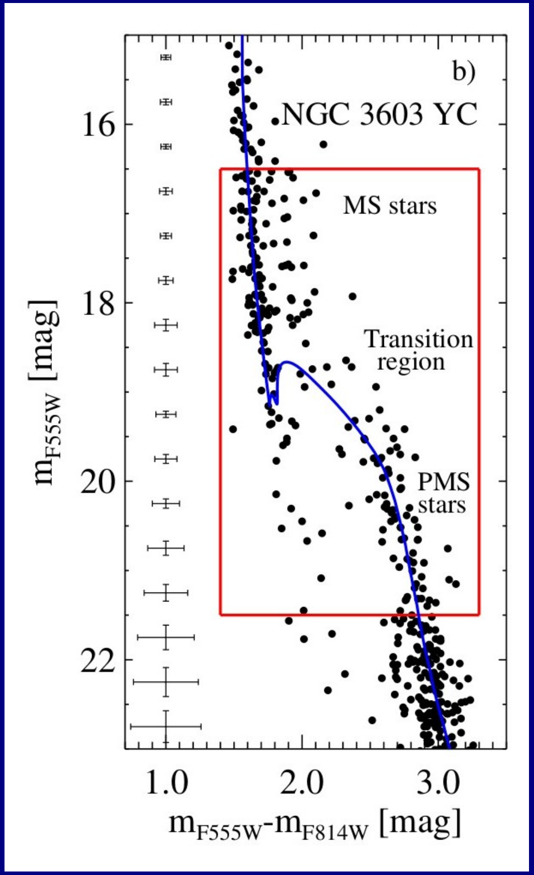
- filled in central are & saturated high-mass stars

→ HST/WFPC2 _optical_

→ vast assumptions about colours!!!

Rochau et al. 2010

Core region



Kudryavtseva et al. 2012

Star cluster simulations – Science Assumptions

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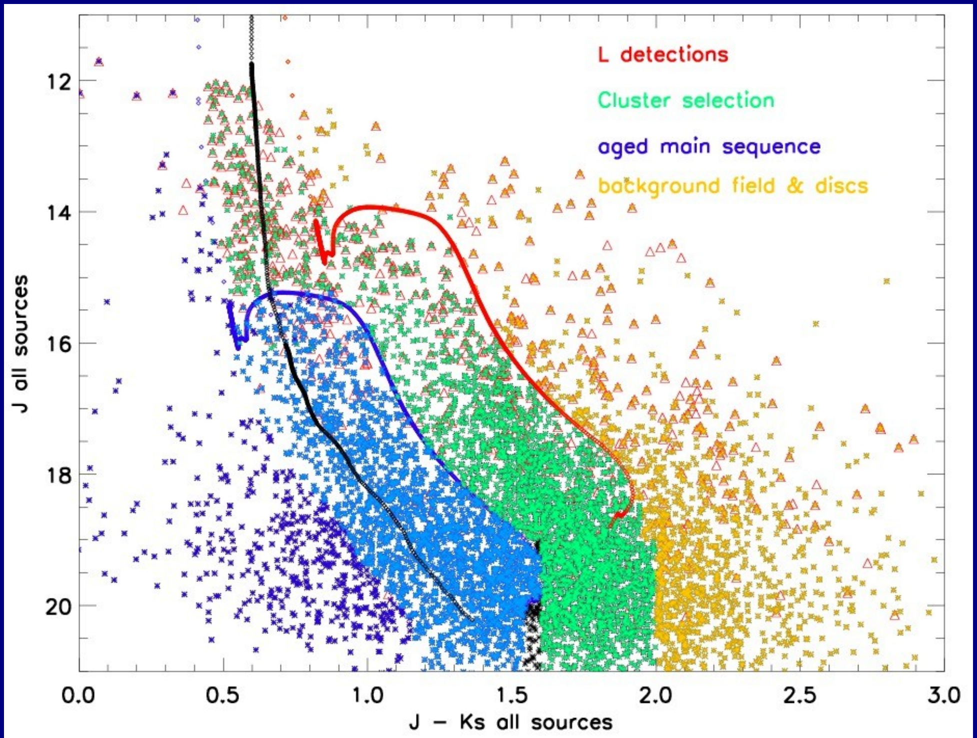

Star cluster simulations – Science Assumptions

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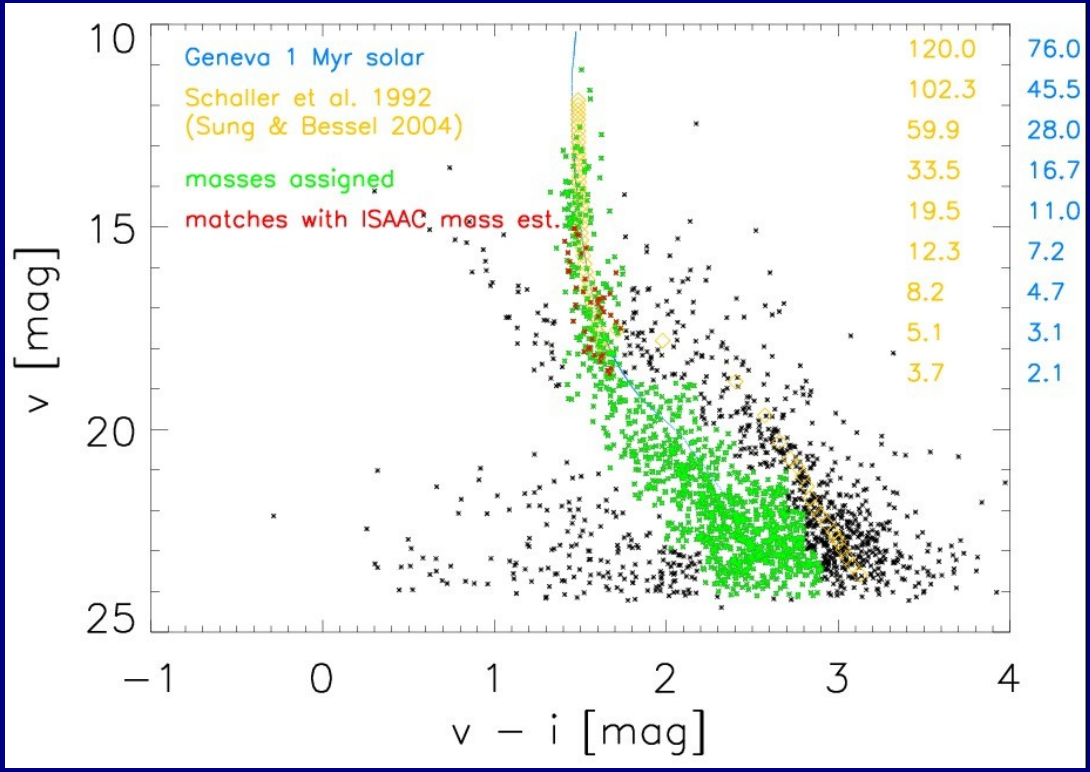
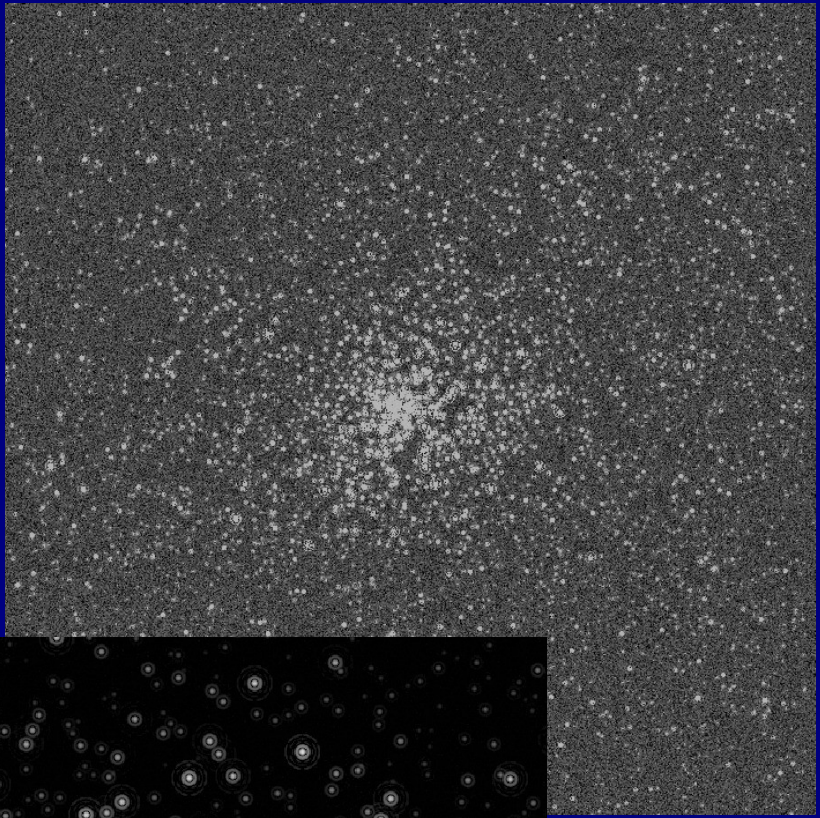
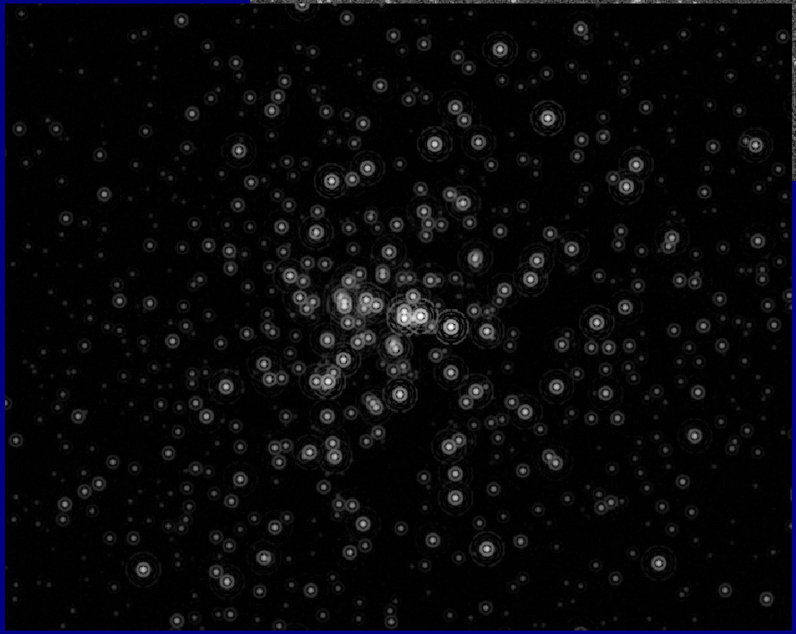


Having L-banded all these stars, what do we get?

Star cluster simulations – Science Results





<u>NGC 3603 – simulation:</u>

Case 1: Milky Way @ 6.3 kpc

9.5 < L < 19.5 mag

(11.6 < Ks < 20 mag)

Not yet scaled to METIS resolution!

<=> **<u>8 x denser cluster</u>**

<u>Science goals:</u>

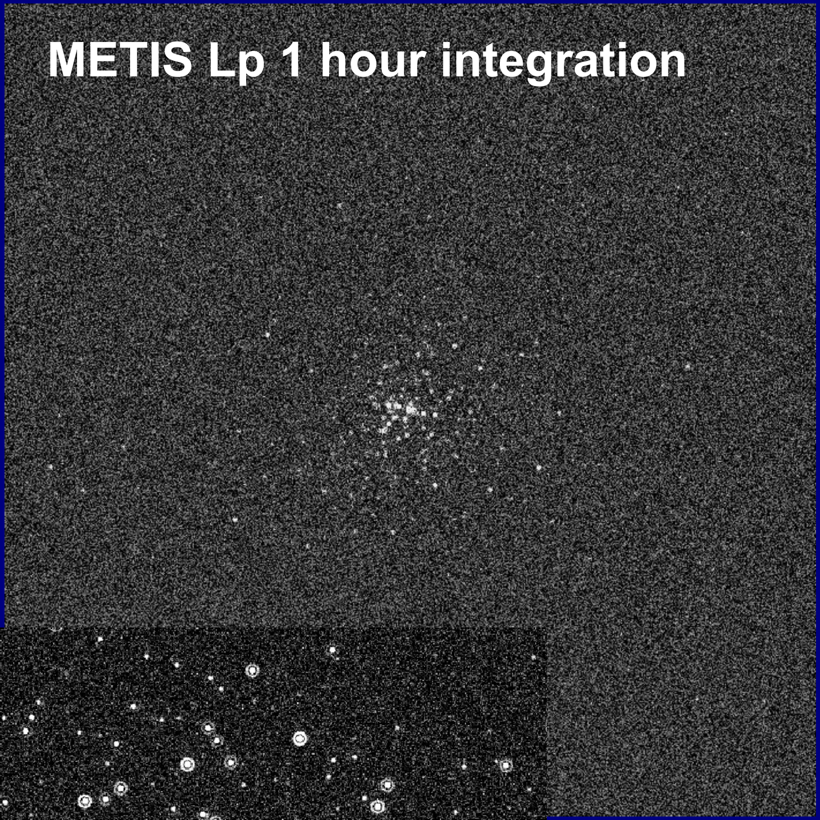
- orbits of individual stars
  In dense clusters:

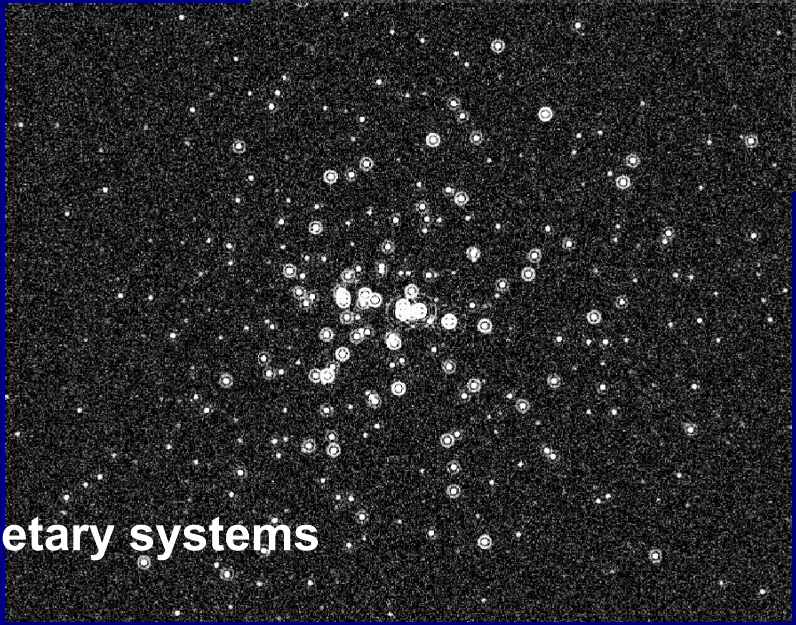
  Starbursts & globulars

- the "far side" of the Milky Way

=> deeply embedded systems & clusters with high foreground extinction

Star cluster simulations – Science Results





NGC 3603 – simulation:

Case 2: LMC @ 48 kpc

13.0 < L < 23.5 mag

Scaled to METIS resolution

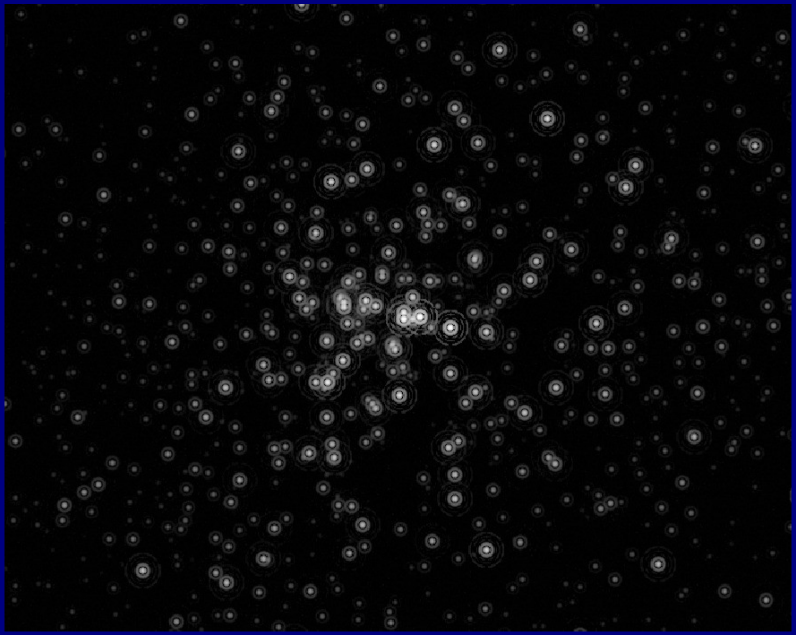
Science goals:

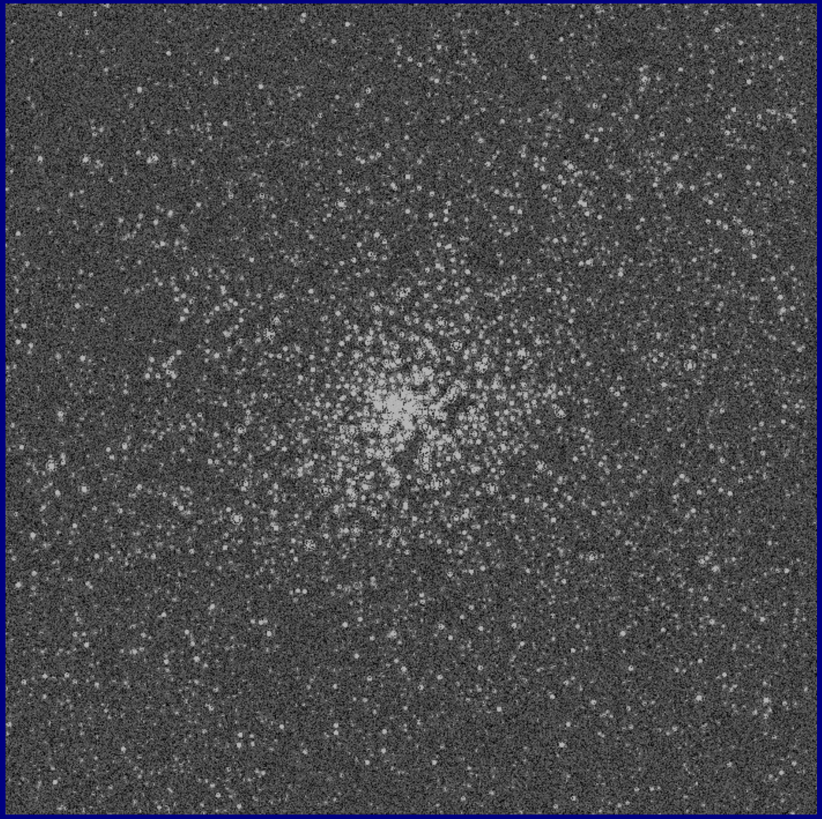
- resolving dense clusters in nearby galaxies
- what is the highest mass star?
- IMF & star formation process
- **disc survival & existence of planetary systems**

Star cluster simulations – Science to be done...

Back to the Milky Way.......

a real NGC 3603 with METIS





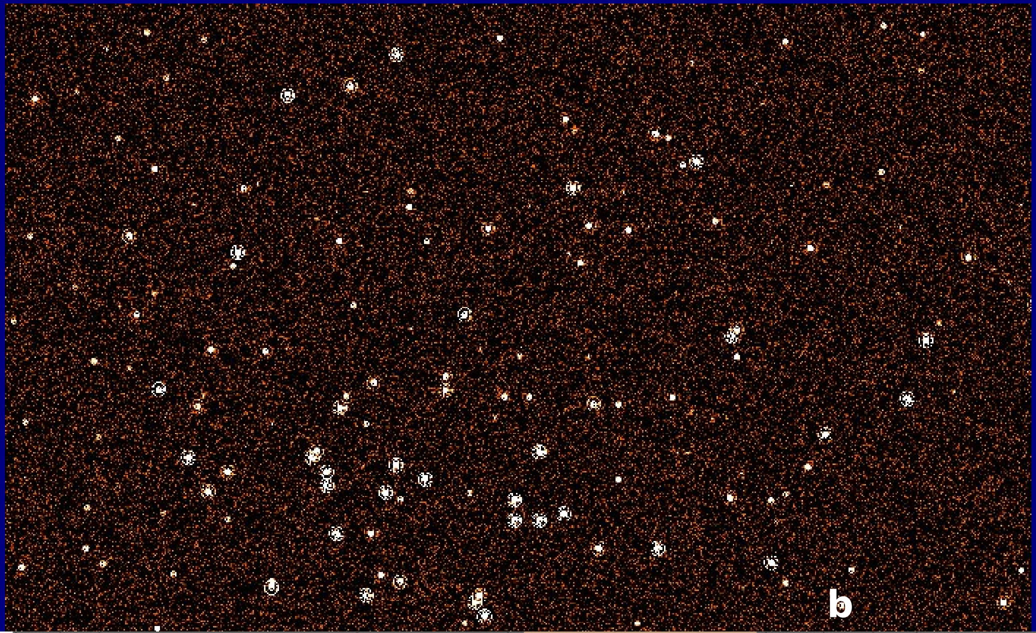
Star cluster simulations – detecting brown dwarfs & planets

NGC 3603 – simulation:

Case 2: Milky Way @ 6.3 kpc

9.5 < L < 19.5 mag

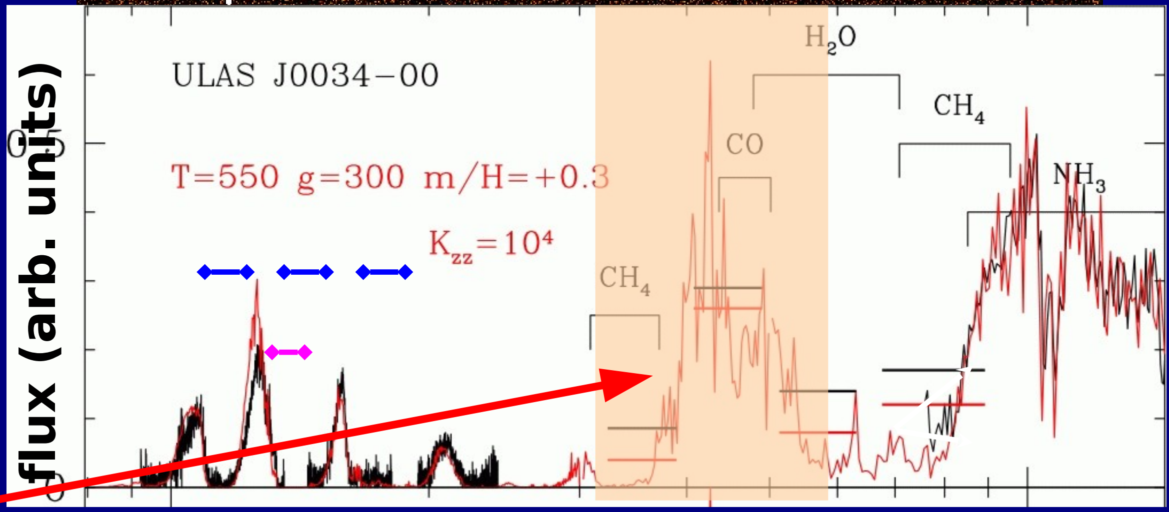
Scaled to METIS resolution



Science goals:

- **detection of brown dwarfs & free-floating planets**
- **disc survival & existence of planetary systems**
- **substellar mass function**

METIS has the ideal bands to detect low-mass objects!



Leggett et al. 2009

Star cluster simulations – resolving Milky Way clusters

NGC 3603 – simulation:

Case 2: Milky Way @ 6.3 kpc

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- **detection of brown dwarfs & free-floating planets**
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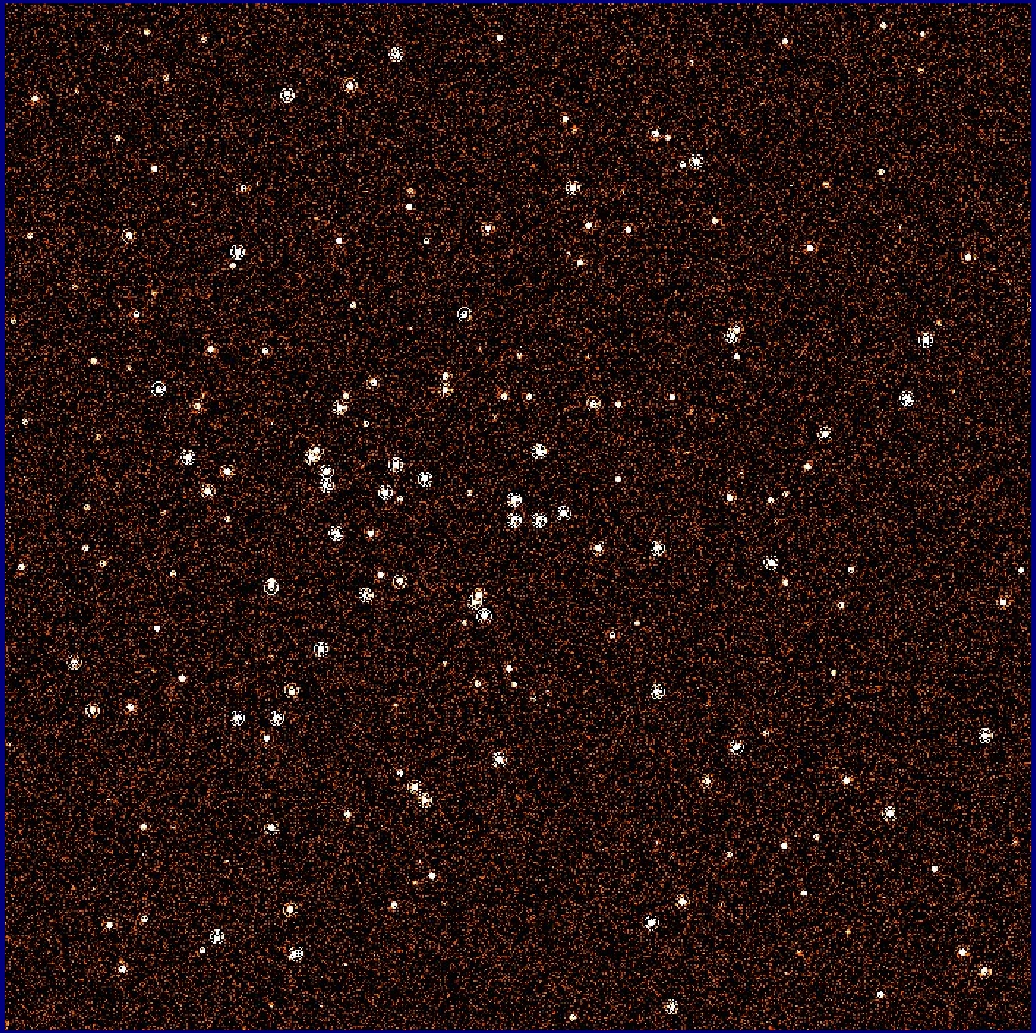


Now, this is a really fluffy cluster... so let's include some faint objects!

Star cluster simulations – adding the faint population

Trapezium cluster:

- detected faint PMS stars & brown dwarfs *Muench et al. 2002*

Observed at Orion: 1.6 < Lp < 13.7 mag
4.4 < Ks < 18.6 mag

ESO, M. McCaughren

At NGC 3603 distance:

5.8 < Lp < 19.5

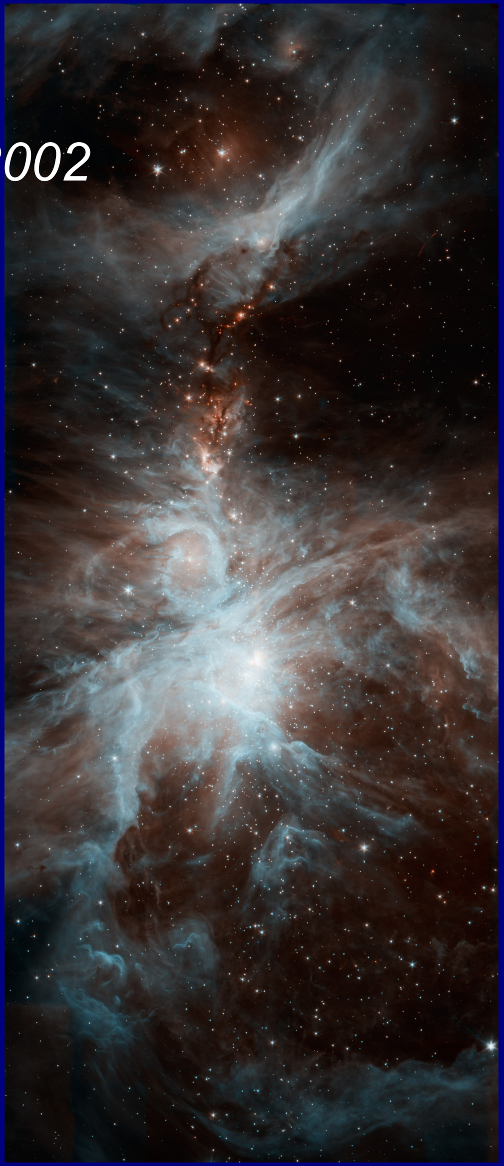
10.2 < Ks < 24.4

Assumption:

2 Myr PMS isochrone

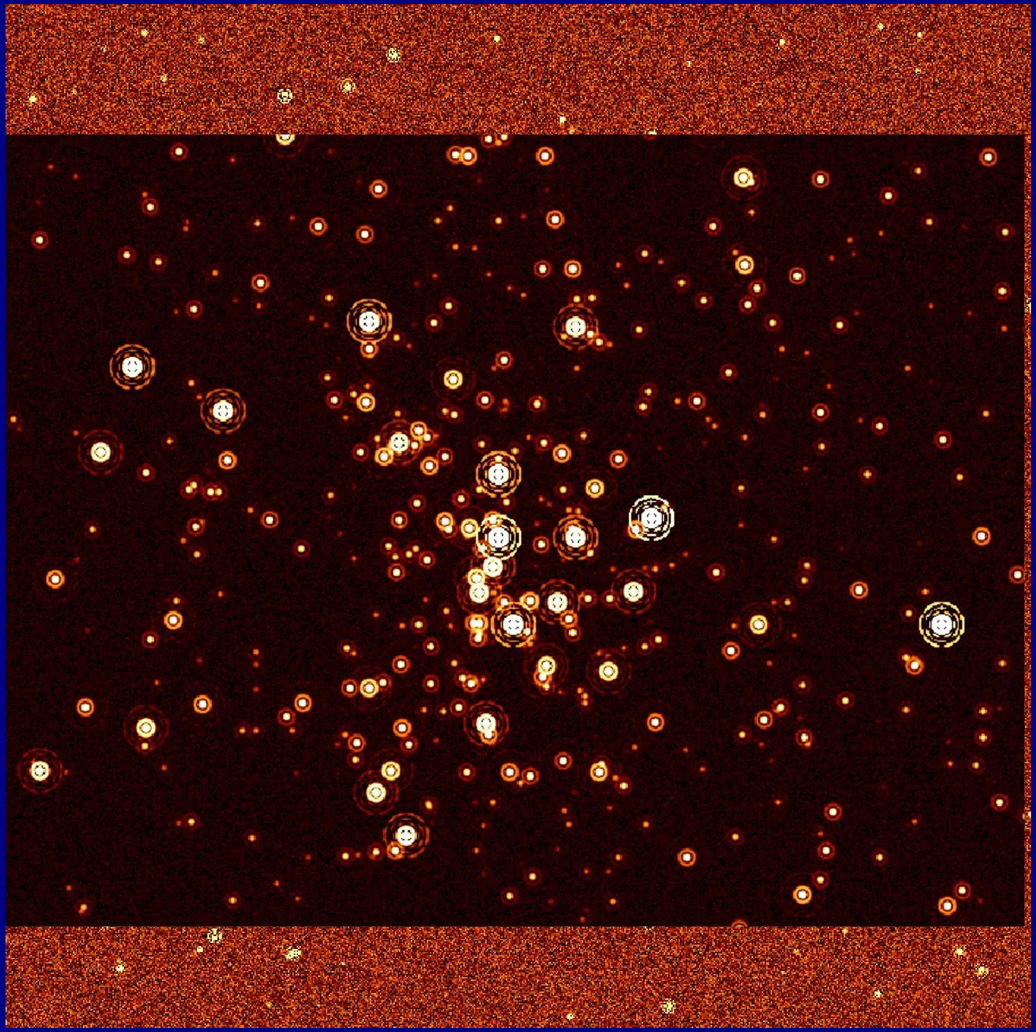
K – L (3603) = 0.3 mag

Tognelli et al. 2012



NASA, JPL, J. Stauffer

Star cluster simulations – the faint low-mass population



NGC 3603 – simulation:

Case 2: Milky Way @ 6.3 kpc

9.5 < L < 19.5 mag

Scaled to METIS resolution

Science goals:

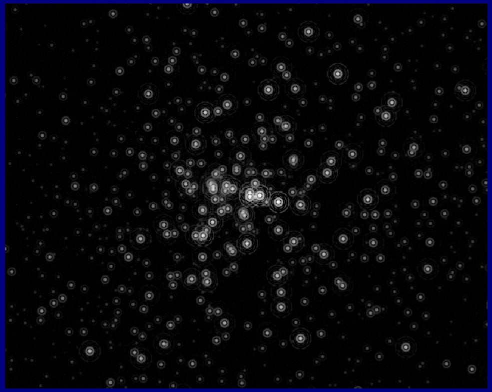
- **detection of brown dwarfs & free-floating planets**
- **disc survival & existence of planetary systems**
- **substellar mass function**
- **low-mass objects as tracers for IMBHs**

=> measurement of accelerations

A. Stolte, Argelander Institut for Astronomy

“Real photometry” on artificial images - Recovery success in cluster simulations

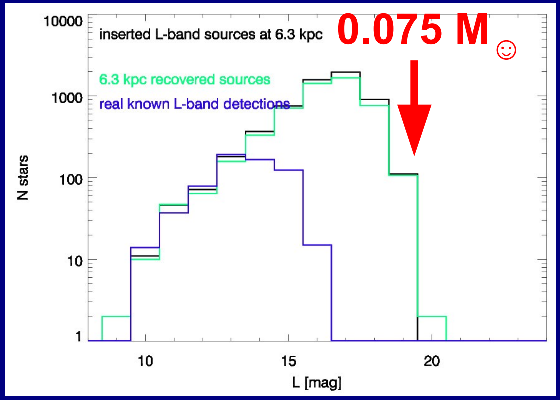
Run your favourite star-finding algorithm on these images & see what you get...



Milky Way starburst @ 6.3 kpc

8 x denser than NGC 3603

9.5 < L < 19.5 well recovered



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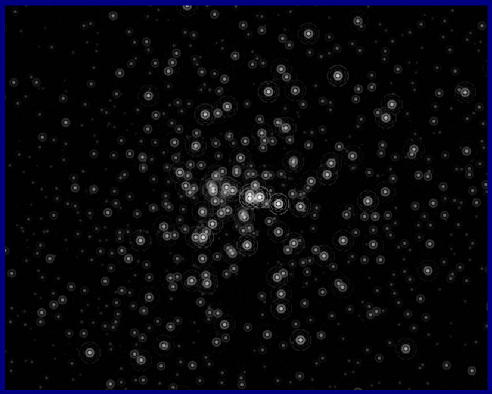

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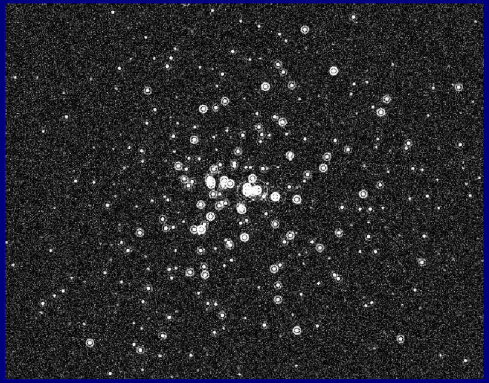
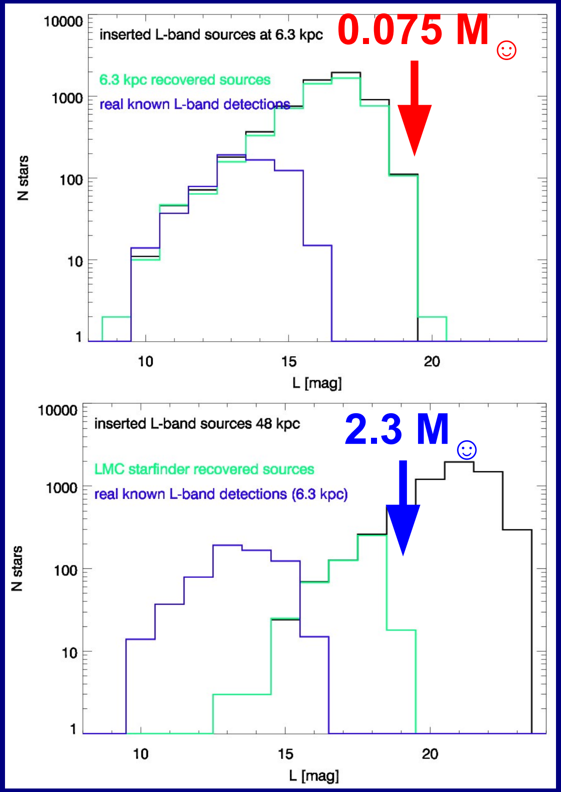


LMC @ 48 kpc

Input: 13.0 < L < 23.5 mag

Output: **13 < L < 19.5 mag**



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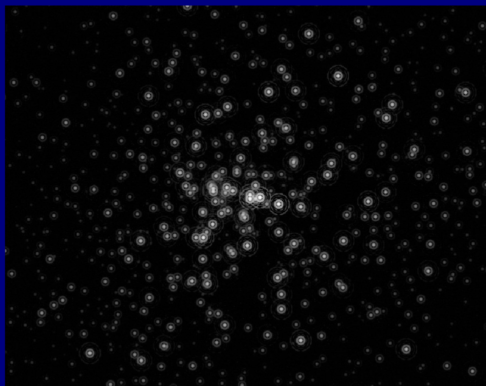

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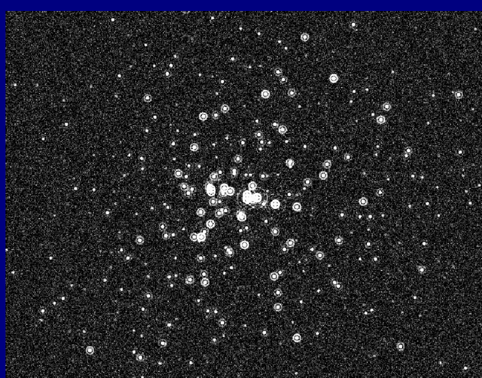

LMC @ 48 kpc

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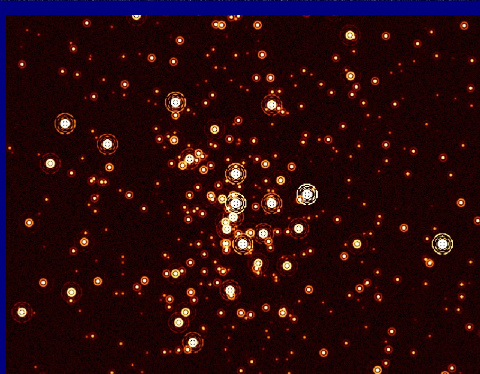
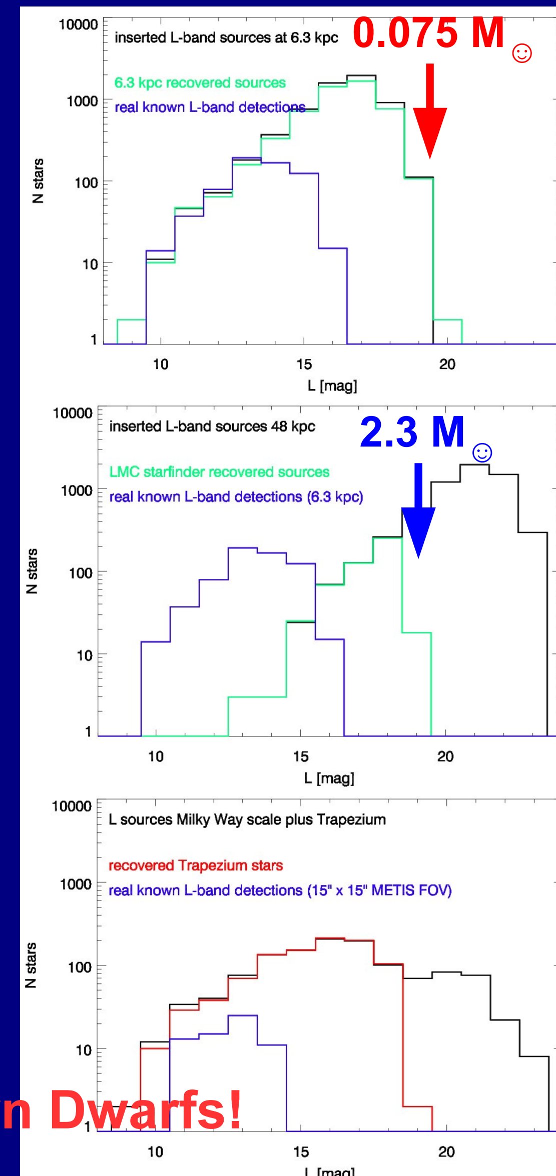
Output: **13 < L < 19.5 mag**



Compact Trapezium (6.3kpc)

Input: 9.5 < L < 23.5 mag

Output: **L < 19.5 = young Brown Dwarfs!**



Starburst clusters with METIS – Summary

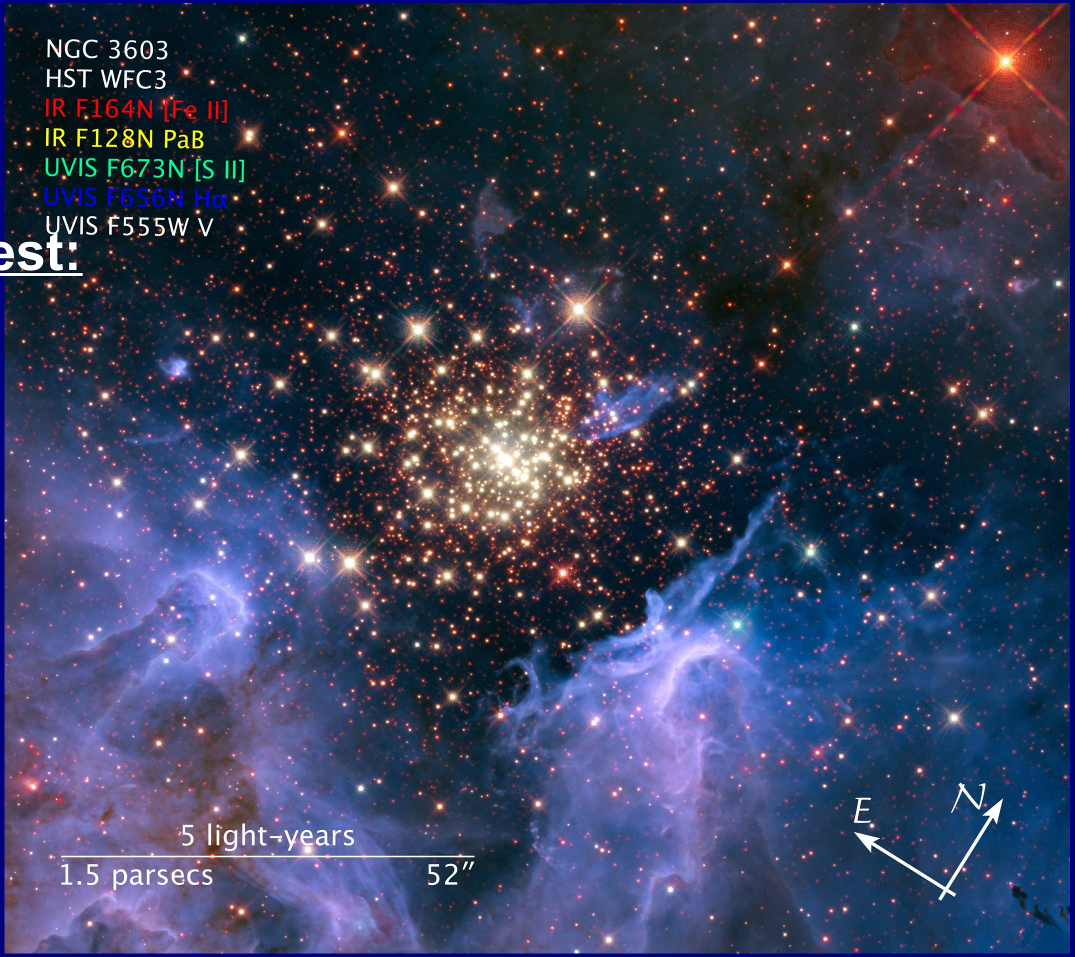
Real clusters as templates:

* NGC 3603 & Trapezium

Preliminary simulation results suggest:

* detect *all* brown dwarfs
  In all young Milky Way clusters

* obtain a *full disc inventory* in
  starburst clusters including
  dense clusters in nearby galaxies



NASA, ESA, R. O'Connell, F. Paresce, E. Young

To be confirmed/complimentary:

* orbits of stars around IMBHs

* free-floating planets & planetary systems in dense, rich clusters

Star cluster simulations – Science Assumptions

NASA, ESA, R. O'Connell, F. Paresce, E. Young