The open cluster Collinder 359

Nicolas Lodieu

in collaboration with

Potsdam, Grenoble, Cambridge, Arcetri, Cardiff, Saclay, Lisbon

ULMSF05 conference in La Palma, 28June-01July 2005

Outline of my talk

1) Overview of the CFHT Key Programme

2) Presentation of the open cluster Collinder 359

3) The deep wide-field optical survey in Collinder 359

4) The near-infrared follow-up

5) Identification of new cluster member candidates

6) Optical spectroscopic observations of cluster candidates

7) Main issues regarding Collinder 359

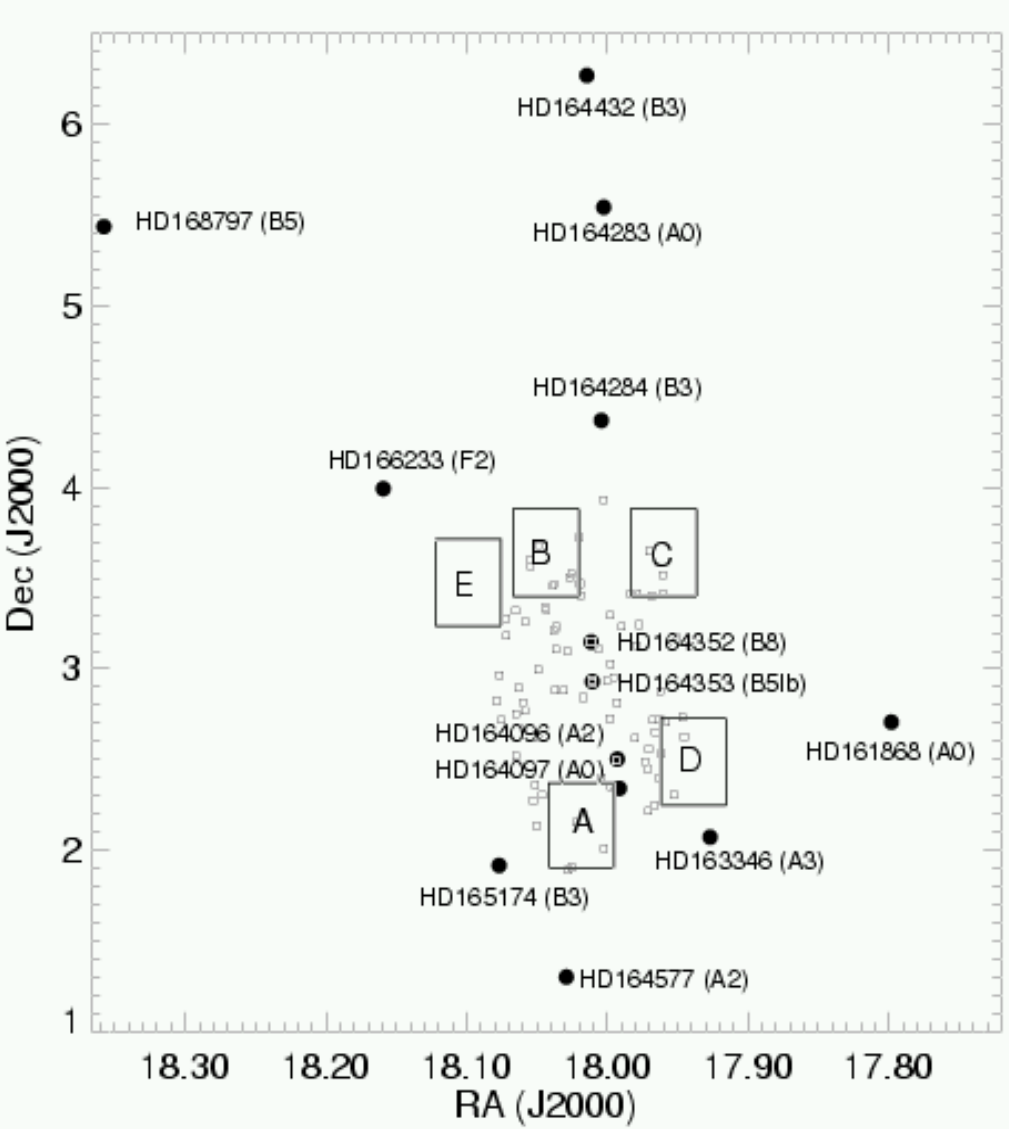
8) Conclusions and outlook

The CFHT Key Programme

- CFHTKP: wide-field optical observations:
  - PI: Bouvier in collaboration with the EC network
  - 30 nights over 2 years
  - CFH12K camera offers a 42'x28' FOV with 0.206 arcsec/pix
  - *I* and *z* CFH12K filters
  - Completeness and detection limits of 22 and 24 mag in *I* and *z* filters
- Targets (age < 200 Myr, d < 500 pc, visible from Hawai'i)
  - SFRs: Perseus, Taurus, Ophiuchus, and Serpens
  - PMS clusters: IC4665, Collinder 359, Stephenson 1
  - The Hyades
- Main goals of the CFHTKP programme:
  - How do brown dwarfs form and at which rate?
  - Is the Initial Mass Function sensitive to the environment?
  - How do substellar objects evolve with time?
  - What is the mass distribution of low-mass stars and brown dwarfs?

Collinder 359: presentation

Location of the CFH12K FOV



- ✔ Unstudied cluster
- ✔ RA=17^{h}58^m, Dec=+02°54'
- ✔ Constellation Ophiuchus
- ✔ Located around 67 Oph *(Melotte 1915)*
- ✔ Galactic latitude = +12.5°
- ✔ Age = 32 Myr *(Wielen 1971)*
- ✔ Distance = 435 pc [200,650] *(Hipparcos)*
- ✔ Diameter = 240 arcmin (~ 20 pc)

- ➢ 13 members belonging to the cluster
  - ✔ *Collinder (1931)*
- ➢ 6 of them confirmed as members
  - ✔ *Rucínski (1980; 1987), Van't Veer (1980)*
- ➢ Latest estimates *(Kharchenko et al. 2004)*
  - ✔ Age = 30 Myr
  - ✔ Distance = 650 pc

Optical and NIR Observations

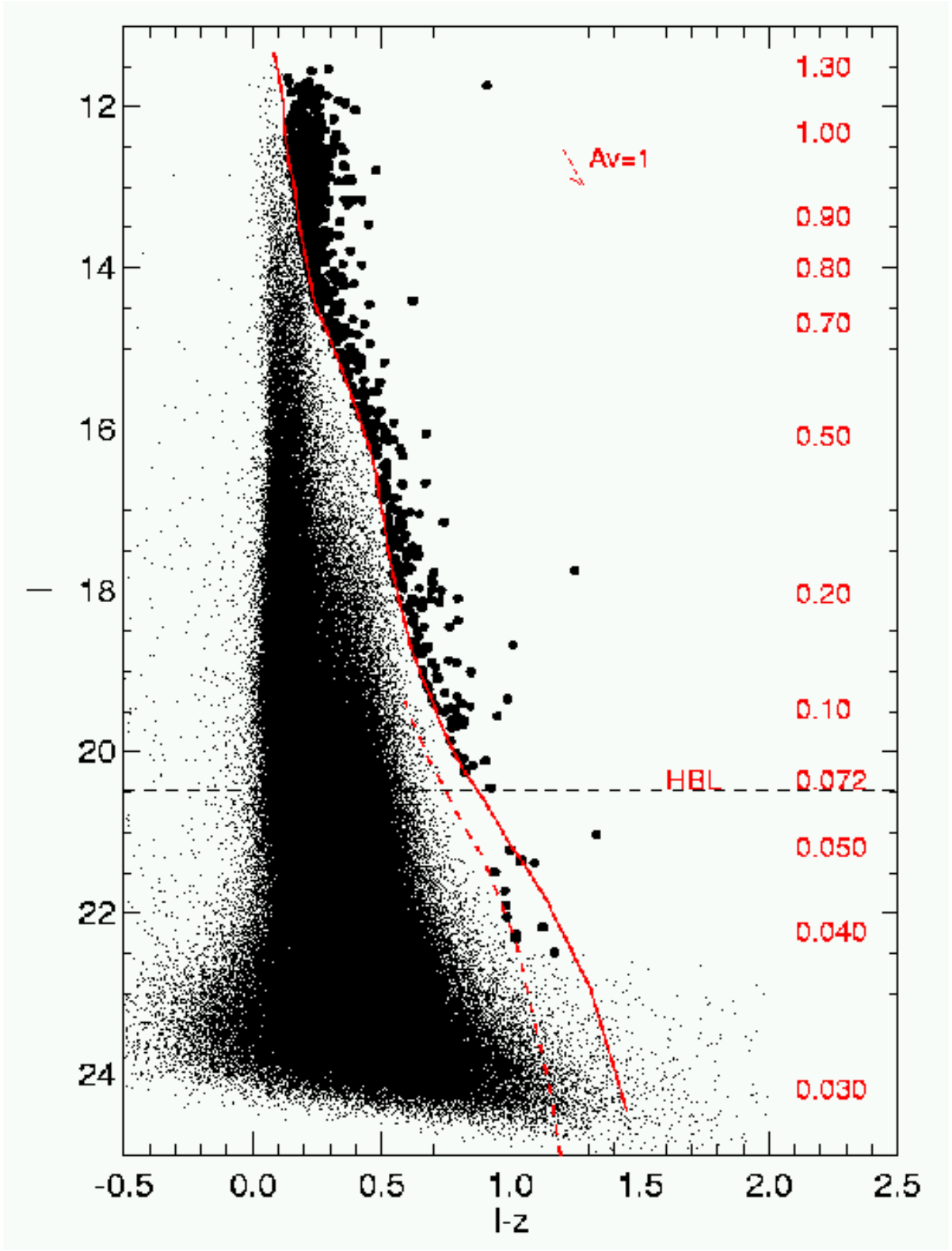
1) Optical wide-field survey within the framework of the CFHTKP

- 5 CFH12K fields-of-view covering 42 arcmin x 28 arcmin
- 1.6 square degree are surveyed in Collinder 359
- *I* and *z* filters
- Completeness limits of *I*, *z* ~ 22.0 mag (40 M_{Jup} at 500 pc and 100 Myr)
- Detection limits of *I*, *z* ~ 24.0 mag (30 M_{Jup} at 500 pc and 100 Myr)

2) Near-infrared follow-up photometry of candidates

- 2MASS counterparts down to *I* = 17.0 mag
- *K'*-band follow-up: CFHT 3.6-m/CFHTIR + CAHA 2.2-m/MAGIC

  29 + 36 objects spanning *I* = 17.0-22.0 mag



(I-z,I) CMD

- Isochrones

  NextGen + Dusty
  Age = 100 Myr
  distance = 500 pc

- Mass scale in solar masses
- HBL @ I = 20.5 mag
- Mass range: 1.3-0.03 Msun

Optical and NIR Observations

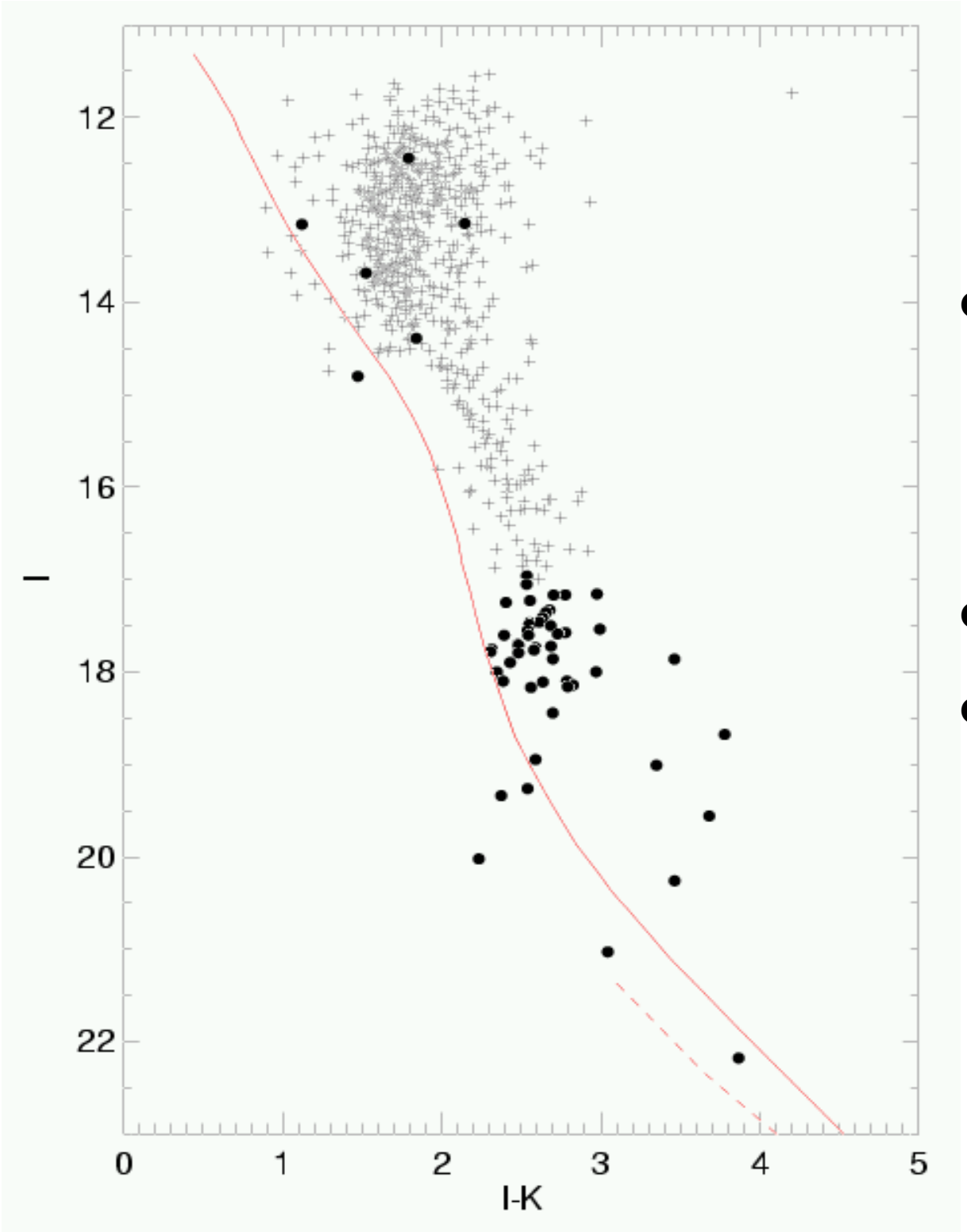
1) Optical wide-field survey within the framework of the CFHTKP

- 5 CFH12K fields-of-view covering 42 arcmin x 28 arcmin
- 1.6 square degree are surveyed in Collinder 359
- *I* and *z* filters
- Completeness limits of *I*, *z* ~ 22.0 mag (40 M_{Jup} at 500 pc and 100 Myr)
- Detection limits of *I*, *z* ~ 24.0 mag (30 M_{Jup} at 500 pc and 100 Myr)

2) Near-infrared follow-up photometry of candidates

- 2MASS counterparts down to *I* = 17.0 mag
- *K'*-band follow-up: CFHT 3.6-m/CFHTIR + CAHA 2.2-m/MAGIC

  29 + 36 objects spanning *I* = 17.0-22.0 mag



(I-K,I) CMD

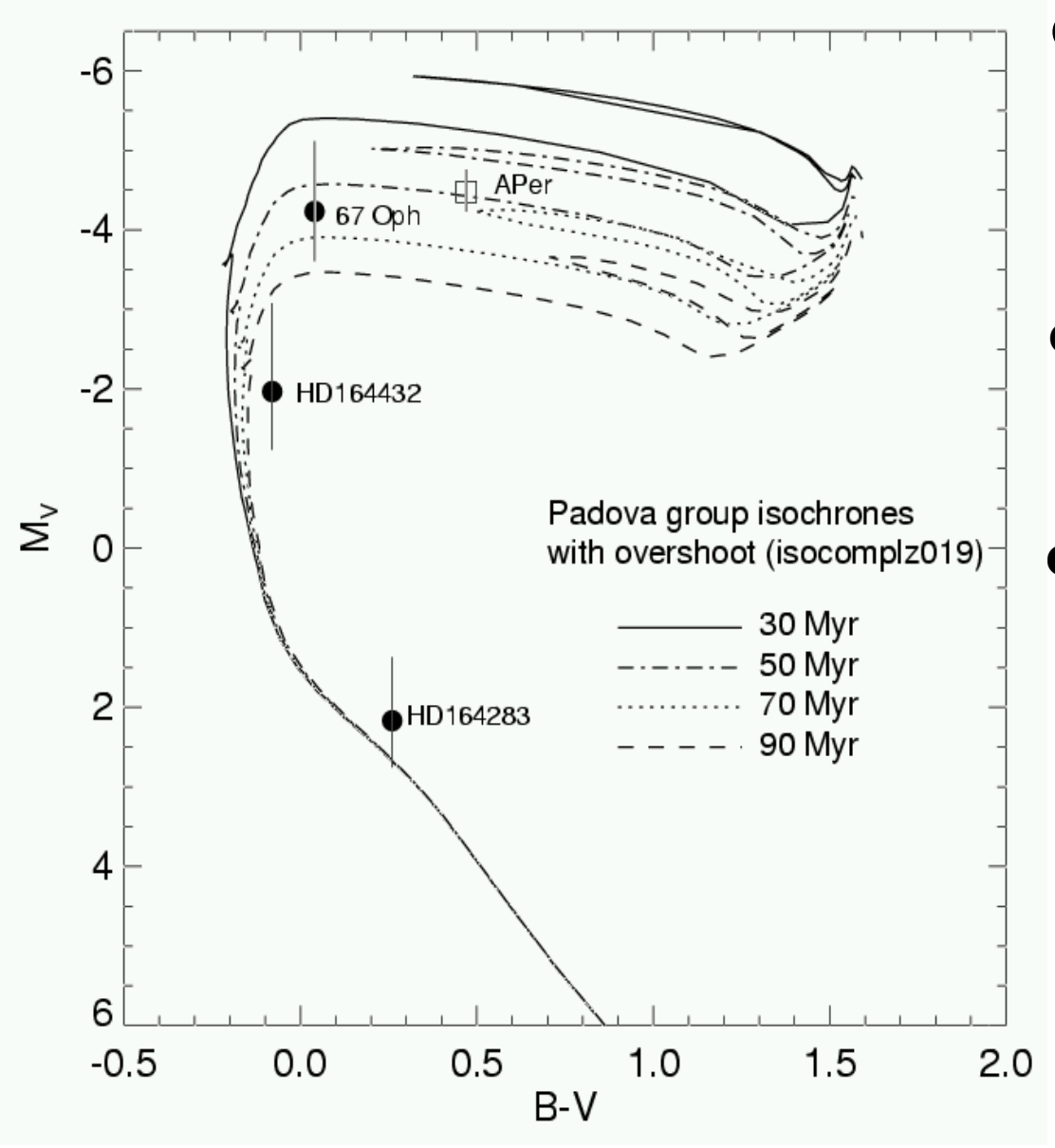
- Isochrones

  NextGen + Dusty
  Age = 100 Myr
  distance = 500 pc

- Crosses = 2MASS

- Filled circles = CFHT + CAHA

Age of Collinder 359



- Girardi tracks (Girardi et al. 2002)

  Solar metallicity
  Moderate overshoot

- Alpha Persei (open square):

  50 Myr (Stauffer et al. 2003)

- Membership of 67 Ophiuchus:

  $P \geq 75\%$ (Baumgardt et al. 2000)

  $P \geq 95\%$ (Kharchenko et al. 2004)

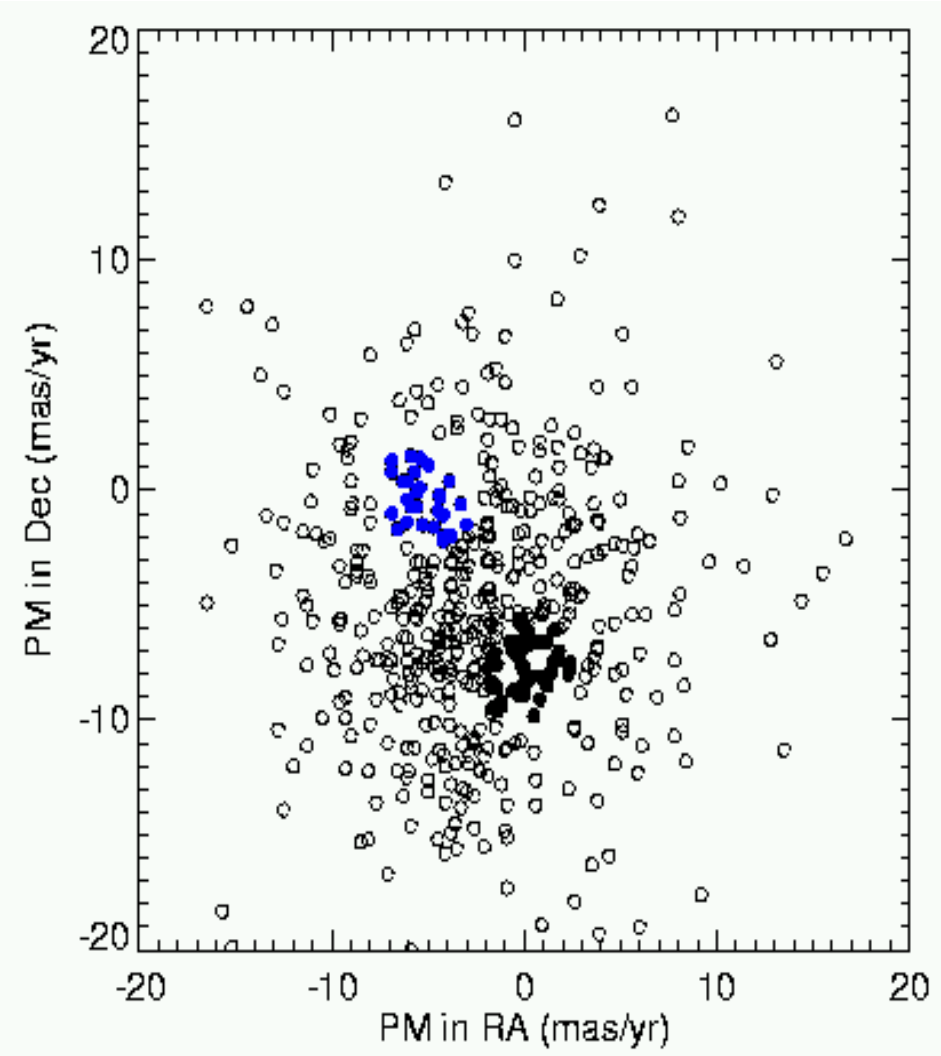
- 67 Ophiuchus (filled hexagon):

  60 ± 20 Myr

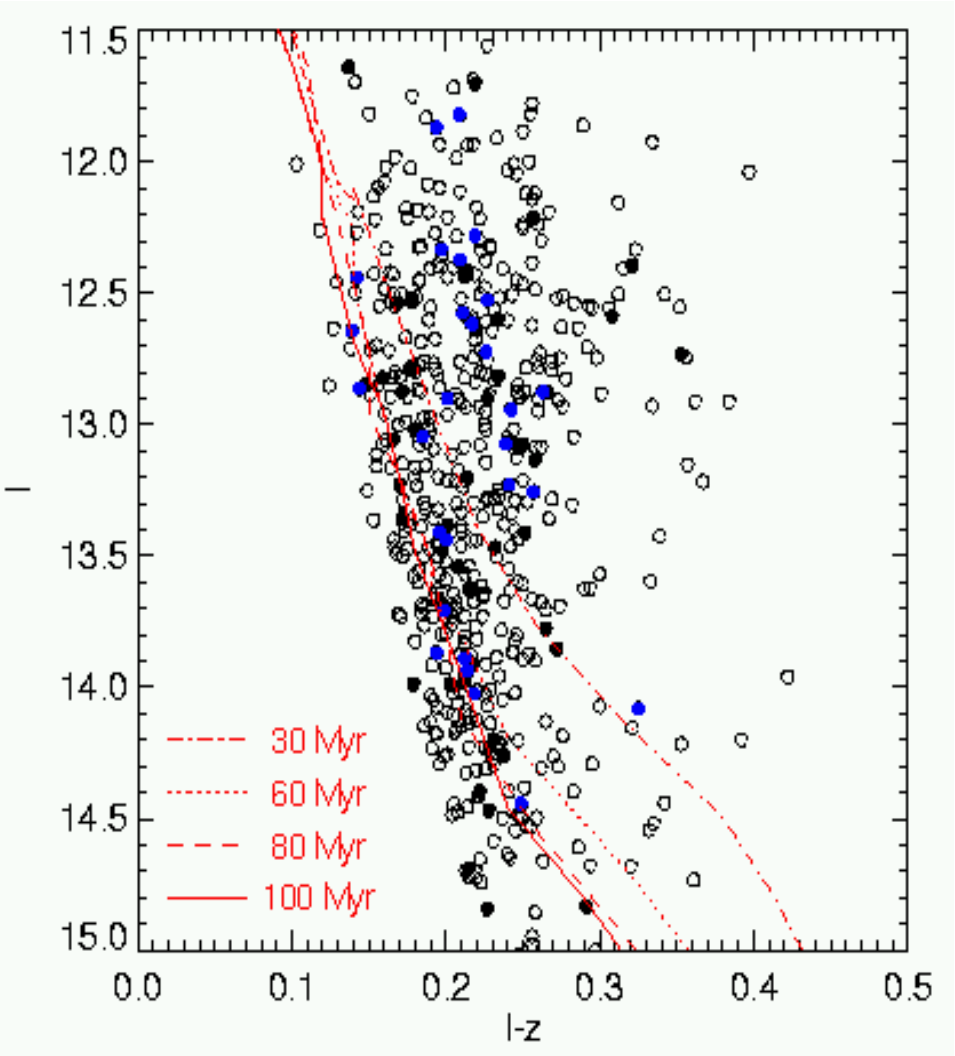
- Lithium test $\Rightarrow$ age $\times$ 2

Age and distance of Collinder 359

Mean cluster Proper Motion: (RA,dec) = (0.4,-8.2) mas/yr

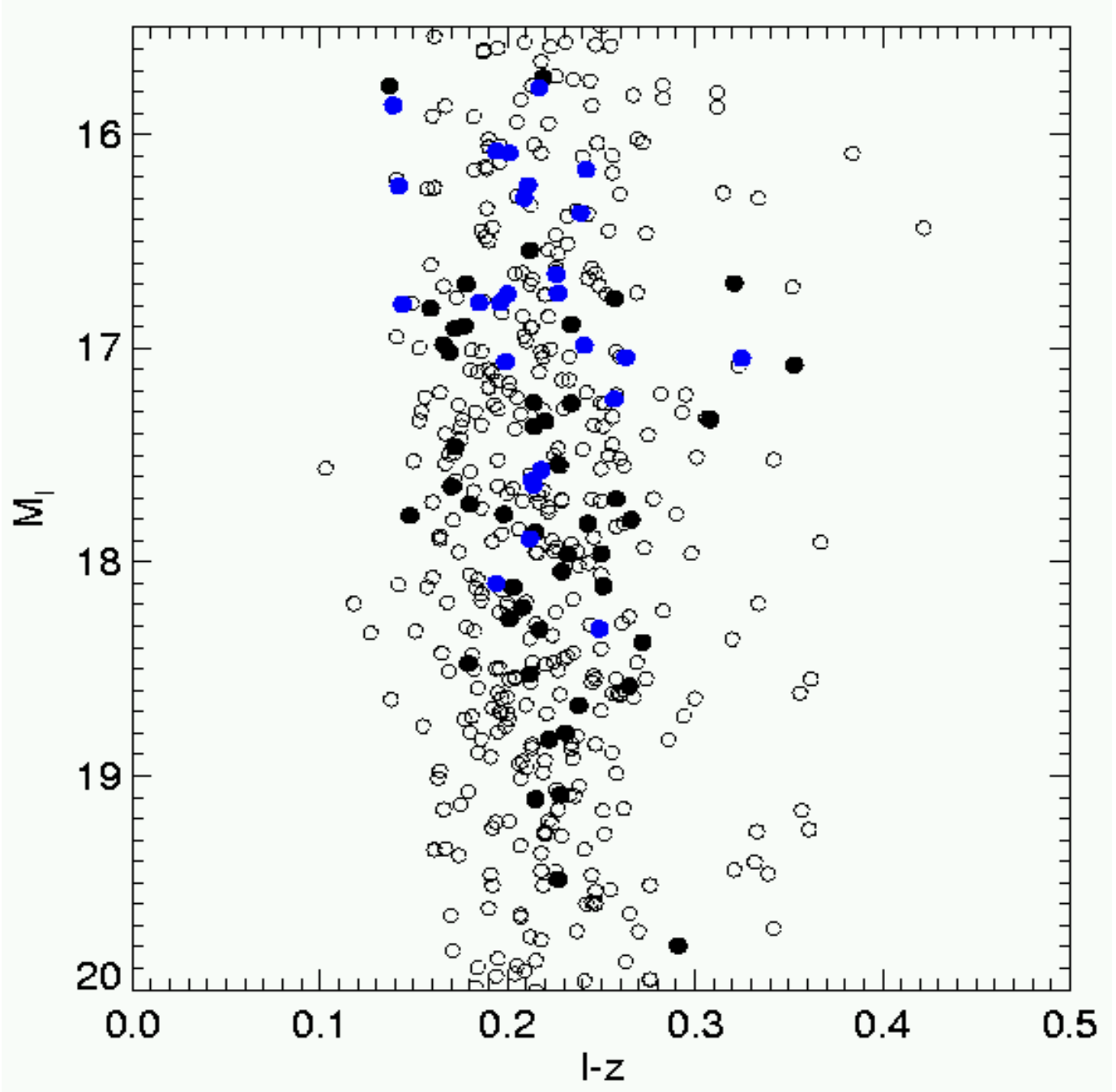


Vector point diagram



Colour-magnitude diagram

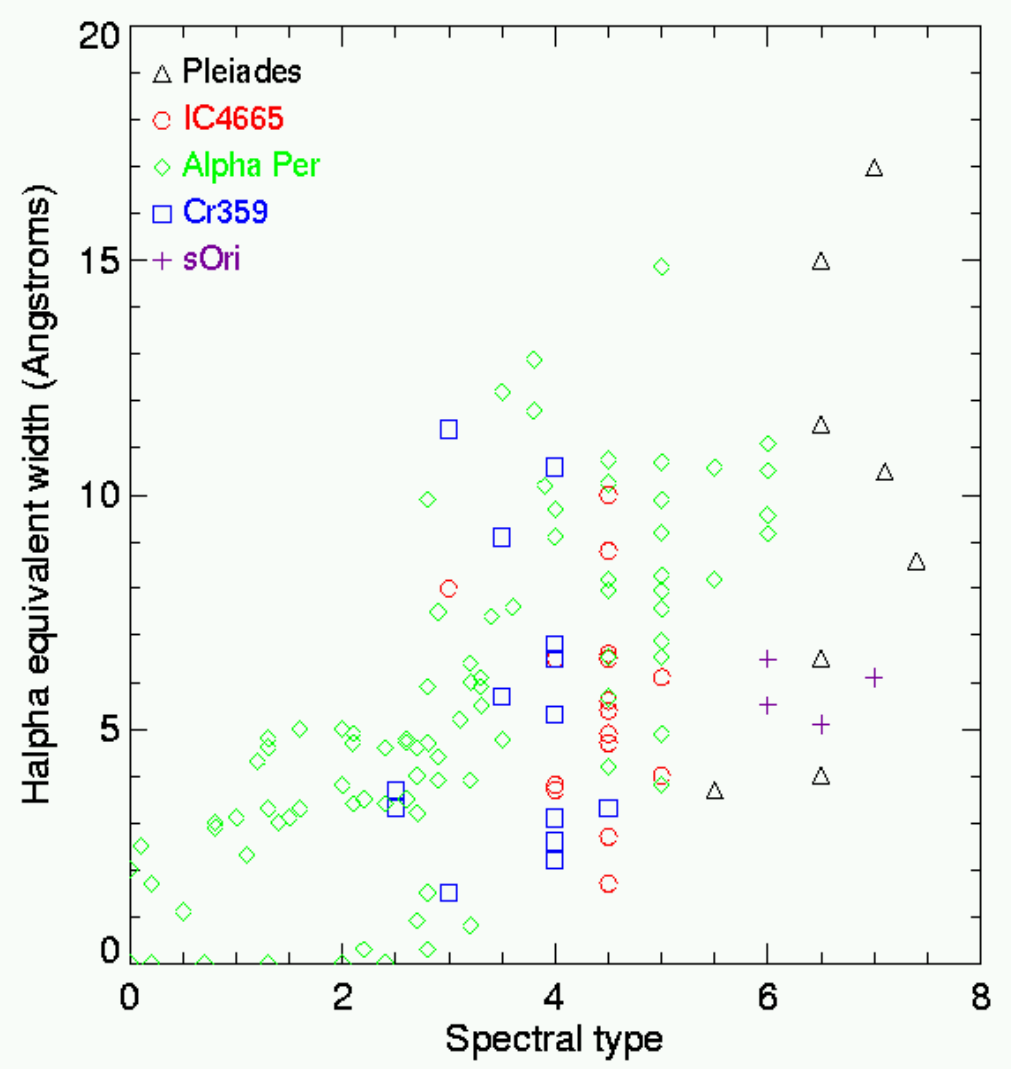
Absolute magnitude vs. colour diagram



Optical spectroscopy: Hα

- Tests for membership:
  - Spectral typing
  - Chromospheric activity: Ha EW
  - Surface gravity: KI and NaI doublets
  - Magnitude vs. SpT relationship
- Spectroscopic observations:
  - TNG/DOLORES: 48 candidates
  - WHT/AF2/WYFFOS: 33 candidates
  - CAHA 3.5-m/Twin: 74 candidates
- Caveat:

  What criterion for M ≥ 0.3 Msun?
  Lithium? Radial velocity?

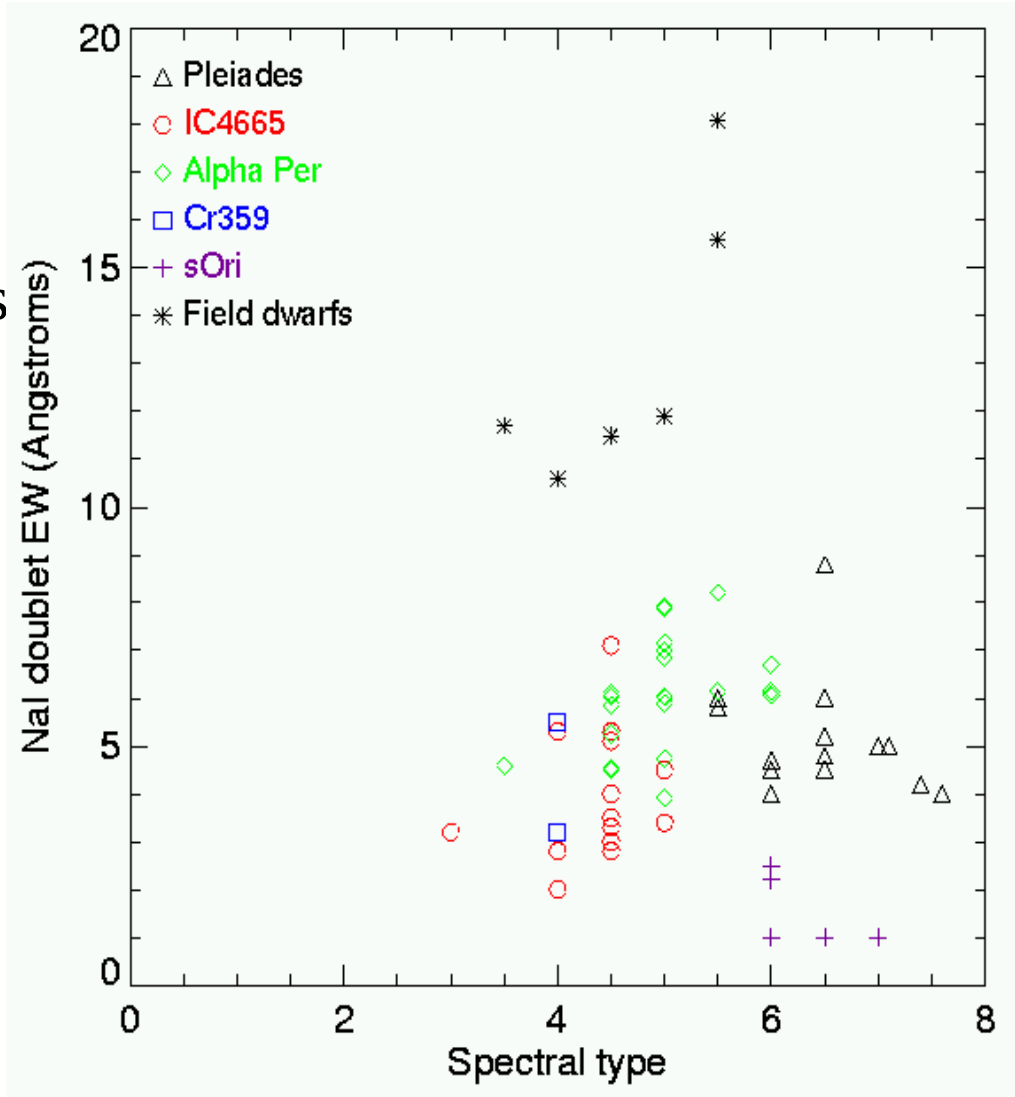


==> A dozen candidates confirmed as members out of 100 candidates with optical spectroscopy

Optical spectroscopy: surface gravity

- Tests for membership:
  - Spectral typing
  - Chromospheric activity: Ha Ews
  - Surface gravity: KI and NaI doublets
  - Magnitude vs. SpT relationship
- Observations:
  - TNG/DOLORES: 48 candidates
  - WHT/AF2/WYFFOS: 33 candidates
  - CAHA 3.5-m/Twin: 74 candidates
- Caveat:

  What criterion for M ≥ 0.3 Msun?
  Lithium? Radial velocity?

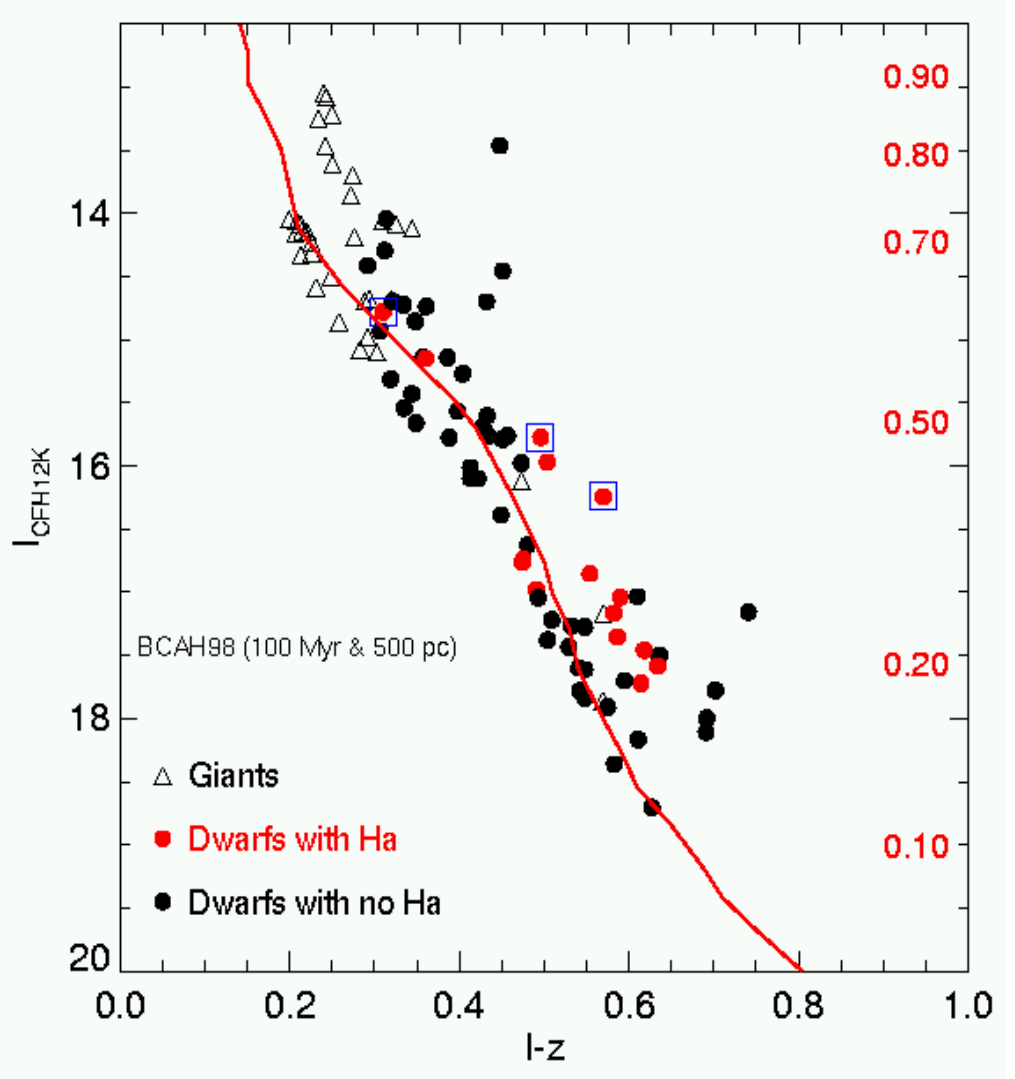


==> A dozen candidates confirmed as members out of 100 candidates with optical spectroscopy

Optical spectroscopy: preliminary results

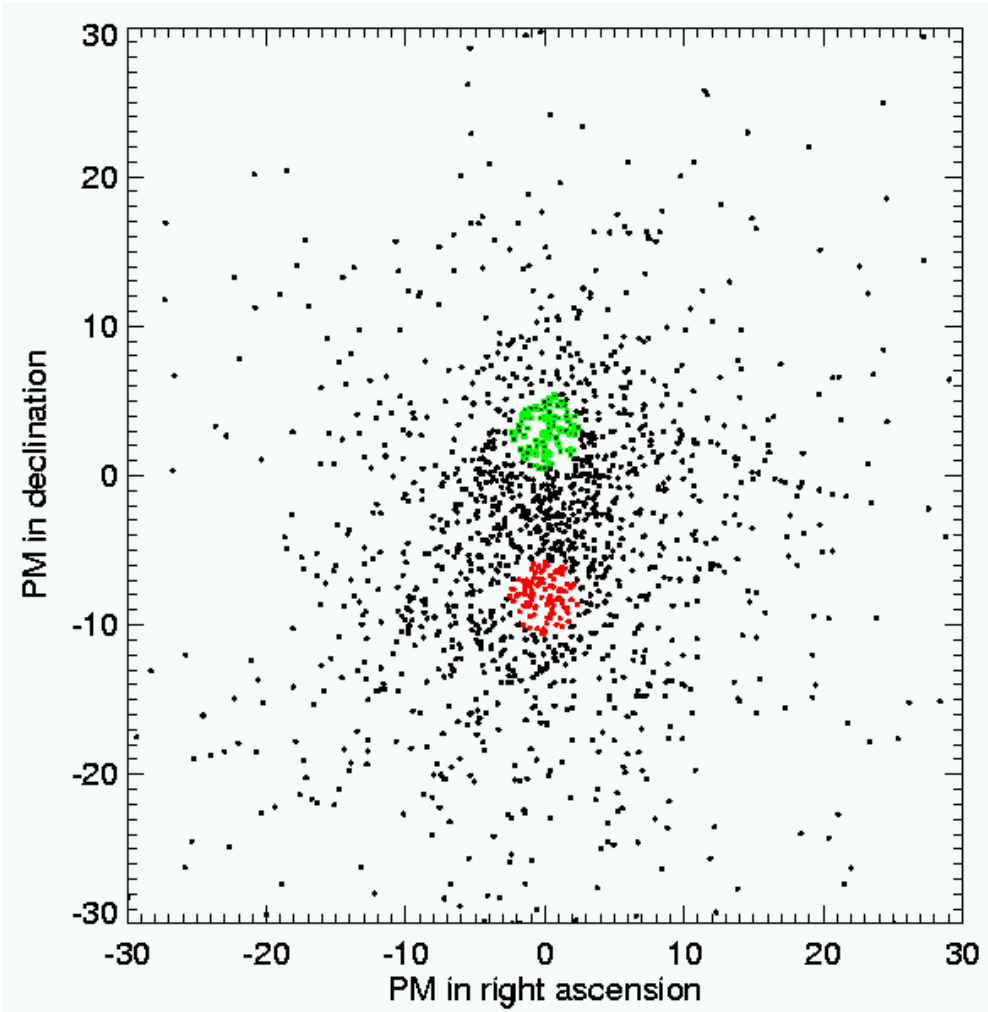
- Tests for membership:
  - Spectral typing
  - Chromospheric activity: Ha EWs
  - Surface gravity: KI and NaI doublets
  - Magnitude vs. SpT relationship
- Observations:
  - TNG/DOLORES: 48 candidates
  - WHT/AF2/WYFFOS: 33 candidates
  - CAHA 3.5-m/Twin: 74 candidates
- Caveat:

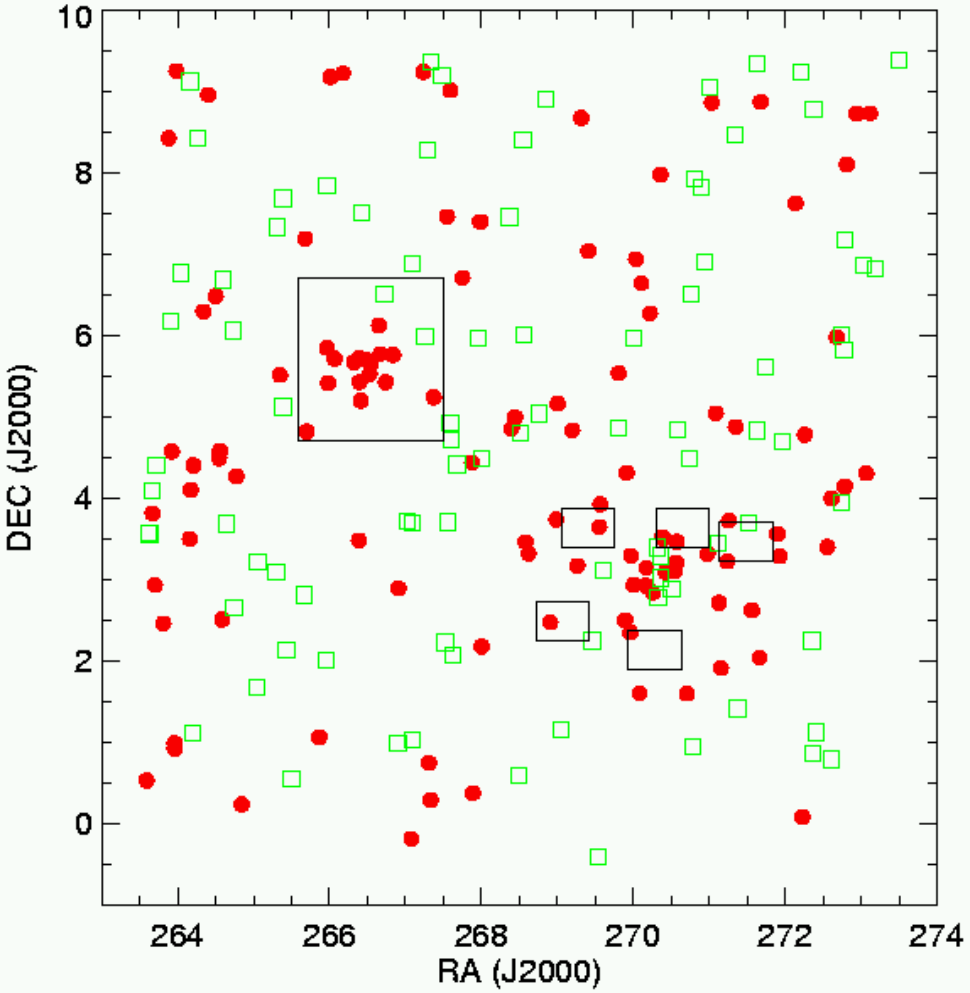
  What criterion for M ≥ 0.3 Msun?
  Lithium? Radial velocity?



==> A dozen candidates confirmed as members out of 100 candidates with optical spectroscopy

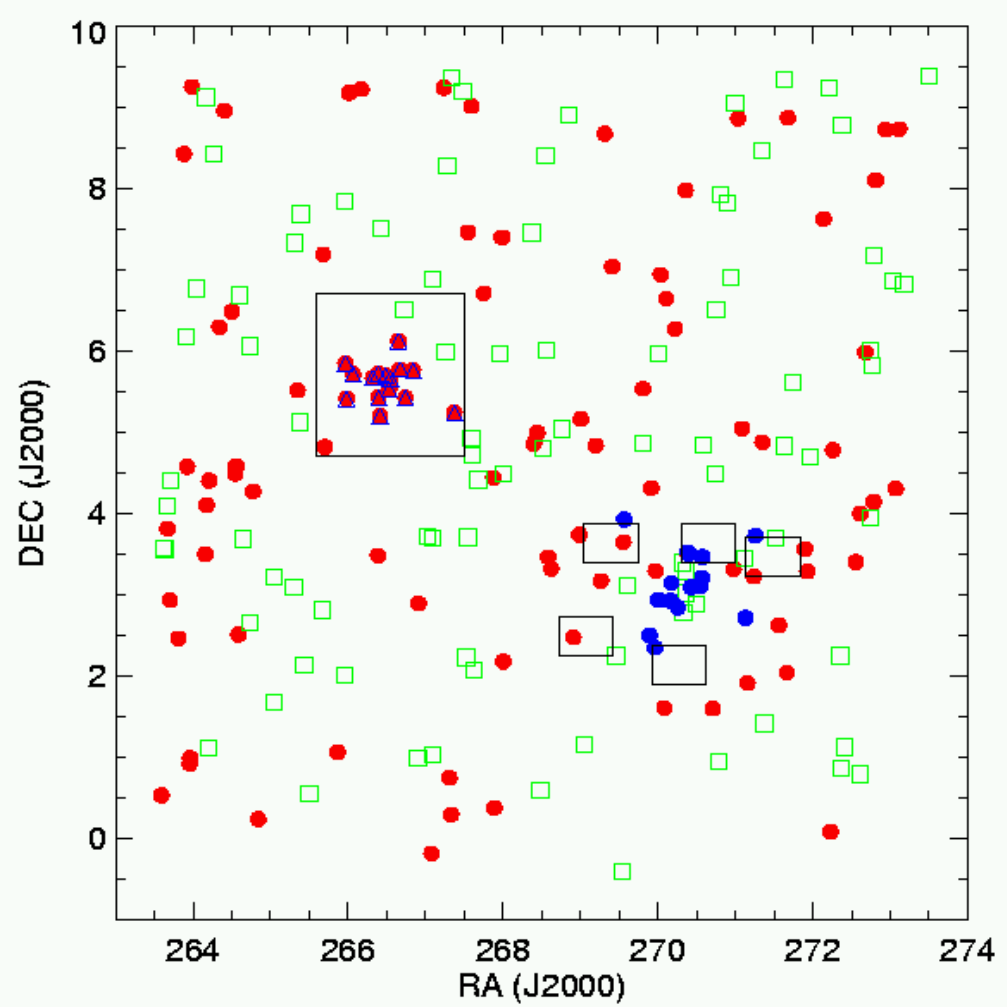
Collinder 359 & IC4665

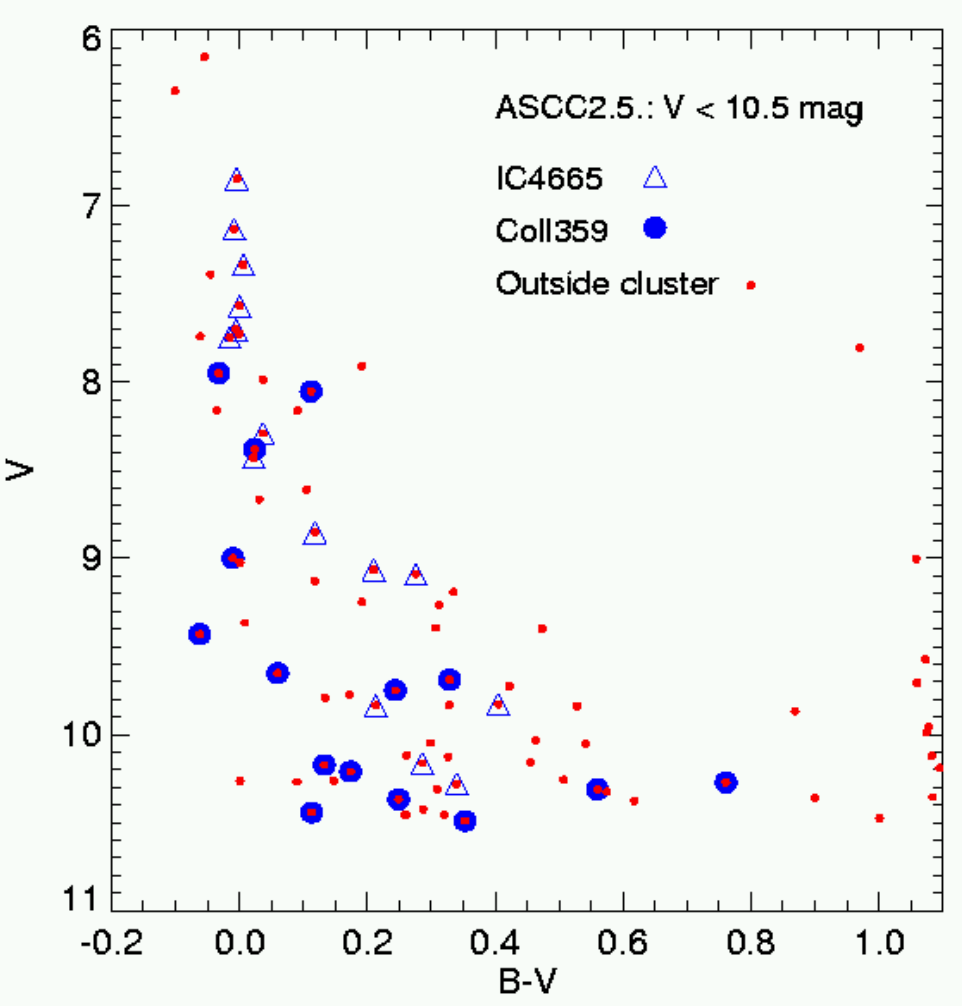




Red dots have proper motion consistent with cluster membership
Green squares represent a control sample
Black boxes represent the coverage in Collinder 359 & IC4665

Collinder 359 & IC4665





Red dots have proper motion consistent with cluster membership
Green squares represent a control sample
Blue dots are within a 2 degree area around Collinder 359 & (B-V) < 1.0
Blue triangles are within a 2 degree area around IC4665 & (B-V) < 1.0

Conclusions and outlook

- Available data for Collinder 359:

  ⇒ Deep optical survey in Collinder 359 complemented by NIR photometry

  - Optical survey of the cluster centre
  - NIR photometry: UKIRT/WFCAM

  ⇒ New cluster members candidates selected with M = 1.3-0.040 M

  ⇒ Distance estimated to 500 pc and age to 100 Myr

  ⇒ Optical spectroscopy obtained for about 100 candidates

  - AAT/2dF

- Main current issues:

  ⇒ Presence of a cluster but lack of clear sequence at bright magnitudes

  ⇒ Possible link between Collinder 359 & IC4665?

  ⇒ Is Collinder 359 only a moving group?