STARRY
STARS THAT 'R' YOUNG

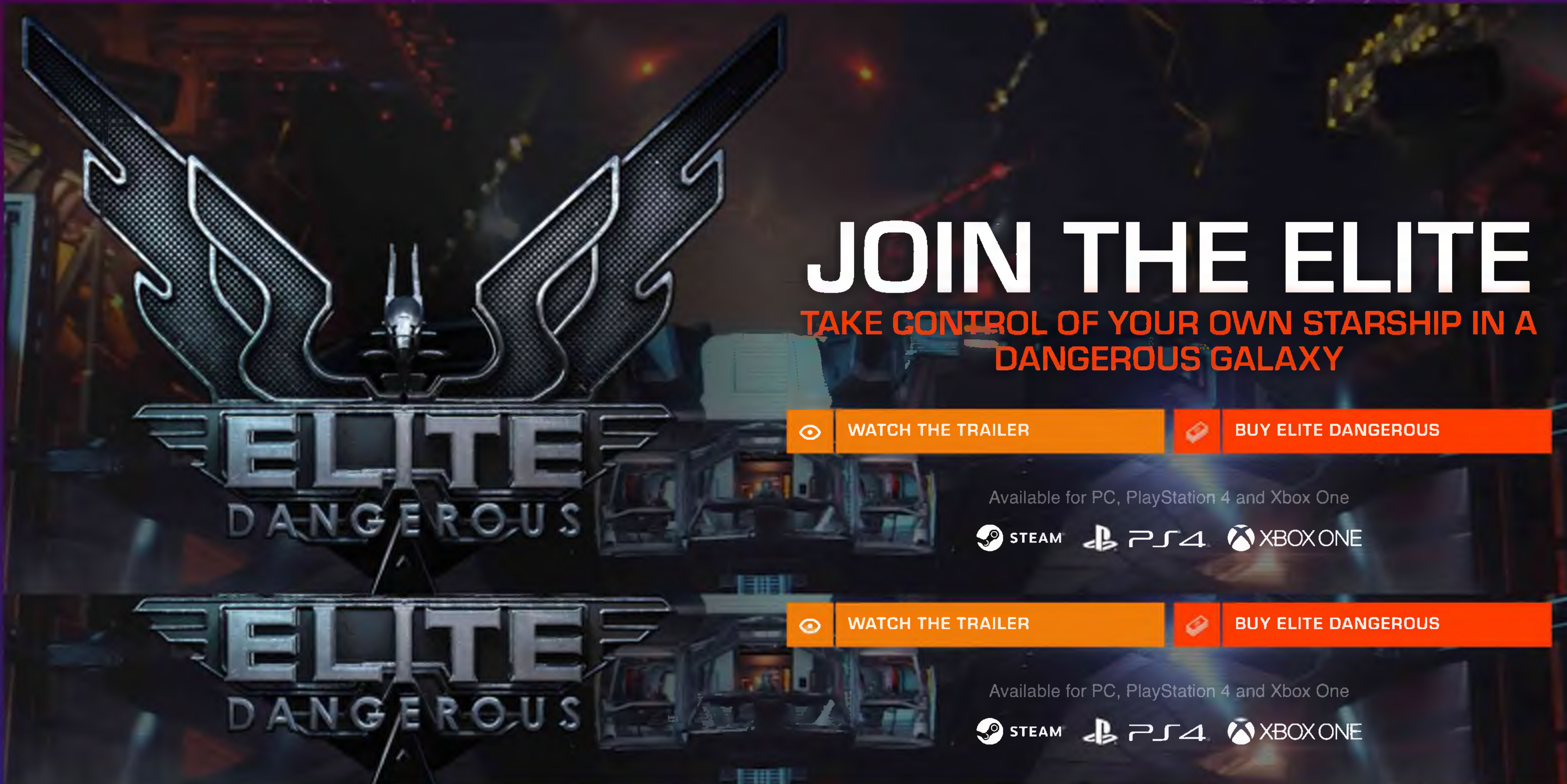
HERBIG AE/BE STARS AND THEIR ASSOCIATED CLUSTERS

LYNNE A. HILLENBRAND
(CALTECH)

Abstract:

Young stellar clusters are our best laboratories for direct measurements of important distributions such as: the stellar/sub-stellar initial mass function, the spread in stellar ages, rotational evolution en route to the main sequence, and the evolution of circumstellar disks. The Herbig Ae/Be stars are found in a range of clustered environments, including as relatively isolated objects, as the most massive stars in small low-mass but dense clusters, and as generic intermediate mass members of large and massive star clusters. The talk will summarize some old and new mysteries of this *still-rare category of young stellar object.*

How rare are they?



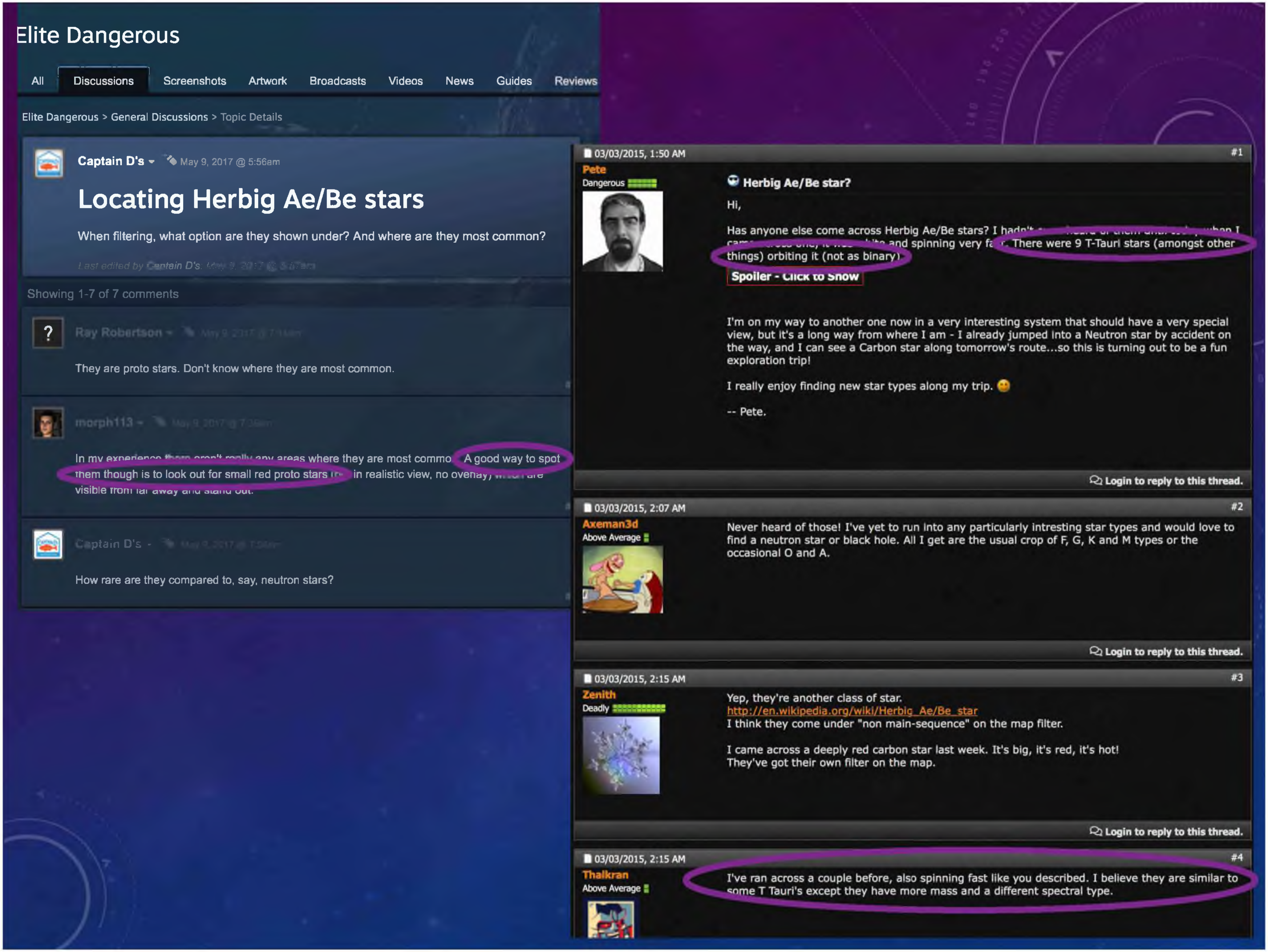
Watch the video for attempted real-astronomy explanation of different star types: https://www.youtube.com/watch?v=yJ0_Fk00M4o

(no endorsement of a commercial product is intended – for illustrative/humor purposes only)

Proto Stars (Herbig Ae/Be, TTS) Edit

With a ratio of ~2.3% [1] of all stars this category can be considered **Rare'** [2]

Image	Class [3]	Fuel-Scoopable	Within Type [4]	Description	Additional Information
  Herbig AE/BE star (DRYAO AOSCS sector)	Herbig Ae/Be	No	Uncommon (~7.5%)	Herbig Ae/Be stars are young stars typically less than 10 million years old with characteristics of either A or B class main sequence stars. They are usually between 2 and 8 solar masses. The mass of the proto-star determines its spectral class when it joins the main sequence.	Herbig Ae/Be stars are more common nearer the galactic core. Before the 2.2 update, Herbig Ae/Be type stars could possess an erroneous blue-white colouration.
 	TTS	No	Very Common (~92%)	T Tauri type stars are very young stars which are in the process of gravitational contraction.	Take caution when travelling and using a fuel scoop, as the TTS' appearance often resembles M or K stars. Before the 2.2 update, T Tauri type stars could possess an erroneous blue-white colouration.



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Captain D's May 9, 2017 @ 5:56am

Locating Herbig Ae/Be stars

When filtering, what option are they shown under? And where are they most common?

Last edited by Captain D's; May 9, 2017 @ 5:57am

Showing 1-7 of 7 comments

Ray Robertson May 9, 2017 @ 7:14am

They are proto stars. Don't know where they are most common.

morph113 May 9, 2017 @ 7:26am

In my experience there aren't really any areas where they are most commo... A good way to spot them though is to look out for small red proto stars (... in realistic view, no overlay) which are visible from far away and stand out.

Captain D's May 9, 2017 @ 7:56am

How rare are they compared to, say, neutron stars?

03/03/2015, 1:50 AM #1

Pete
Dangerous

Herbig Ae/Be star?

Hi,

Has anyone else come across Herbig Ae/Be stars? I hadn't ... heard of them until today when I came across one, it was ... white and spinning very fa... There were 9 T-Tauri stars (amongst other things) orbiting it (not as binary)

Spoiler - Click to Show

I'm on my way to another one now in a very interesting system that should have a very special view, but it's a long way from where I am - I already jumped into a Neutron star by accident on the way, and I can see a Carbon star along tomorrow's route...so this is turning out to be a fun exploration trip!

I really enjoy finding new star types along my trip.

-- Pete.

Login to reply to this thread.

03/03/2015, 2:07 AM #2

Axeman3d
Above Average

Never heard of those! I've yet to run into any particularly intresting star types and would love to find a neutron star or black hole. All I get are the usual crop of F, G, K and M types or the occasional O and A.

Login to reply to this thread.

03/03/2015, 2:15 AM #3

Zenith
Deadly

Yep, they're another class of star.
http://en.wikipedia.org/wiki/Herbig_Ae/Be_star
I think they come under "non main-sequence" on the map filter.

I came across a deeply red carbon star last week. It's big, it's red, it's hot!
They've got their own filter on the map.

Login to reply to this thread.

03/03/2015, 2:15 AM #4

Thalkran
Above Average

I've ran across a couple before, also spinning fast like you described. I believe they are similar to some T Tauri's except they have more mass and a different spectral type.

WIKIPEDIA :

(HOW OUR SOURCES WIND UP IN POPULAR CULTURE LIKE VIDEO GAMES!)

A **Herbig Ae/Be star** (**HAeBe**) is a pre-main-sequence star – a young (<10Myr) star of spectral types A or B. These stars are still embedded in gas-dust envelopes and are sometimes accompanied by circumstellar disks.[1] Hydrogen and calcium emission lines are observed in their spectra. They are 2-8 Solar mass ($M_\odot$) objects, still existing in the star formation (gravitational contraction) stage and approaching the main sequence (i.e. they are not burning hydrogen in their center). In the Hertzsprung–Russell diagram these stars are located to the right of the main sequence. They are named after the American astronomer George Herbig, who first distinguished them from other stars in 1960. The original Herbig criteria were:

- Spectral type earlier than F0 (in order to exclude T Tauri stars),
- Balmer emission lines in the stellar spectrum (in order to be similar to T Tauri stars),
- Projected location within the boundaries of a dark interstellar cloud (in order to select really young stars near their birthplaces),
- Illumination of a nearby bright reflection nebula (in order to guarantee physical link with star formation region).

There are now several known isolated Herbig Ae/Be stars (i.e. not connected with dark clouds or nebulae). Thus the most reliable criteria now can be:

- Spectral type earlier than F0,
- Balmer emission lines in the stellar spectrum,
- Infrared radiation excess (in comparison with normal stars) due to circumstellar dust (in order to distinguish from classical Be stars, which have infrared excess due to free-free emission).

E.D. GALACTIC WIKI:

COMMENTS ON YOUNG STAR NOMENCLATURE

- Massive Young Stellar Objects (MYSOs) → Main sequence O/B stars (dust free)
  - Early type, luminous/massive (>8 Msun), stars with disks.
  - Typically completely embedded objects, seen only in the infrared and submm/mm.
- Herbig Ae/Be (HAe/Be or HAEBE) → Main Sequence B and A stars (some Vega-like)
  - Typically ~2-8 Msun – and yes, spinning fast.
  - Original definition by Herbig, but some expansion from that starting point.
  - NOT synonymous with intermediate-mass pre-main sequence star (requires the signs of youthful location AND the "activity").
- GTTS and IMTTS → IMPs → Main Sequence A and F stars (some with debris disks)
  - Herbst promoted term GTTS for 1-2 Msun (never caught on).
  - Calvet discussed IMTTS.
  - Povich proposing IMPs (discussed only in context of disk-free IM pre-main sequence stars).
- T Tauri (TTS) → PTTS → Main Sequence K and M stars
  - Typically <1 Msun (Note that T Tauri itself is really an intermediate-mass star!).
  - NOT synonymous with low-mass pre-main sequence star.
  - divide into CTTS (like Herbig Ae/Be but lower mass) and WTTS categories.

1960

THE SPECTRA OF Be- AND Ae-TYPE STARS ASSOCIATED WITH NEBULOSITY*

George H. Herbig
Lick Observatory, University of California
Received November 2, 1959

ABSTRACT

An argument based on the relative rates of contractive and nuclear (hydrogen-burning) evolution for stars of masses 3 to 20 $m_{\odot}$ enables an estimate to be made of the number of still-contracting stars of these masses within an observable distance of the sun. For example, within 1 kpc of the sun and 100 pc of the galactic plane one would expect there to be, somewhere in their contractive phase, about 18 stars that will in time reach the main sequence at types B2 and B3. A purely empirical attempt was made to identify some of these objects by examining in detail a list of 26 Be- and Ae-type stars that both lie in obscured regions and illuminate nearby nebulosity. The list contains such well-known variables as T Ori, AB Aur, RR Tau, Z CMa, and R Mon, as well as some newly found emission-line stars. In the course of the investigation two new variable nebulae were found. Two main types of stars were encountered: one with emission lines mainly of hydrogen plus absorption features due to a weak overlying shell; and another group with higher velocities of ejection, stronger emission lines, and line structure of the P Cygni type. Although it is entirely possible that this list of peculiar objects does contain examples of still-contracting stars of large mass, no convincing proof of this supposition could be found. The essential reason was that, although there are some striking spectroscopic peculiarities among the stars examined, at the dispersions employed in this investigation the peculiarities did not appear to be unique to this group: they may be found as well in stars that are not associated with nebulosity.

The stars listed in Table 3 were chosen for study because they met the following conditions: (*a*) The spectral type is A or earlier, with emission lines. (*b*) The star lies in an obscured region. (*c*) The star illuminates fairly bright nebulosity in its immediate vicinity.

1960

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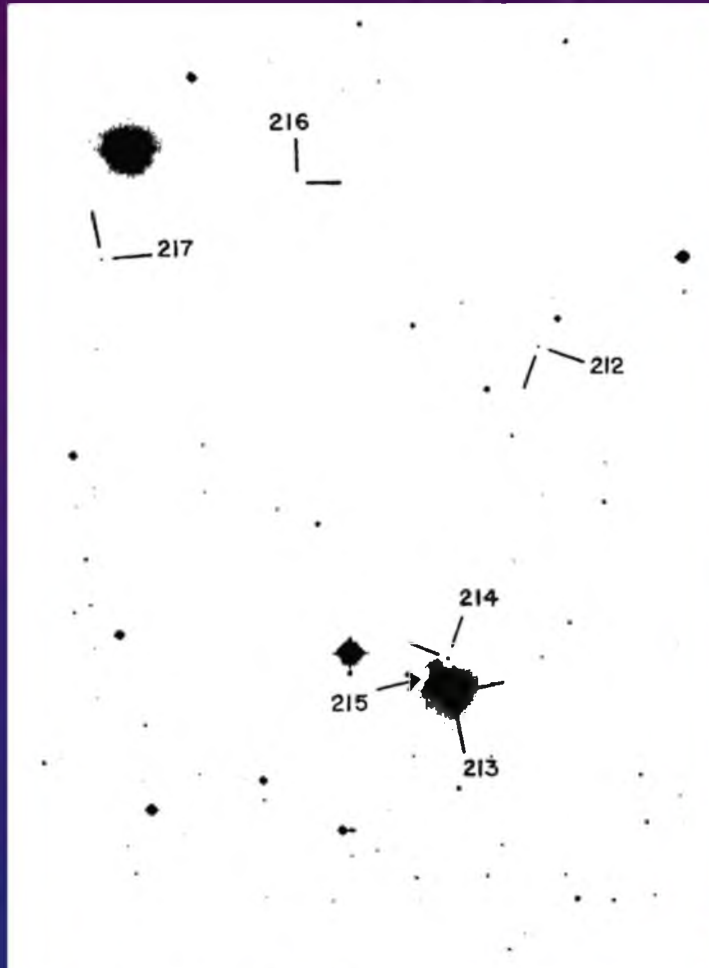

FIG. 9.—Two exposures of the region of NGC 2245 (*lower right*) and NGC 2247

Additional ubiquitous characteristics:

- variability
- infrared excess

TABLE 13

EMISSION-Hα STARS NEAR NGC 2245, 2247

LkHα	Approximate m_{pg}	Hα Intensity	LkHα	Approximate m_{pg}	Hα Intensity
210*...........	16	w	215...........	11	m
211*...........	15	m	216...........	17	m
212...........	17 var	s	HD 259431.....	9	s
213...........	18:	m	217...........	17	m
214...........	16	s			

*These two stars are outside the area shown in Fig. 9. LkHα 210 is 3ʹ.1 south, 0ʹ.7 east of BD+10°1161. LkHα 211 is 2ʹ.3 north, 2ʹ.4 west of +10°1165.

1995

ISOLATED STAR-FORMING REGIONS CONTAINING HERBIG AE/BE STARS. I. THE YOUNG STELLAR AGGREGATE ASSOCIATED WITH BD +40° 4124

LYNNE A. HILLENBRAND,[1,2,3,4] MICHAEL R. MEYER,[2] STEPHEN E. STROM,[1] AND MICHAEL F. SKRUTSKIE
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Received 1994 July 5; revised 1994 August 24

ABSTRACT

We use optical and infrared photometry in combination with red optical spectra to study the star-forming region associated with the two Herbig Ae/Be stars BD +40° 4124 and V1686 Cyg. We identify a partially embedded, dense, isolated cluster of pre-main sequence stars concentrated within 0.15 pc of the two young high-mass stars. The cluster is isolated in that it is separated by approximately 0.7 pc from a surrounding Hα-bright rim and lies at the center of a molecular core with peak column density corresponding to 45 mag of visual extinction. The fraction of the stellar population with evidence for circumstellar activity is 100% amongst the optically visible cluster members and at least 50% amongst the embedded sources. This small region is characterized by an apparent age spread of approximately 3 Myr with evidence for both high- and low-mass stars forming relatively simultaneously (within several hundred thousand years). Comparison of the derived stellar mass distribution to that expected from Monte-Carlo sampling of the solar neighborhood
mass ... ediate- and
high-n ... ra, and that
"unive ... and/or over
many ... region, the
popula ... to ten Myr
until t ... nds all star
format ... uced in this
region ... ilar to that
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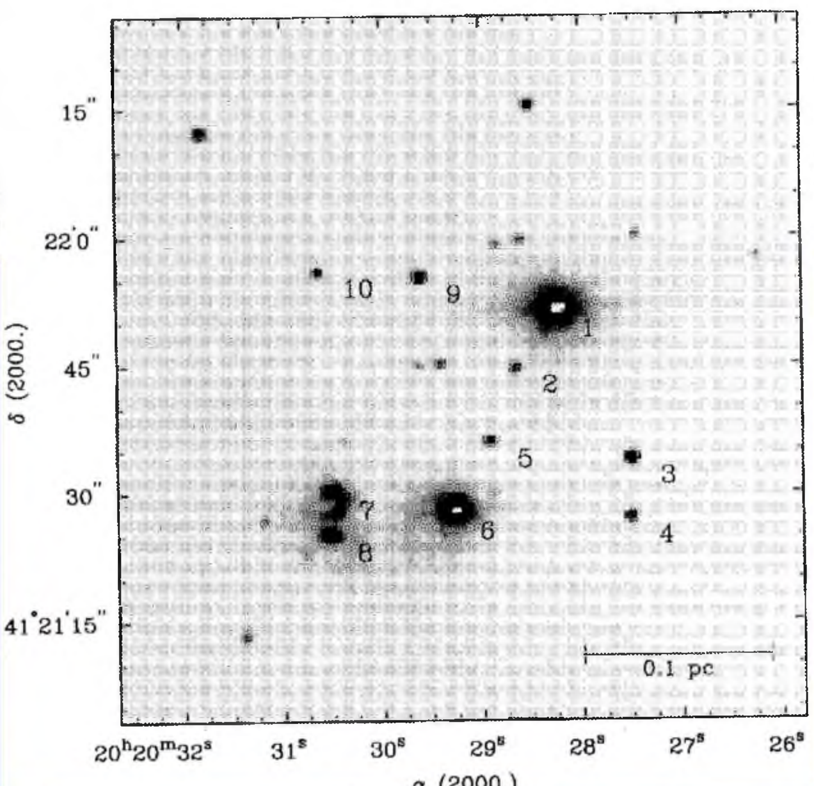


1998

A search for clustering around Herbig Ae/Be stars

II. Atlas of the observed sources*

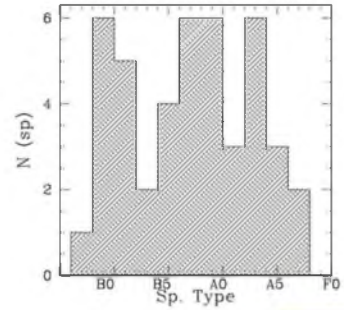
L. Testi[1,**], F. Palla[2], and A. Natta[2]

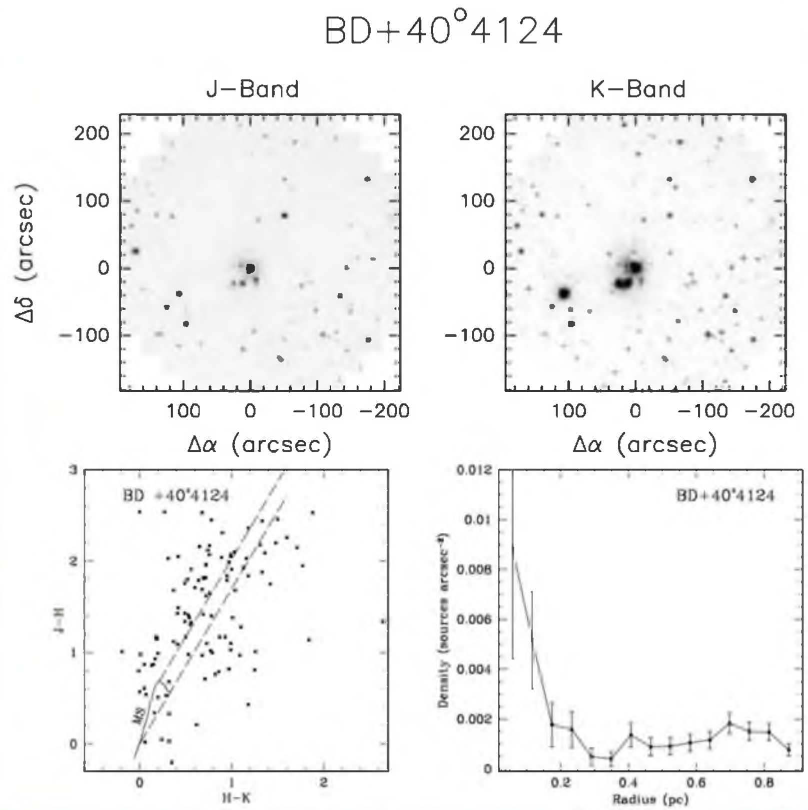
[1] Division of Physics, Mathematics and Astronomy, California Institute of Technology, MS 105-24, Pasadena CA 91125, U.S.A.
[2] Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, I-50125 Firenze, Italy

Received March 25; accepted May 11, 1998

Abstract. We present large field infrared images of a sample of 45 Herbig Ae/Be stars. Stellar parameters, such as age and luminosity, have been derived for all of them in a consistent way. The images have been used to identify stellar groups or clusters associated with the Herbig Ae/Be star. The results presented in this paper form the database for a study of clustering around intermediate mass stars (Testi et al. 1998).

Key words: stars: formation — stars: pre-main sequence — infrared: stars

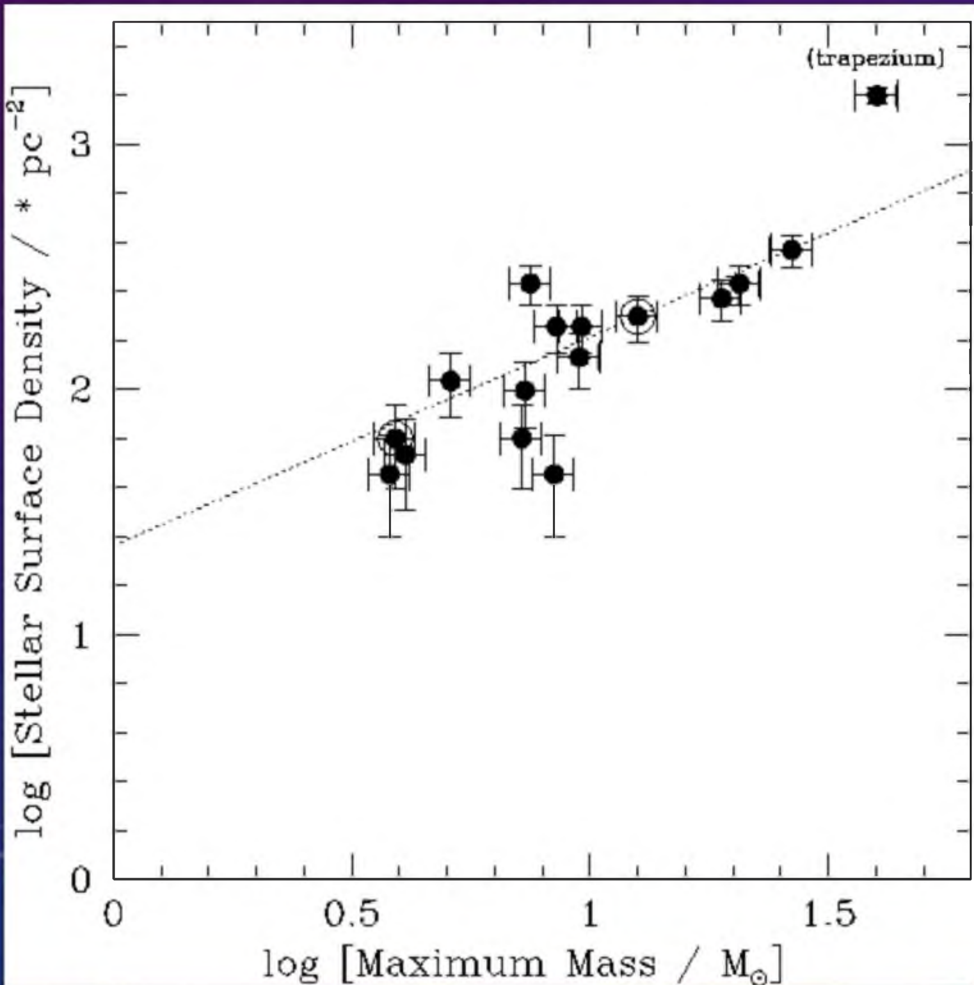




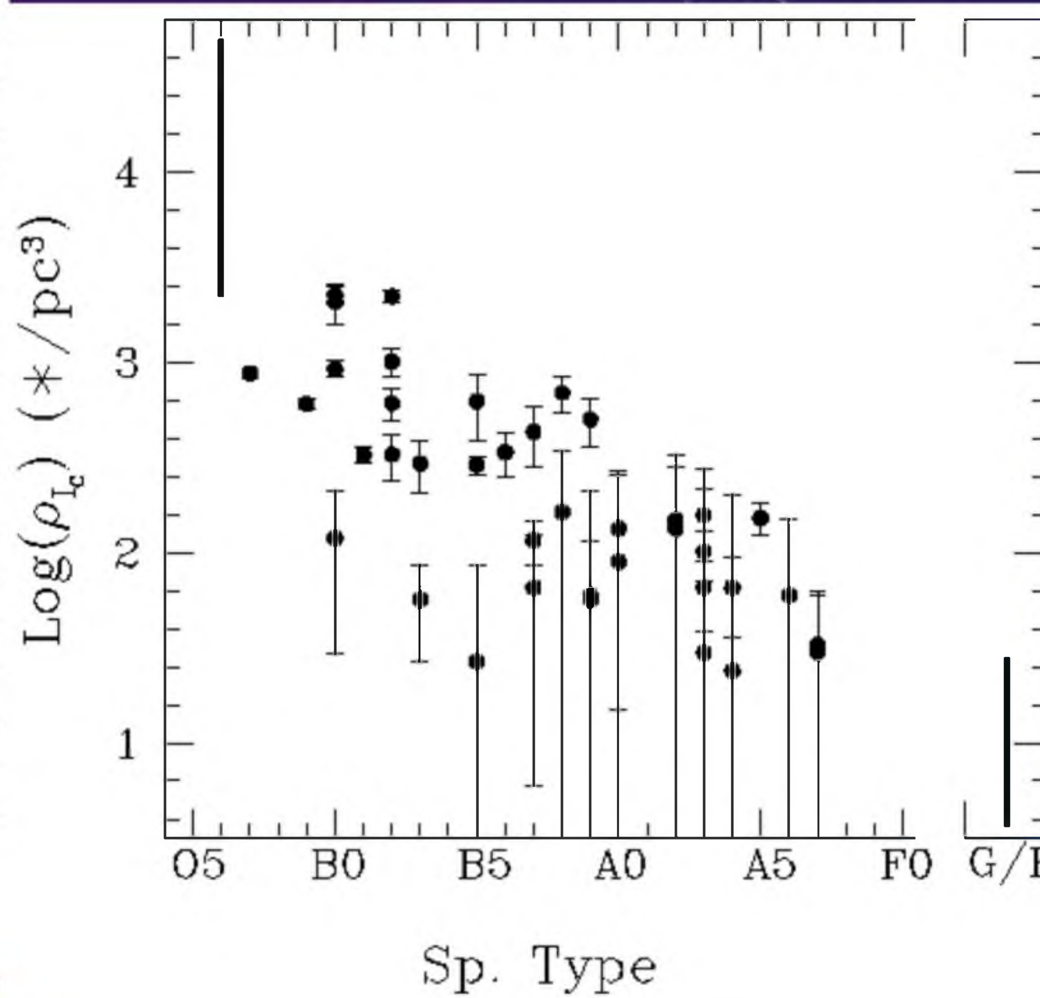
OBSERVED CLUSTER PROPERTIES

Denser clusters are associated with higher mass stars.

Hillenbrand 1995



Testi et al. 1998



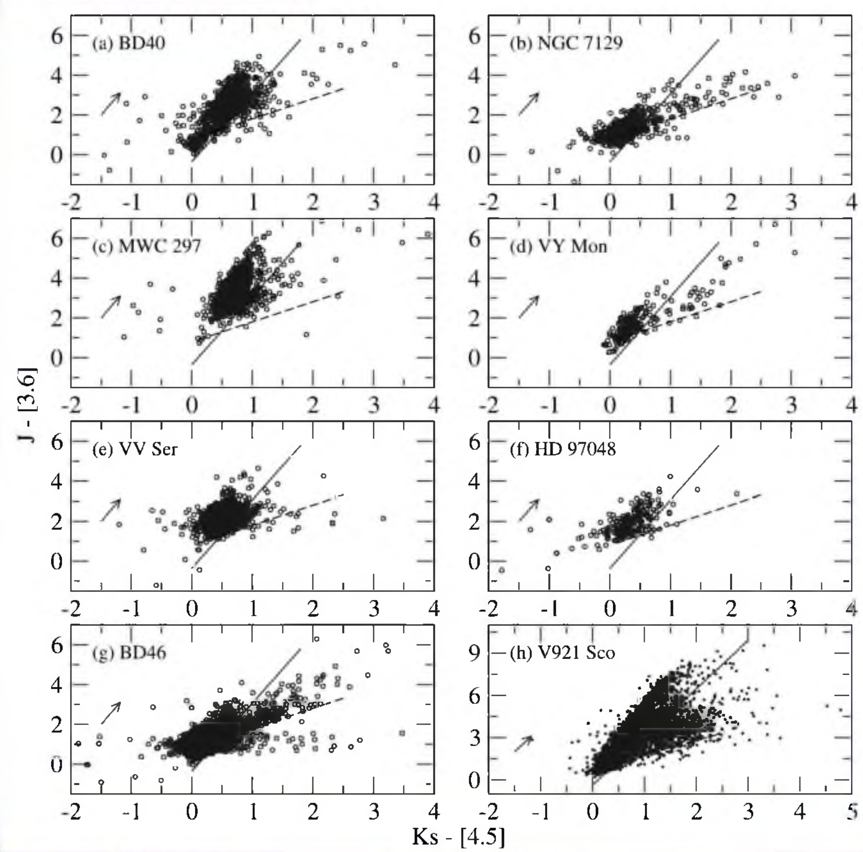
2007

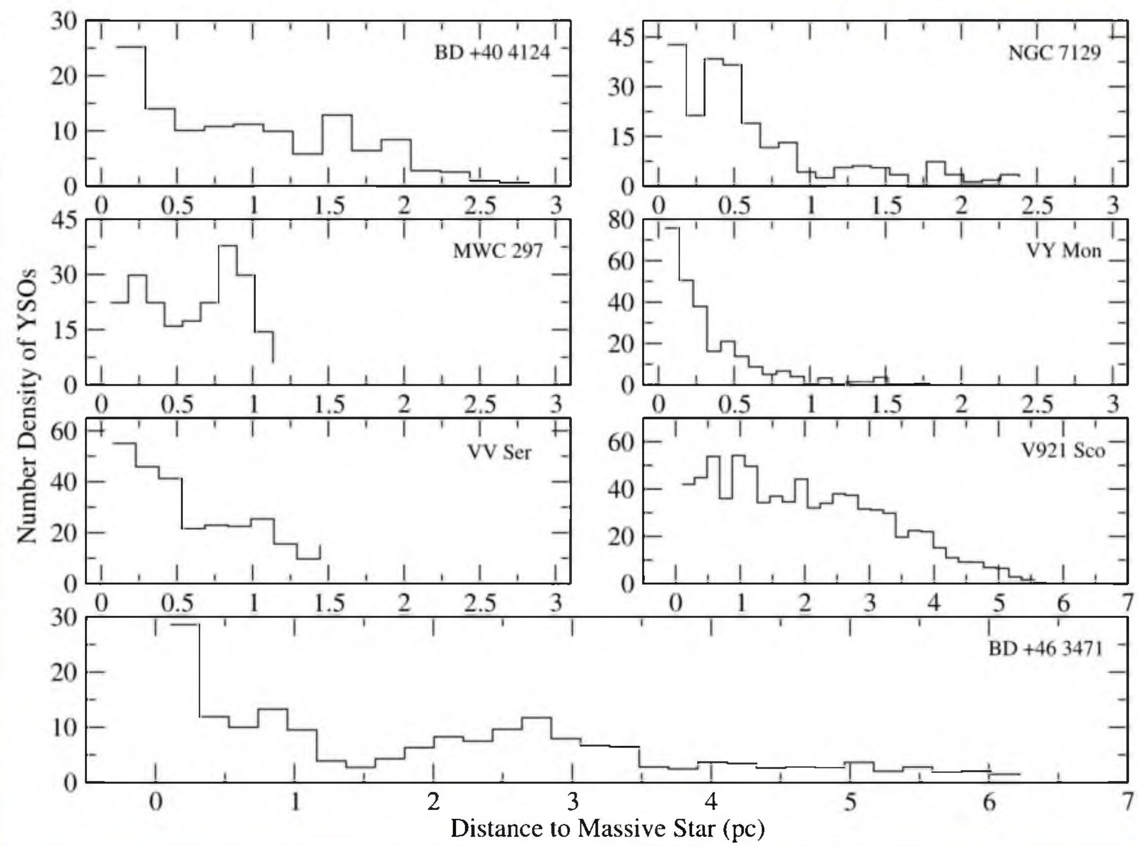
YOUNG STELLAR GROUPS AROUND HERBIG Ae/Be STARS: A LOW-MASS YSO CENSUS

Shiya Wang and Leslie W. Looney
Department of Astronomy, University of Illinois, Urbana, IL 61801; swang9@astro.uiuc.edu, lwl@uiuc.edu
Received 2006 July 6; accepted 2007 January 10

ABSTRACT

We present near-IR and mid-IR observations of eight embedded young stellar groups around Herbig Ae/Be stars (HAEBEs) using archived *Spitzer* IRAC data and 2MASS data. These young stellar groups are nearby (≤1 kpc) and still embedded within their molecular clouds. In order to identify the young stellar objects in our sample, we use the color-color diagram of $J-[3.6]$ versus $K_s-[4.5]$. The *Spitzer* images of our sample show that the groups around HAEBEs, spectral types earlier than B8, are usually associated with bright infrared nebulosity. Within this, there are normally 10–50 young stars distributed close to the HAEBEs (<1 pc). Not only are there young stars around the HAEBEs, there are also young stellar populations throughout the whole cloud, some of which are distributed and some of which are clumped. The groups around the HAEBEs are substructures of the large young population within the molecular cloud. The sizes of groups are also comparable with those substructures seen in massive clusters. Young





THAT WAS THEN, THIS IS NOW

1960

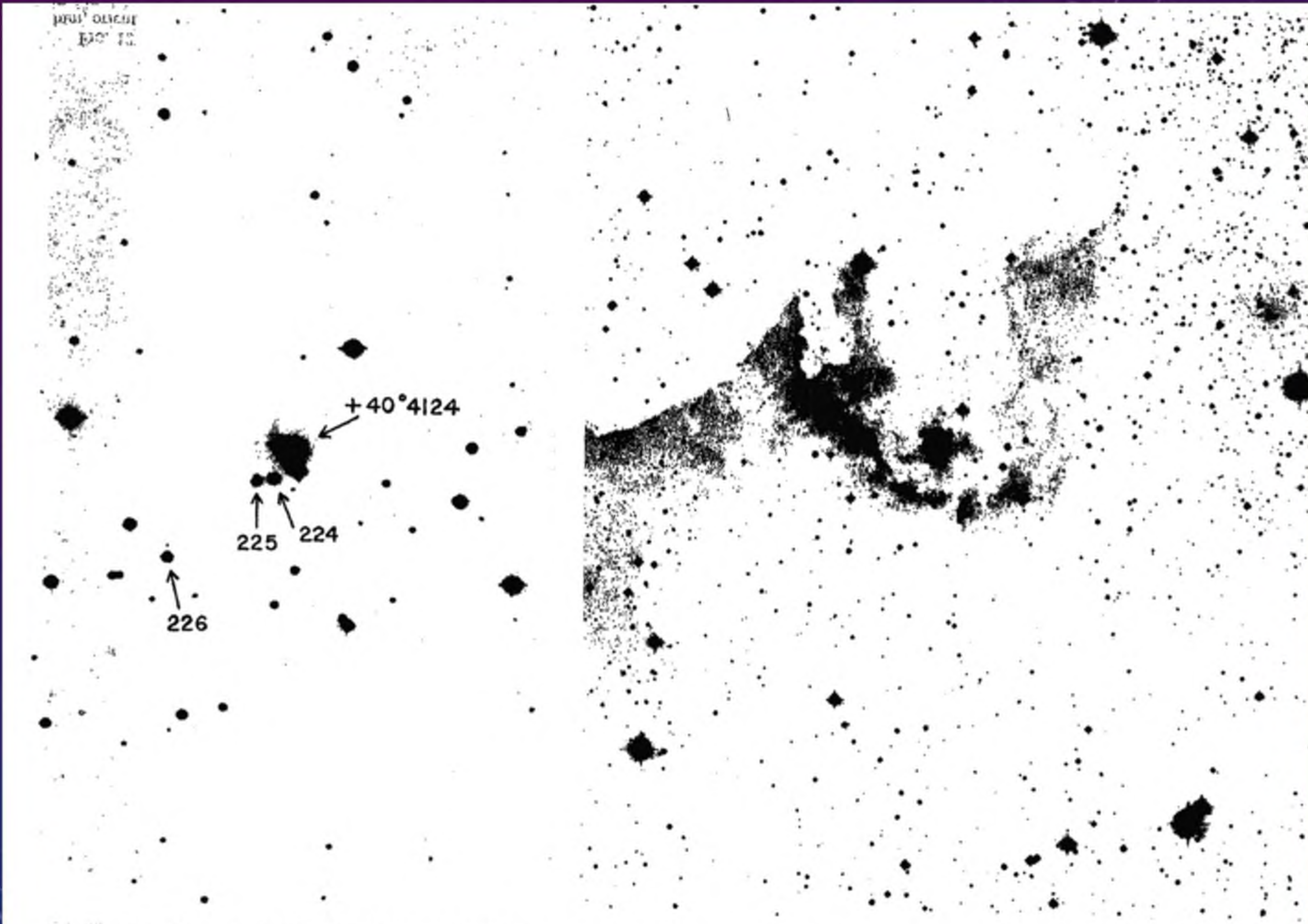
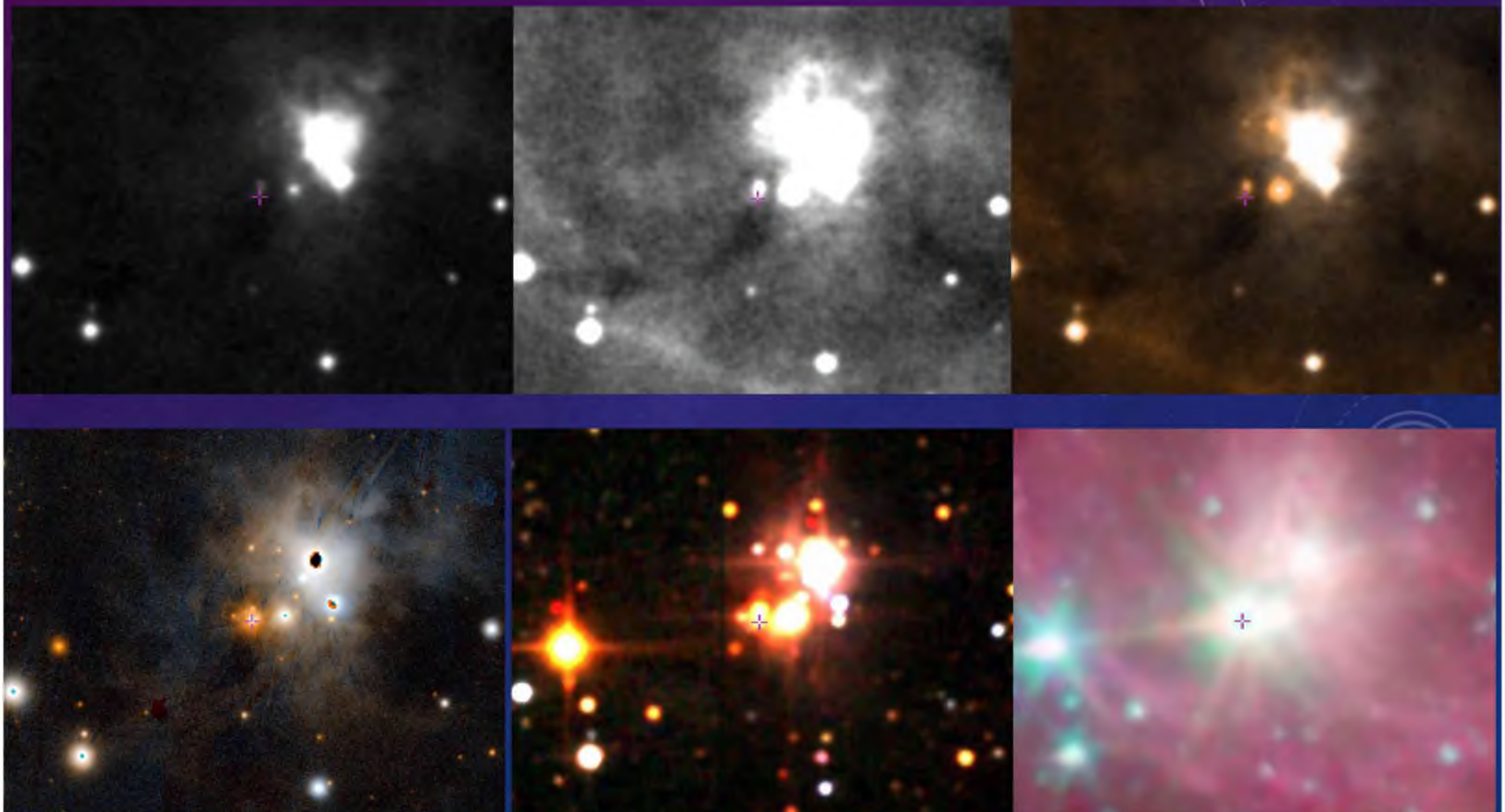


FIG. 11.—*Left:* The region of BD+40°4124 (= MWC 340) from a Crossley red exposure. (July 1, 1956, 60^m on 103*a*-E(2) plus 2 mm Schott RG-1; the scale is 5″.0/mm, orientation as in Fig. 1.) Emission-Hα stars are identified with their LkHα numbers. *Right:* The region of +40°4124 in red light, copied from plate E754 of the Palomar Sky Survey. (The scale is 13″/mm, orientation as in Fig. 1.) (Copyright National Geographic Society—Palomar Observatory Sky Survey.)

BD+40 4124 REGION

[d_{gaia}= 915 pc]

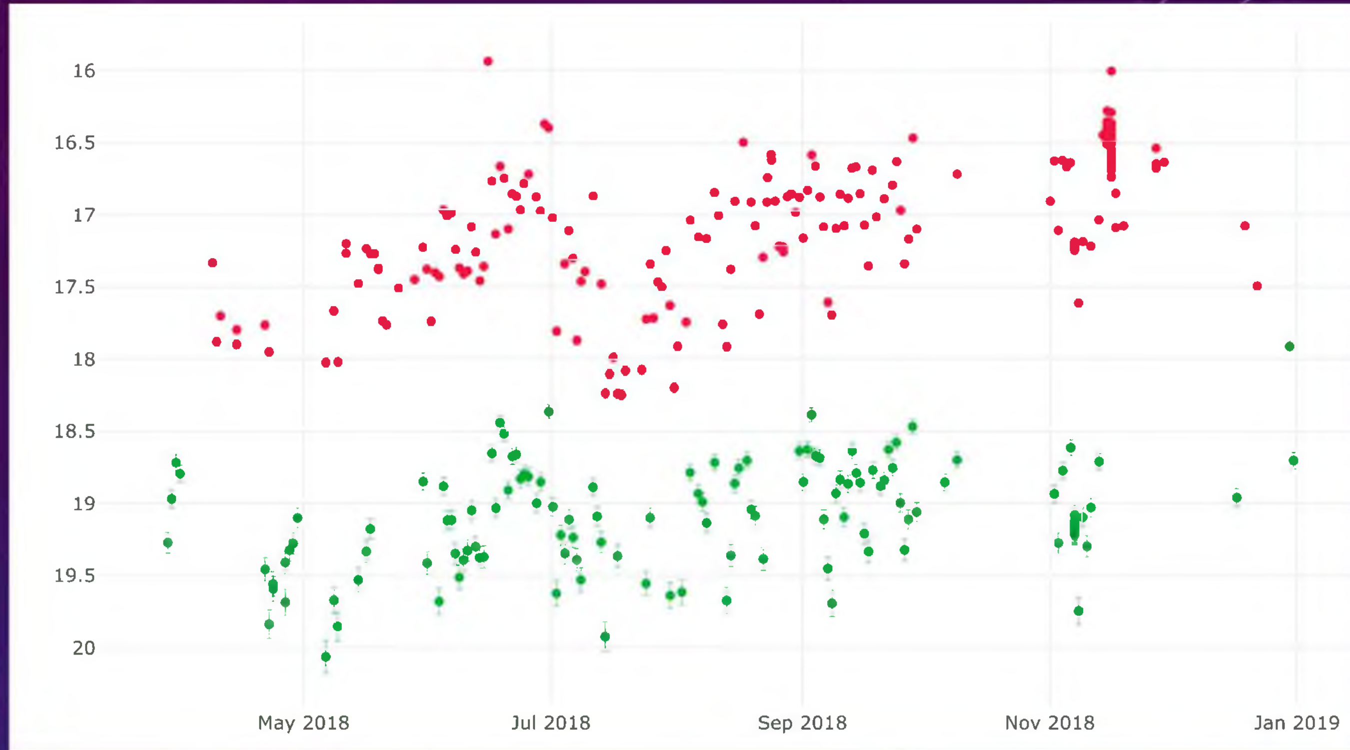
POSS-blue POSS-red POSS-color



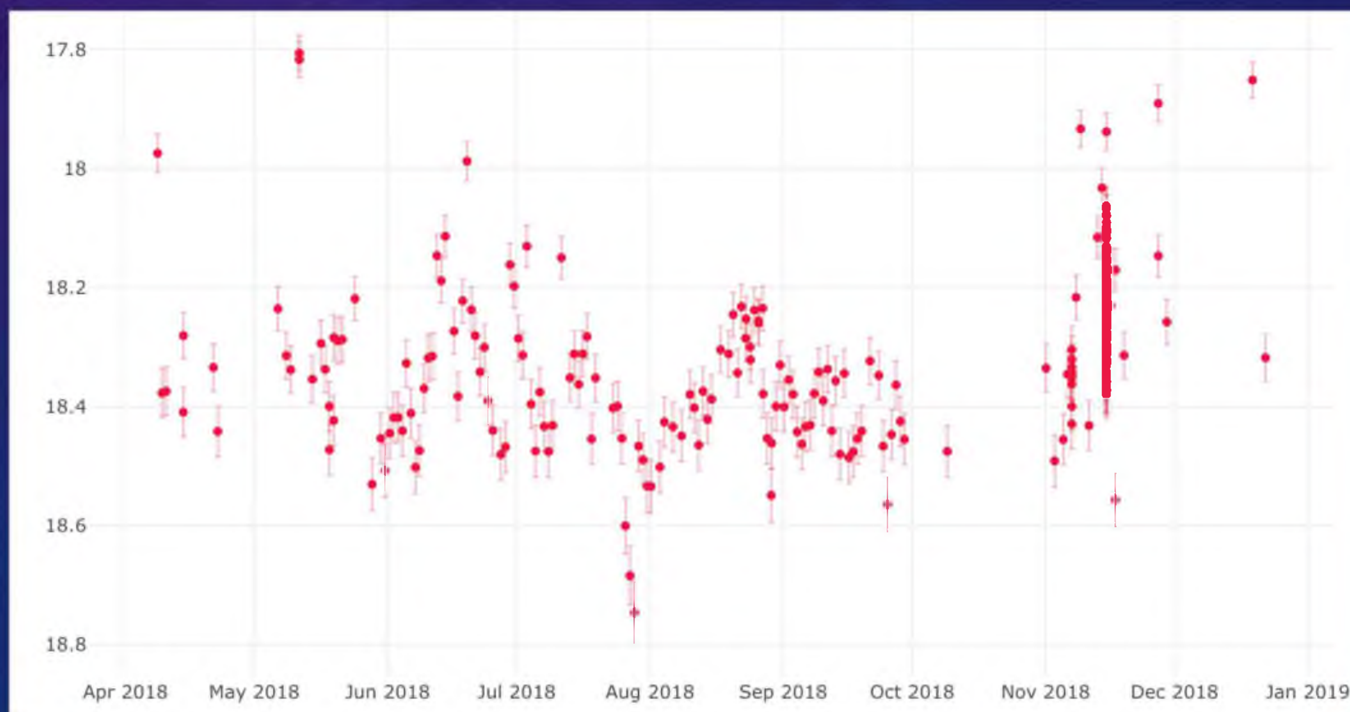
PanSTARRS 2MASS Spitzer

SOME VARIABLES IN THE REGION (ZTF DATA)

[HMS95] 9



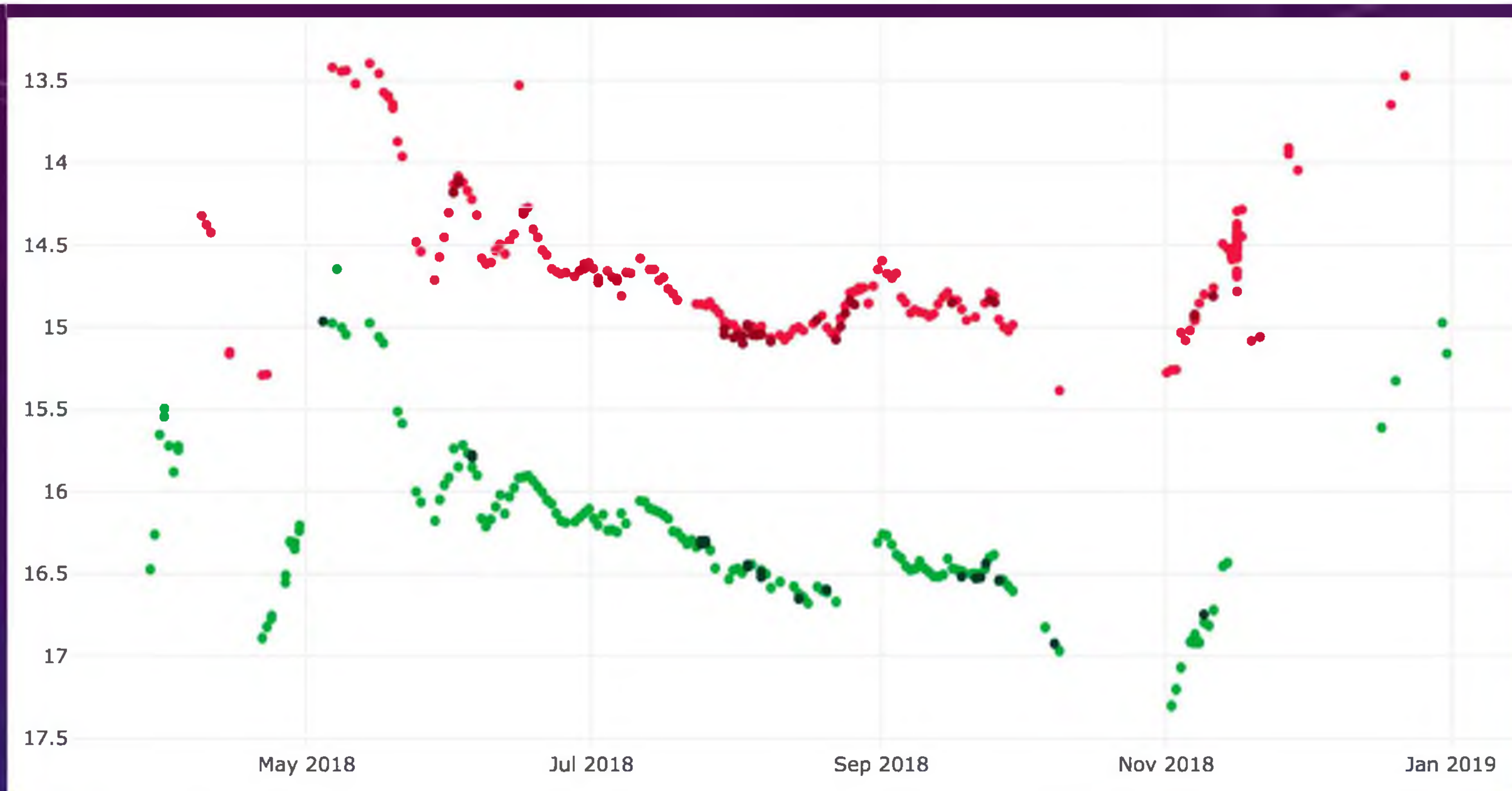
[HMS95] 10



THE TWO LARGEST AMPLITUDE VARIABLES IN THE REGION (ZTF DATA)

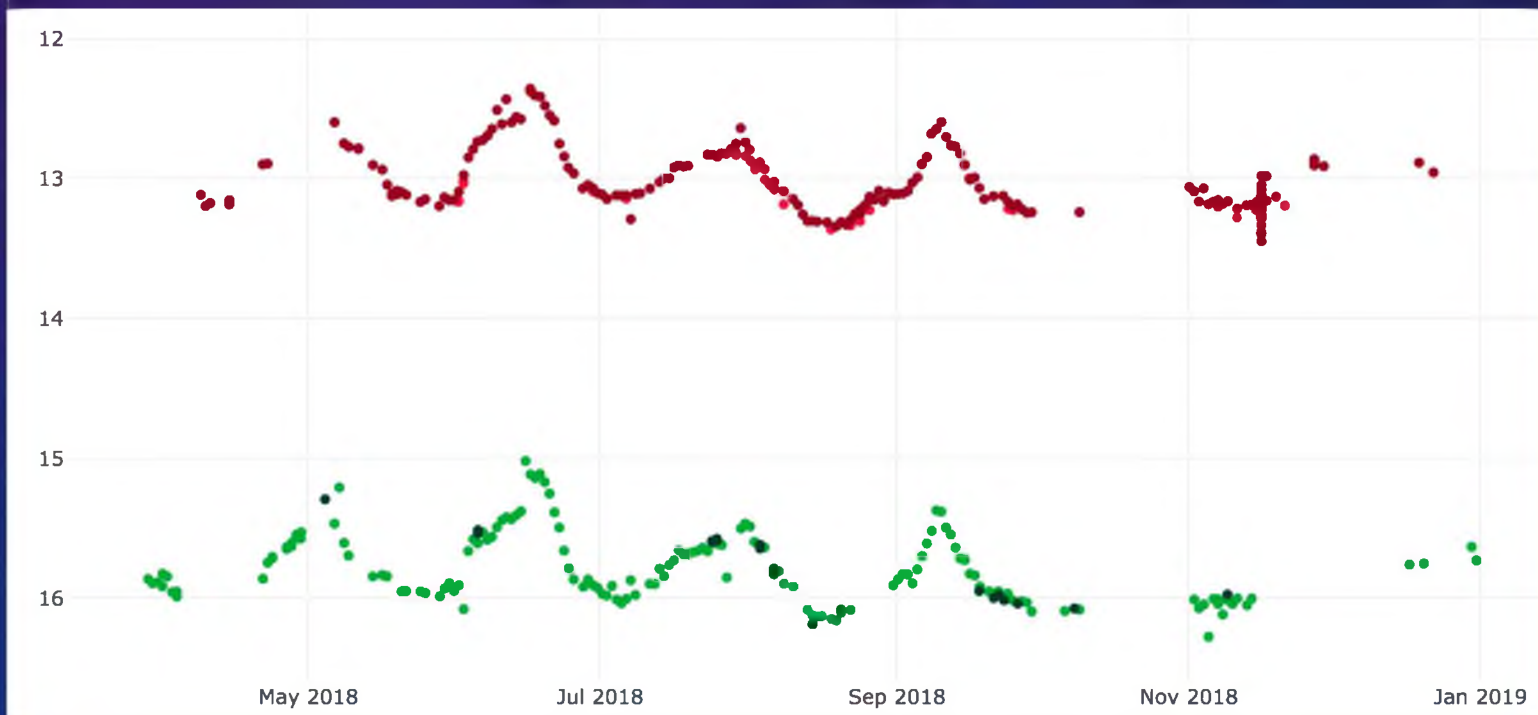
(no color variation in either case)

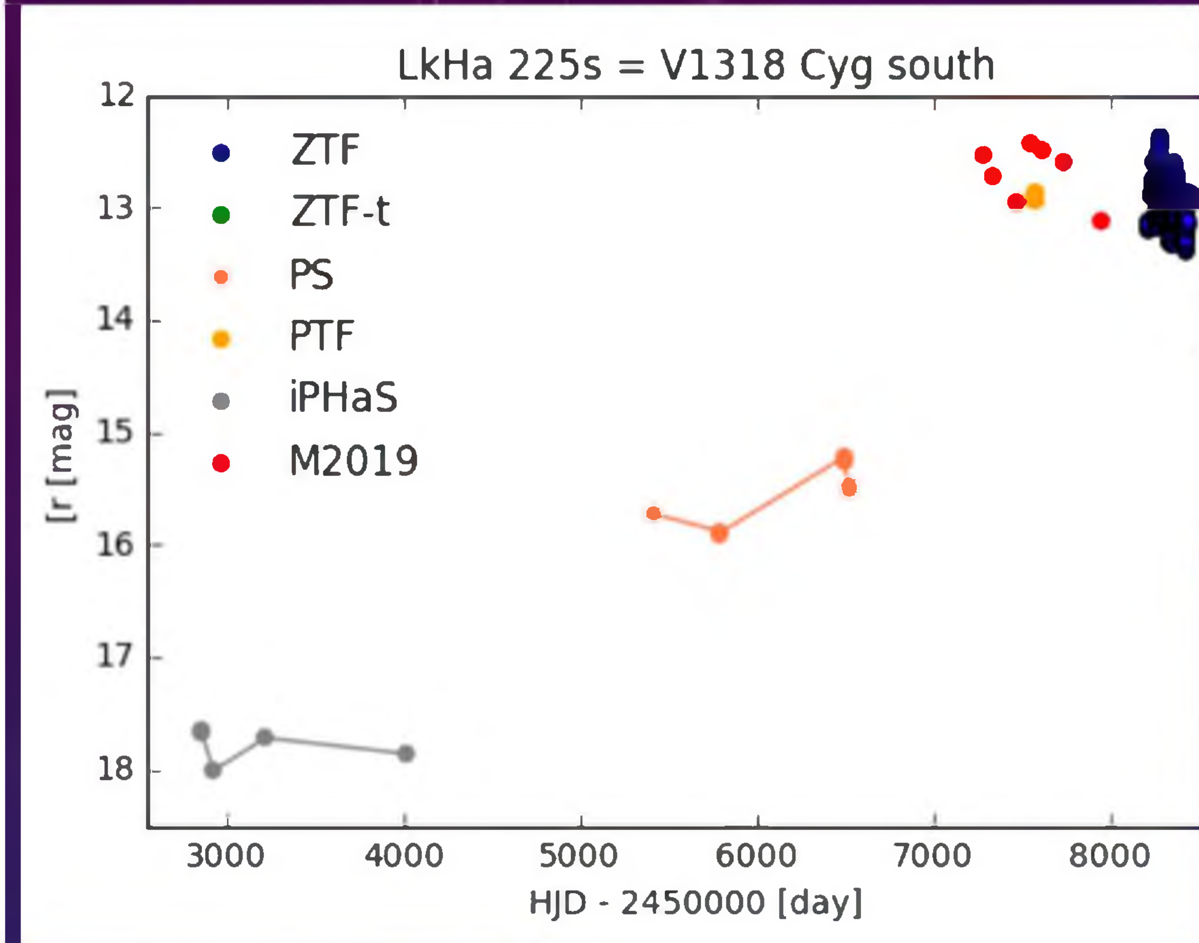
LkHa 224
aka
V1686 Cyg

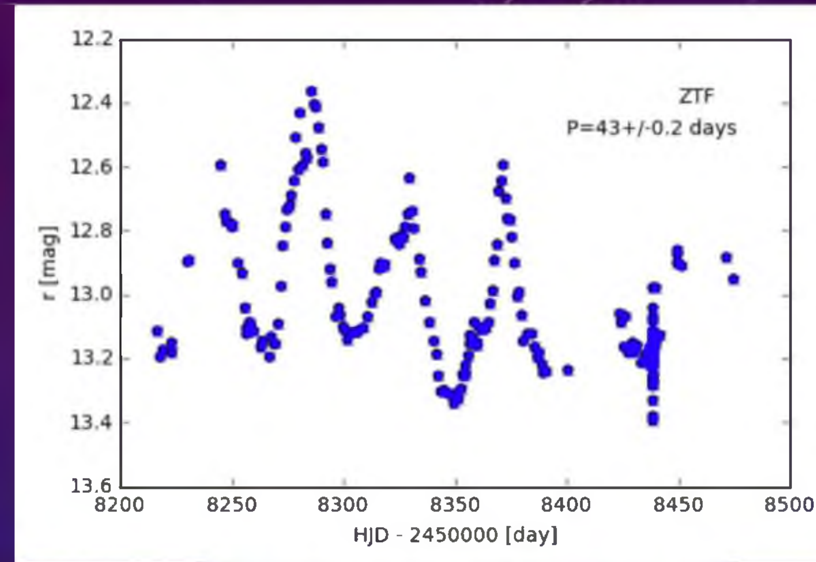


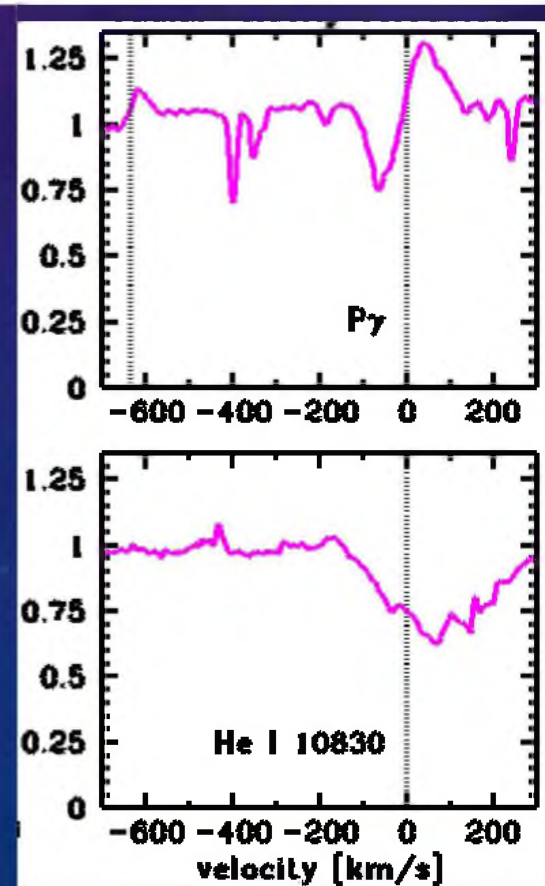
LkHa 225
aka
V1318 Cyg

(south)



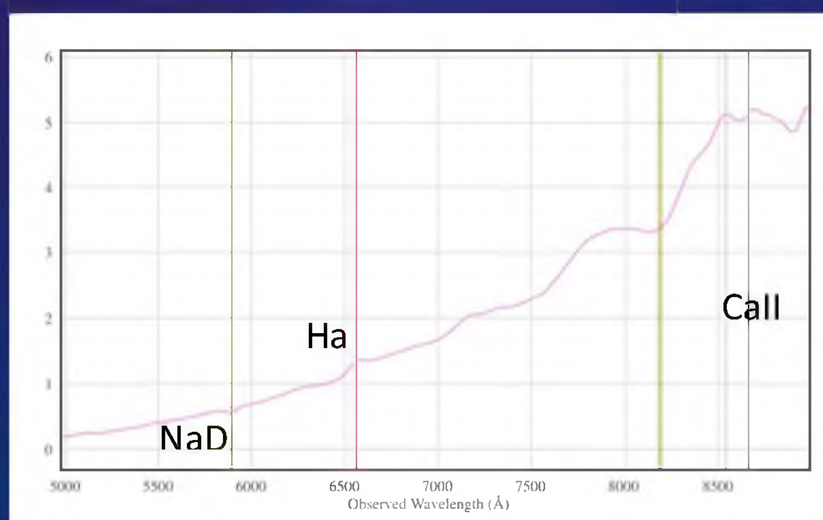




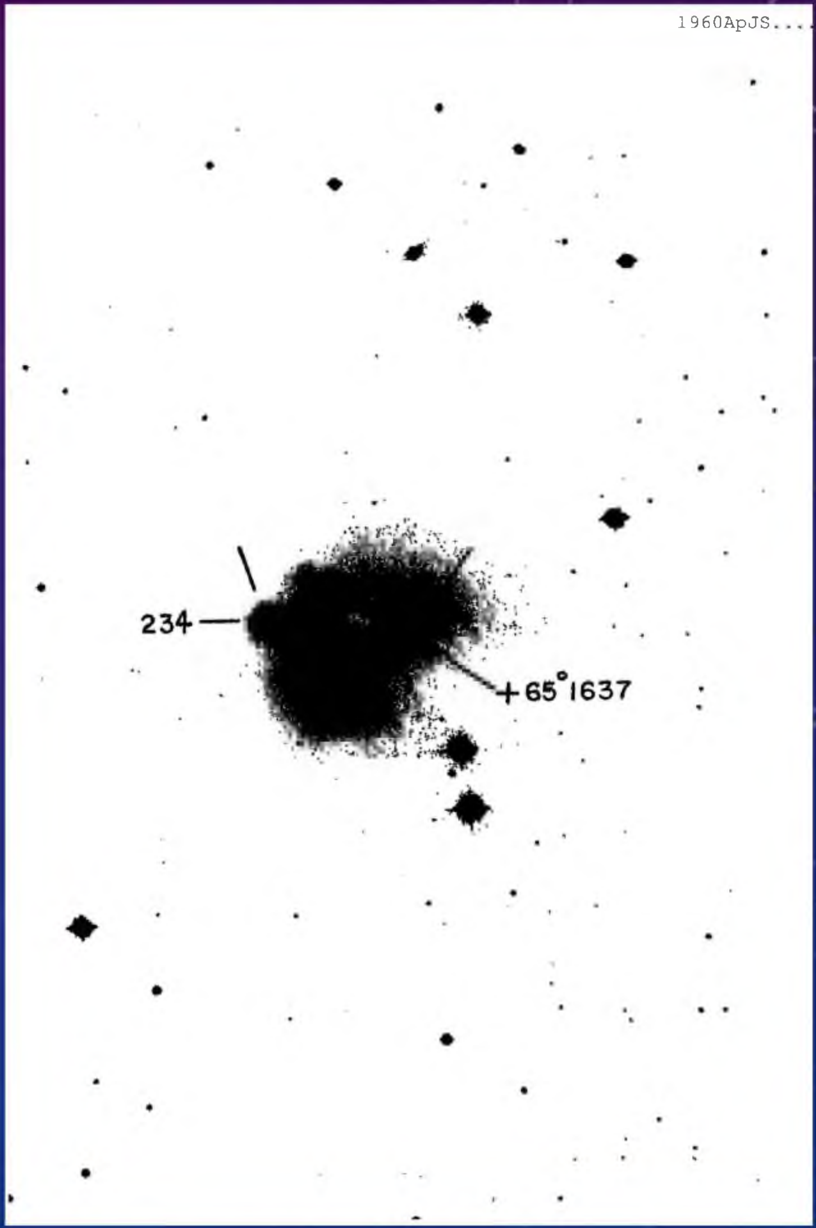


LkHa 225
aka
V1318 Cyg

(south)

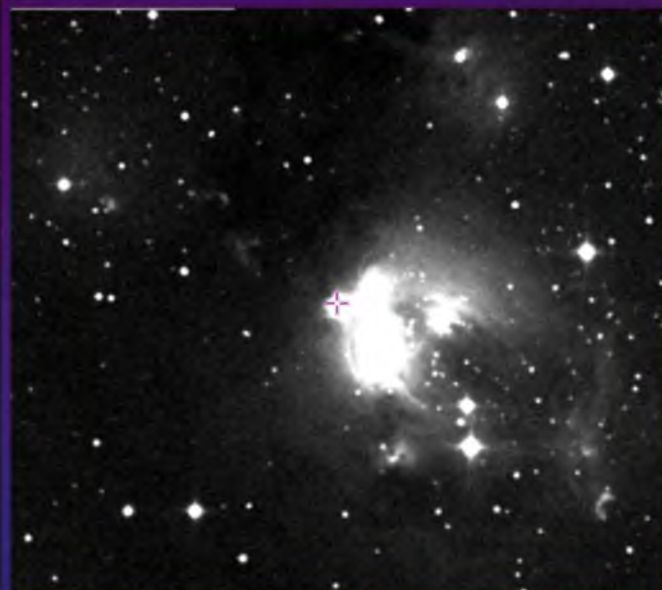


NGC 7129 REGION



NGC 7129 REGION

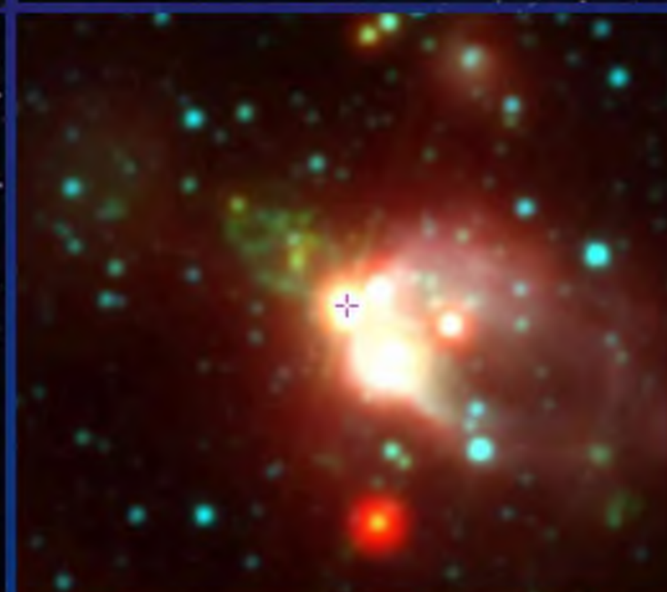

POSS-blue


POSS-red


POSS-color

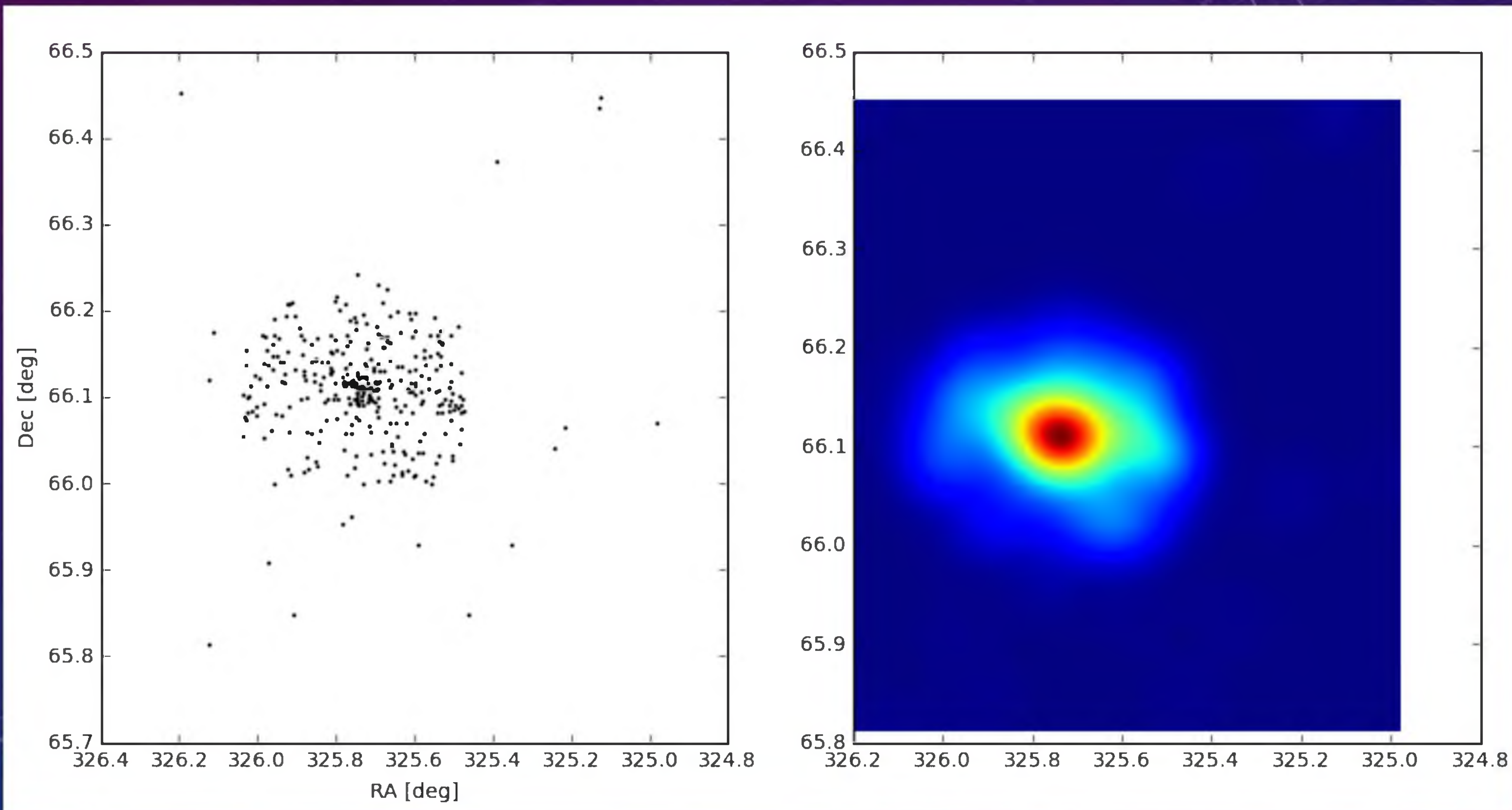

PanSTARRS


2MASS


Spitzer

NGC 7129 REGION

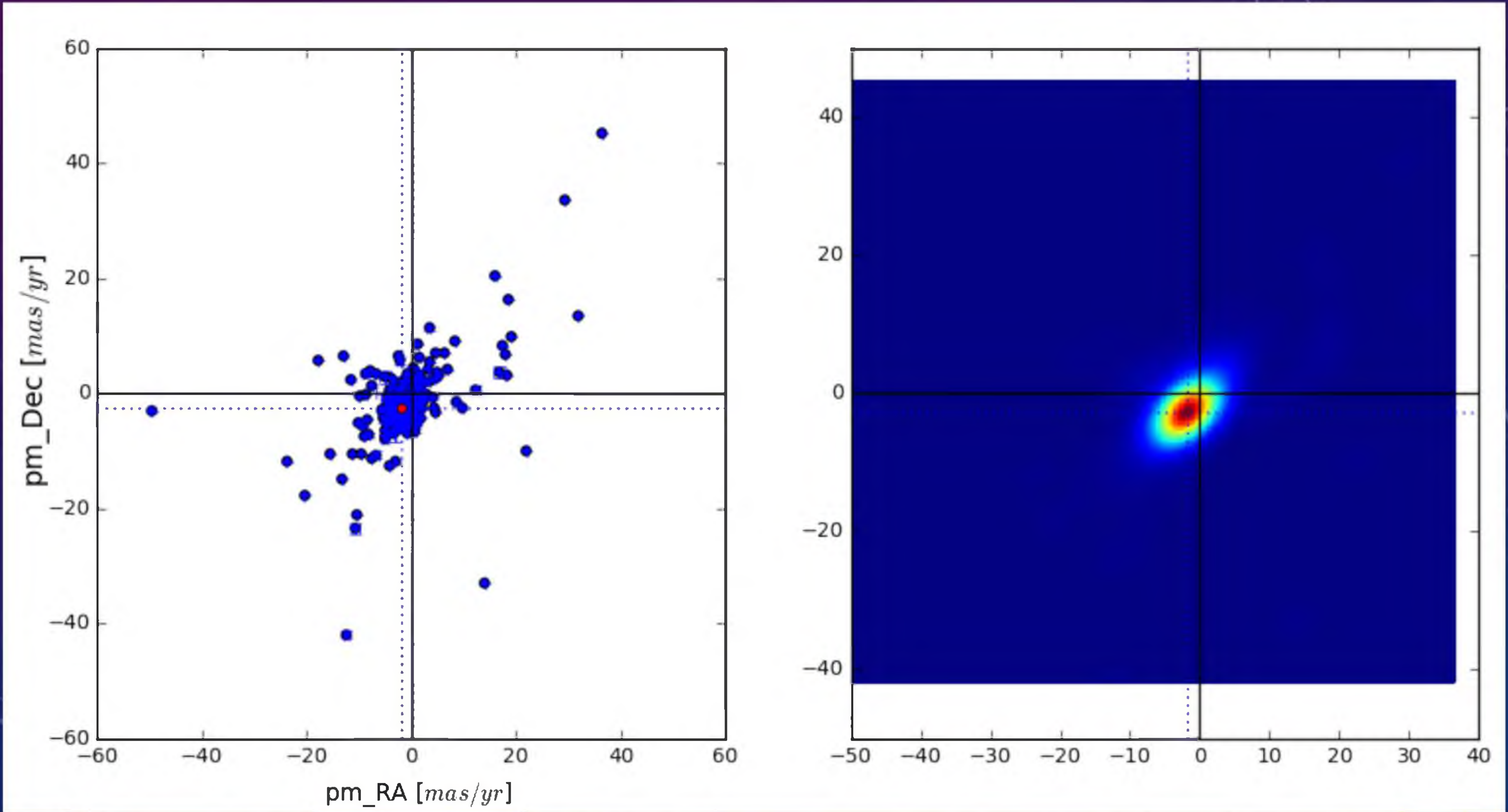
All previously claimed members or candidate members:



NGC 7129 REGION

Assess proper motions:

- median pm_ra = -1.81 +/- 0.39 mas/yr with dispersion 1.31 mas/yr
- median pm_dec = -2.67 +/- 0.36 mas/yr with dispersion 1.44 mas/yr



NGC 7129 REGION

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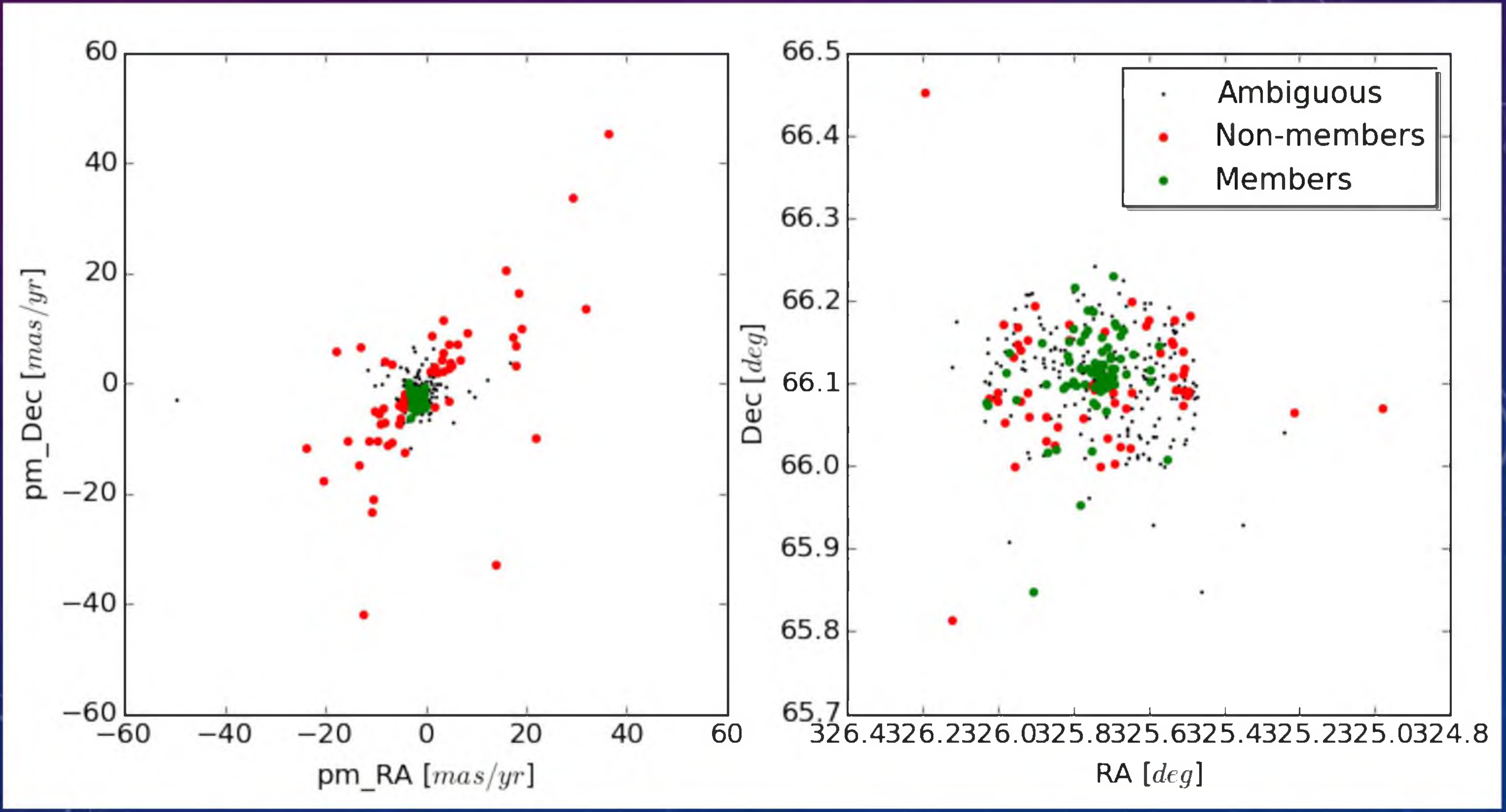


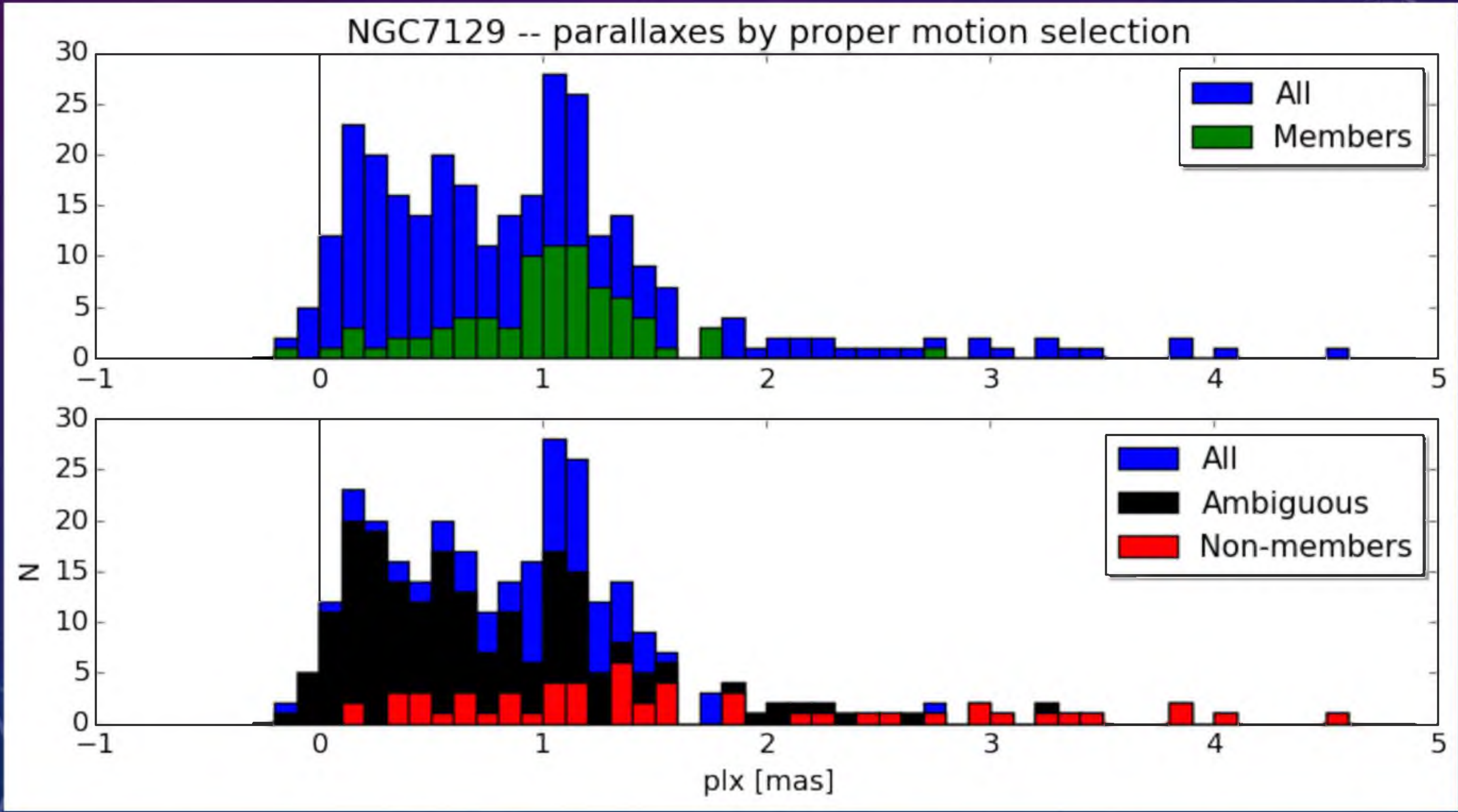
NGC 7129 REGION

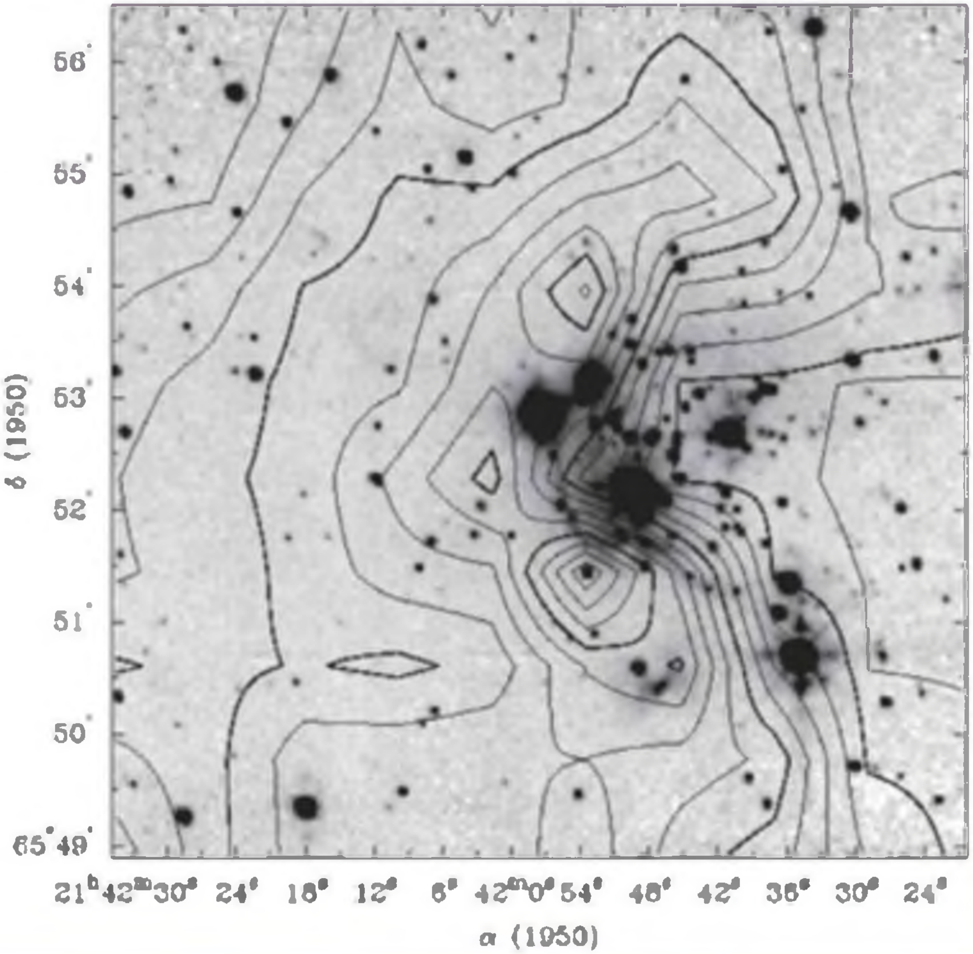
All previously claimed members or candidate members:

→ Select only proper motion members

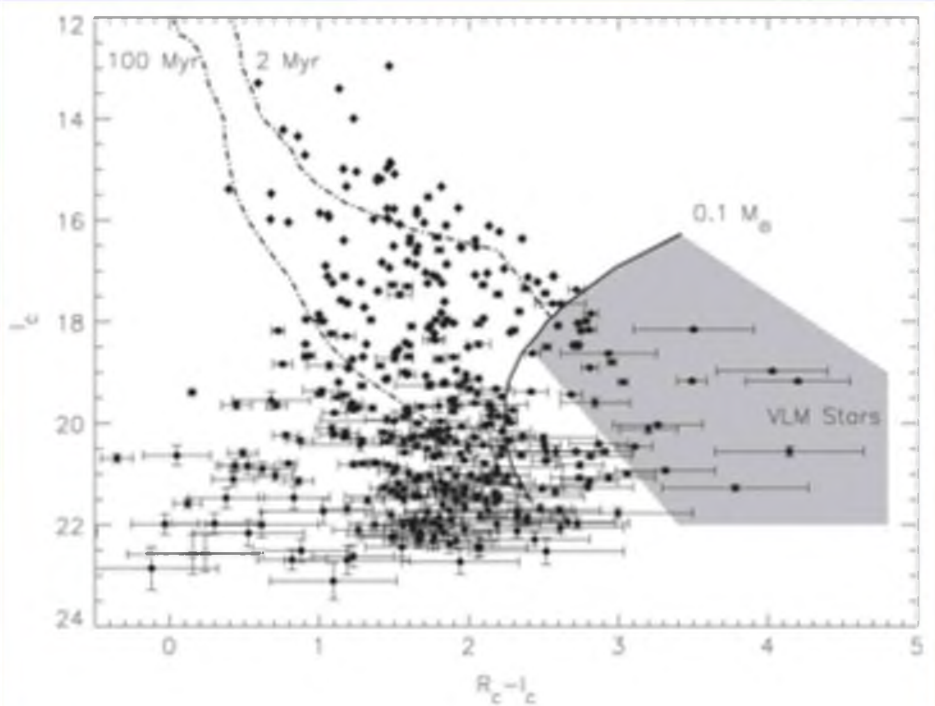
→ Assess parallax distribution: 1.04 +/- 0.05 mas with dispersion 0.23 mas.

Cluster appears closer than previously thought – 960 pc instead of 1260 pc





Dahm & Hillenbrand 2015

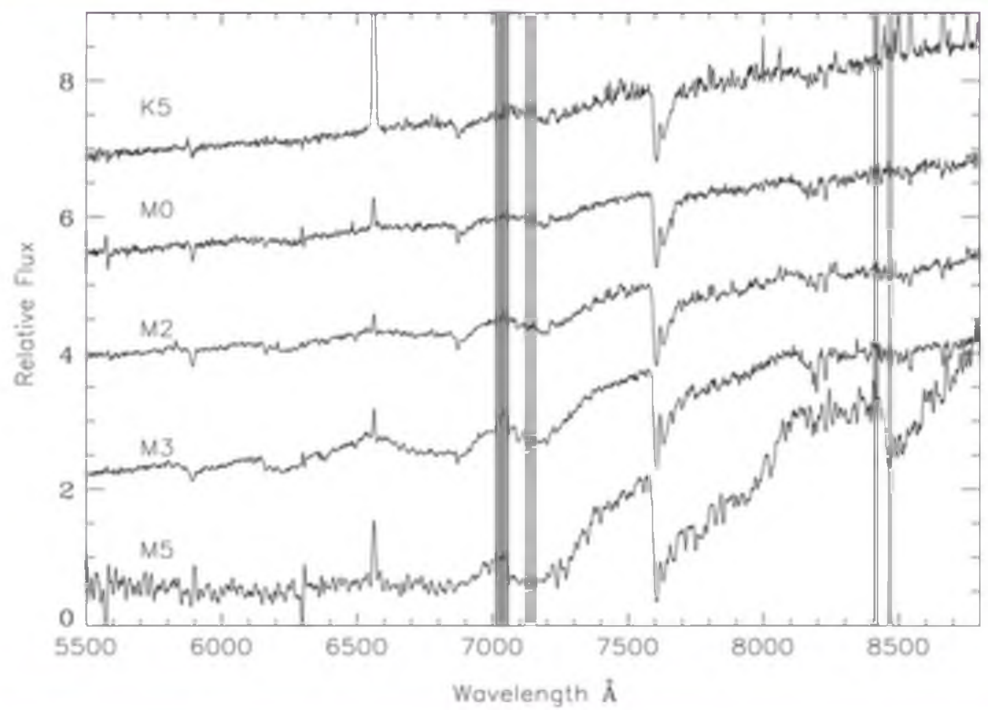


NGC 7129 REGION

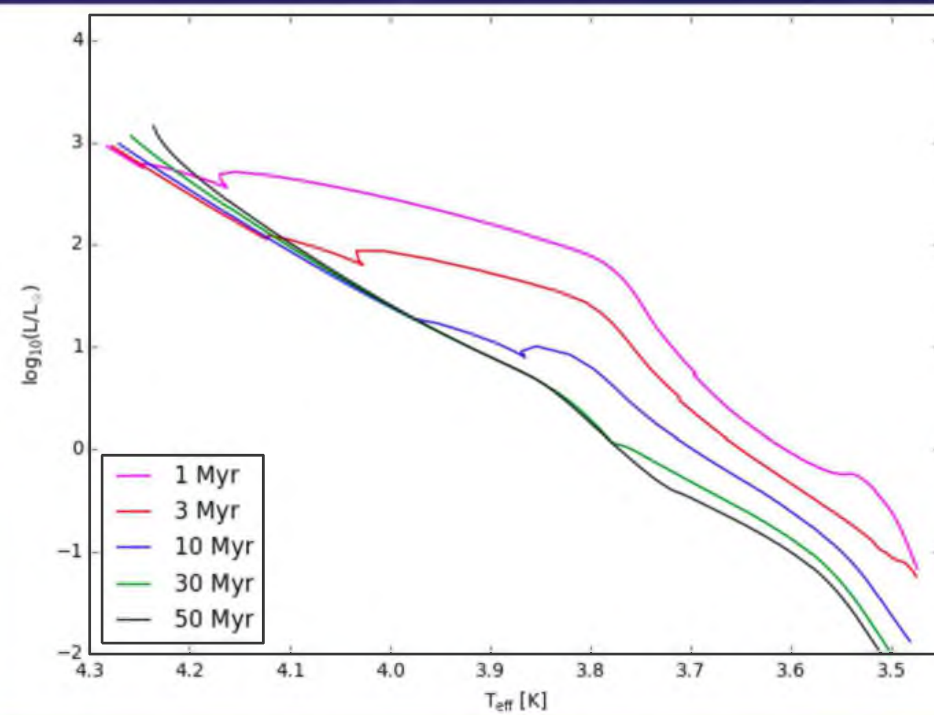
NGC 7129 REGION

All previously claimed members or candidate members: N=374

Look at HRD: N=229 stars with some spectral type constraint,
N=174 good enough for HRD placement.



In young cluster studies, spectroscopy is ***still*** the bottleneck!



Dahm & Hillenbrand 2015

PRE-MAIN SEQUENCE EVOLUTIONARY TRACKS STILL CARRY SYSTEMATICS BETWEEN MODEL SETS

Amard et al. 2019

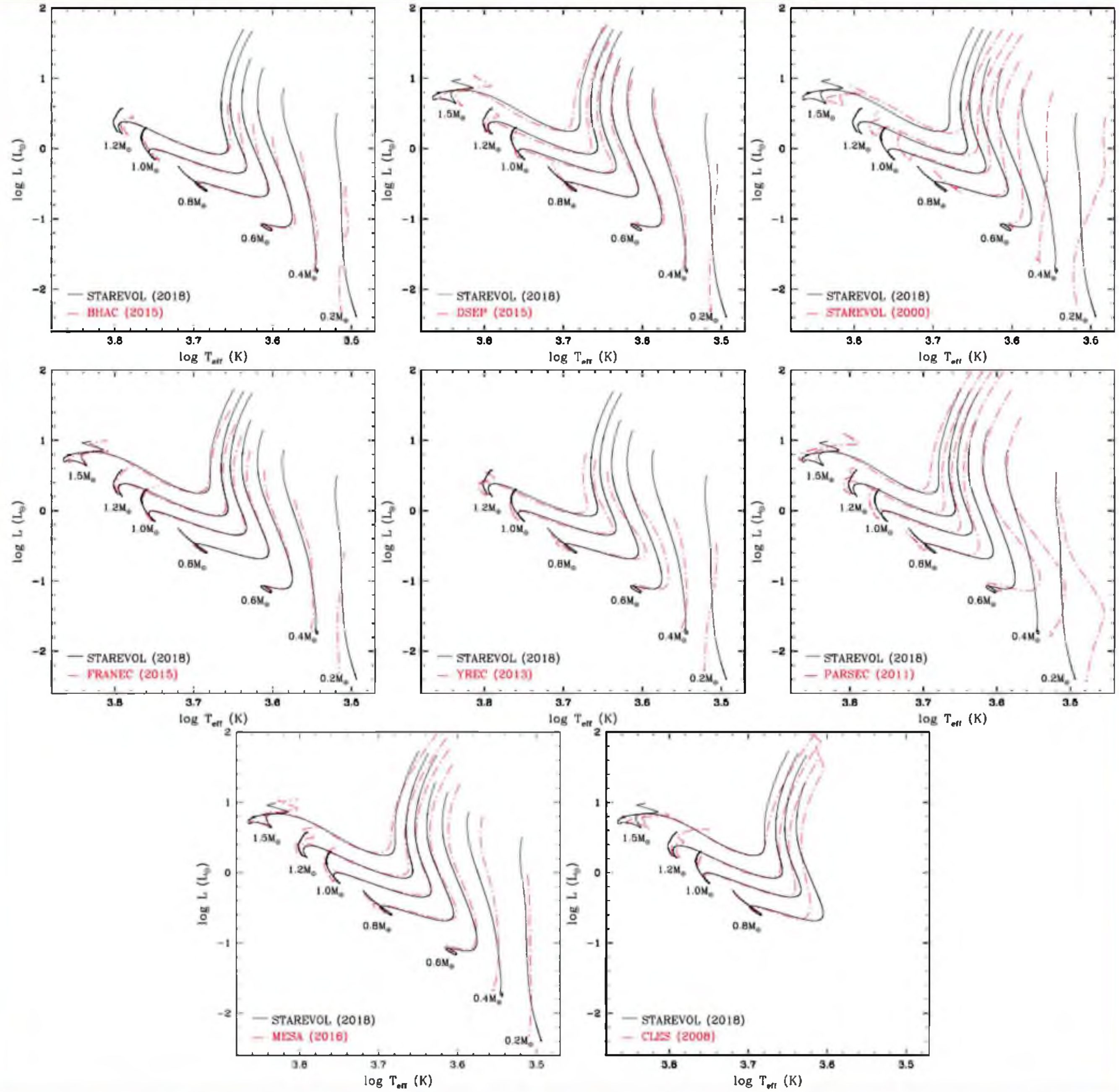
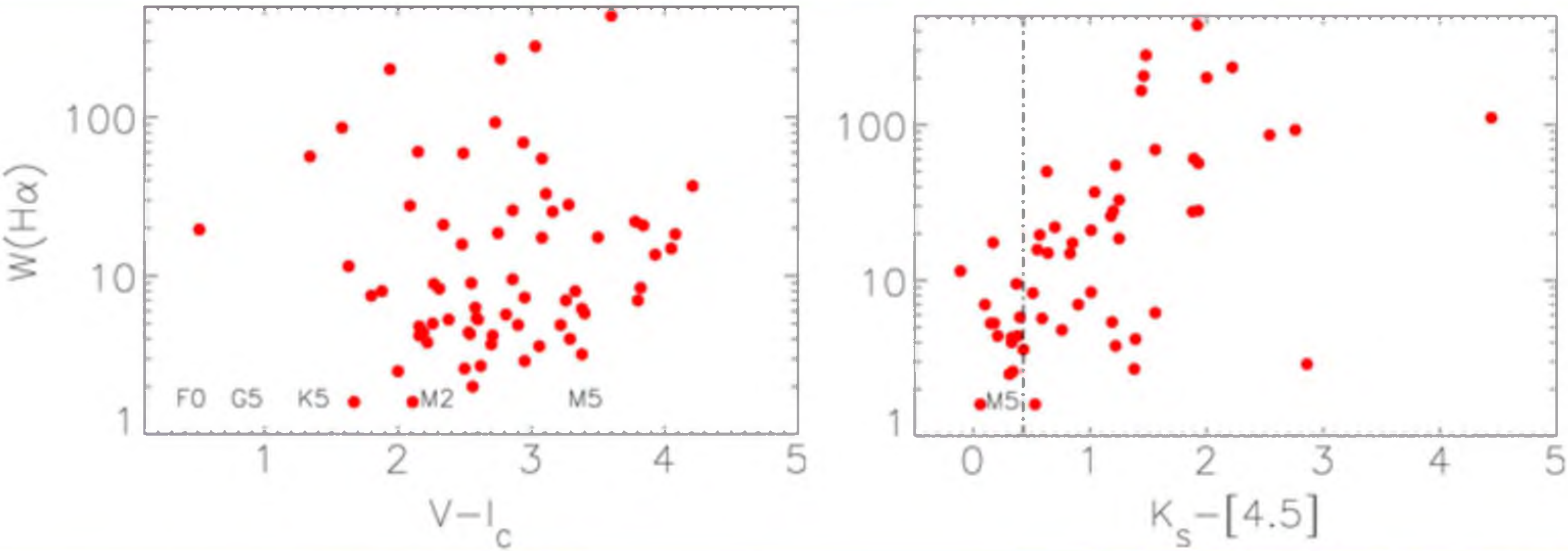


Fig. 3. Comparison of our standard solar metallicity models with other available grids as described in Table 4 and indicated on each panel.

THIS IS WELL-DOCUMENTED AT LOW MASSES, BUT ALSO TRUE AT HIGHER MASSES WHEN "BIRTHLINE" EFFECTS ARE CONSIDERED

NGC 7129 REGION

Look at evidence for gas accretion and circumstellar dust.

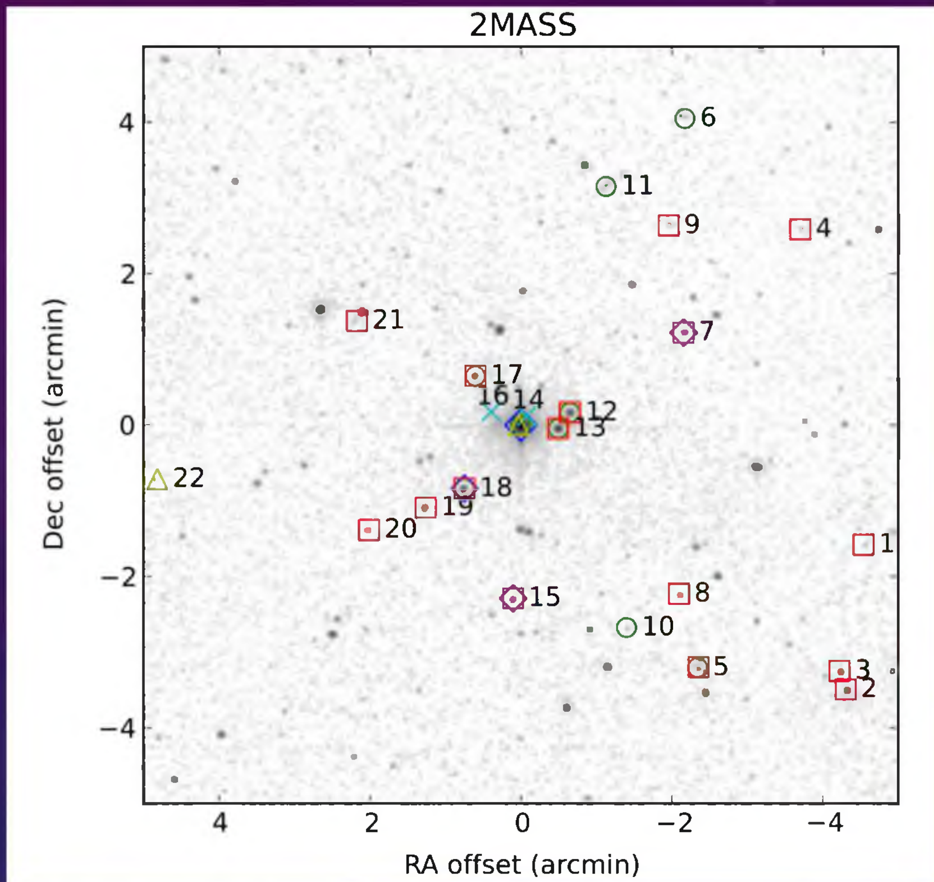


Dahm & Hillenbrand 2015

NON-TRADITIONAL AE/BE STARS: V1818 ORI

[d_{gaia}= 700 pc]

Chiang et al. 2015



ZTF monitoring in g,r

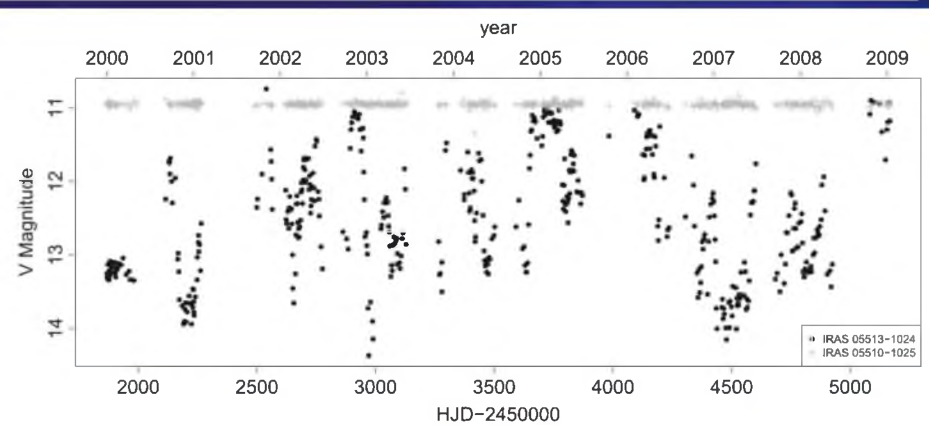
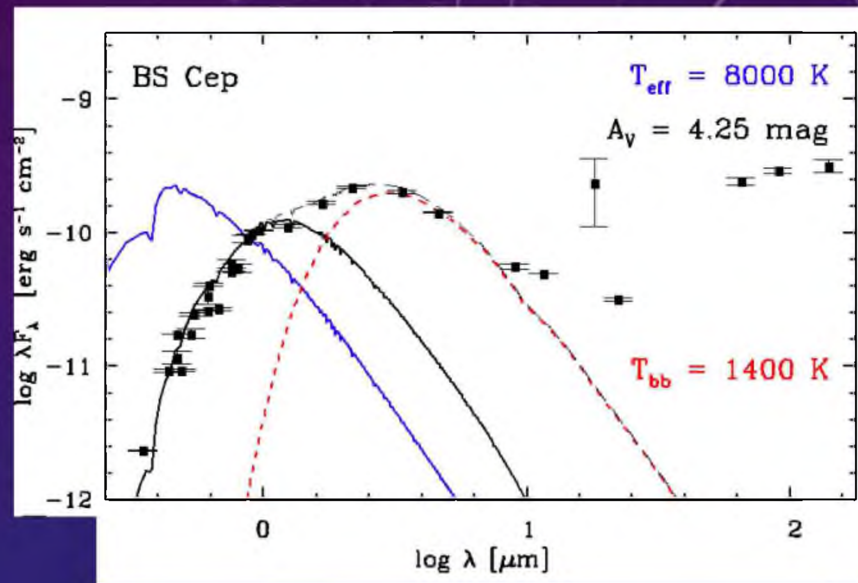
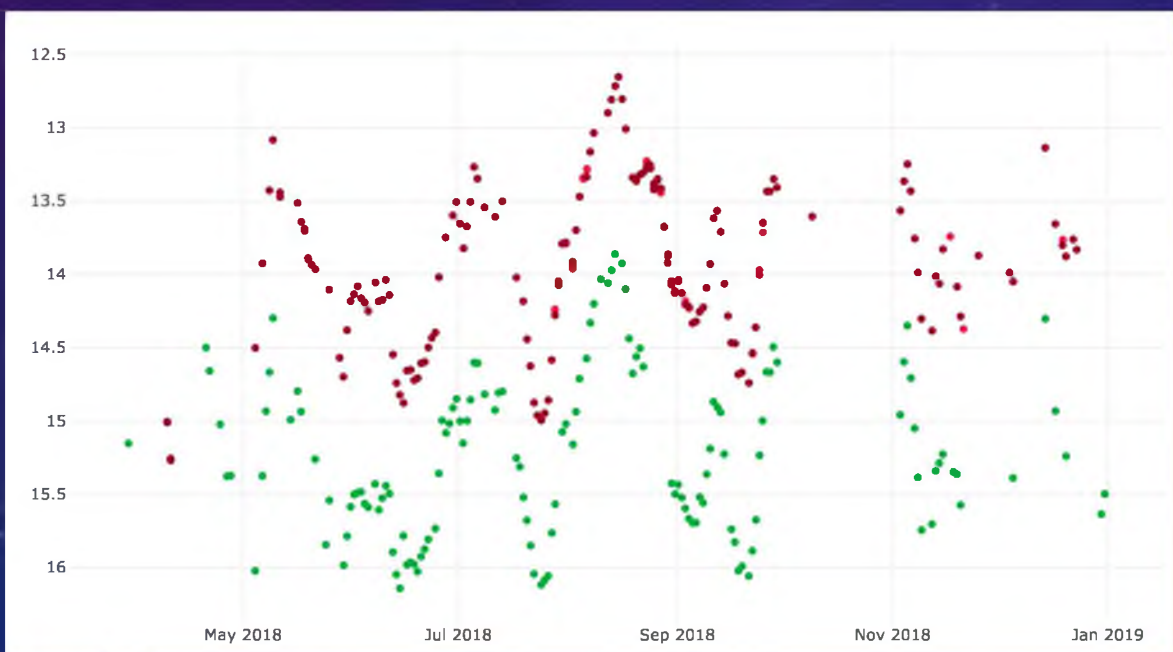


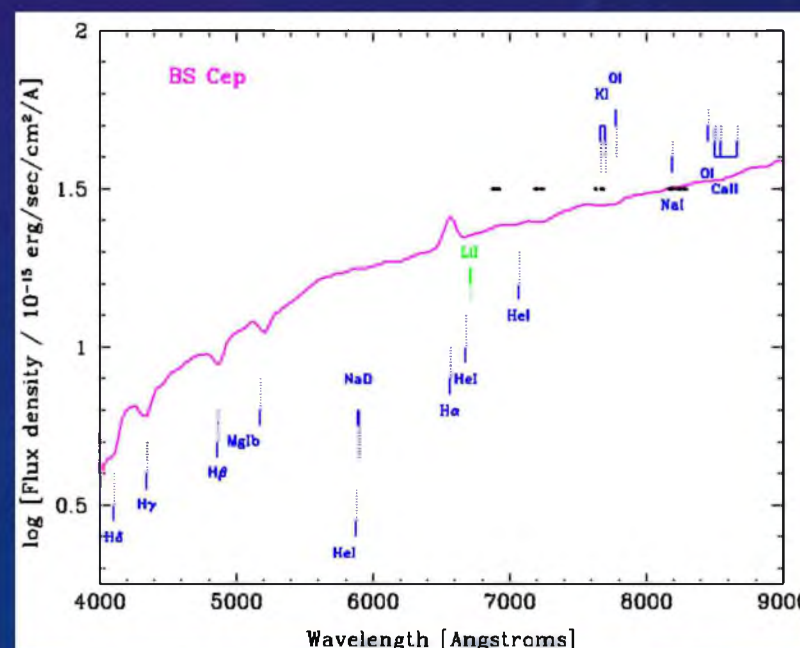
Figure 4. *V*-band brightness variation of V1818 Ori (*IRAS* 05513–1024, black dots) and *IRAS* 05510–1025 (gray crosses) as measured by ASAS.

PREVIOUSLY UNAPPRECIATED AE/BE STARS: BS CEP

- Appears in the literature and catalogs as a CV.
- Time series photometry suggests behavior more like a young star; variability timescale ~40 days.
- Spectrum confirms emission but only in Halpha.
- SED indicates disk (and envelope?).
- Environment clearly a star-forming region.
- No obvious small-N cluster though.



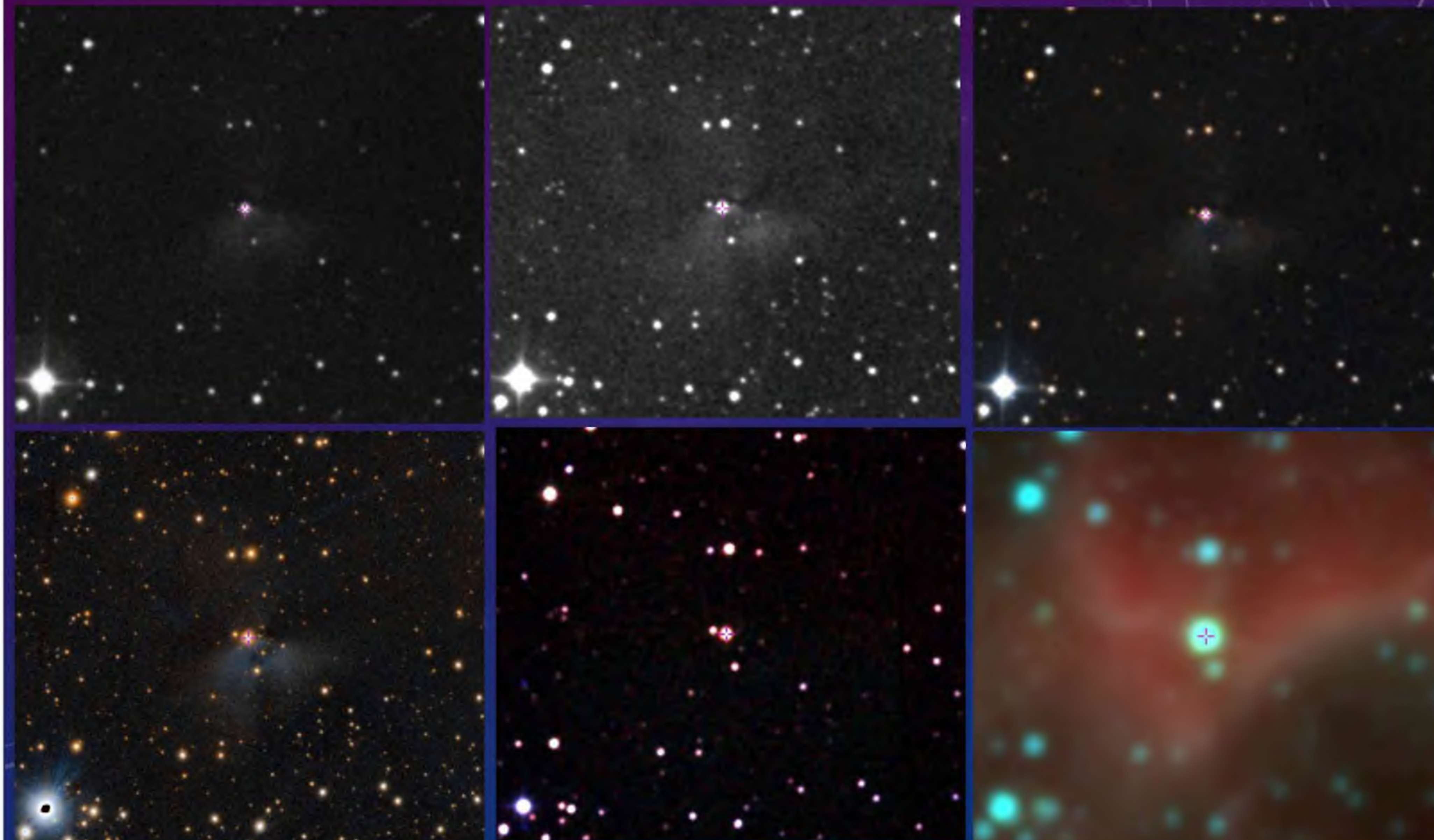




BS CEP REGION

[d_{gaia}= 900 pc]

POSS-blue POSS-red POSS-color



PanSTARRS 2MASS Spitzer

HERBIG AE/BE STARS IN LARGE / POPULOUS STAR FORMING REGIONS

Why are there so few (known)?

Example: How many Herbig Ae/Be stars are there in the ONC?
How many *should* there be?
Data: 23 objects with spectral types O, B, or early A

Answer: ? 

?

We believe that every <1 Msun star goes through a CTTS stage.
Does every 2-8 Msun experience a Herbig Ae/Be phase?

DISCOVERY AND OBSERVATIONS OF STARS OF CLASS Be[1]

By PAUL W. MERRILL, MILTON L. HUMASON, AND CORA G. BURWELL

1925

ABSTRACT

Stars of class B whose spectra contain emission lines of hydrogen.—Three reasons for studying these spectra are suggested: (1) possible assistance in the interpretation of the typical nova spectrum; (2) the bright lines appear to be sensitive indicators of conditions in stellar atmospheres; (3) unusual properties of hydrogen atoms may be involved.

H.D.	Hβ		Hγ		Hδ		Type
	Ch.	Int.	Ch.	Int.	Ch.	Int.	
37115......	D	3	D	1	A	....	B(5)e

→ MWC 114

Par 2271

(the only Be star in the ONC)

of the lines (Ch.) is described by means of the following symbols:[1]

A = absorption
C = continuous
P = P Cygni type, i.e., a bright line with a dark line on its short wave-length edge.
S, D refer to bright components
S = single
D = double

The intensities (Int.) refer only to the bright components and are on the following basis:

0.5 = very weak
1 = weak
2 = medium
3 = strong
4 = very strong

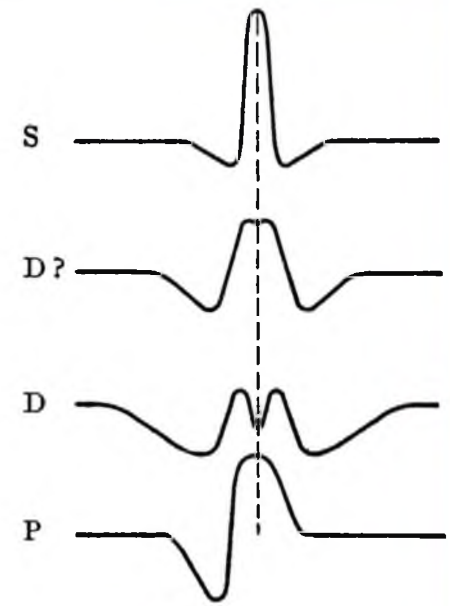


FIG. 1.—Typical intensity curves of hydrogen lines.

MESSAGES OF THIS TALK:

WE ARE NOW ABLE TO LOOK AT *OLD FRIENDS (YOUNG INTERMEDIATE-MASS STARS AND THEIR CLUSTERS) IN NEW WAYS*, USING TIME DOMAIN PHOTOMETRY AND KINEMATICS.

WE ARE ALSO ABLE TO USE SAME THESE TOOLS TO FIND YOUNG STAR *NEW FRIENDS*.

SEVERAL INTERESTING MYSTERIES OF THE HERBIG AE/BE CLASS REMAIN!

QUESTIONS IT IS NOW POSSIBLE TO ADDRESS IN DETAIL

- Environmental context of individual Herbig Ae/Be stars?
  - Immediate vicinity:
    - almost never truly isolated (nearest comparably young star never >0.1 pc away)
    - relatively low density *vs* dense small-N cluster *vs* member of a large cluster/association
  - Large scale:
    - varied locations relative to broad molecular cloud and dust morphology
    - at centers of small cloud cores *vs* along bright rims *vs* substructure within larger SFR
- Ages of individual Herbig Ae/Be stars and how long this phase lasts?
- Cluster contraction/formation and then expansion/dispersal times?