Távolabbi csillagok: túl a parallaxison

Túl a parallaxison

- szekuláris parallaxis
- statisztikus parallaxis

asztrometria
\+ spektroszkópia

- mozgási halmaz módszer
- fősorozat-illesztés (izokrón-illesztés)
- spektroszkópiai parallaxis

HRD

Radiális sebesség, térbeli sebesség

Csillagok radiális sebessége:

$$z = \frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$ nem-relativisztikus közelítésben

(csillagok abszolút sebessége: ~ km/s

relatív sebessége ~ m/s)

A térbeli sebesség két komponensből áll:

- radiális sebesség
- transzverzális sebesség

Θ : látóiránnyal bezárt szög

$$v_r = v \cos\theta$$

$$v_t = v \sin\theta$$

Radiális sebesség, térbeli sebesség

Ha ismerjük a parallaxisból a távolságot, illetve megmérjük a sajátmozgást, v_t számolható

$$v_t\,(\mathrm{km/s}) = d\,(\mathrm{km}) \times \mu\,(\mathrm{rad/s})$$

Mértékegységek átváltása után: $[\mu] = {}''/\text{év}$ (rekordere a Barnard-csillag; $10.''3/\text{év}$)

$1\,\mathrm{rad} = 206265''$ $\quad 1\,\text{év} = 31 \cdot 10^6\,\mathrm{s}$ $\quad 1\,\mathrm{pc} = 3.086 \cdot 10^{13}\,\mathrm{km}$

Beírva, végigszámolva $\quad v_t\,(\mathrm{km/s}) = 4.74\,\mu \cdot d$

$$[\mu] = {}''/\text{év}\ ;\ [d] = \mathrm{pc}$$

Doppler-eltolódásból $\quad v_r$

$$\pi, \mu \rightarrow v_t$$

$$v^2 = v_r^2 + v_t^2$$

Astrometric observations show that Barnard's star has a proper motion of 10.3″ per year and a parallax of 0.55″. Spectroscopic studies show that the lines in its spectrum are shifted to the red by 0.036%. Calculate the space velocity of Barnard's star. When will the star make its closest approach to Earth? How far will it be from Earth at that time?

Solution. First, calculate the transverse velocity. A parallax of 0.55″ tells us that $d = 1.82$ pc. So, from (6.9), we have

$$v_t = 4.74 \times 1.82 \times 10.3 = 88.8\,\mathrm{km\,s^{-1}}.$$

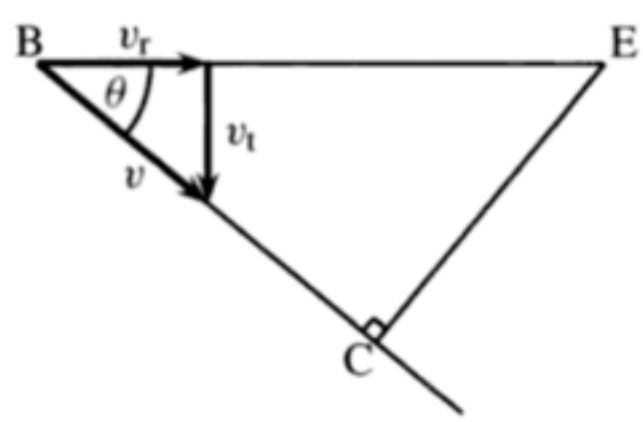
Second, calculate the radial velocity. Since the redshift is small, we can safely use the non-relativistic Doppler formula:

$$z = \frac{v_r}{c} = 3.6 \times 10^{-4} \longrightarrow v_r = 3.6 \times 10^{-4} \times 3 \times 10^5\,\mathrm{km\,s^{-1}} = 108\,\mathrm{km\,s^{-1}}.$$

Finally, to calculate the space velocity we must combine v_r and v_t using Pythagoras:

$$v = \sqrt{v_r^2 + v_t^2} = 140\,\mathrm{km\,s^{-1}}.$$

In the diagram below, E represents Earth, B represents the position of Barnard's star now, and C is Barnard's star at closest approach. We know that EB $= 1.82$ pc. Furthermore, $\theta = \tan^{-1}(v_t/v_r) = 39.4°$.



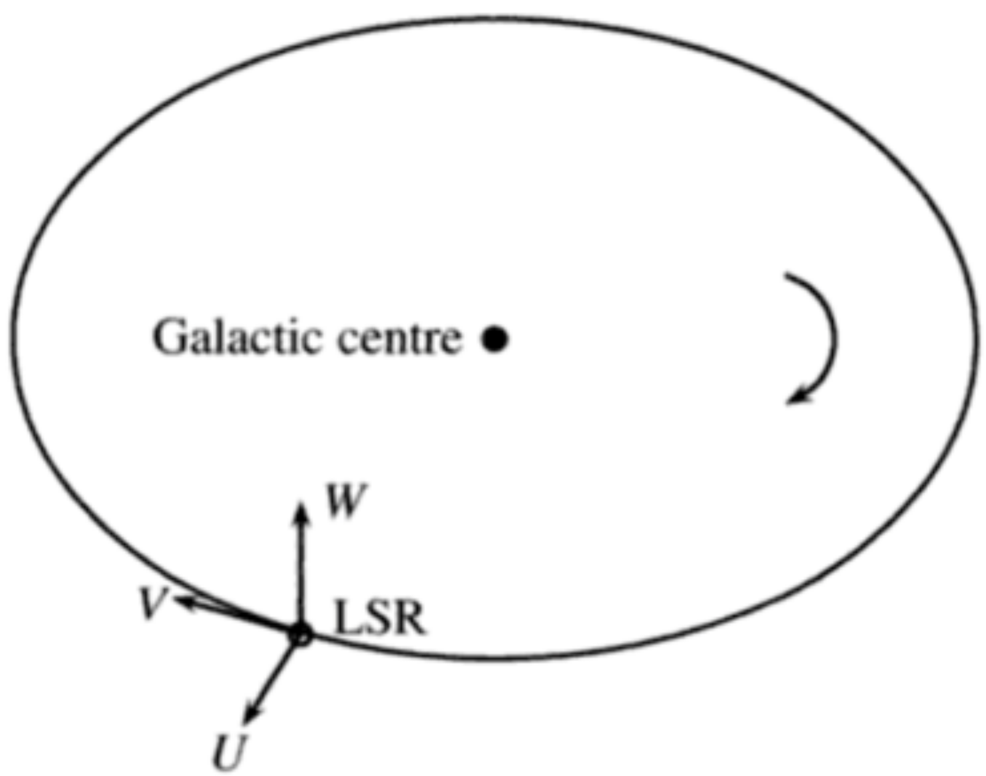
From the diagram, BC $=$ EB $\cos\theta = 1.4$ pc. If Barnard's star travels at $140\,\mathrm{km\,s^{-1}}$, it will take roughly 100 centuries to cover this distance. At closest approach:

$$\mathrm{EC} = \mathrm{EB}\sin\theta = 1.16\,\mathrm{pc}.$$

LSR, apex

Hogyan növelhetjük a parallaxismérés bázisvonalát?

Local Standard of Rest (LSR): a közeli csillagok Naphoz viszonyított átlagsebessége 0.



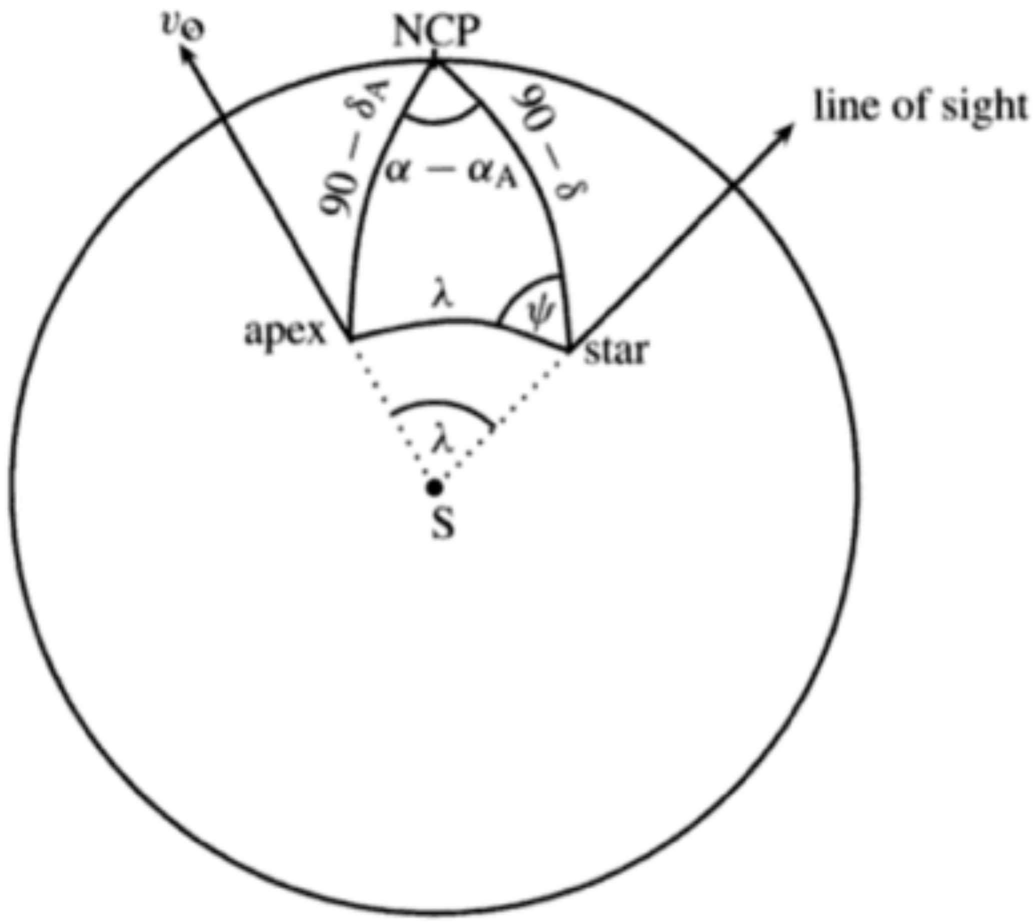
$$U_\odot = -10.00 \pm 0.36\,\mathrm{km\,s^{-1}}$$
$$V_\odot = 5.23 \pm 0.62\,\mathrm{km\,s^{-1}}$$
$$W_\odot = 7.17 \pm 0.38\,\mathrm{km\,s^{-1}}.$$

Ebből a Nap LSR-hez viszonyított térbeli sebessége

$$|v_{Nap}| = 13,7 \pm 0,7 km/s \sim 2,83 cs.e./év,$$

mozgása a Her csillagkép felé mutat (szoláris apex).

Szekuláris parallaxis



Gömbháromszögtani alapössz. alapján:

$$\cos\lambda = \sin\delta \sin\delta_A + \cos\delta \cos\delta_A \cos(\alpha - \alpha_A)$$

$$\sin\lambda \cos\psi = \cos\delta \sin\delta_A - \sin\delta \cos\delta_A \cos(\alpha - \alpha_A)$$

λ, ψ kiszámítható a minta összes csillagára.

Szekuláris parallaxis

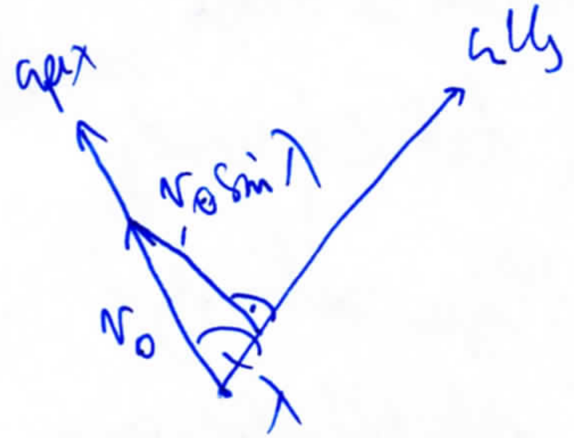
Bontsuk fel a sajátmozgást két komponensre:

υ: sajátmozgás a apex felé mutató főkörre vetítve (pozitív, ha elfelé mutat)

τ: υ-ra merőleges

$$\upsilon = \mu_\alpha \cos\delta \sin\psi - \mu_\delta \cos\psi$$

$$\tau = \mu_\delta \sin\psi + \mu_\alpha \cos\delta \cos\psi$$



$v_\odot \sin\lambda$: a Nap mozgásának komponense a csillag látóirányára merőlegesen.

→ sajátmozgást okoz

$$v_\odot \sin\lambda / 4.74 d = \pi'' v_\odot \sin\lambda / 4.74$$

↳ ezt nevezzük $\upsilon_\odot$-nak

Emellett a ★ LSR-hez viszonyított mozgása is okoz υ_*-t. Tehát

(1) $$\upsilon = \upsilon_* + \pi'' \frac{v_\odot \sin\lambda}{4.74}$$ → ez minden ★-ra igaz a mintában

Szekuláris parallaxis

Ezek után átlagoljuk a sokaságra:
szorozzuk be (1)-et $\sin\lambda_i$-vel, majd összegzünk:

$$\sum_{i=1}^{n} v_i \sin\lambda_i = \sum_{i=1}^{n} v_{*i} \sin\lambda_i + \frac{\bar{\pi}'' v_\odot}{4.74} \sum_{i=1}^{n} \sin^2\lambda_i$$

ahol $\bar{\pi}''$ a minta átlagos parallaxisa.
Ha az összes csillag random eloszlásban mozog LSR-hez képest → v_* összeg átlagolás zérus lesz

Osszuk el n-nel, $\langle\rangle$ átlag:

$$\bar{\pi}'' = \frac{4.74 \langle v \sin\lambda \rangle}{v_\odot \langle \sin^2\lambda \rangle}$$

$v_\odot$-t tudjuk; átlagokat számolhatunk, $\bar{\pi}''$ értelmes lesz, ha jól választjuk a mintát.

Statisztikus parallaxis

Feltevés: ha elég nagy egy minta, akkor a csillagok átlagos radiális sebessége megegyezik a csillagok átlagos transzverzális sebességével (hiszen nincs kitüntetett irány).

Gondosan megválasztott mintára kiszámítjuk v_r átlagát, majd azt mondjuk, ez megfelel v_t átlagának, majd azt mondjuk, hogy a sajátmozgásból átváltva v_t-be a minta átlagos távolságát meghatározzuk.

Hasonló megfontolással, mint a szekuláris parallaxisnál:

$$\pi'' = \frac{4.74 \langle |\tau| \rangle}{\langle | v_r + v_\odot \cos\lambda | \rangle}$$

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SECULAR PARALLAX OF THE S STARS

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ABSTRACT

The available radial velocities for 27 S stars do not indicate any significant deviation in the solar motion from the basic solar motion, which has therefore been used to derive the group mean parallax from 23 AGK3 and Yale–Cape (Hoffleit 1967–1971) proper motions. Variable and nonvariable stars have been treated together. The solar motion is poorly reflected in the proper motions, as it was in earlier data. If apparent magnitudes at maximum are used for the variables, the indicated mean visual absolute magnitude for all the stars is $+2.4 \pm 0.8$ (p.e.), the quoted p.e. being internal; if the space motion given by the radial velocities is adopted, $<M_v>$ rises to $+1.7$. Thus, newer data, representing somewhat more stars than earlier studies, confirm previous evidence that the S stars are not, on the average, highly luminous objects. The uncertainties, mainly in the proper motions, are great enough that this result is not in serious conflict with previous estimates of $<M_v>$ near -1. There is some evidence that the apex of solar motion determined from small AGK3 proper motions is influenced by color index, in the case of the reddest stars.

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THE ABSOLUTE MAGNITUDE OF RRc VARIABLES FROM STATISTICAL PARALLAX

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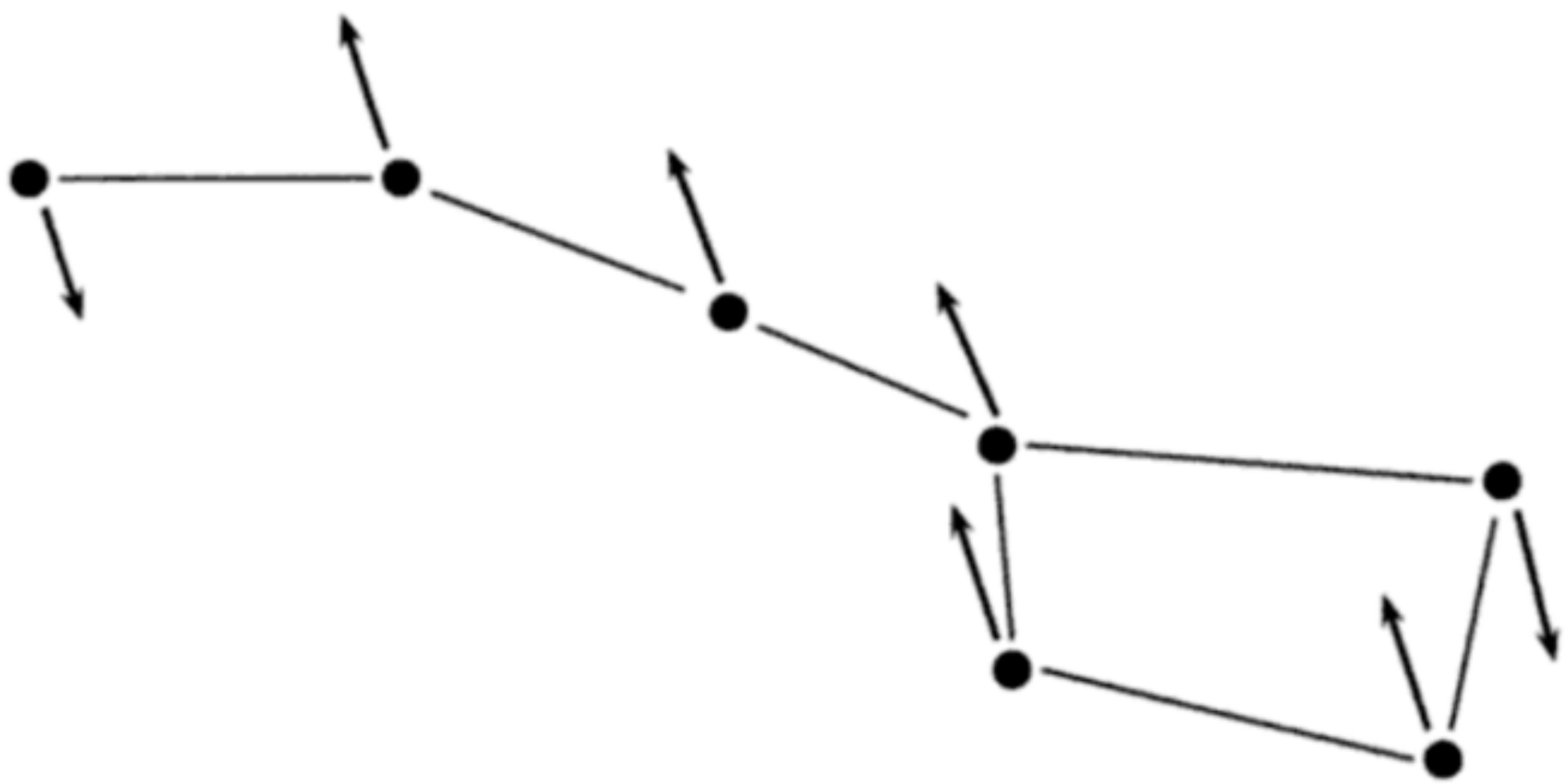
ABSTRACT

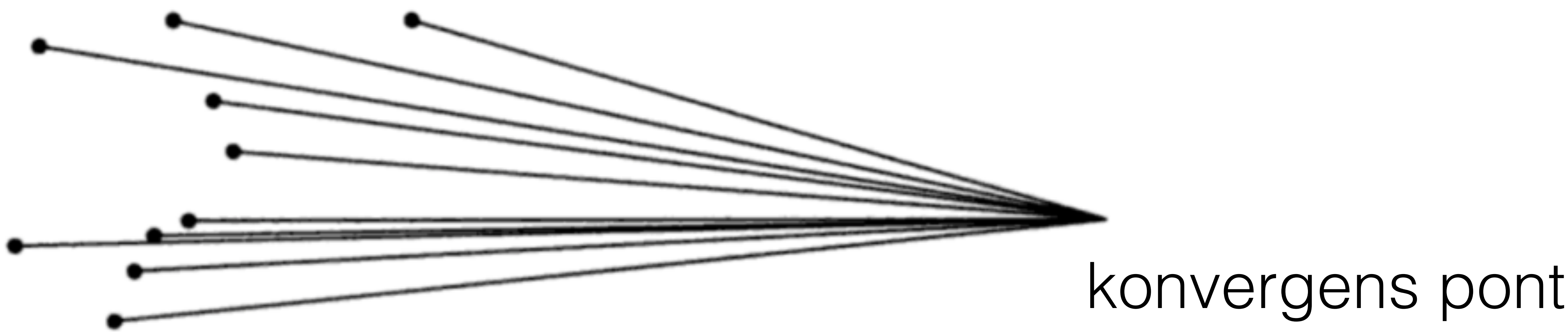
We present the first definitive measurement of the absolute magnitude of RR Lyrae c-type variable stars (RRc) determined purely from statistical parallax. We use a sample of 242 RRc variables selected from the All Sky Automated Survey for which high-quality light curves, photometry, and proper motions are available. We obtain high-resolution echelle spectra for these objects to determine radial velocities and abundances as part of the Carnegie RR Lyrae Survey. We find that $M_{V,\mathrm{RRc}} = 0.59 \pm 0.10$ at a mean metallicity of [Fe/H] $= -1.59$. This is to be compared with previous estimates for RRab stars ($M_{V,\mathrm{RRab}} = 0.76 \pm 0.12$) and the only *direct* measurement of an RRc absolute magnitude (RZ Cephei, $M_{V,\mathrm{RRc}} = 0.27 \pm 0.17$). We find the bulk velocity of the halo relative to the Sun to be $(W_\pi, W_\theta, W_z) = (12.0, -209.9, 3.0)\,\mathrm{km\,s^{-1}}$ in the radial, rotational, and vertical directions with dispersions $(\sigma_{W_\pi}, \sigma_{W_\theta}, \sigma_{W_z}) = (150.4, 106.1, 96.0)\,\mathrm{km\,s^{-1}}$. For the disk, we find $(W_\pi, W_\theta, W_z) = (13.0, -42.0, -27.3)\,\mathrm{km\,s^{-1}}$ relative to the Sun with dispersions $(\sigma_{W_\pi}, \sigma_{W_\theta}, \sigma_{W_z}) = (67.7, 59.2, 54.9)\,\mathrm{km\,s^{-1}}$. Finally, as a byproduct of our statistical framework, we are able to demonstrate that UCAC2 proper-motion errors are significantly overestimated as verified by UCAC4.

Key words: distance scale – Galaxy: fundamental parameters – Galaxy: kinematics and dynamics – Galaxy: structure – stars: distances – stars: variables: RR Lyrae

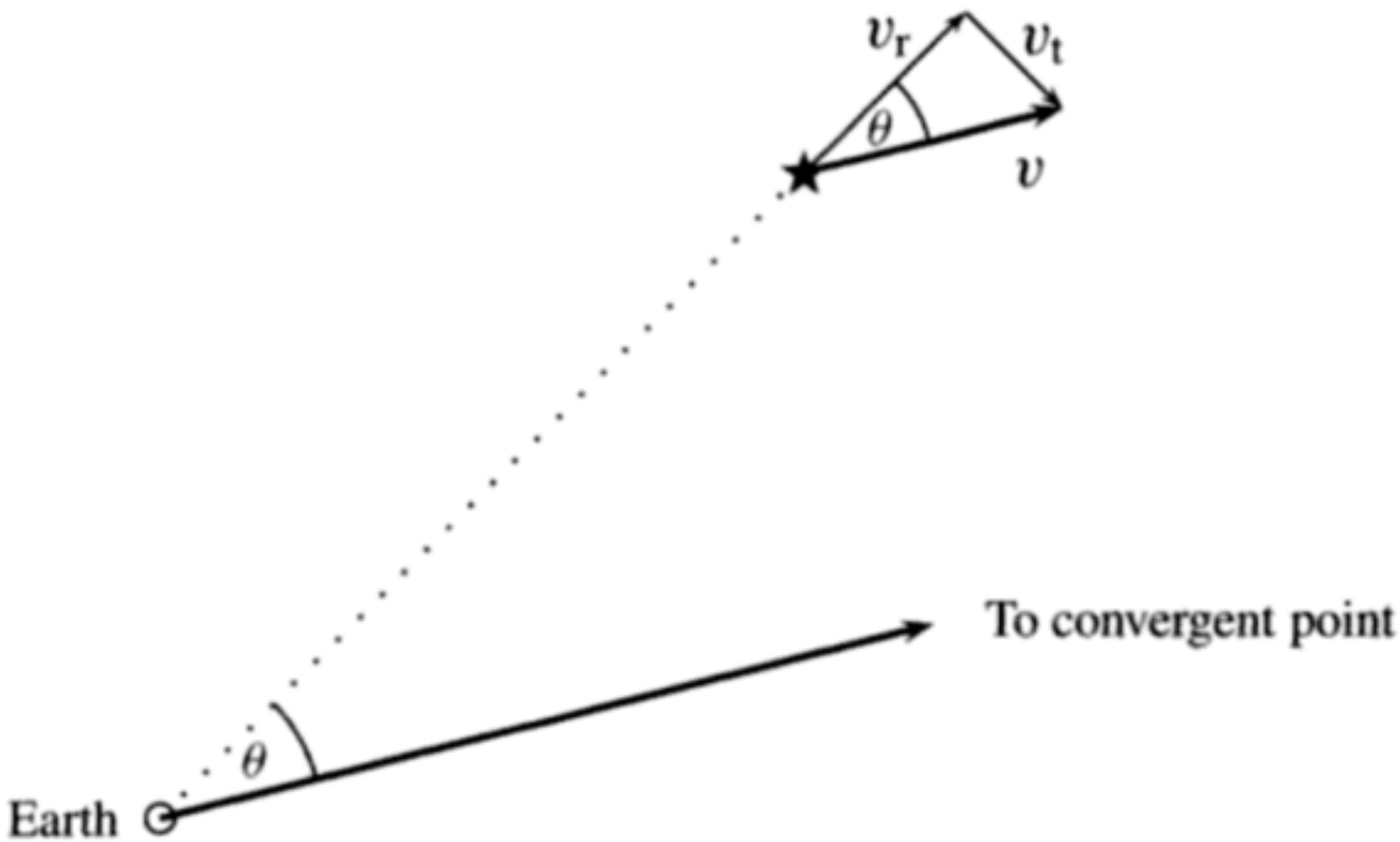
Mozgási halmaz módszer (moving cluster)



Mozgási halmaz módszer (moving cluster)



Mozgási halmaz módszer (moving cluster)



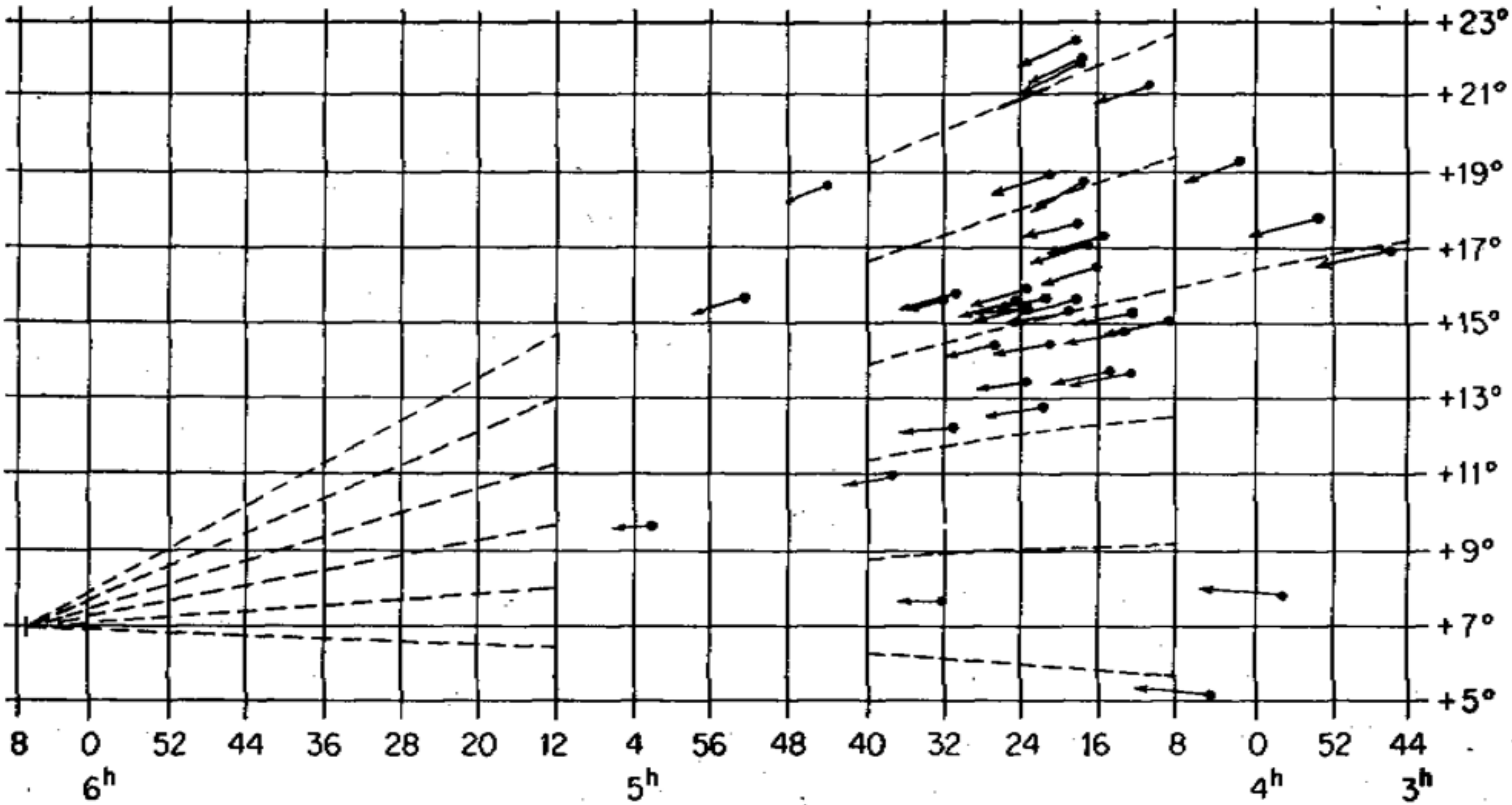
$v_t = v_r \, tg\, \Theta$

Θ; v_r ismeretében v_t számítható.

μ sajátmozgás mérése a távolság adódik

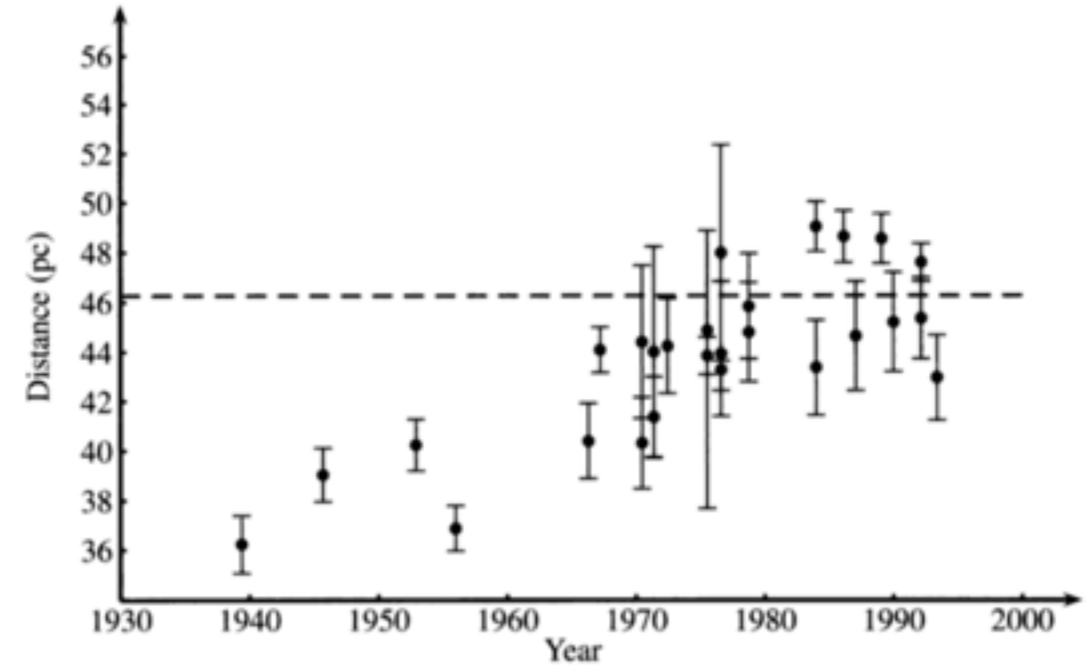
$$d = \frac{v_r \, tg\, \Theta}{4.74 \mu}$$

Mozgási halmaz módszer (moving cluster)

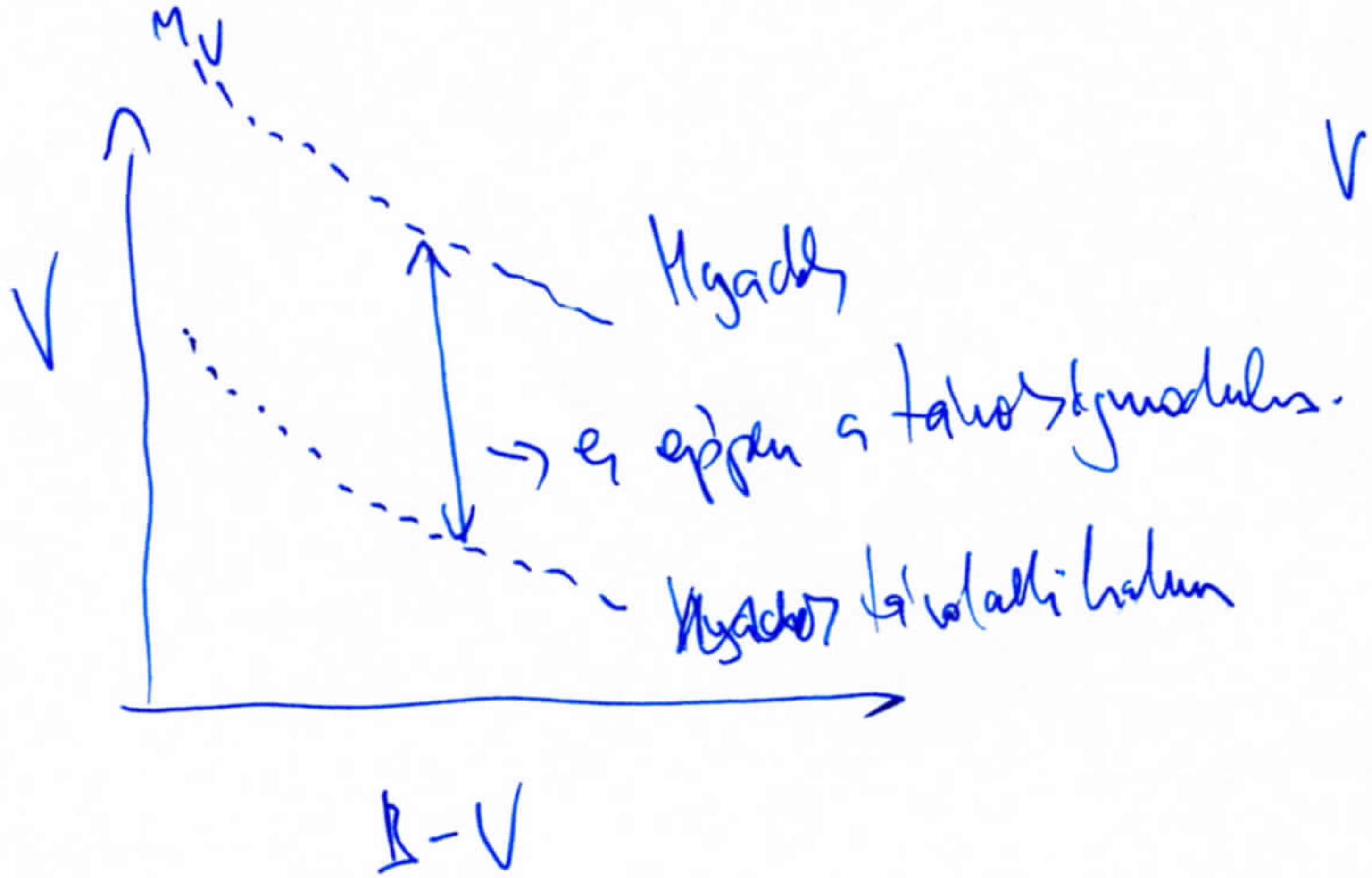


Mozgási halmaz módszer (moving cluster)

UMa, ~60 csillag, 24 pc
Sco-Cen, ~100 csillag, 170 pc
Hyadok, nyílthalmaz, ~46 pc



A Hyadok fősorozatához tartozó csillagokat felhasználva lehetségessé válik a fősorozat-illesztés:



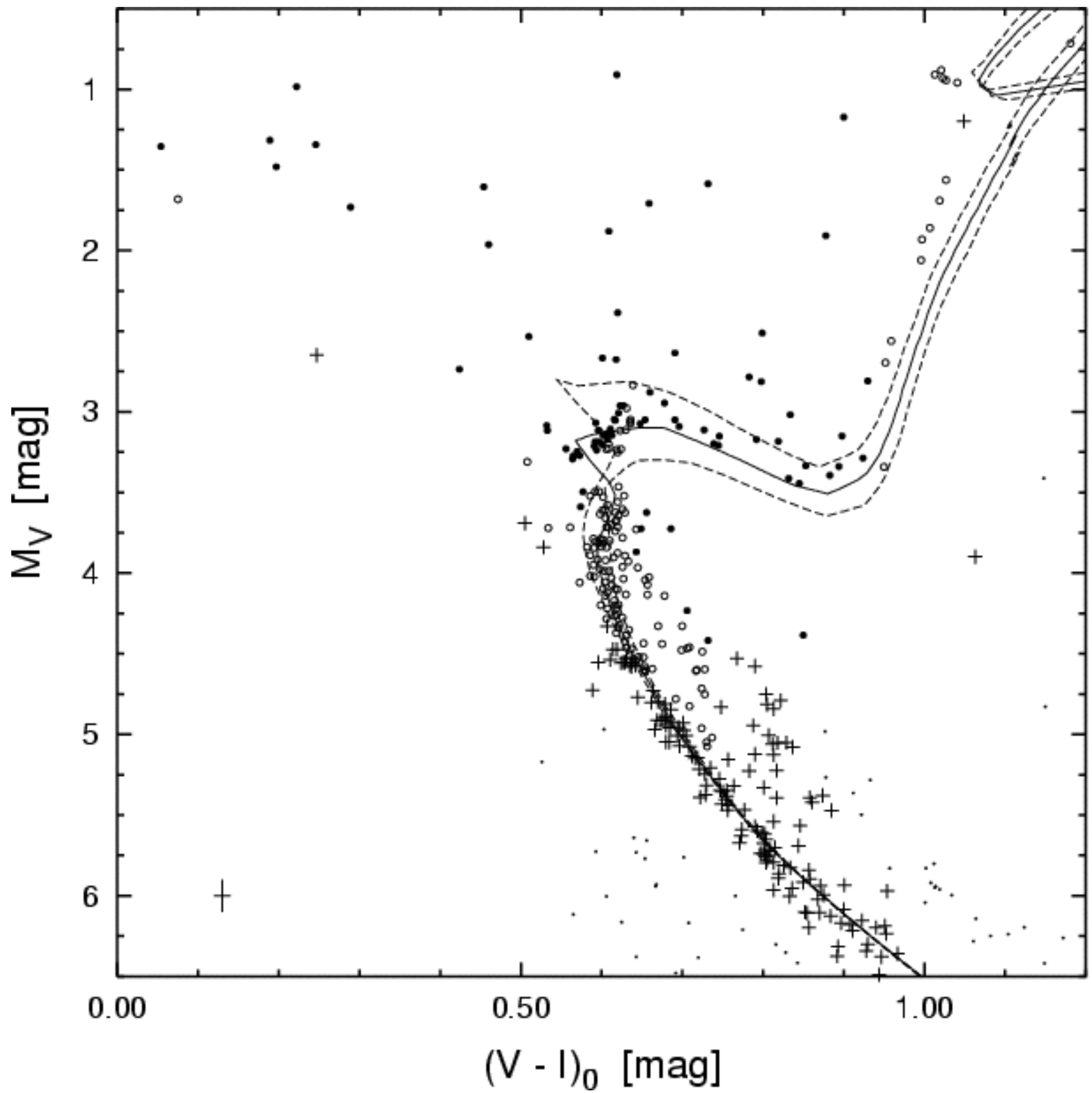
$V - M_V = -5 + 5 \lg d$

általában ~10 kpc távolságig hatékony

Spektroszkópiai parallaxis: elég pontatlan, de sokszor egyetlen lehetőség:
a kalibrált fősorozat alapján tudjuk, hogy mi az összefüggés
a spektráltípus és az abszolút fényesség között.

$$\left.\begin{array}{l}\text{Sp. típus} \rightarrow M_V \,; \\ V\end{array}\right\} \rightarrow \underline{\underline{d}}$$

Izokrón-illesztés (izokrón: azonos korú csillagmodellek eltérő tömegekre)



M67

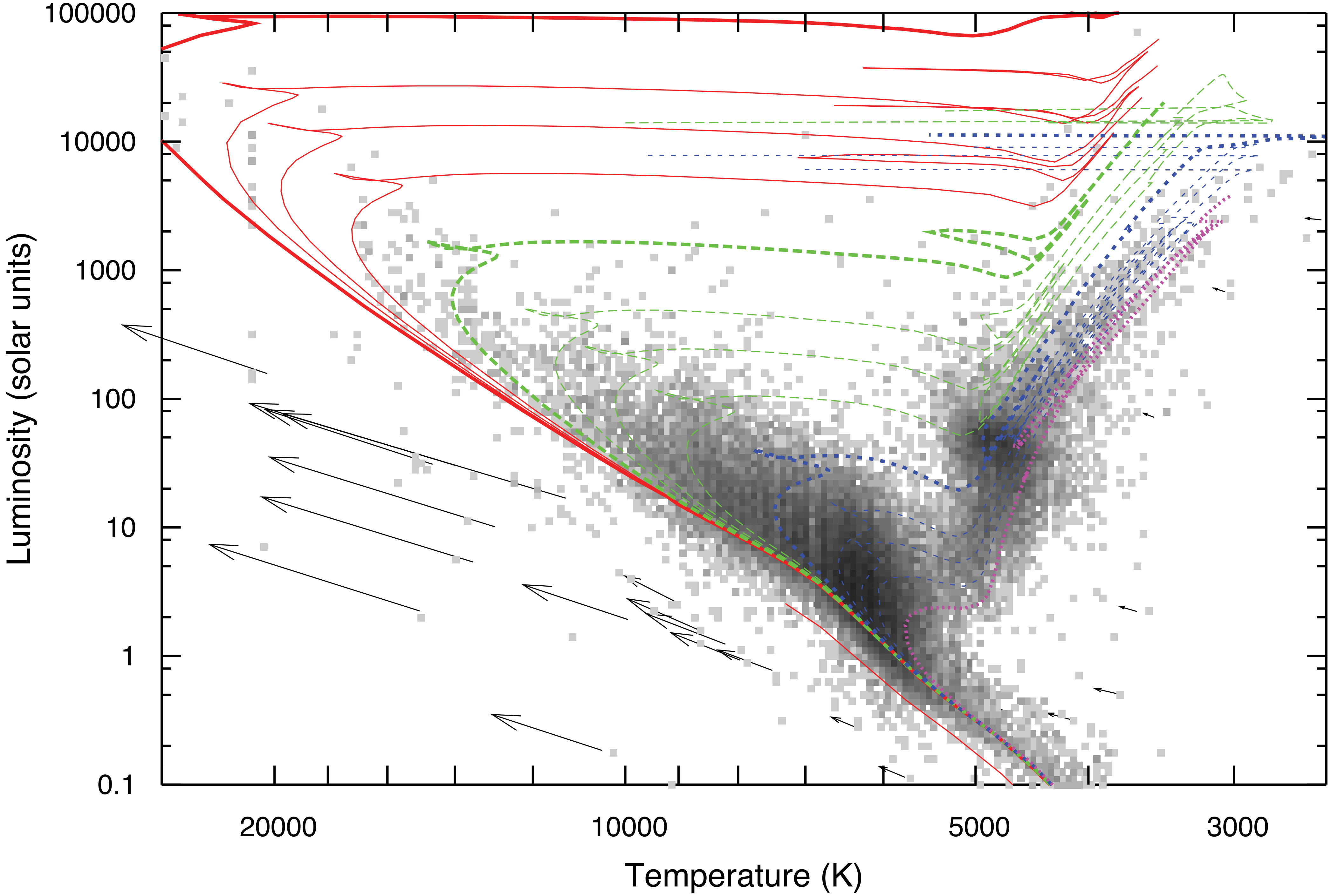


Figure 2. Density-coded HR diagram for the 200-pc sample (grey-scale). Overplotted are solar-metallicity isochrones from the Padova models (Bertelli et al. 2008; Marigo et al. 2008) at 10, 20, 30 and 50 Myr (solid, red lines); 100, 200, 300 and 500 Myr (long-dashed green lines); 1, 2, 3 and 5 Gyr (short-dashed blue lines) and 10 Gyr (dotted magenta line). The thin red line to the left of the main sequence is a zero-age isochrone at [Fe/H] = −1 to illustrate the blueward shift caused by decreasing metallicity. The black arrows show the effect of de-reddening individual sources by $E(B - V) = 0.1$ mag.

(McDonald et al. 2012)

Mon. Not. R. Astron. Soc. **000**, 1–14 (2013) Printed 9 September 2013 (MN LATEX style file v2.2)

Unveiling new members in five nearby young moving groups

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Accepted ... Received ...; in original form ...

ABSTRACT

In the last decade many kinematic groups of young stars (< 100 Myr) were discovered in the solar neighbourhood. Since the most interesting period of planet formation overlaps with the age of these groups, their well dated members are attractive targets for exoplanet searches by direct imaging. We combined astrometric, photometric and X-ray data, and applied strict selection criteria to explore the stellar content of five nearby moving groups. We identified more than 100 potential new candidate members in the β Pic moving group, and in the Tucana-Horologium, Columba, Carina, and Argus associations. In order to further assess and confirm their membership status, we analysed radial velocity data and lithium equivalent widths extracted from high-resolution spectra of 54 candidate stars. We identified 35 new probable/possible young moving group members: 4 in the β Pic moving group, 11 in the Columba association, 16 in the Carina association, and 4 in the Argus association. We found serendipitiously a new AB Dor moving group member as well. For four Columba systems *Hipparcos* based parallaxes have already been available and as they are consistent with the predicted kinematic parallaxes, they can be considered as secure new members.

Mon. Not. R. Astron. Soc. **411,** 117–123 (2011) doi:10.1111/j.1365-2966.2010.17660.x

A search for new members of the β Pictoris, Tucana–Horologium and ϵ Cha moving groups in the RAVE data base

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ABSTRACT

We report on the discovery of new members of nearby young moving groups, exploiting the full power of combining the Radial Velocity Experiment (RAVE) survey with several stellar age diagnostic methods and follow-up high-resolution optical spectroscopy. The results include the identification of one new and five likely members of the β Pictoris moving group, ranging from spectral types F9 to M4 with the majority being M dwarfs, one K7 likely member of the ϵ Cha group and two stars in the Tucana–Horologium association. Based on the positive identifications, we foreshadow a great potential of the RAVE data base in progressing towards a full census of young moving groups in the solar neighbourhood.