How far is it? Distance measurements and their consequences
Part II

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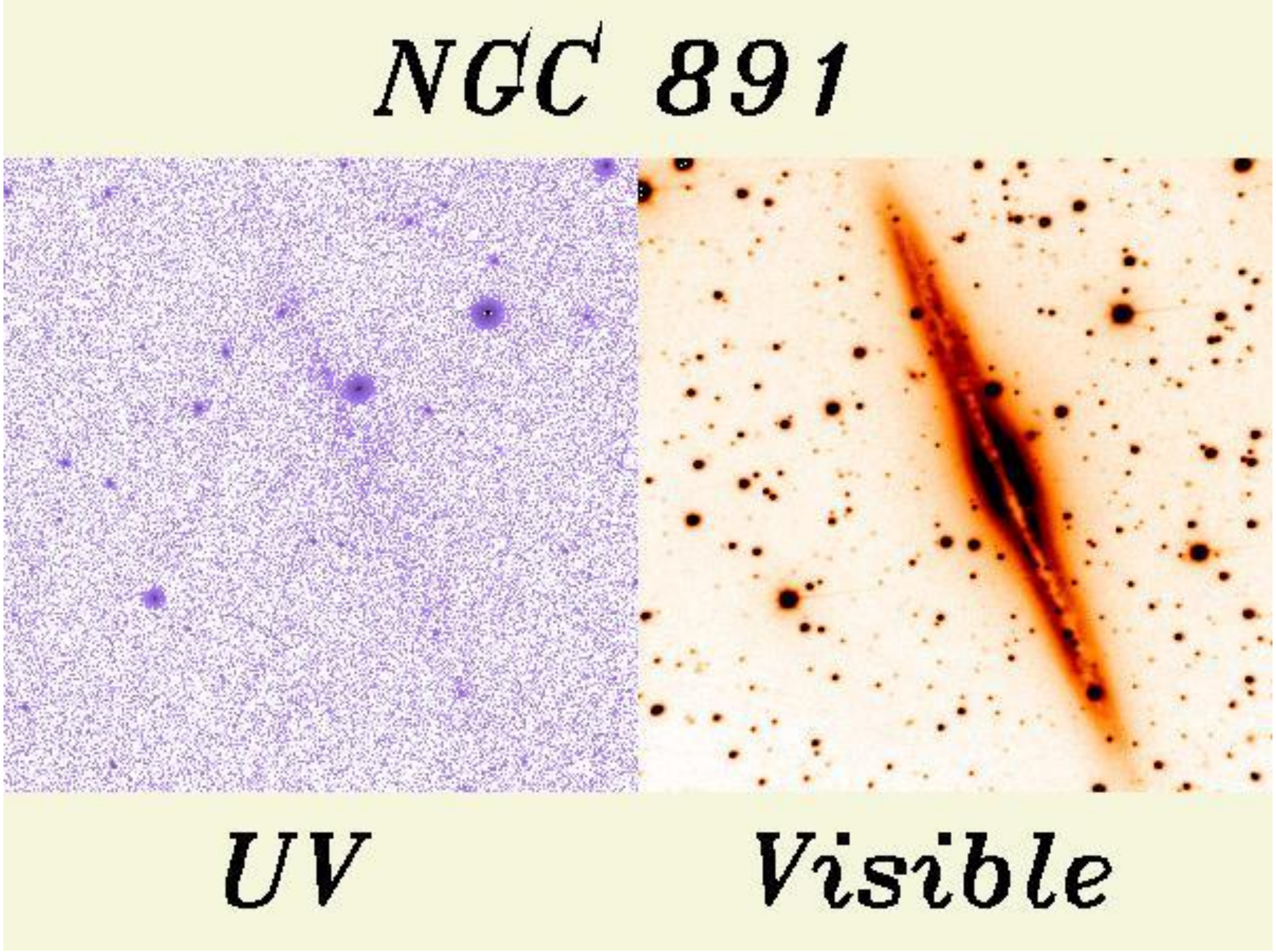
Dark, absorbing disc is typical for spiral galaxies

The absorbing discs are made of dust – shining in IR

The same edge-on galaxy seen in visible light and satellite UV

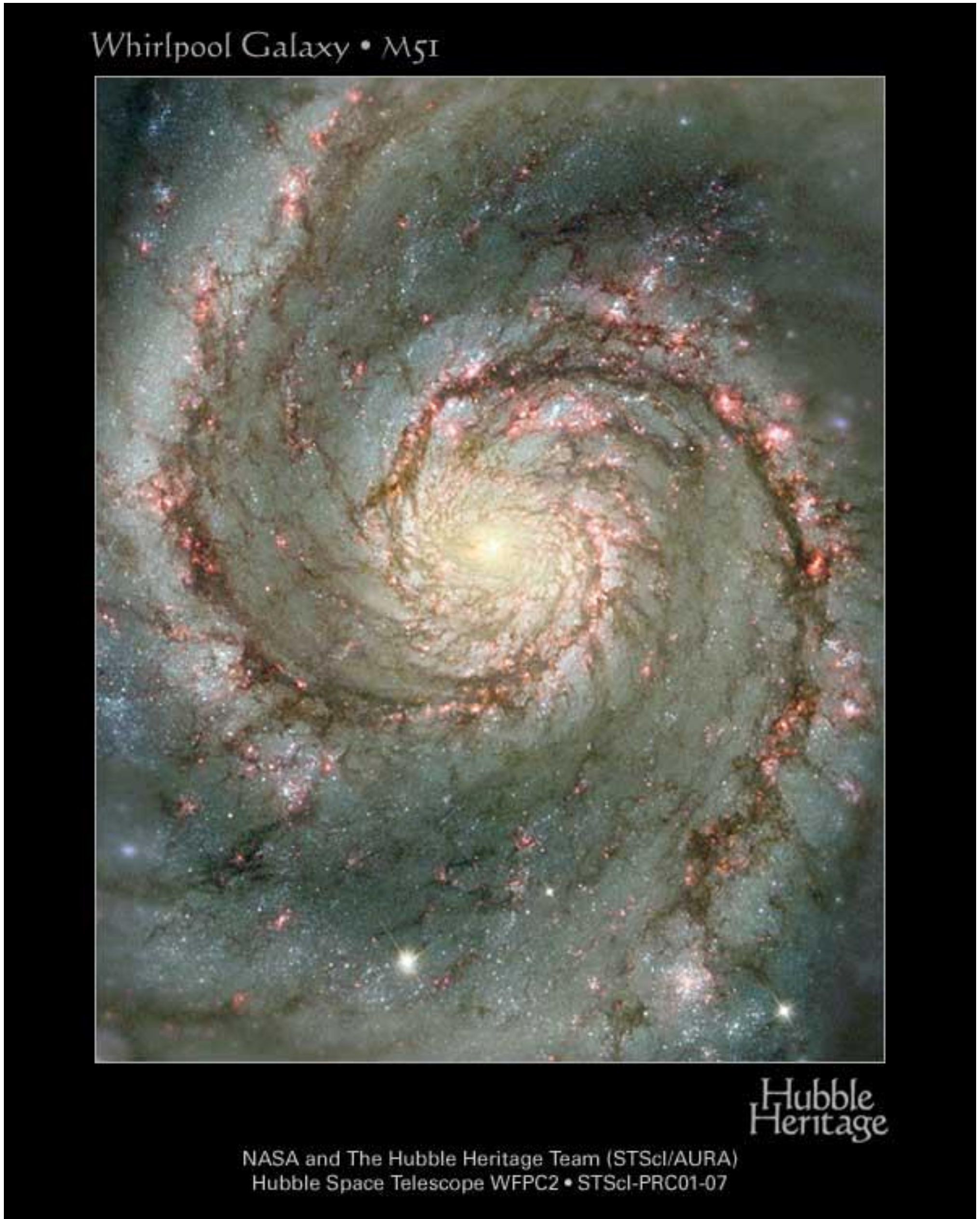


Whirlpool Galaxy • M51

Hubble Heritage

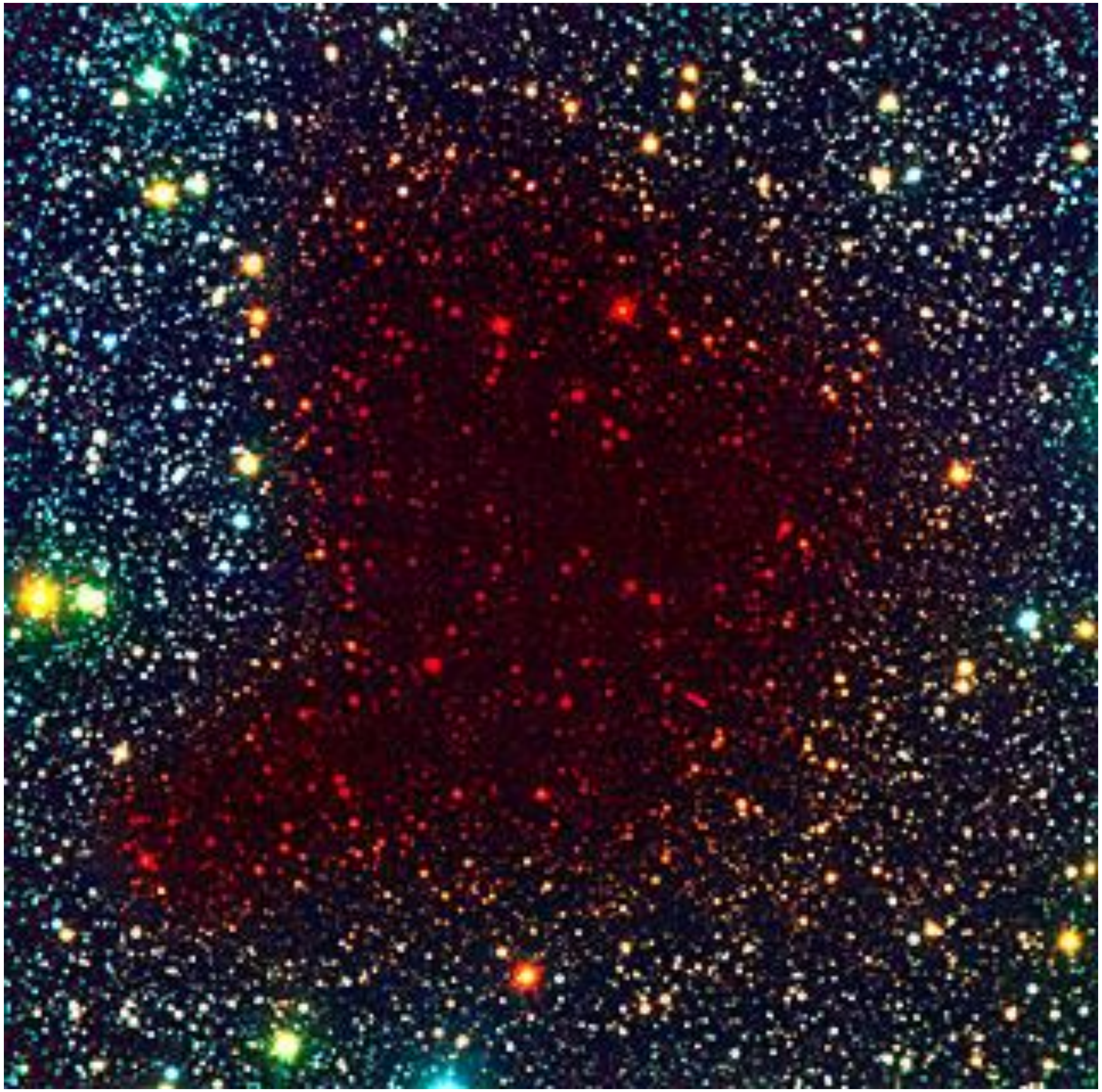
NASA, ESA, S. Beckwith (STScI), and The Hubble Heritage Team (STScI/AURA) • Hubble Space Telescope ACS • STScI-PRC05-12a

„Necklace" seen because of shining beads but the chain is made of IS clouds



„Hole in the sky” – similar to that observed by W. Herschel in XVIII cent.

Infrared allows to see through the „hole”

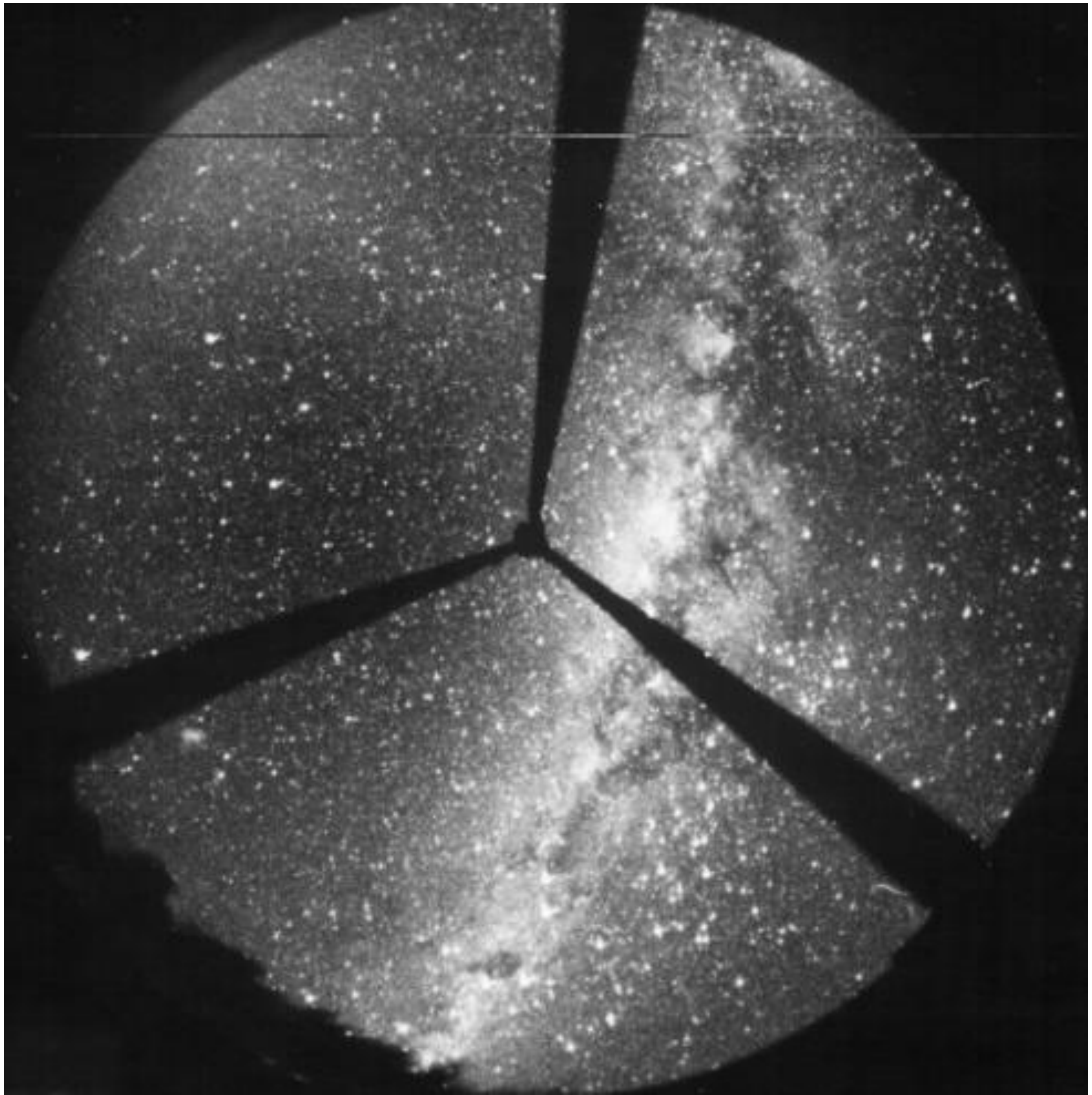


Dark clouds among bright stars

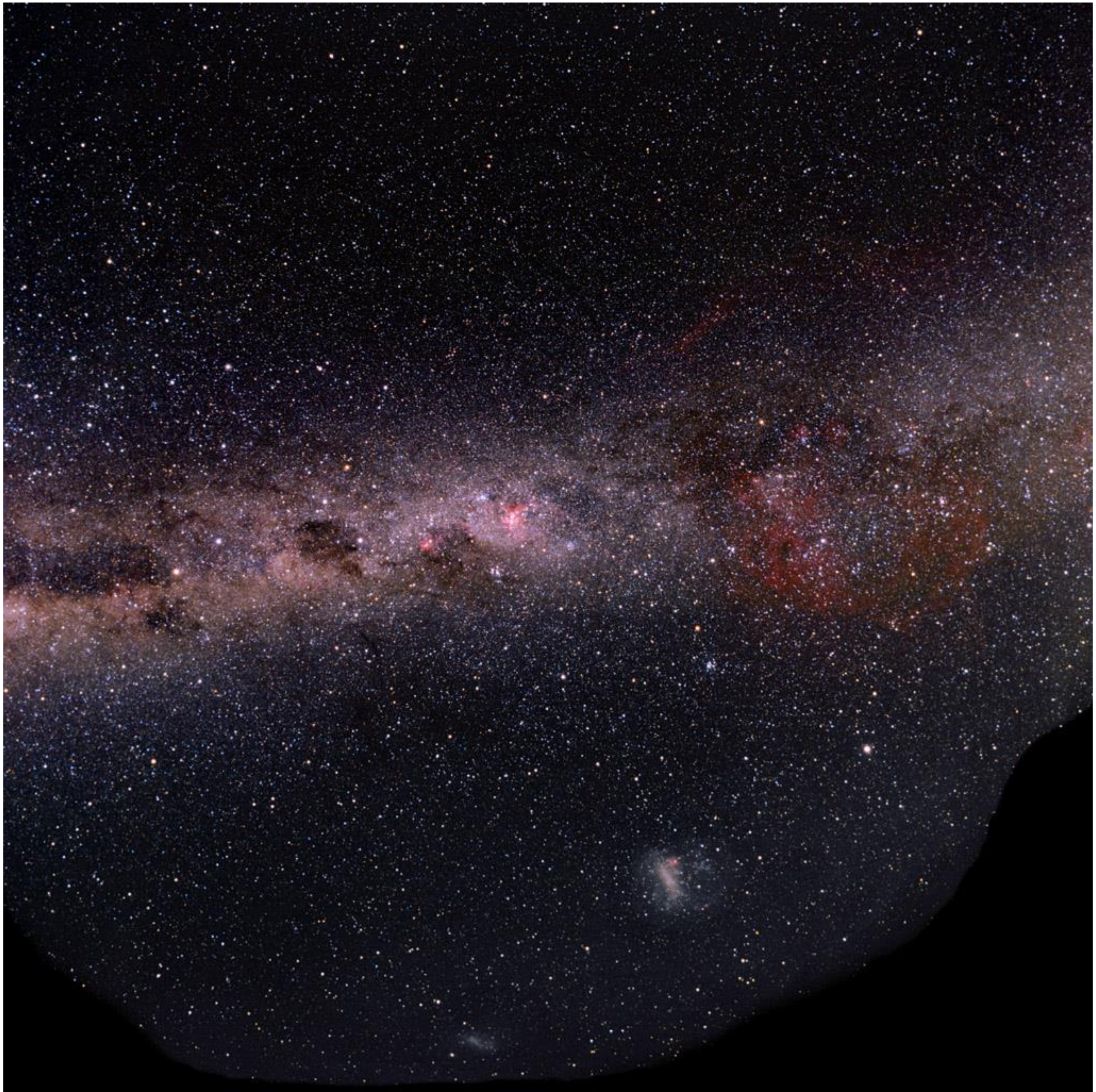
Sagittarius constellation – near the center of Milky Way

Composition of Milky Way photos – seen the layer of absorbing matter

Milky Way as seen using a wide angle camera

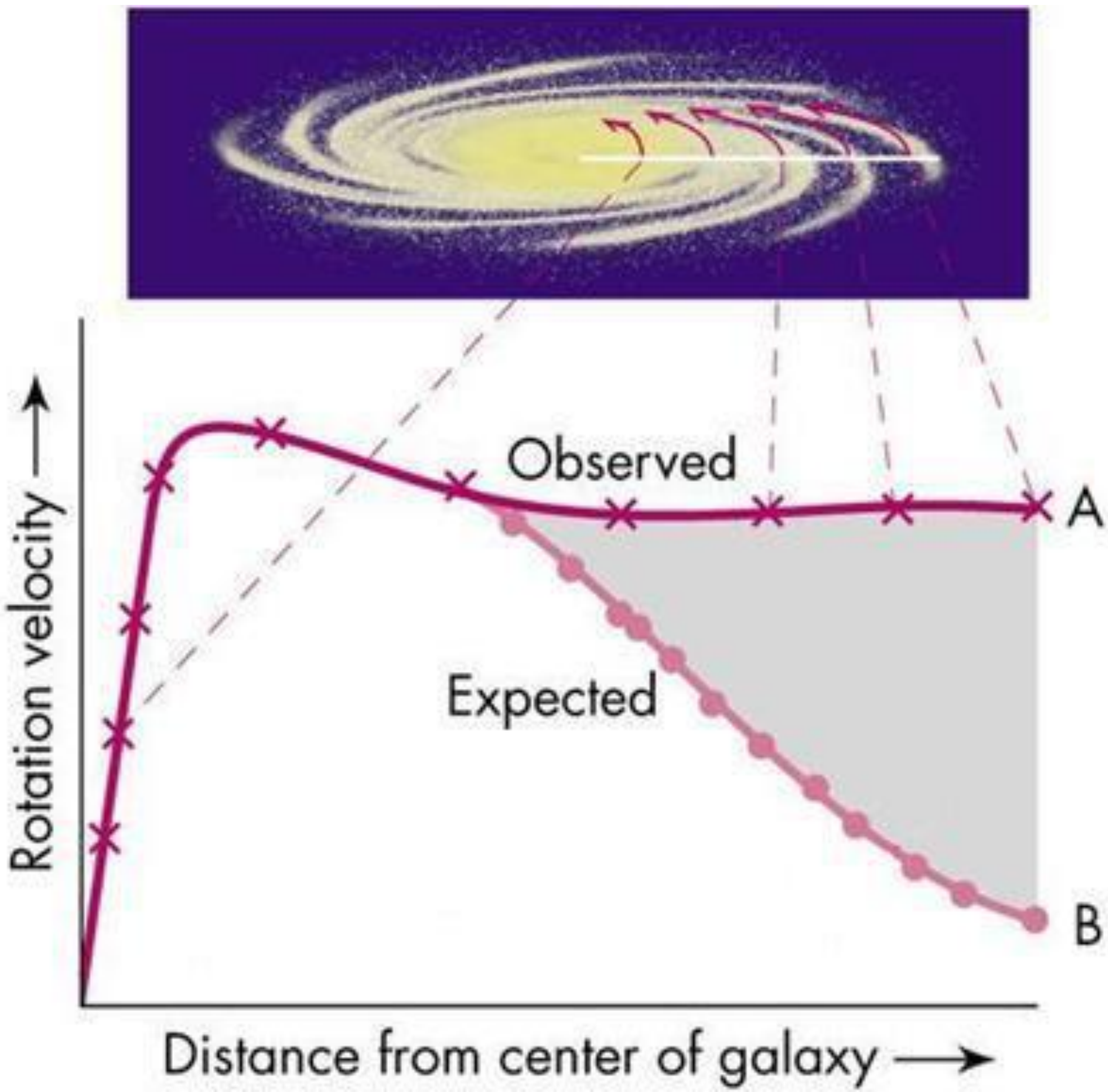


Southern Milky Way – as seen by Inkas

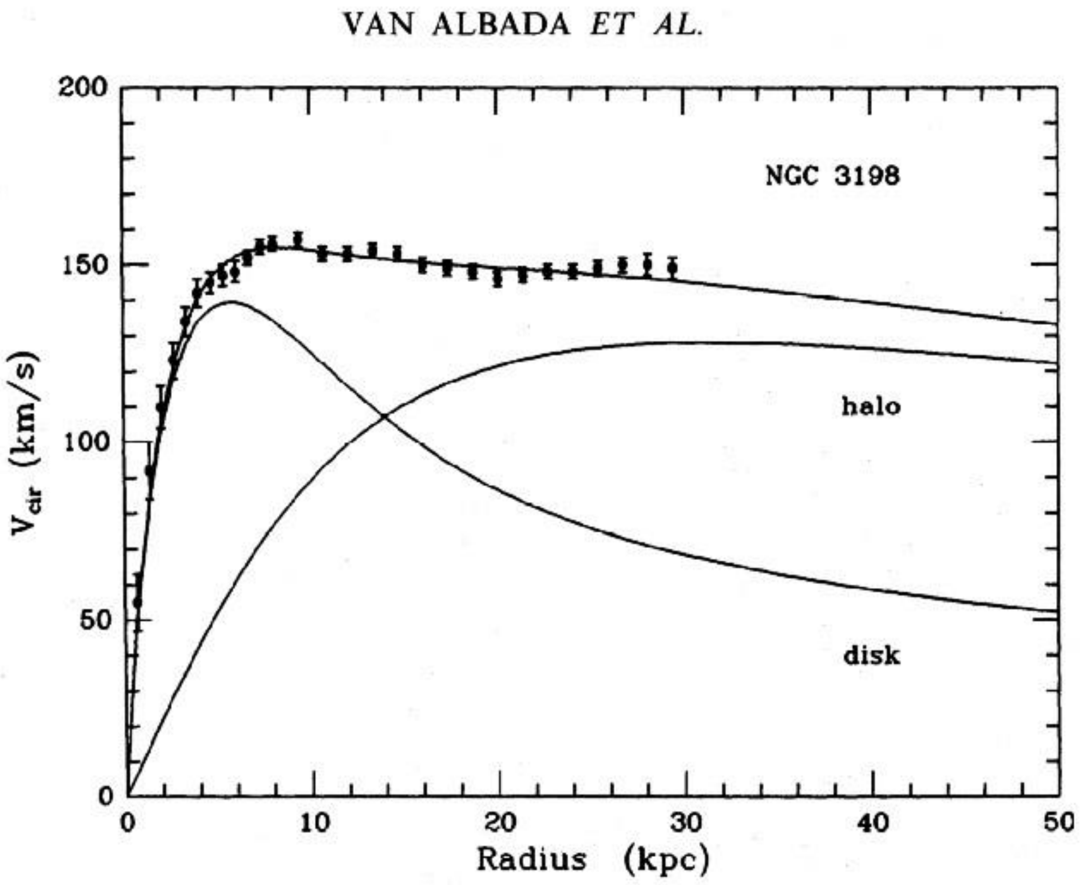


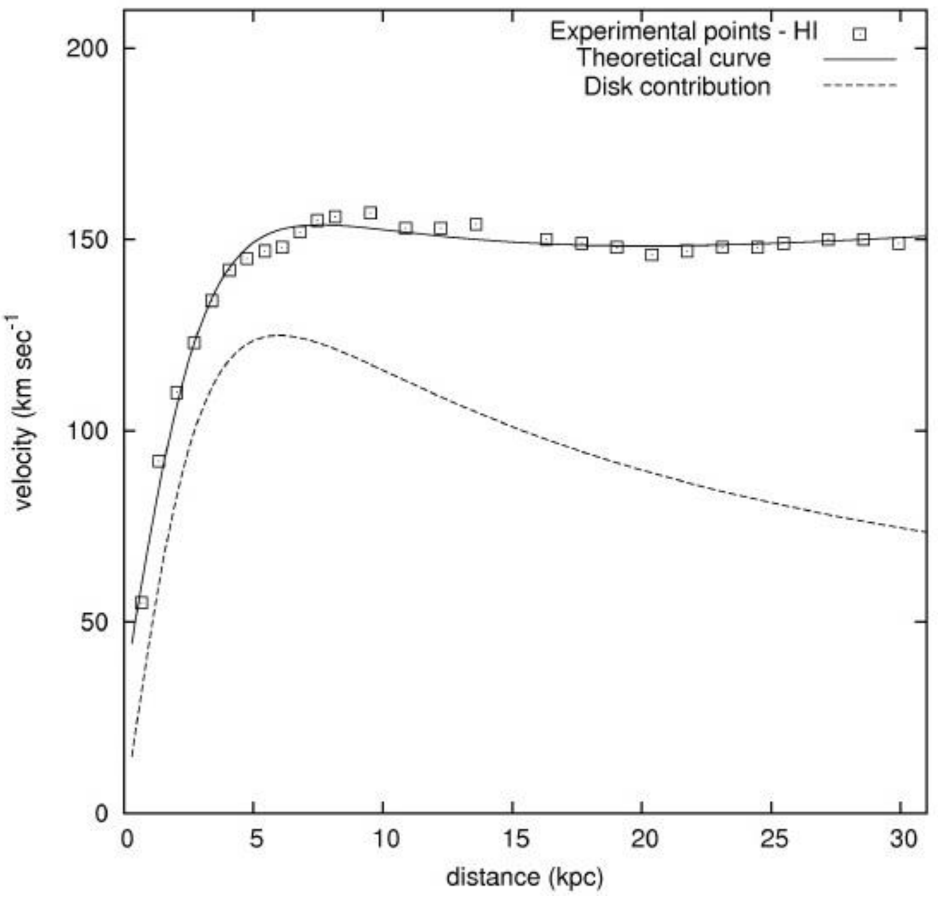
...who one of the dark clouds called „Fox”…

The idea of flat rotation curve

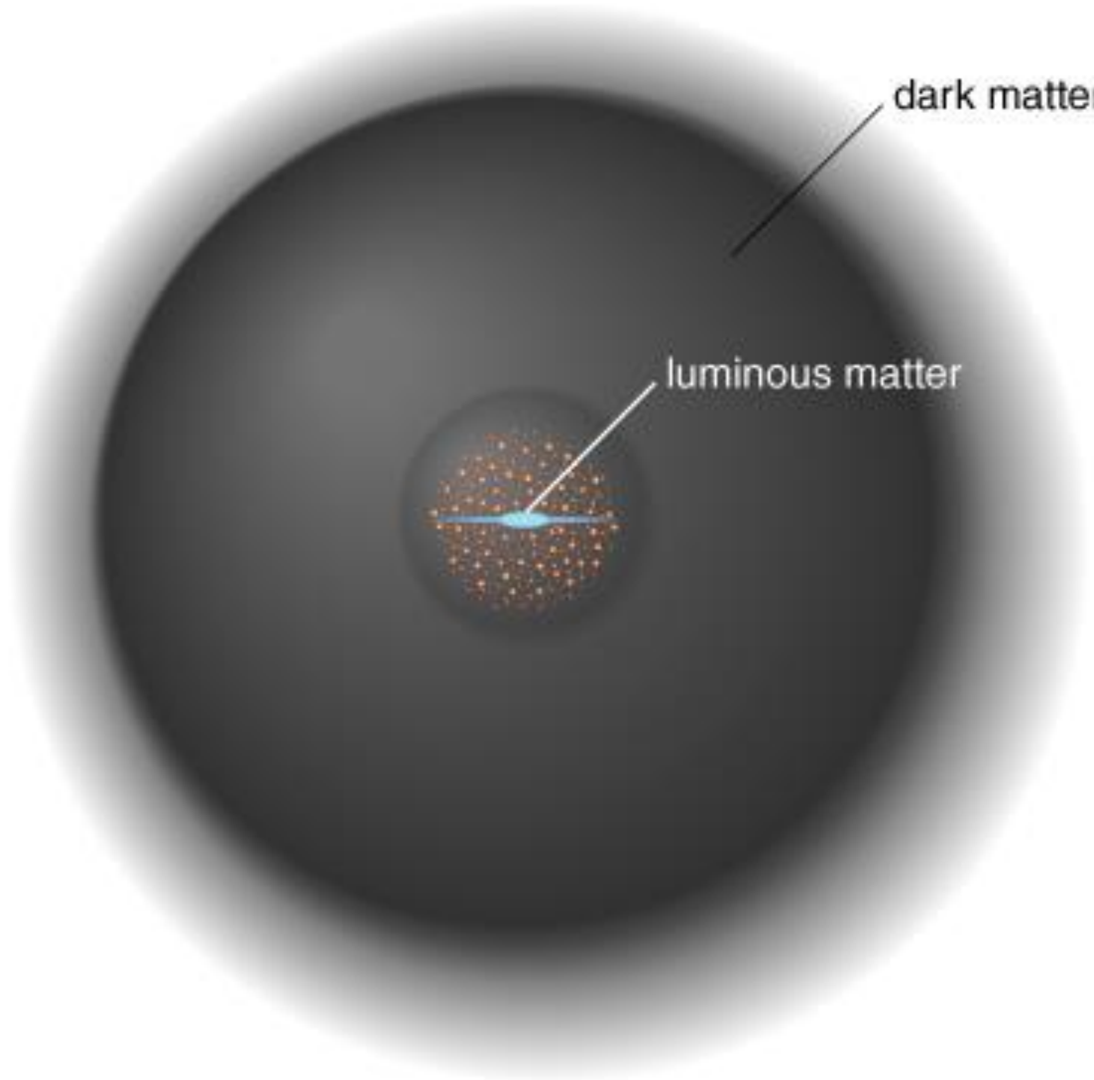


The idea of flat rotation curve as the result of growing Dark Matter gravitation at galatic peripherals

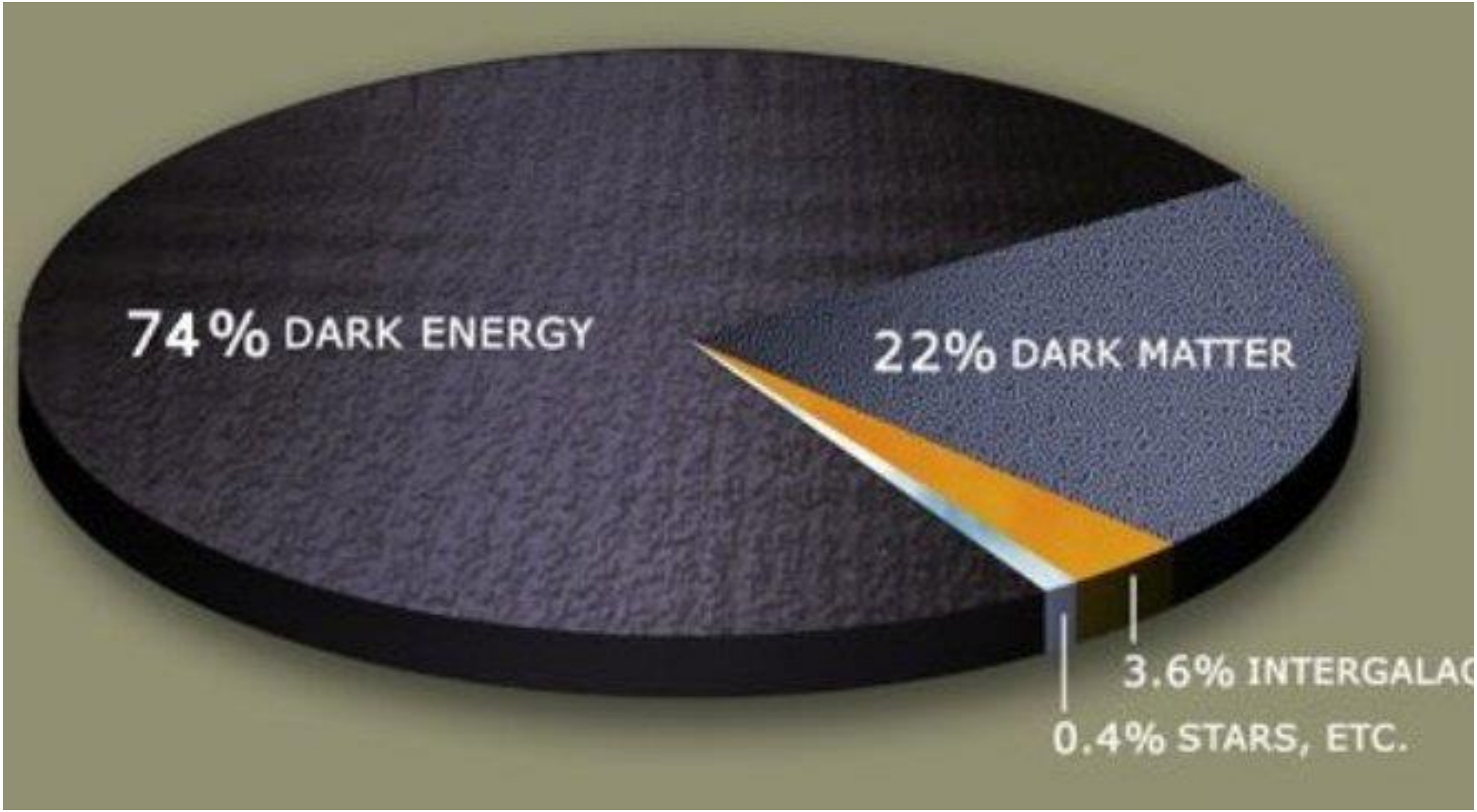




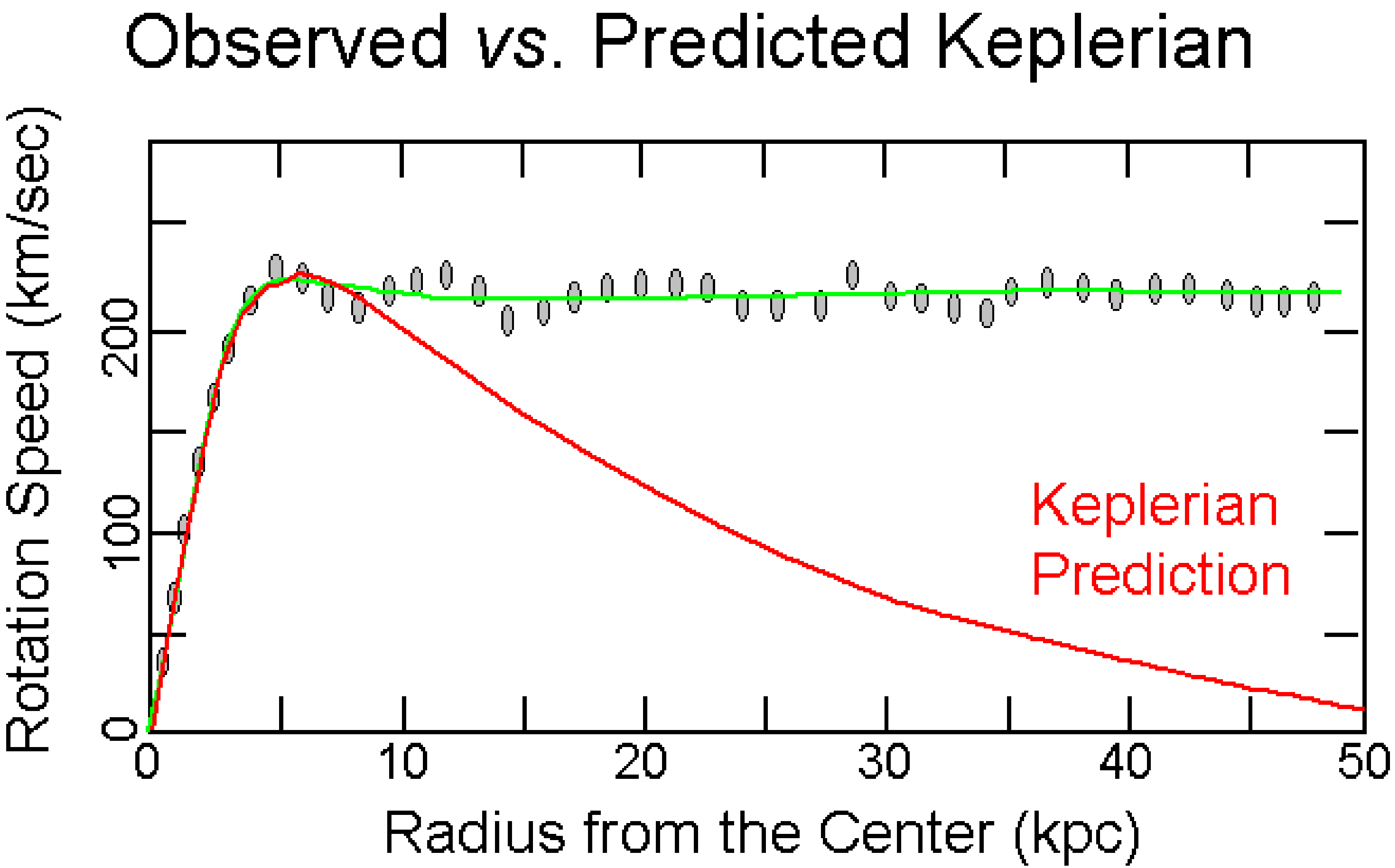
The postulated dark halo around a spiral galaxy



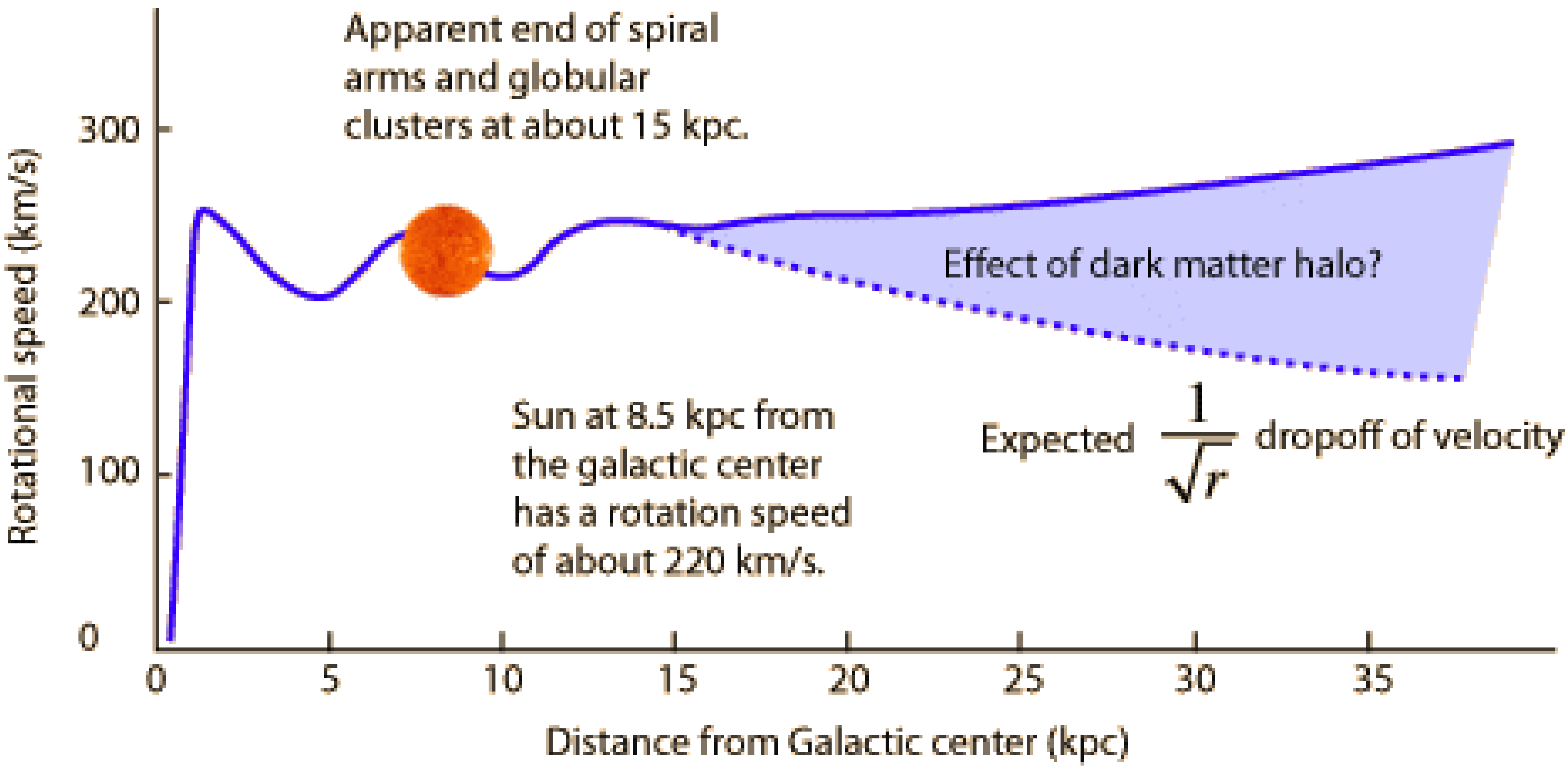
We are likely a minority…



Popular picture evidencing the Dark Matter in our Galaxy



Nice, schematic picture…



Rotation curve of DM based on CO lines: Clemens, D.P. 1985, ApJ, 295, 422; method description: Moffat et al. 1979, A&A, 38, 197

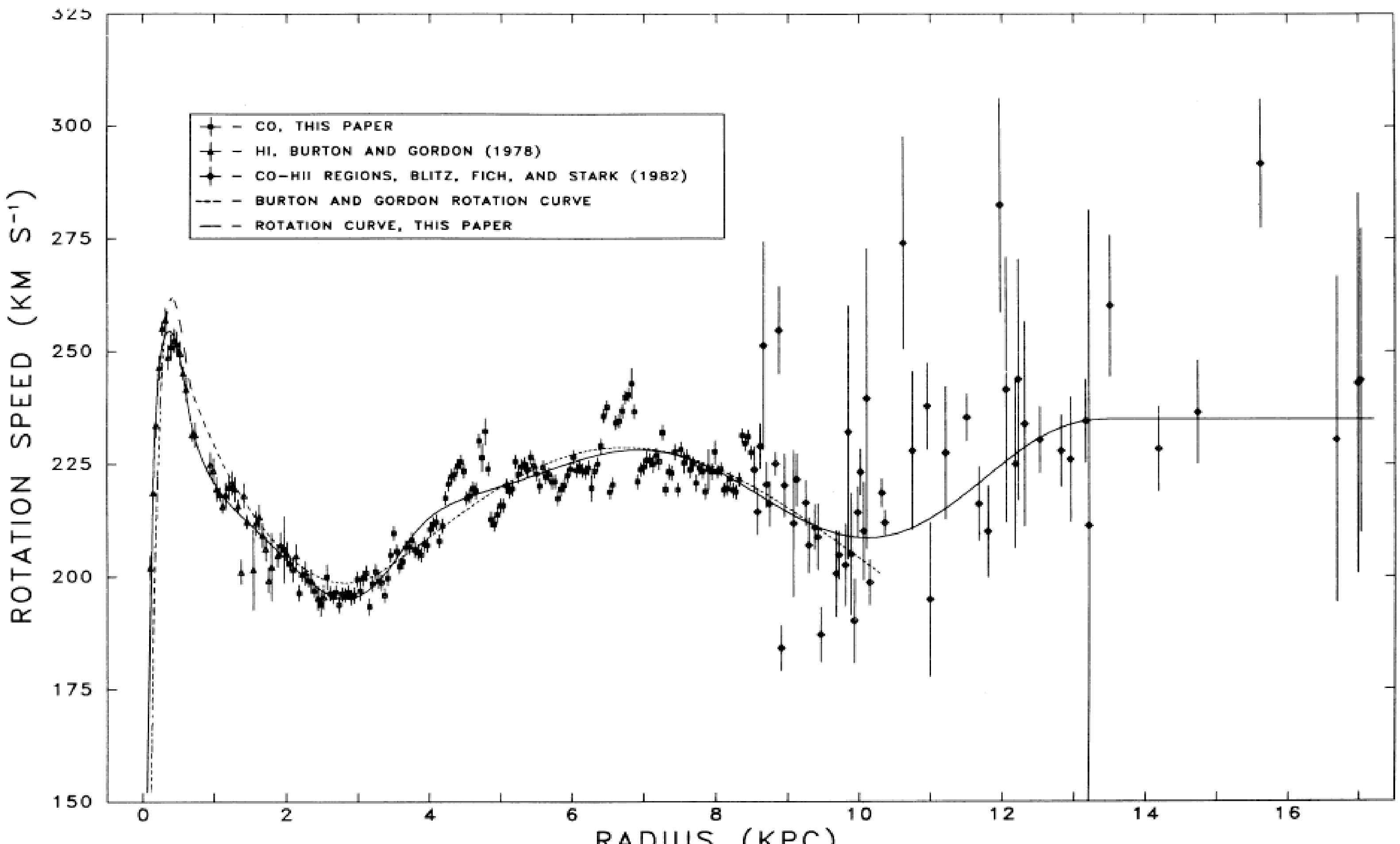
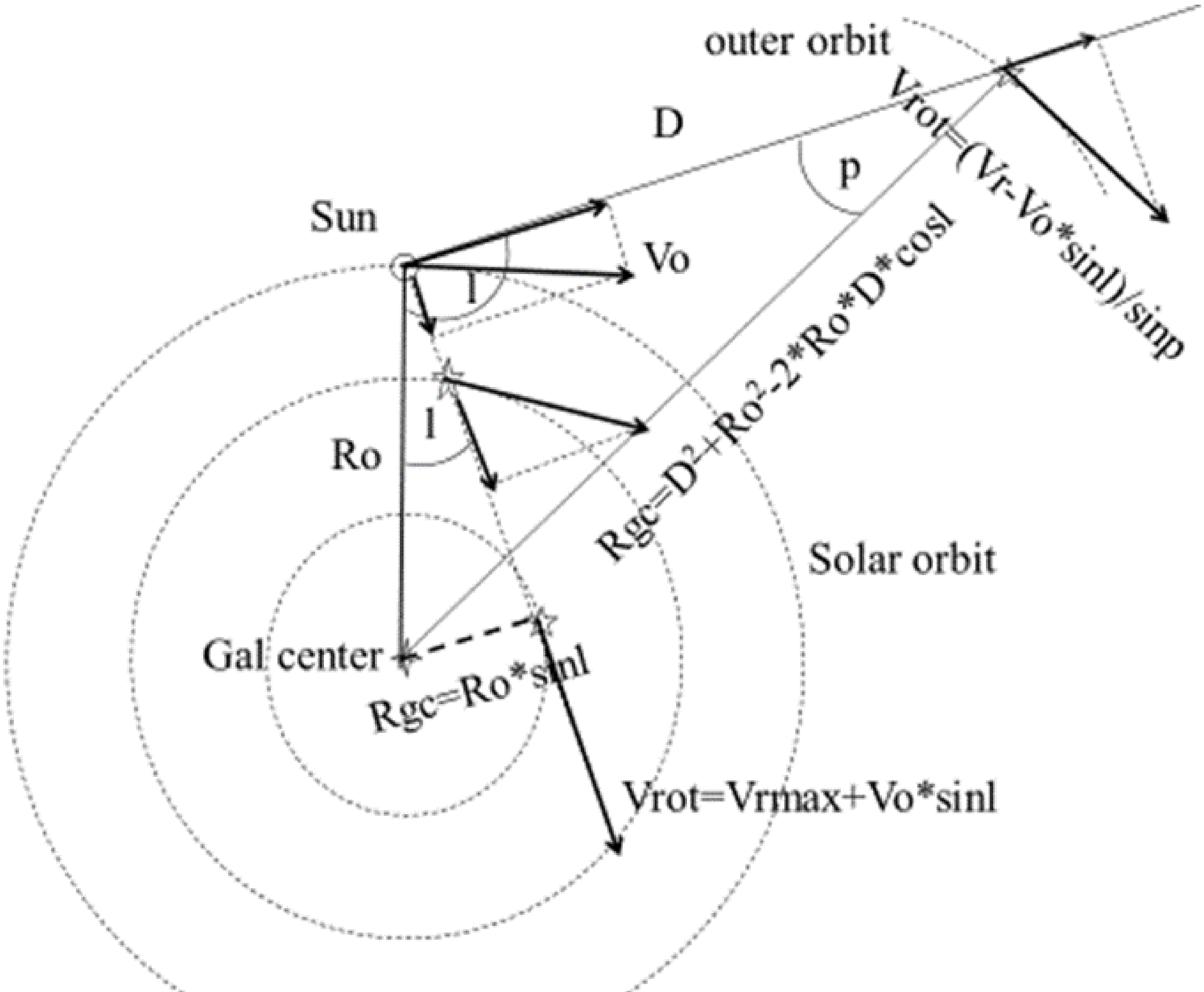
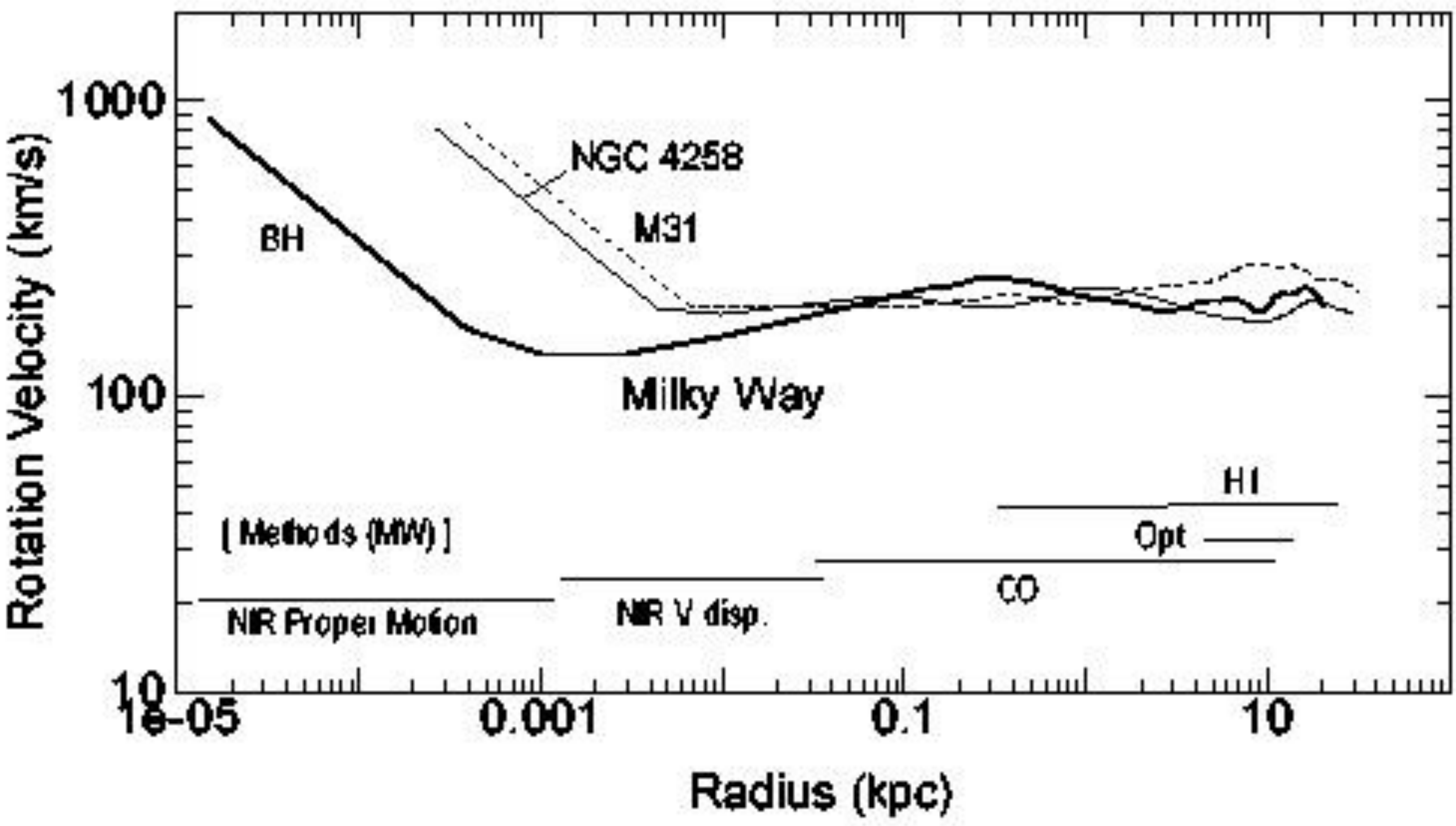


FIG. 3.—Plots of the rotation speed versus galactocentric radius. The solid lines correspond to the polynomials, and the dashed lines are the BG rotation curve. (*upper panel*)(R_0, θ_0) = (10 kpc, 220 km s^{-1}); (*lower panel*) (8.5 kpc, 220 km s^{-1}).

Calculations of orbital speeds inside and outside the solar orbit



Rotation curves and the methods of their determination



RECENT EVIDENCE ON THE ROTATION CURVE OF OUR GALAXY FOR $R > R_o$

1979IAUS...84..221J

P. D. Jackson
University of Maryland

M. P. FitzGerald
University of Waterloo

A. F. J. Moffat
Université de Montréal

Studies of the rotation curve of our Galaxy at galactocentric radii, R, greater than the solar distance, R_o , from the center require the use of conventional optical techniques since the distances to as well as the radial velocities of Population I objects are needed.

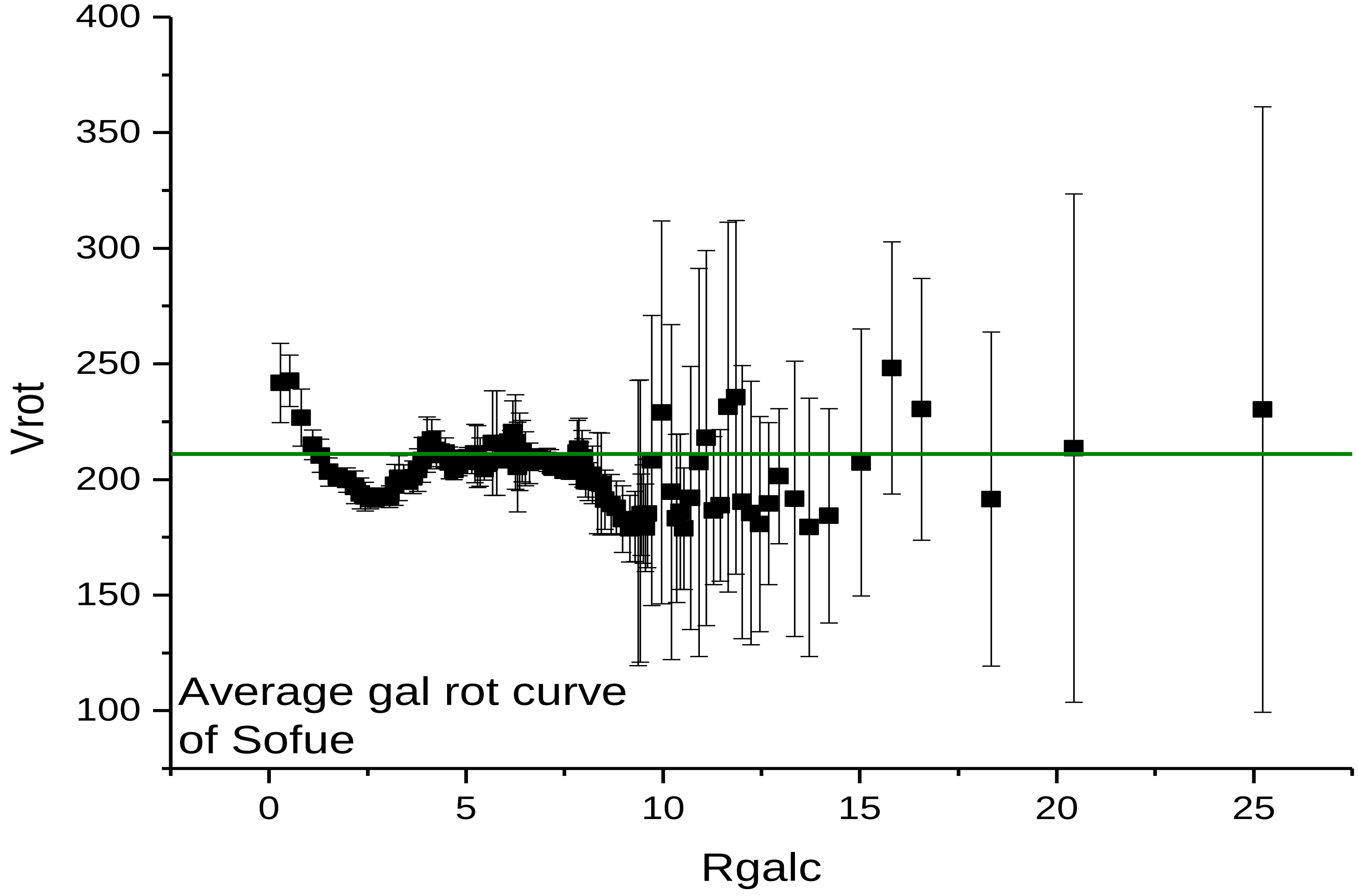
HII regions are the best objects to use for a study of the rotation curve over large distances because (i) they can be detected easily on, say, Palomar red prints, (ii) they have high intrinsic luminosity and (iii) they have low (~ 8 km/sec) dispersion from circular galactic rotation. Y. M. Georgelin's thesis (Georgelin 1975) provides us with H α radial velocities for HII regions which are sufficiently accurate that the measurement error is usually less than the actual velocity dispersion. However, she usually relied on MK spectral classification of presumed exciting stars in order to determine the distance to the regions. This procedure is subject to the relatively large errors in MK luminosity determination for a single star as well as possible misidentification of the exciting star. Nevertheless, Georgelin's work clearly showed a discre-

The present authors have undertaken extensive UBV observations (Moffat, FitzGerald, and Jackson 1978 - in preparation) in order to determine more accurate distances by ZAMS fitting to de-reddened color-magnitude diagrams for stars in the neighborhood of distant (mostly Sharpless) HII regions, in the longitude range ℓ = 150° to 260°. Many of the HII regions have such stellar 'aggregates' (clusters or associations) surrounding them. Image tube slit spectrograms for MK classification and (some) for radial velocity determinations were taken for many of the brighter member stars. The distances we determined by ZAMS fitting were not systematically different from spectrophotometric distances we determined for the same aggregates, nor were they systematically different from Georgelin's (1975) distances for stars studied in common.

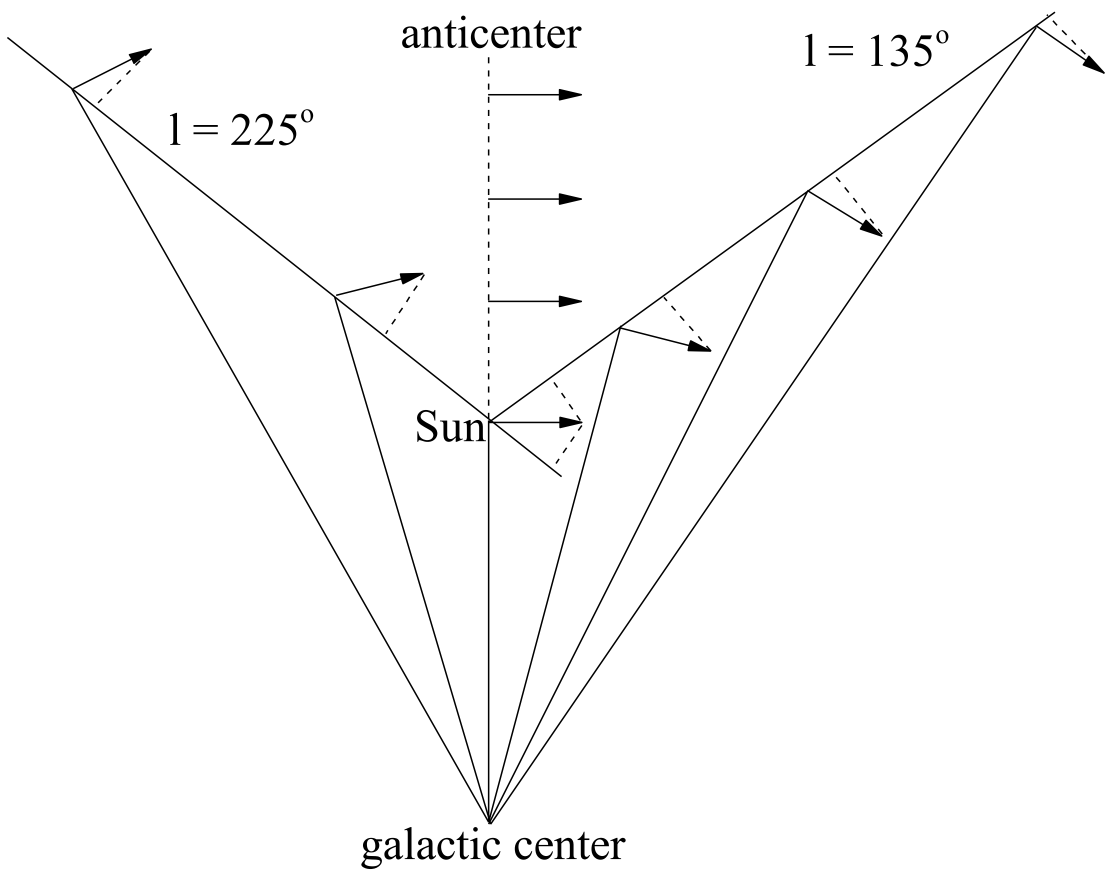
14-4-17

Rotation curve of the Galaxy

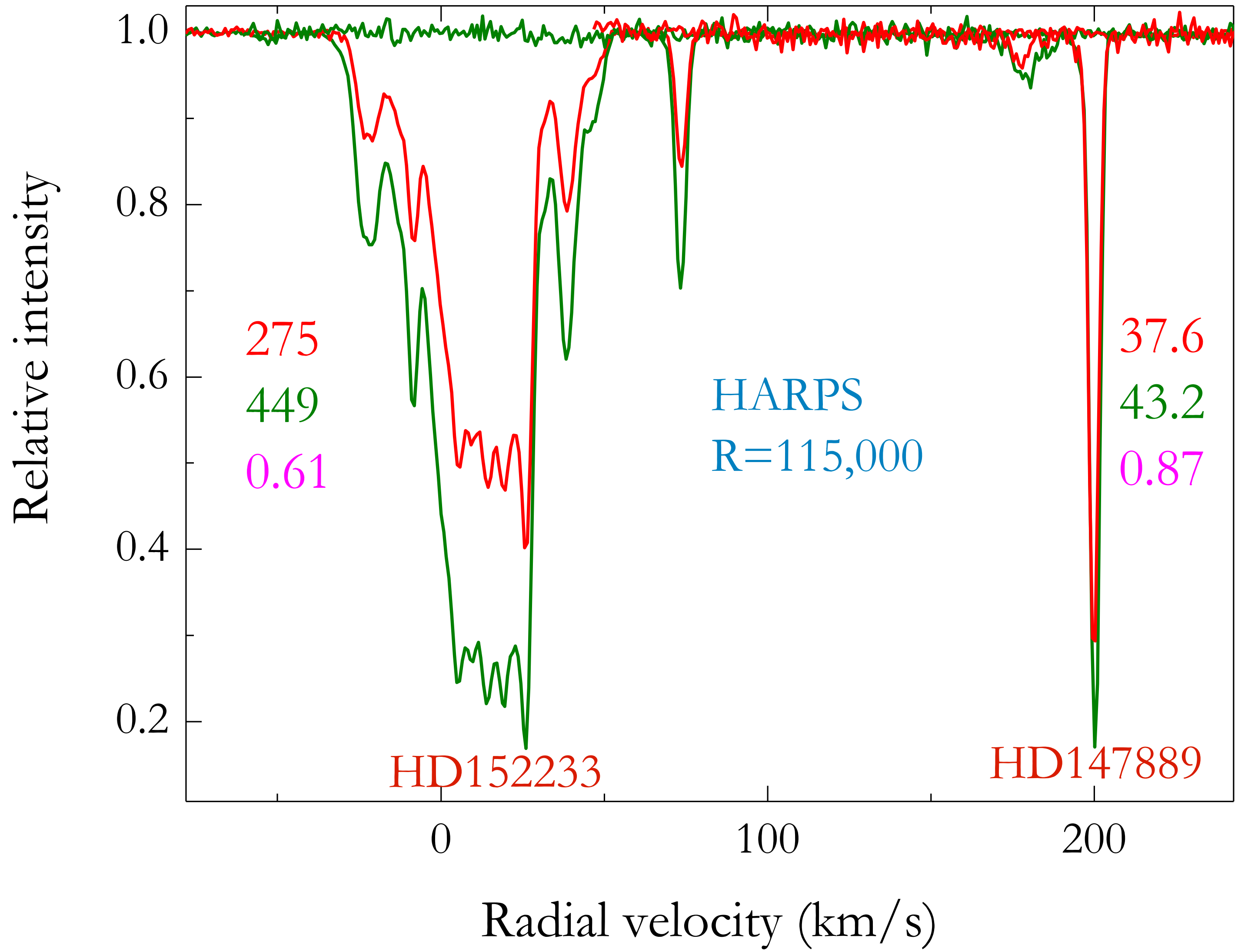
Sofue, Y. et al. (2009, PASJ, **61,** 227)



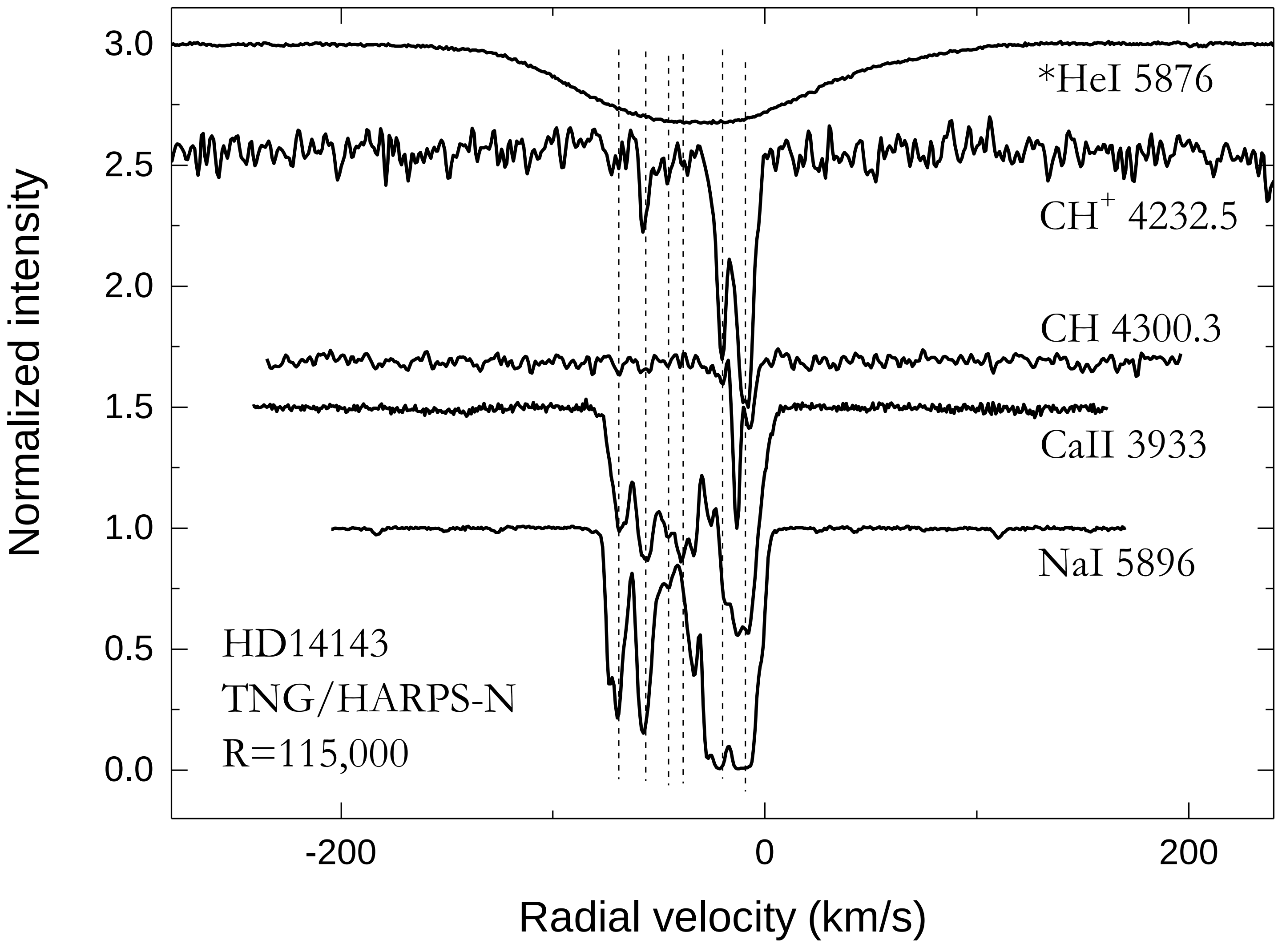
Schematic sketch of the galactic rotation



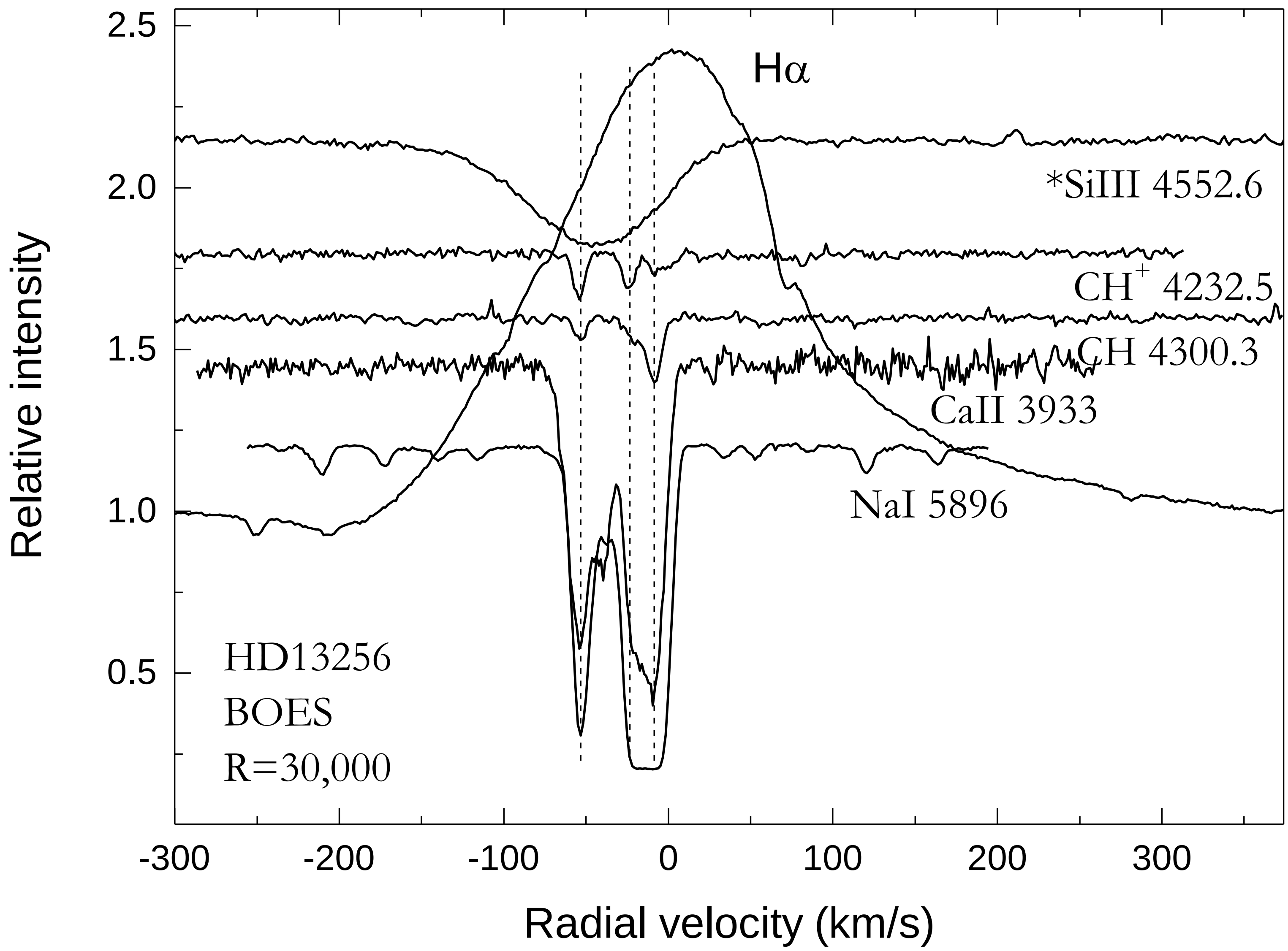
Galactic disk is full of evenly distributed tiny clouds



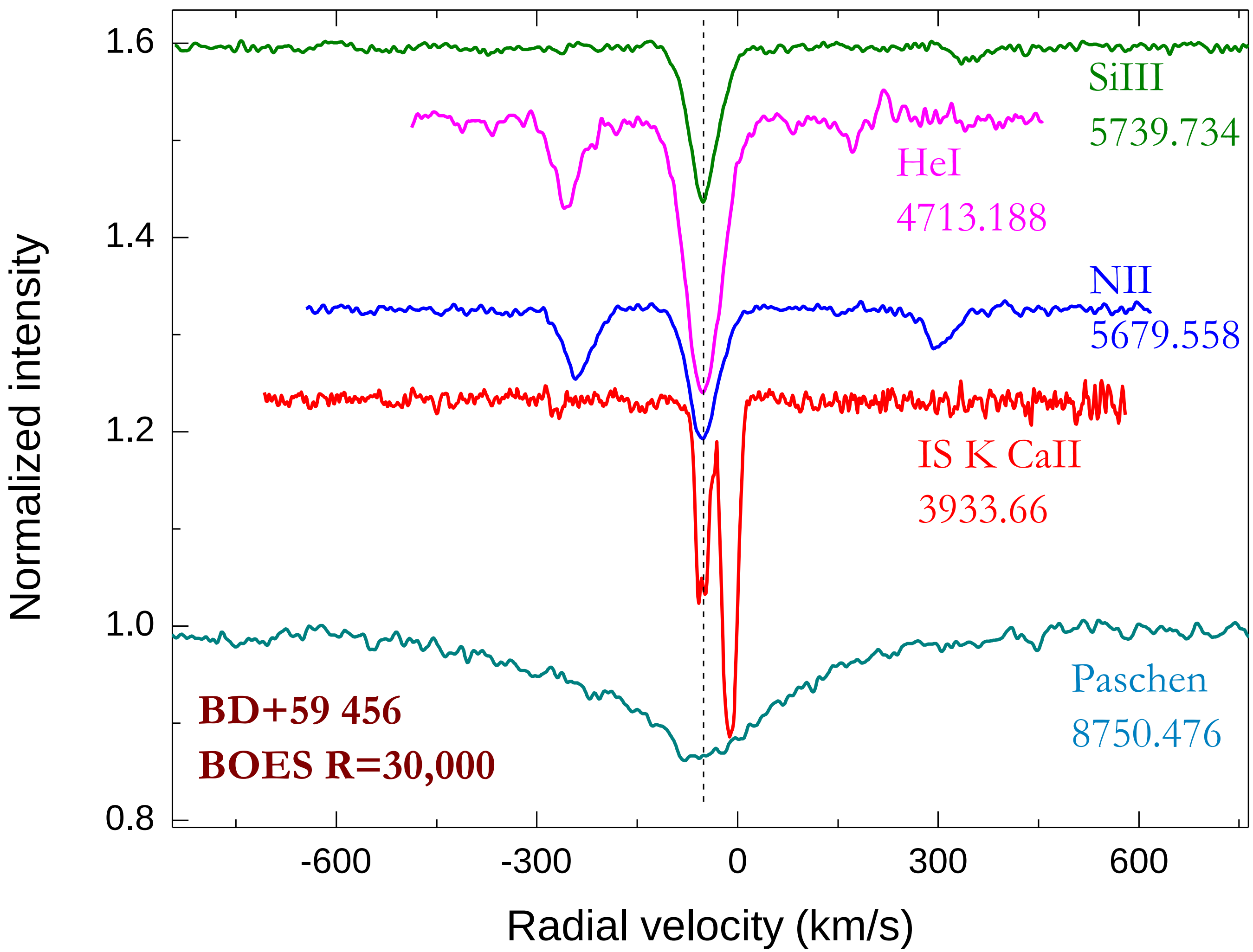
CH and CH+ radial components share radial velocities with those of CaII and NaI



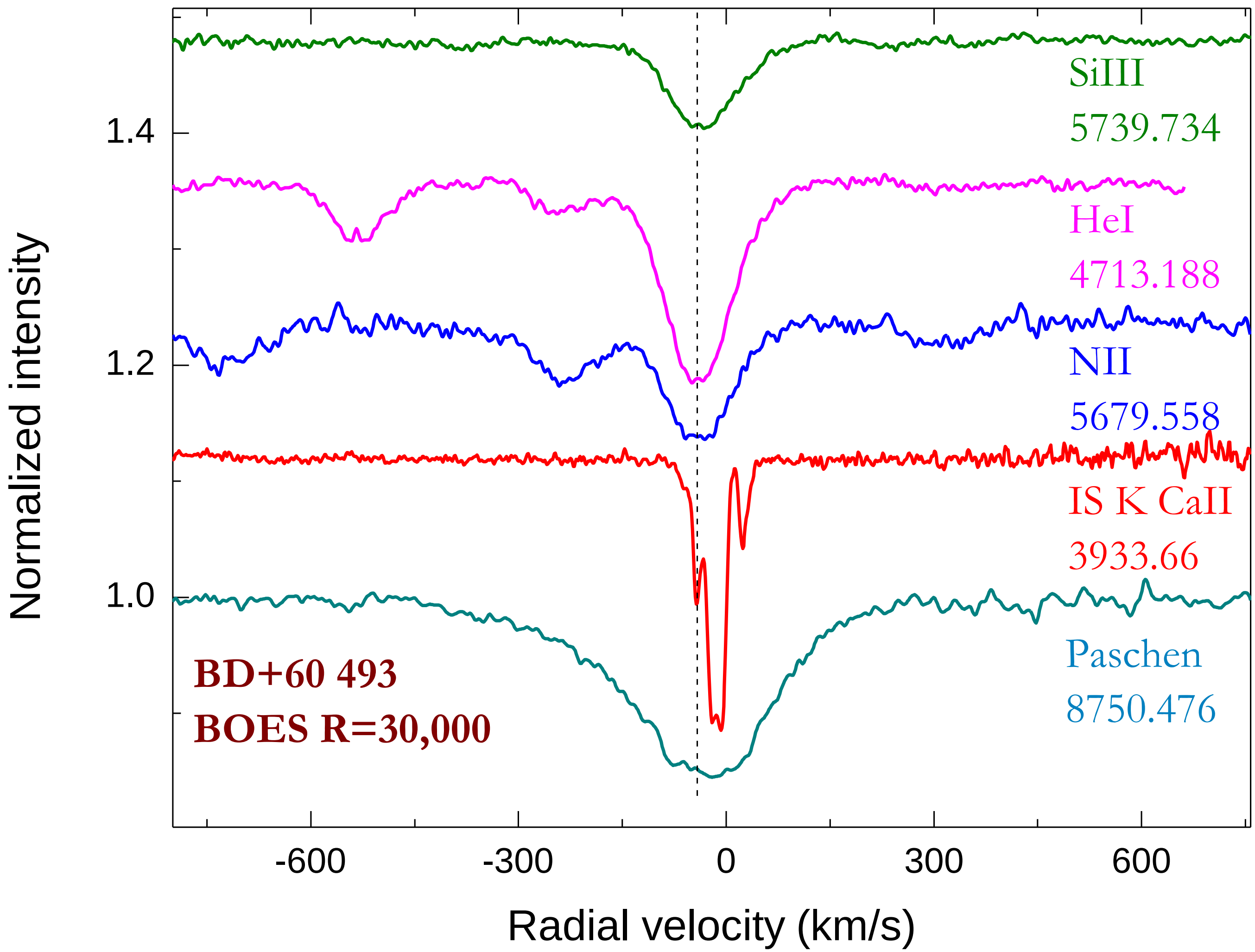
The same effect in another object



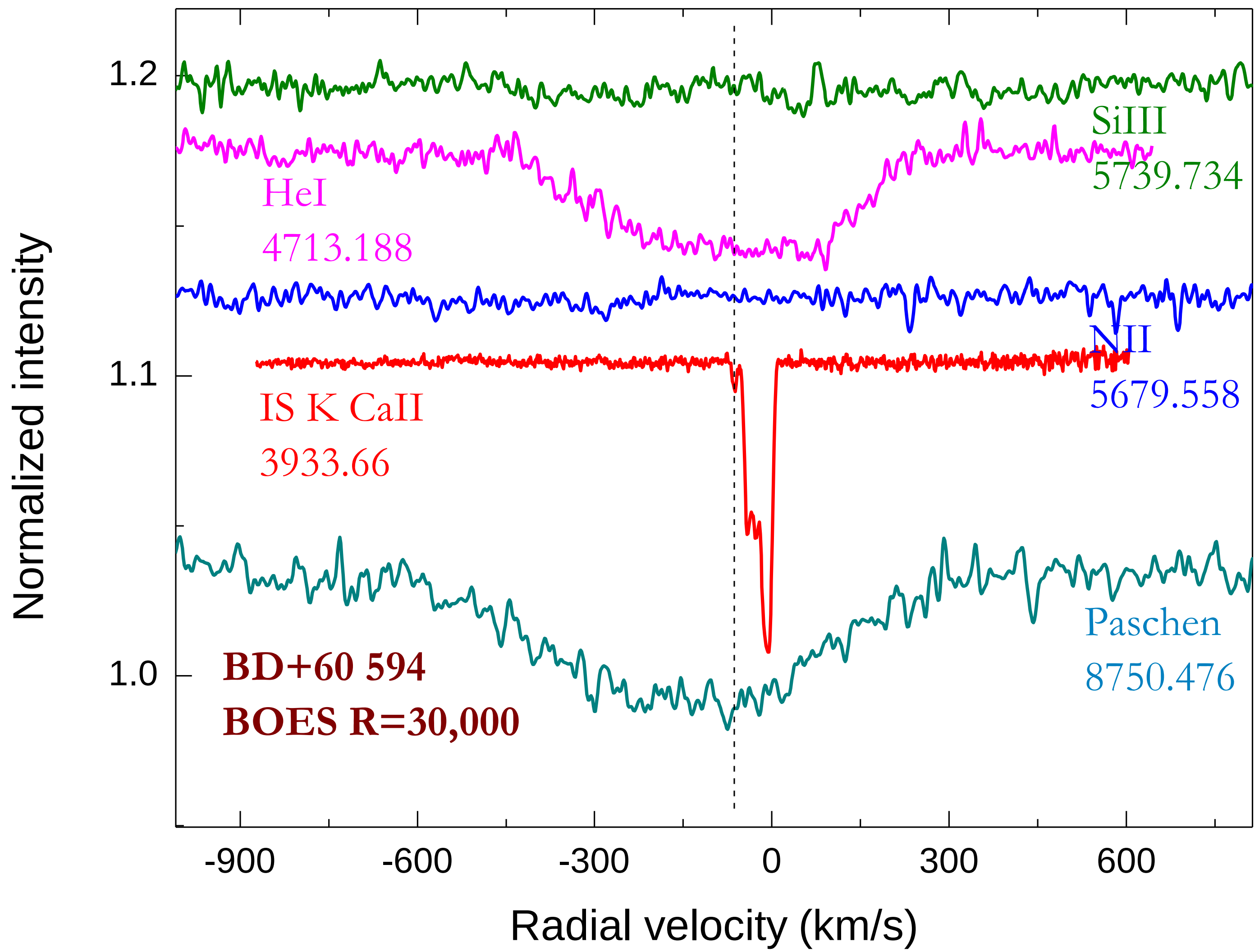
Accordant stellar and interstellar radial velocities
D=3300pc



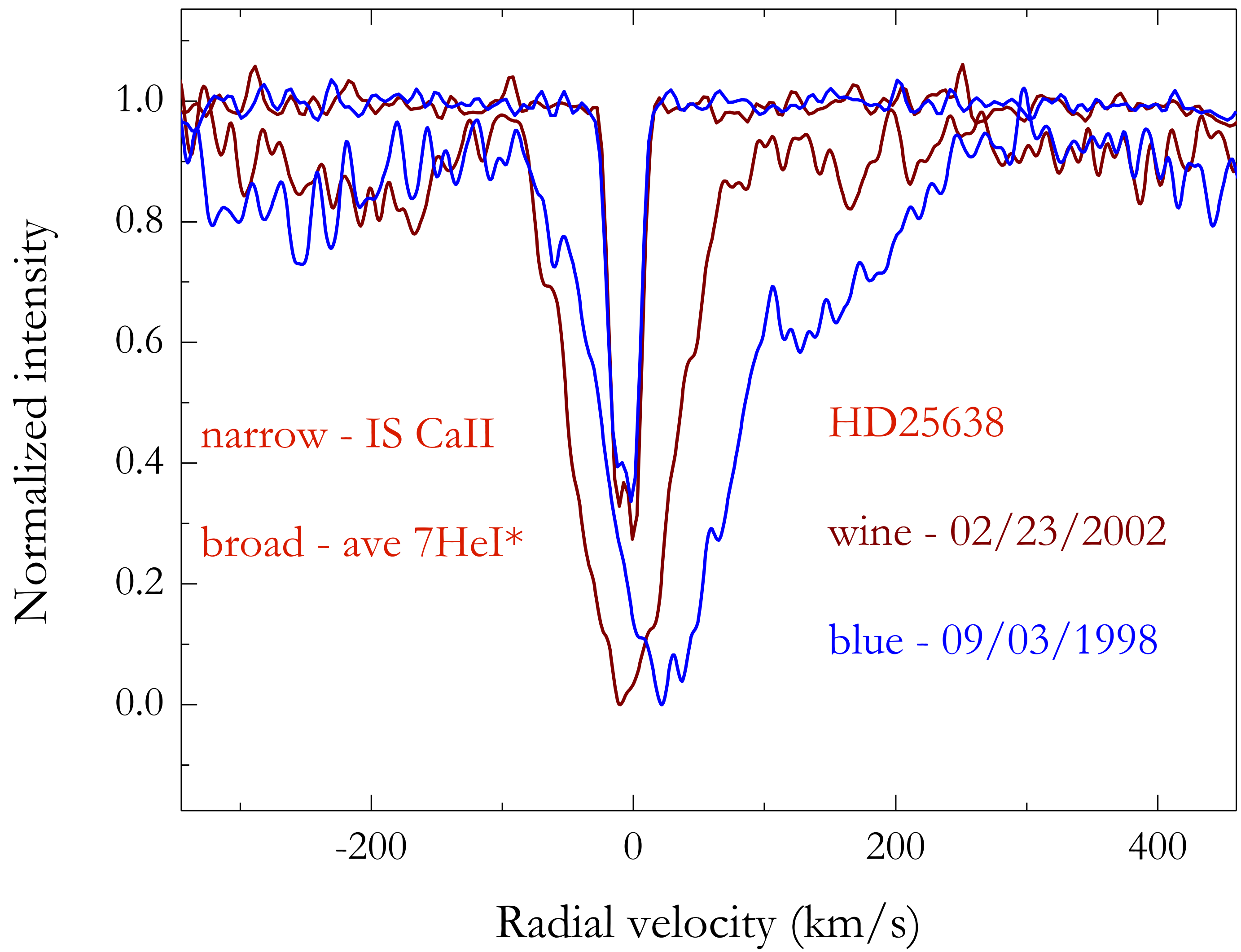
Another similar example D=3000pc



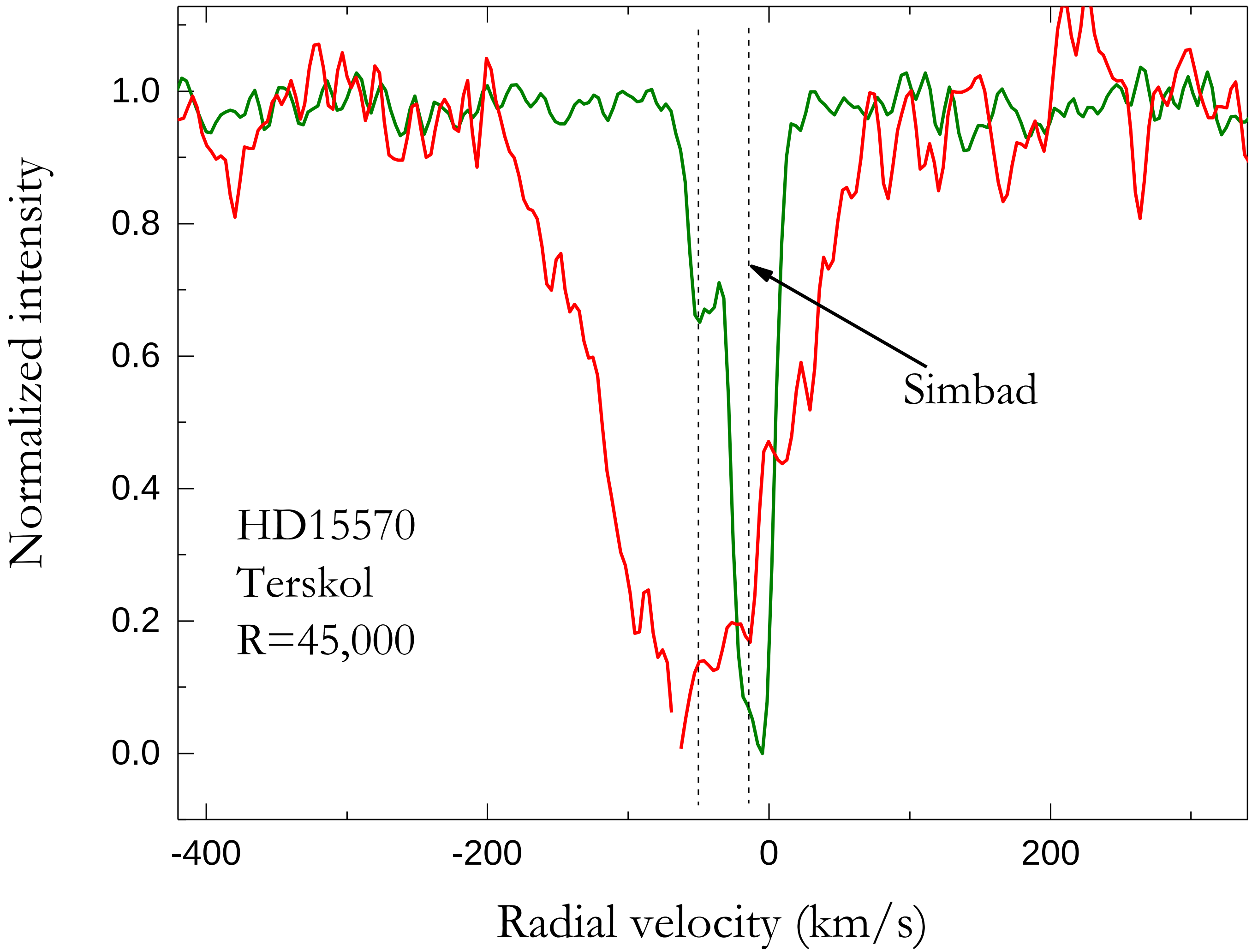
For majority of OB stars rad vels are hardly precise (variability, binarity) D=2200pc



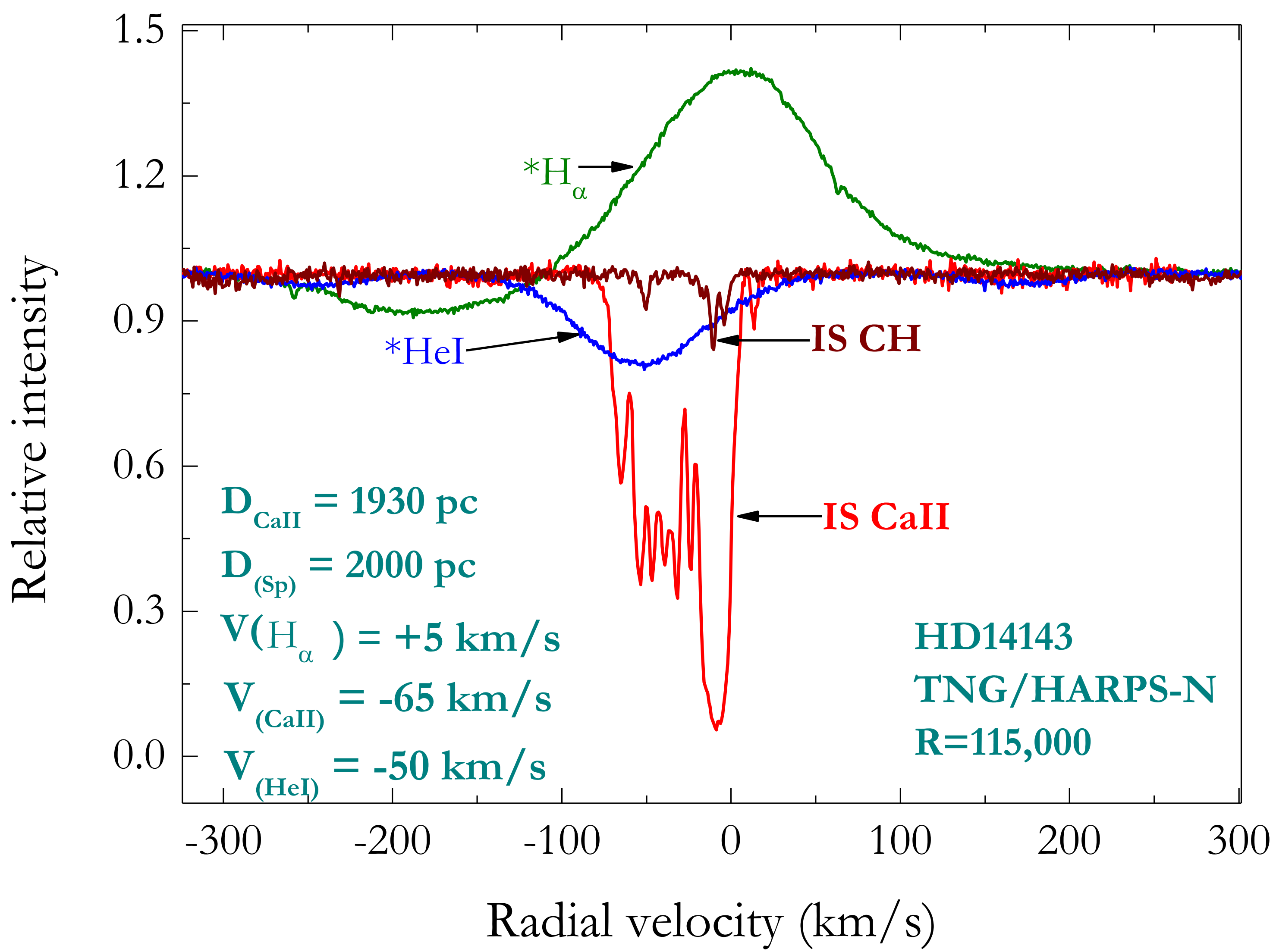
Troubles while determining radial velocity of a star (spectra from Terskol)



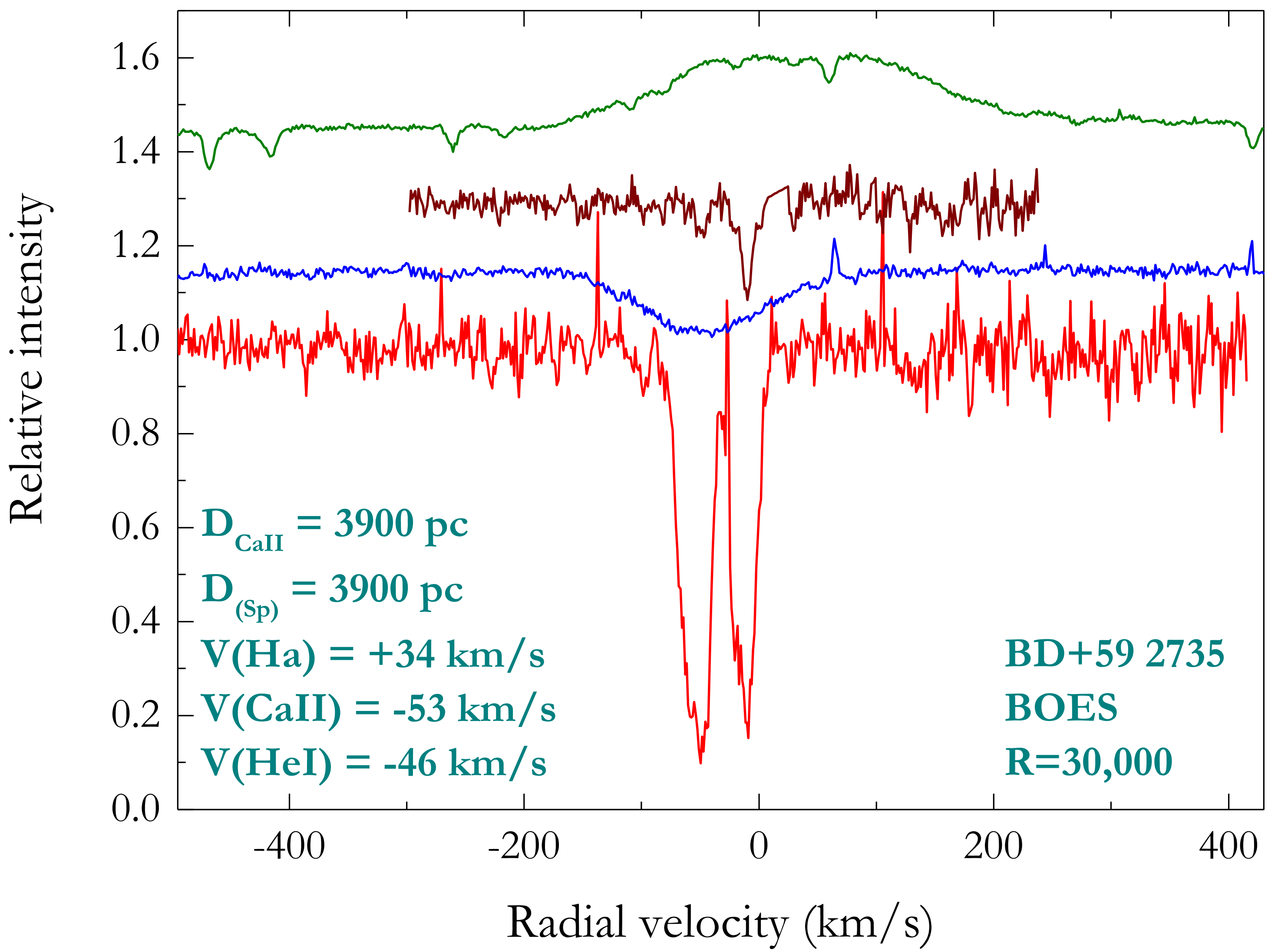
Our radial velocity vs. that given in Simbad



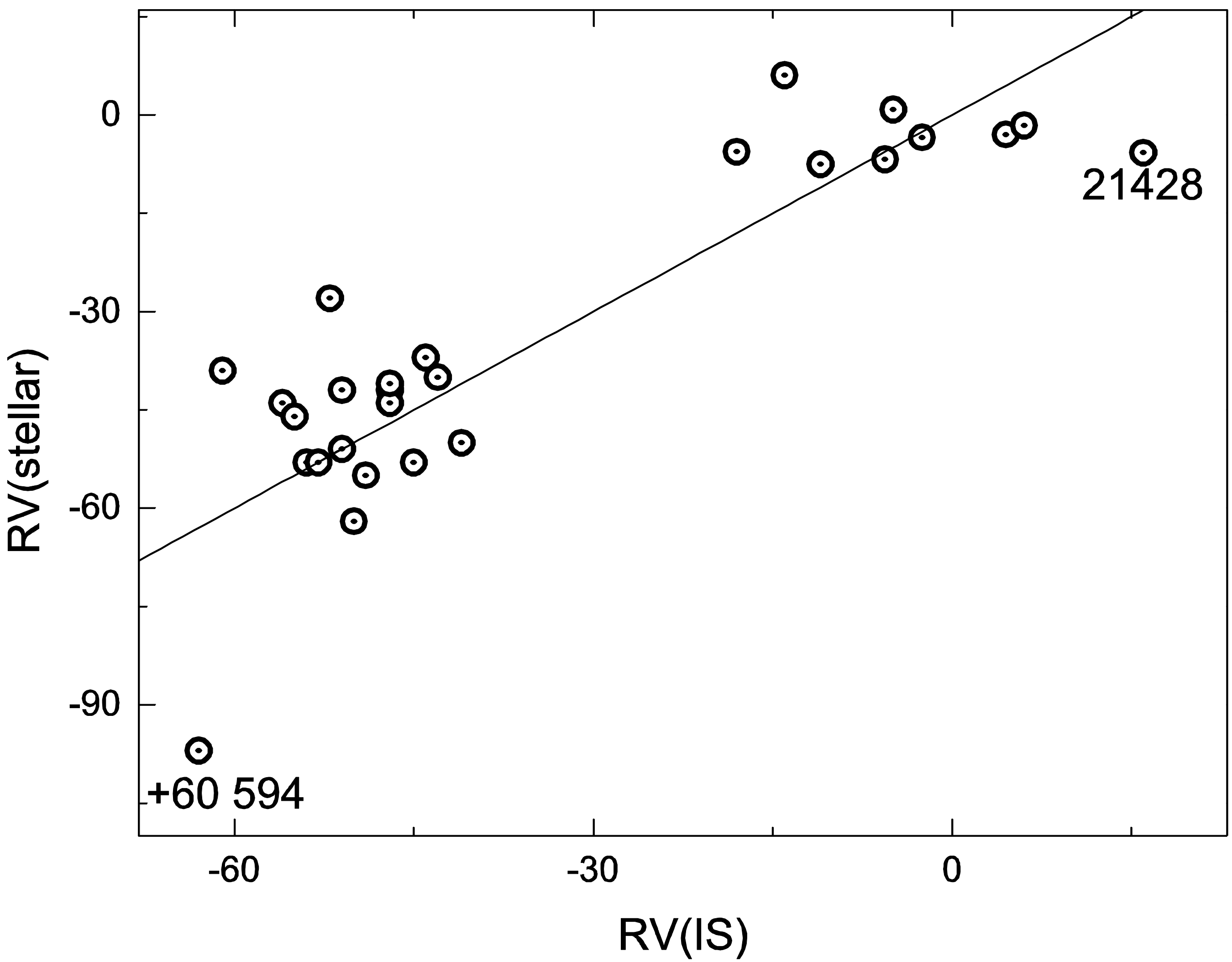
Which lines should be used for measuring radial velocities?



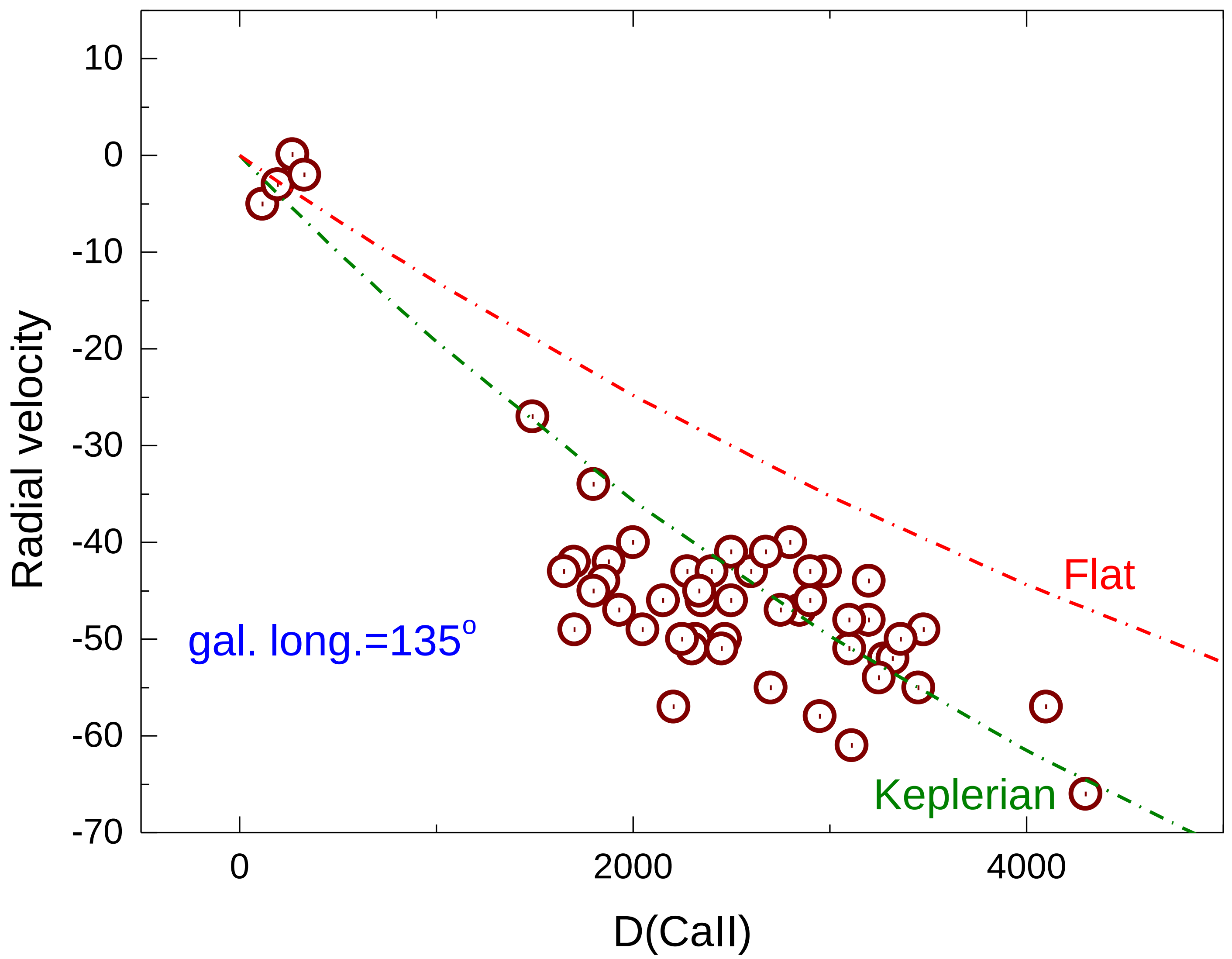
Hα line, originated in the HII region is hardly useful as the spiral tracer



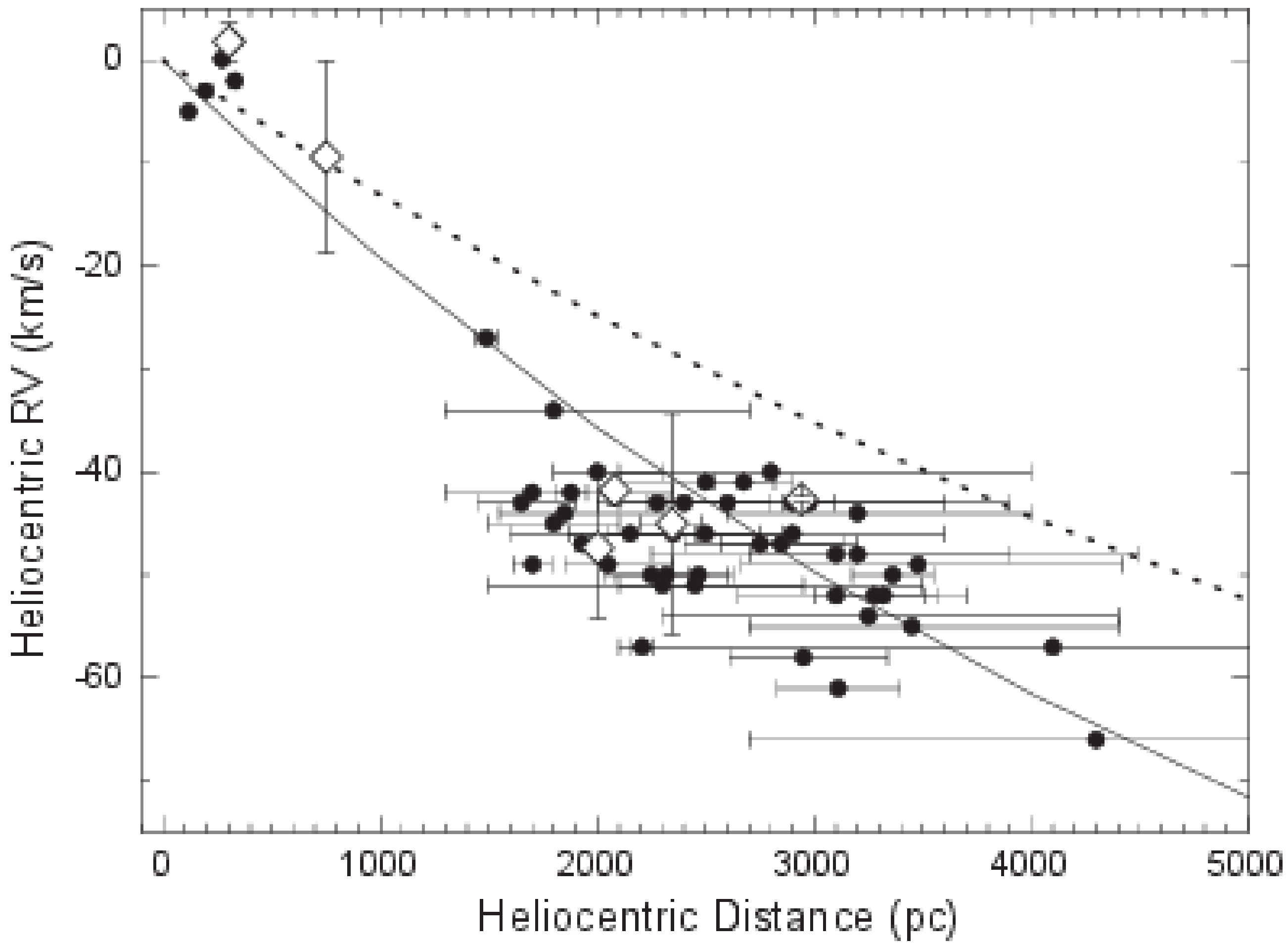
Stellar (Simbad) vs. Interstellar radial velocities



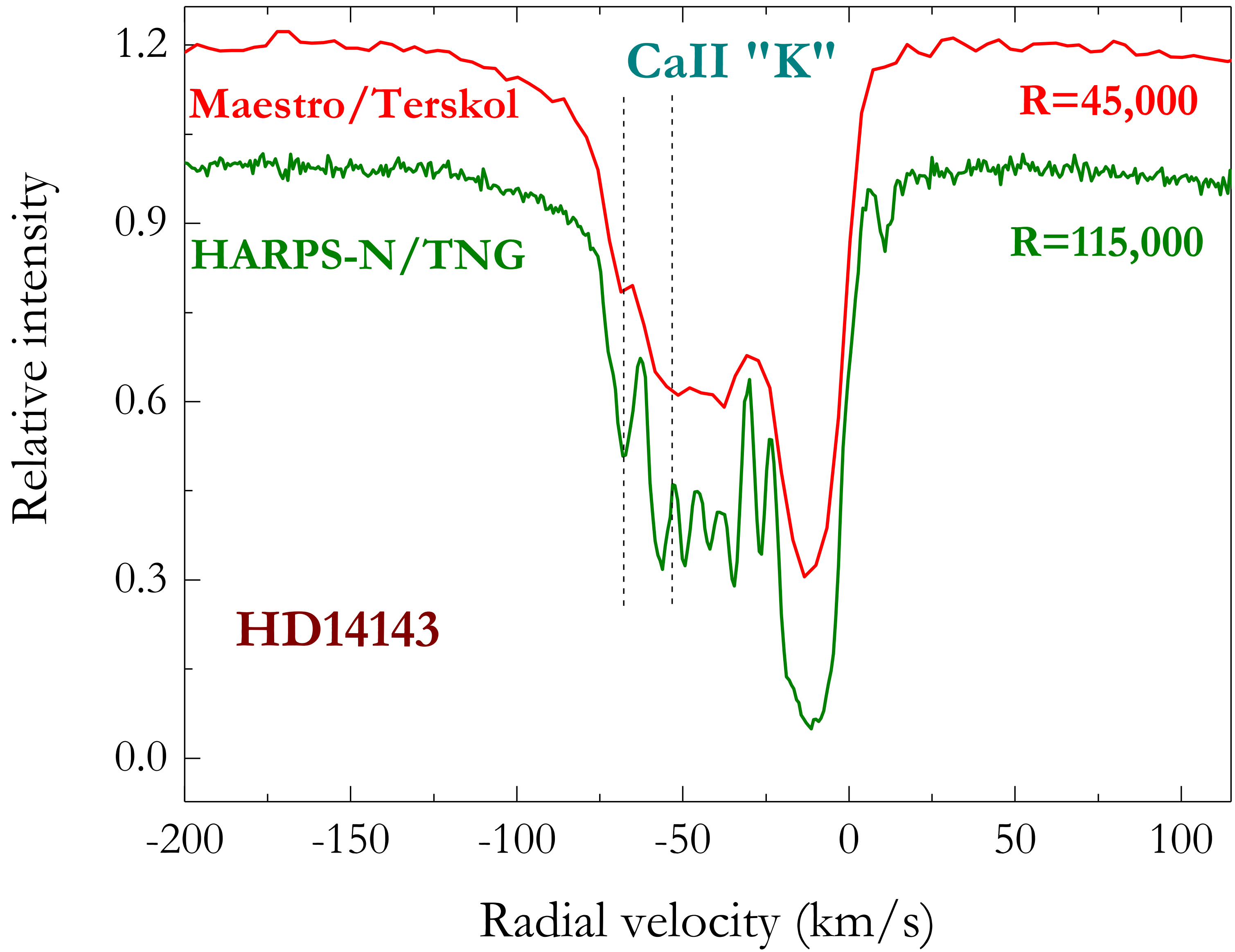
Radial velocities of CaII clouds and model curves



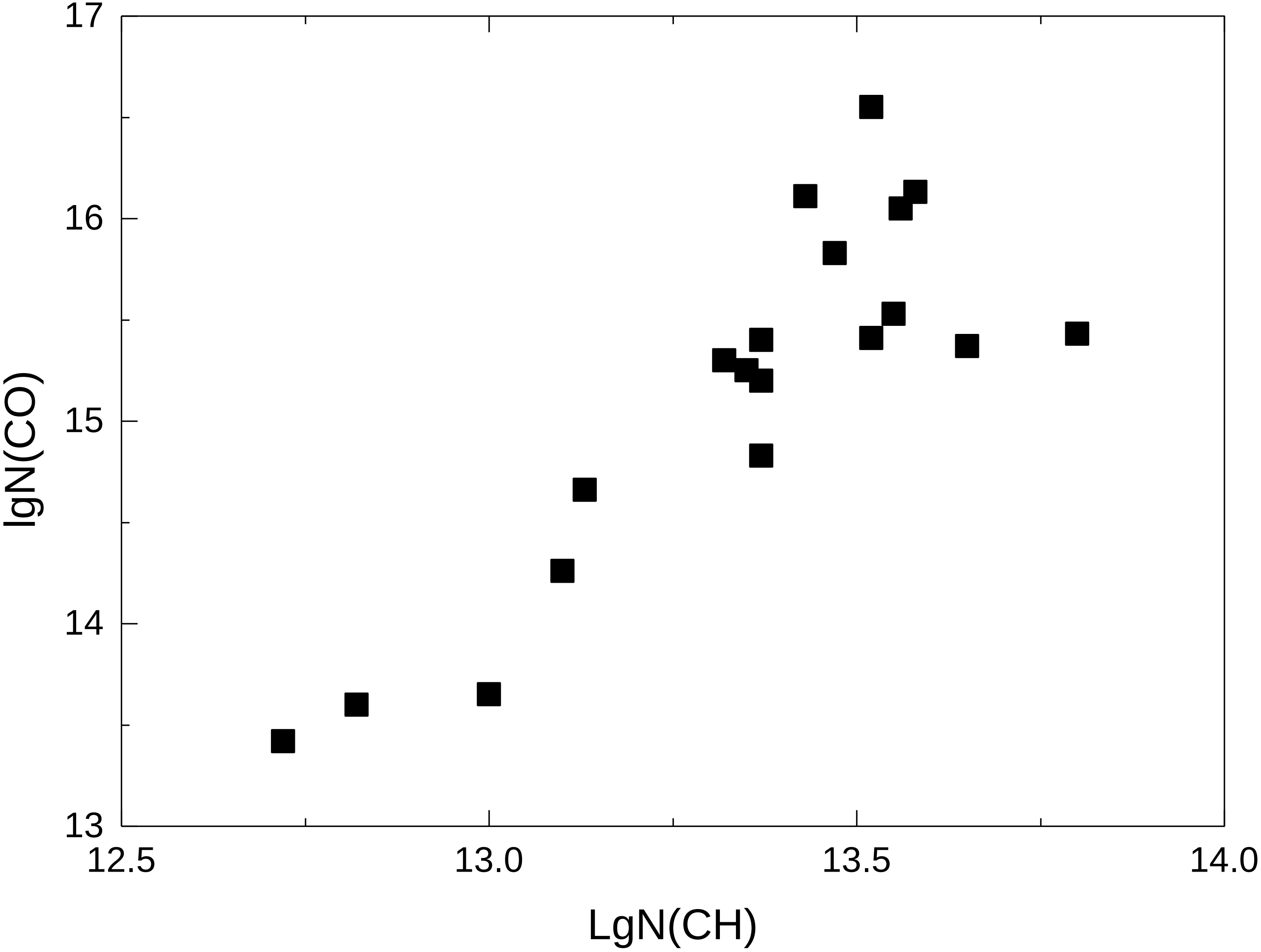
The same plot but with open clusters shown as open diamonds



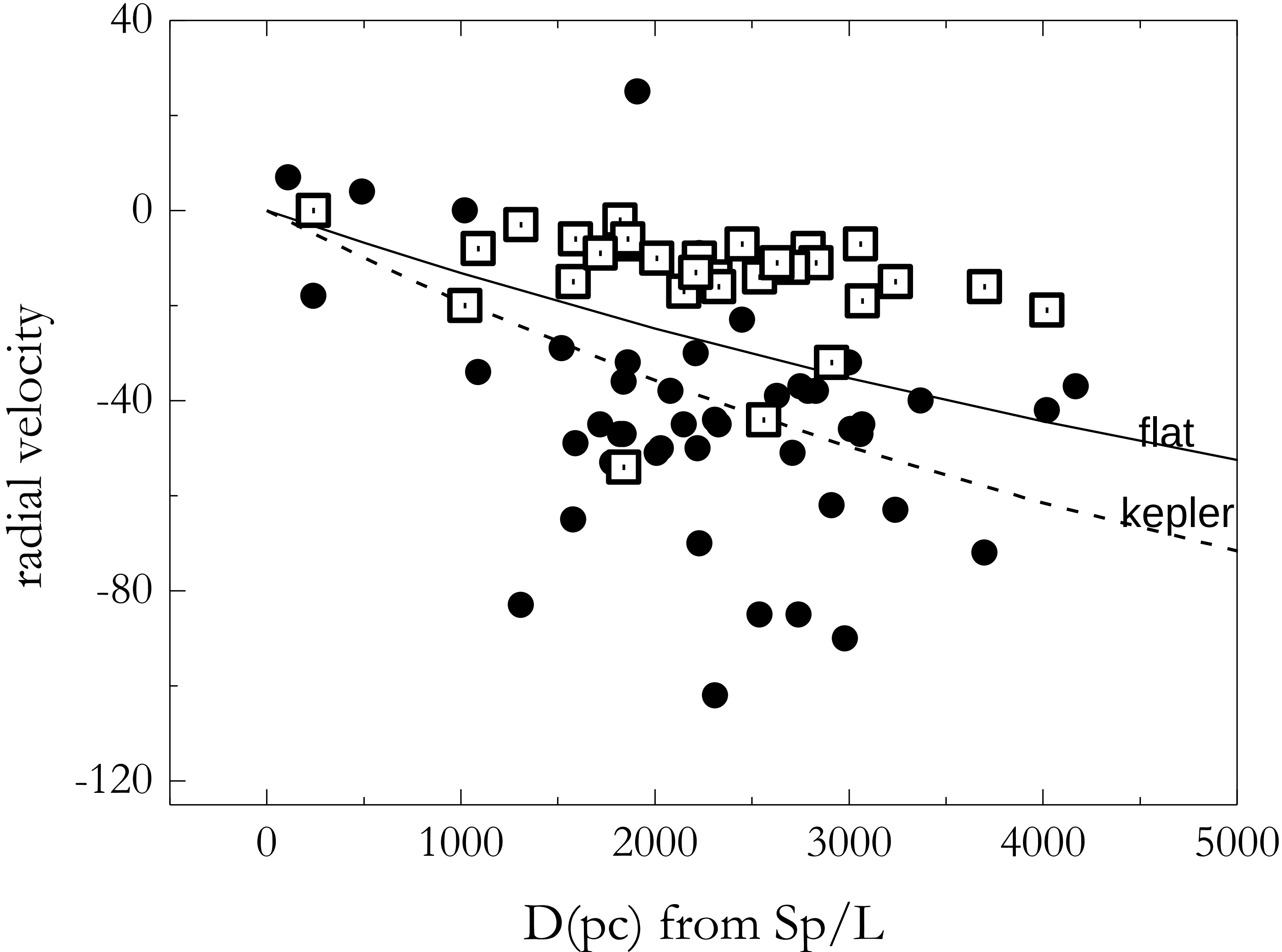
What can the spectral resolution change?



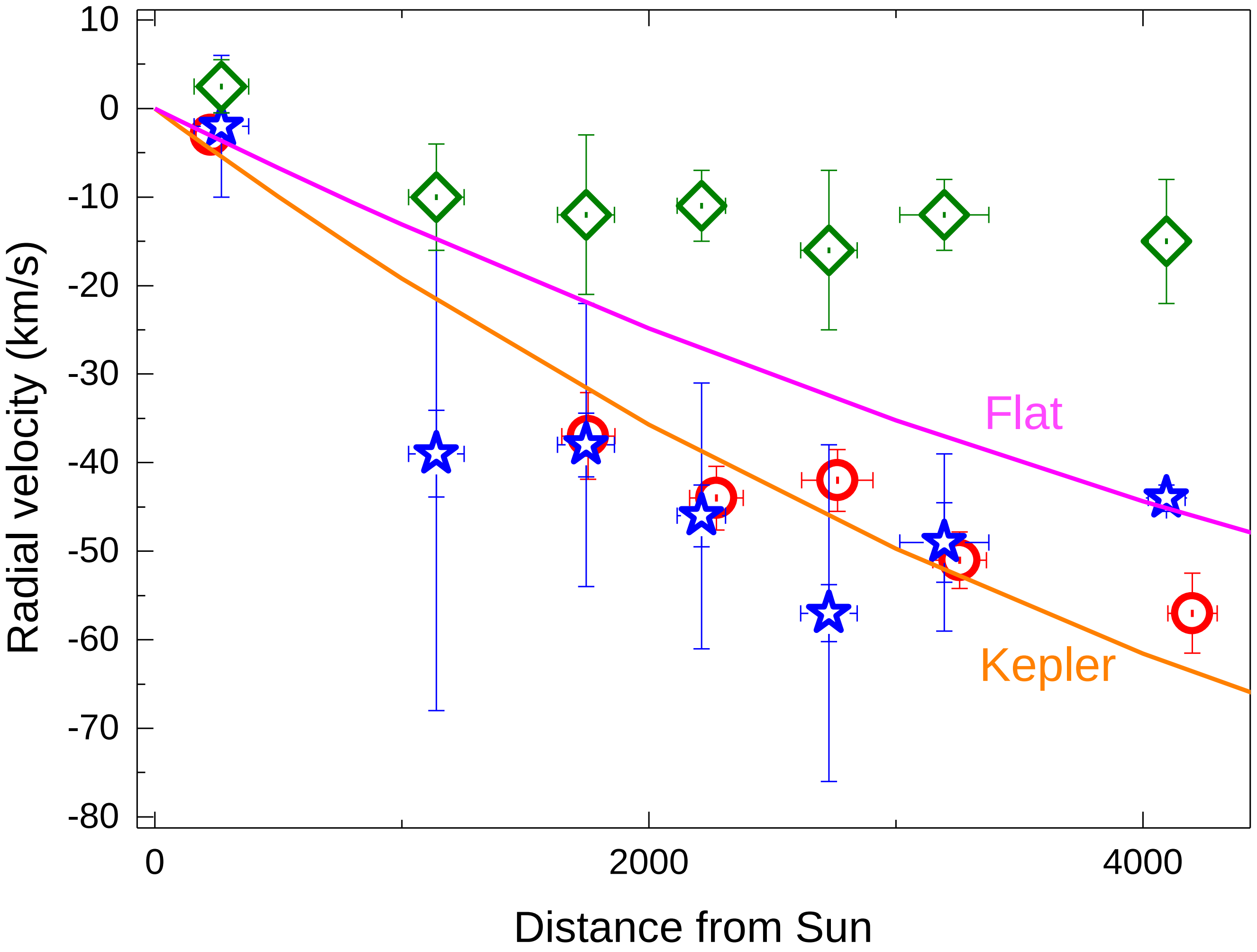
Correlated abundances of CO and CH molecules



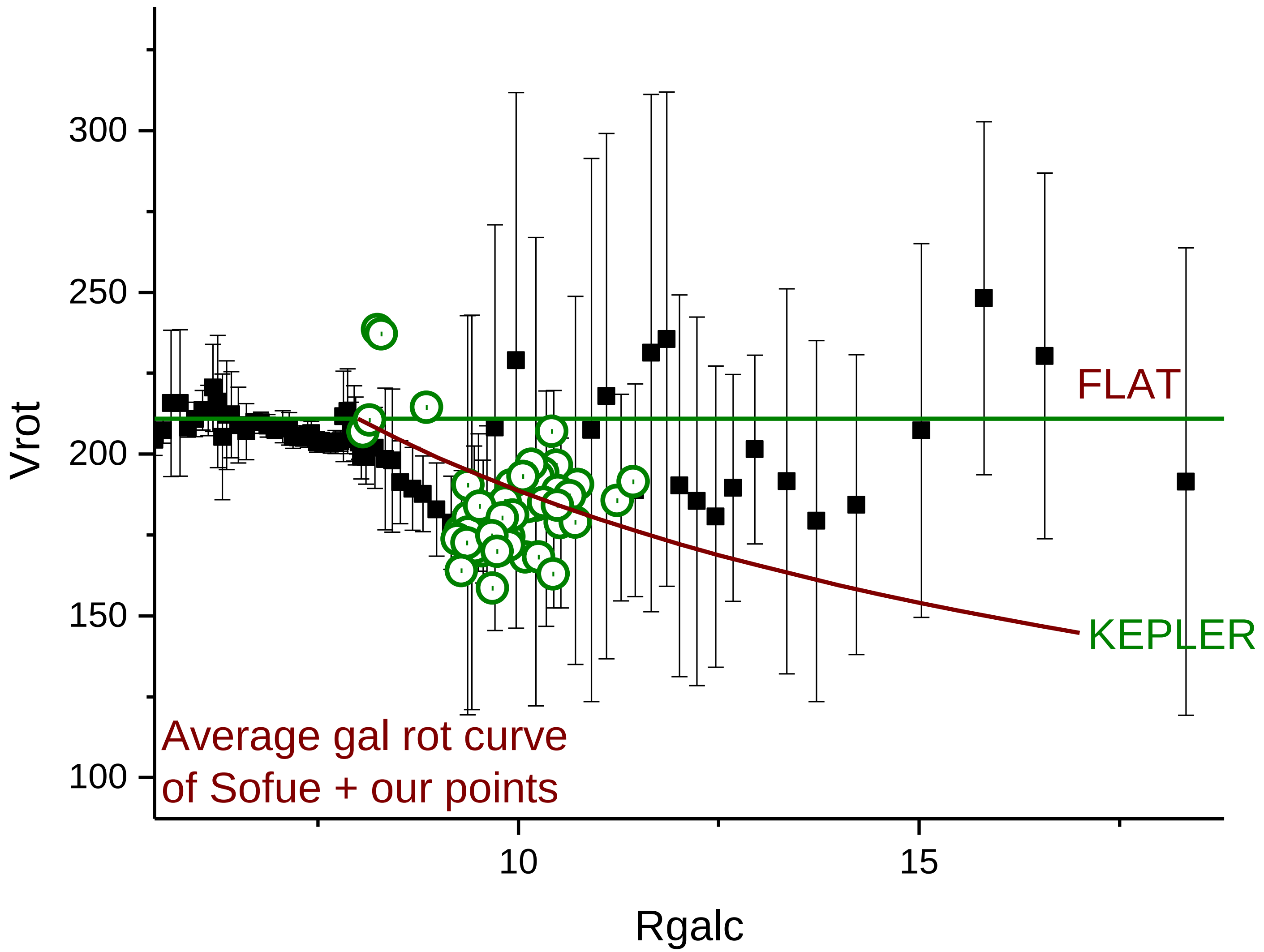
The rotation curve for stars – distances from Sp/L and CH main components - squares



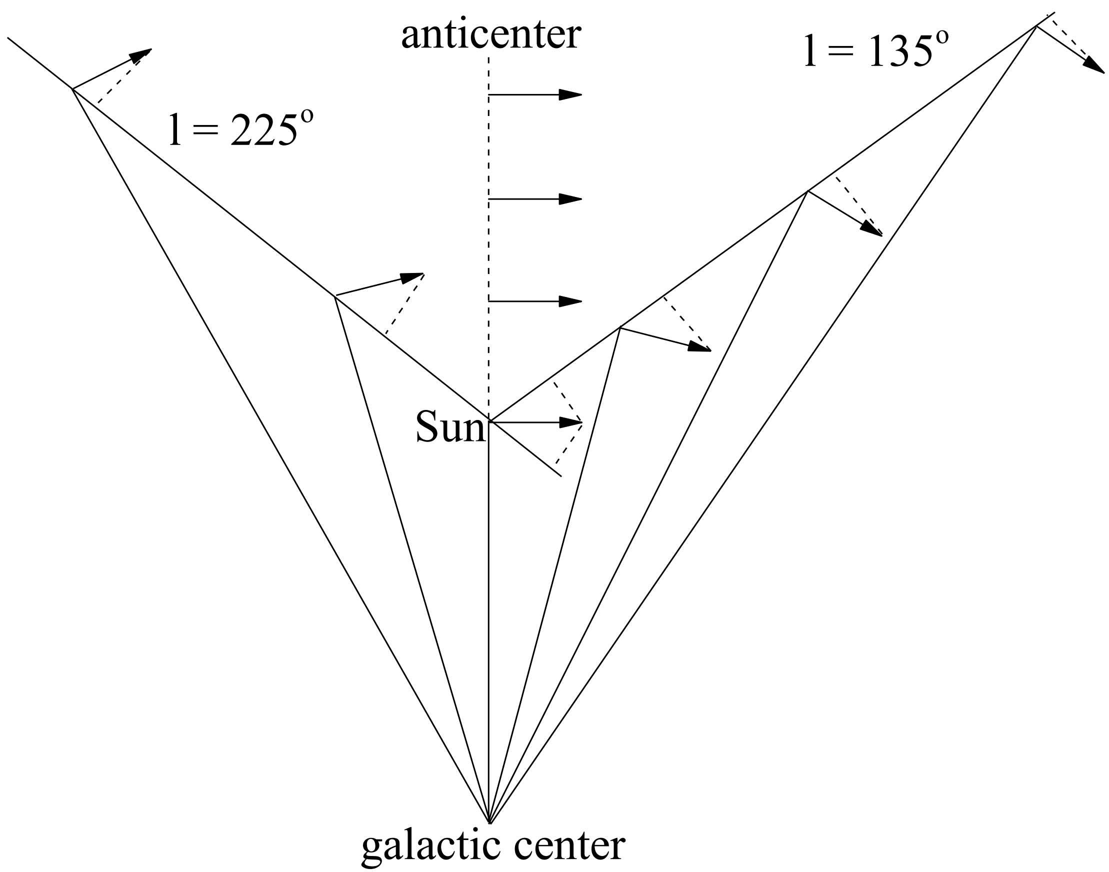
Averaged rotation curves: red circles – CaII distances and radial velocities; blue asterisks – stellar values, green diamonds – stellar distances + CH radial velocities; lines: magenta – flat, orange – Keplerian;



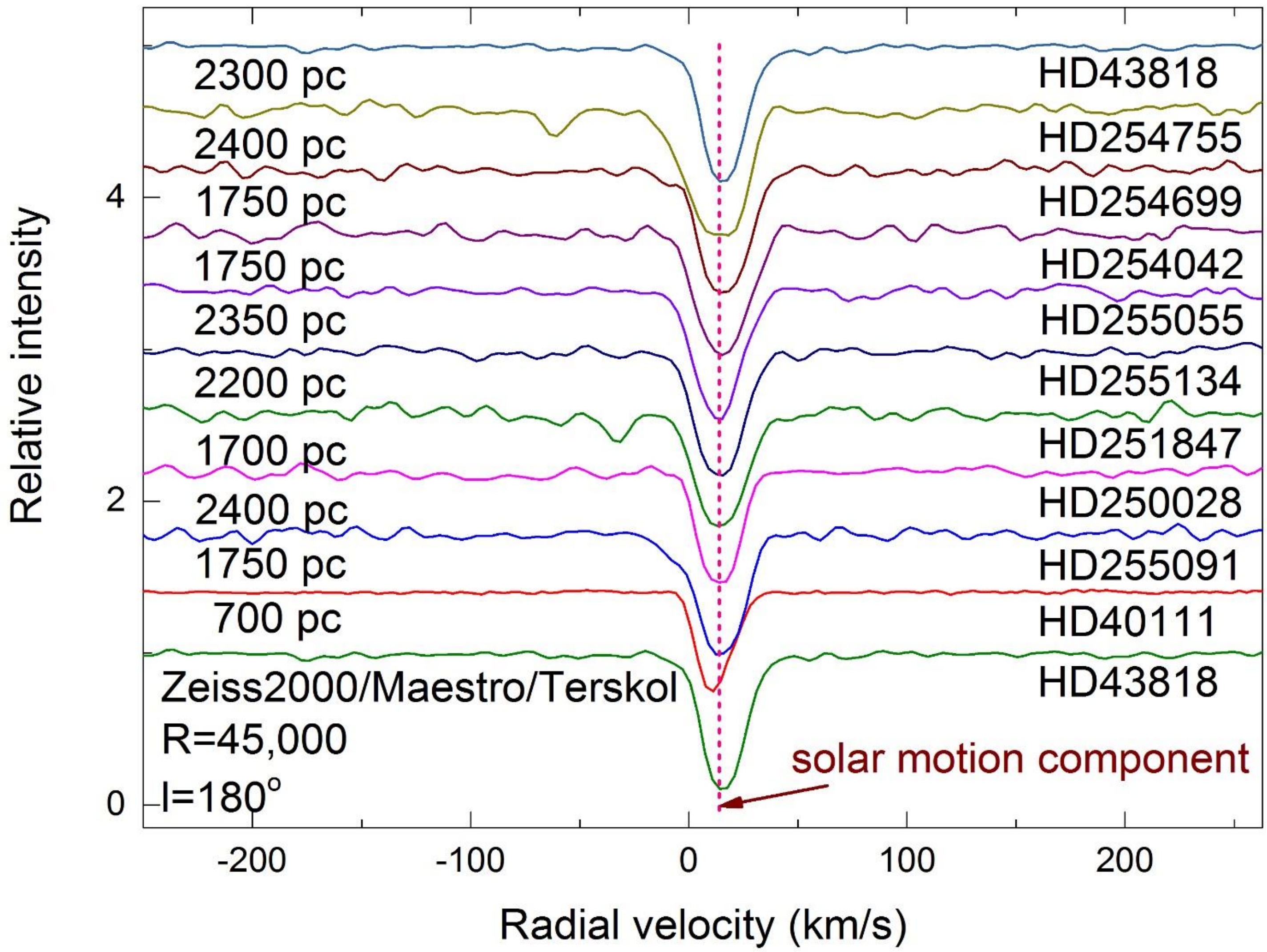
The same plot in another coordinates and with the Sofue points added



Schematic sketch of the galactic rotation



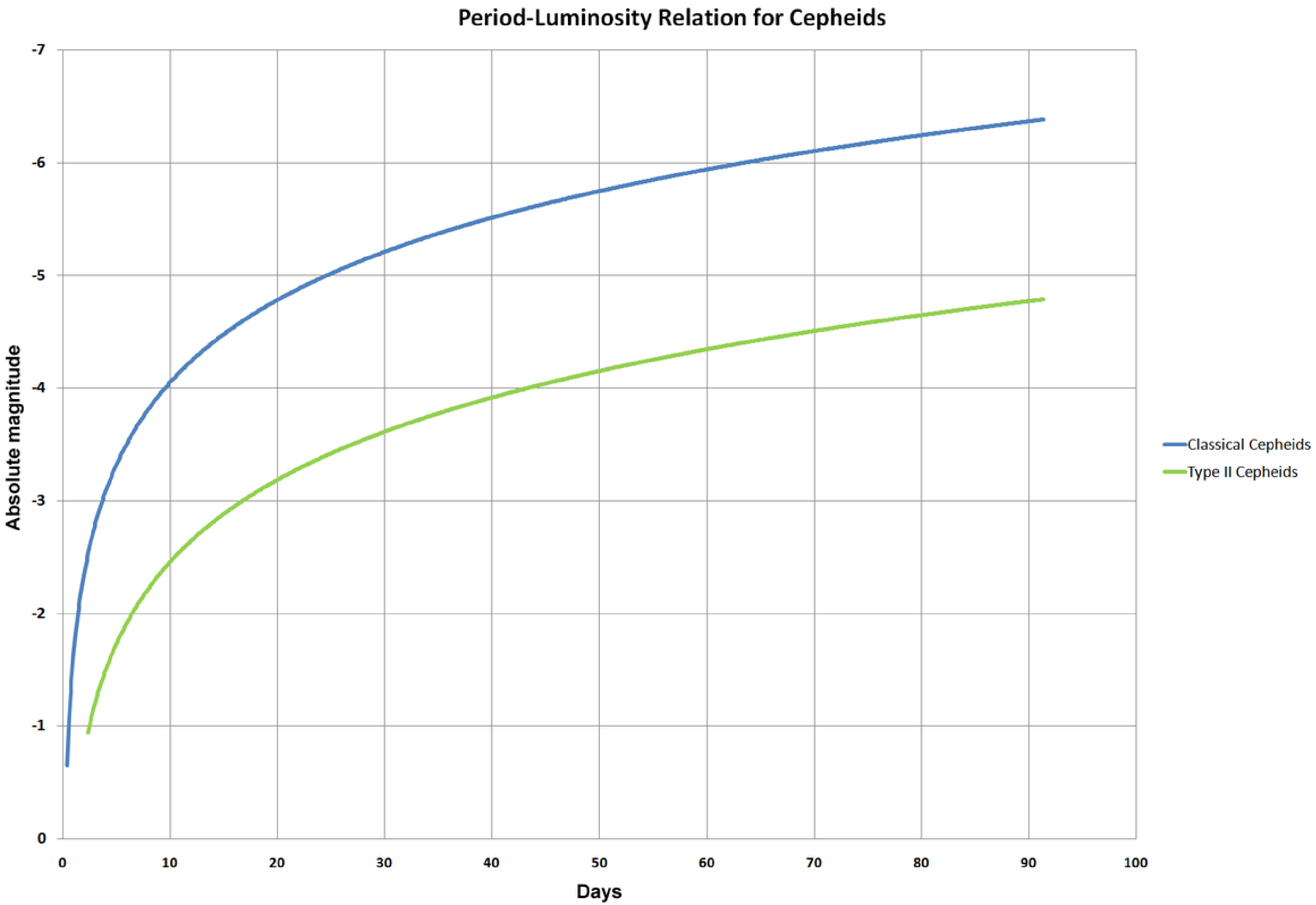
Rotation curve in the anticenter direction



Conclusions

- CaII clouds and open clusters, observed along the $l=135^{o}$ sightline, clearly suggest the keplerian rotation of the disk of our Galaxy
- A majority of radial velocities toward the galactic anticenter supports the idea of circular (thermalized) orbits of galactic objects until a certain radius
- CaII radial velocities are radial components of orbital velocities only
- The DM rotation curve is keplerian and does not suport the idea of DM halo

Very large distances – cepheids as possible standard candles



Formulae for distance measurements

The following relationship between a Population I Cepheid's period P and its mean absolute magnitude M_v was established from Hubble Space Telescope trigonometric parallaxes for 10 nearby Cepheids:

$$M_v = (-2.43 \pm 0.12)(\log_{10}(P) - 1) - (4.05 \pm 0.02)$$

with P measured in days.[19][23] The following relations can also be used to calculate the distance d to classical Cepheids:

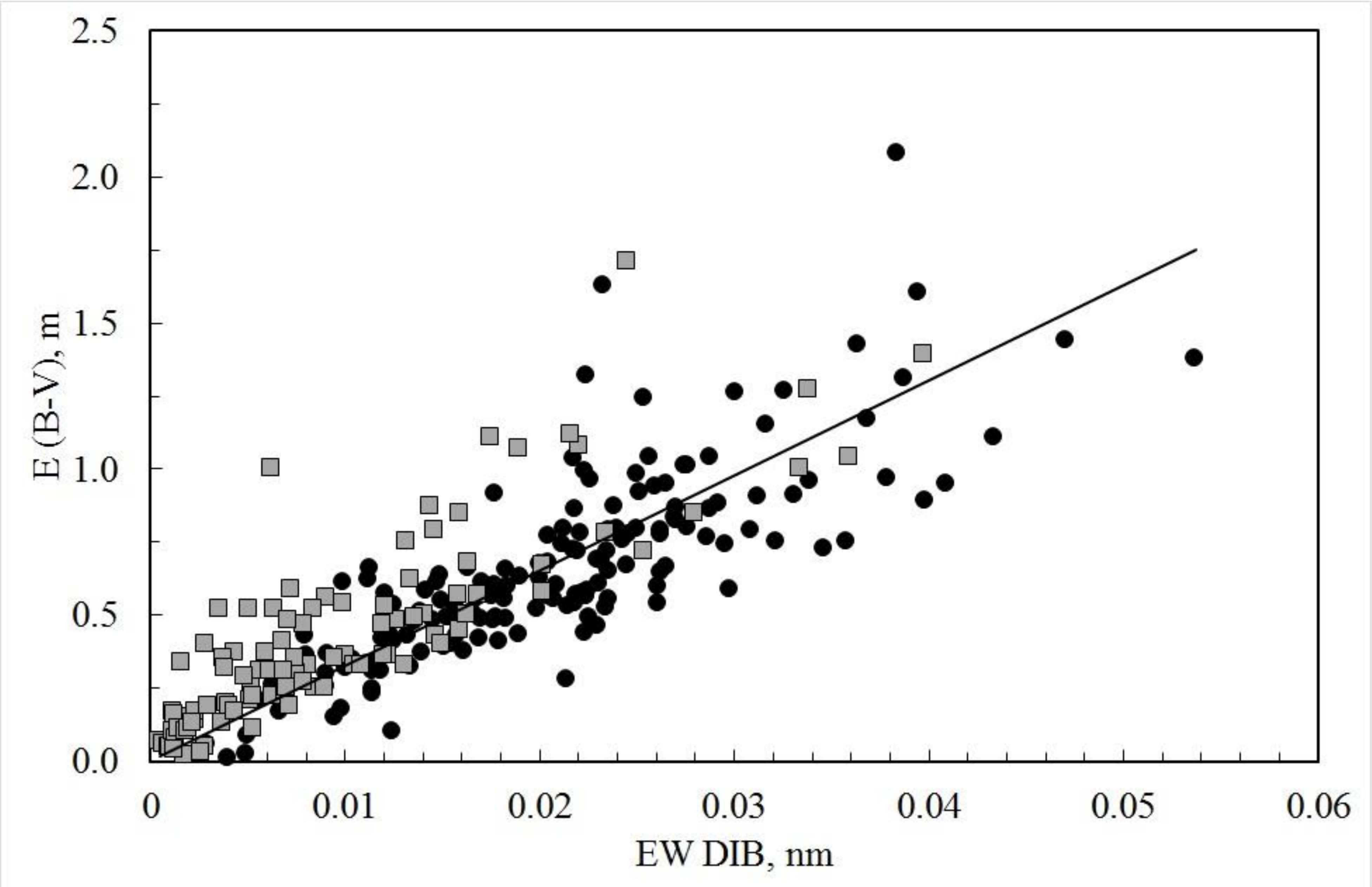
$$5\log_{10} d = V + (3.34)\log_{10} P - (2.45)(V - I) + 7.52\,.$$ [23]

or

$$5\log_{10} d = V + (3.37)\log_{10} P - (2.55)(V - I) + 7.48\,.$$[26]

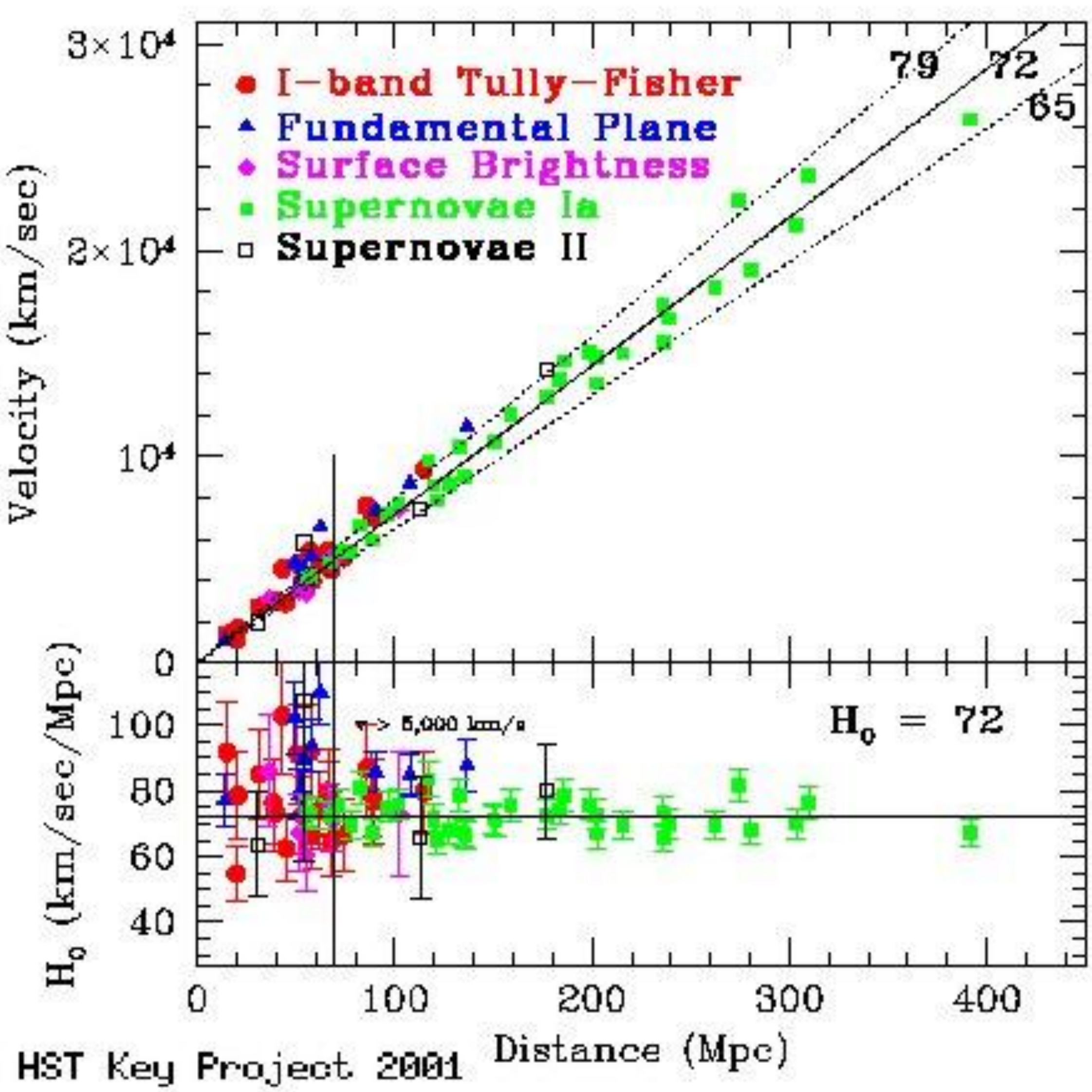
I and V represent near infrared and visual apparent mean magnitudes, respectively.

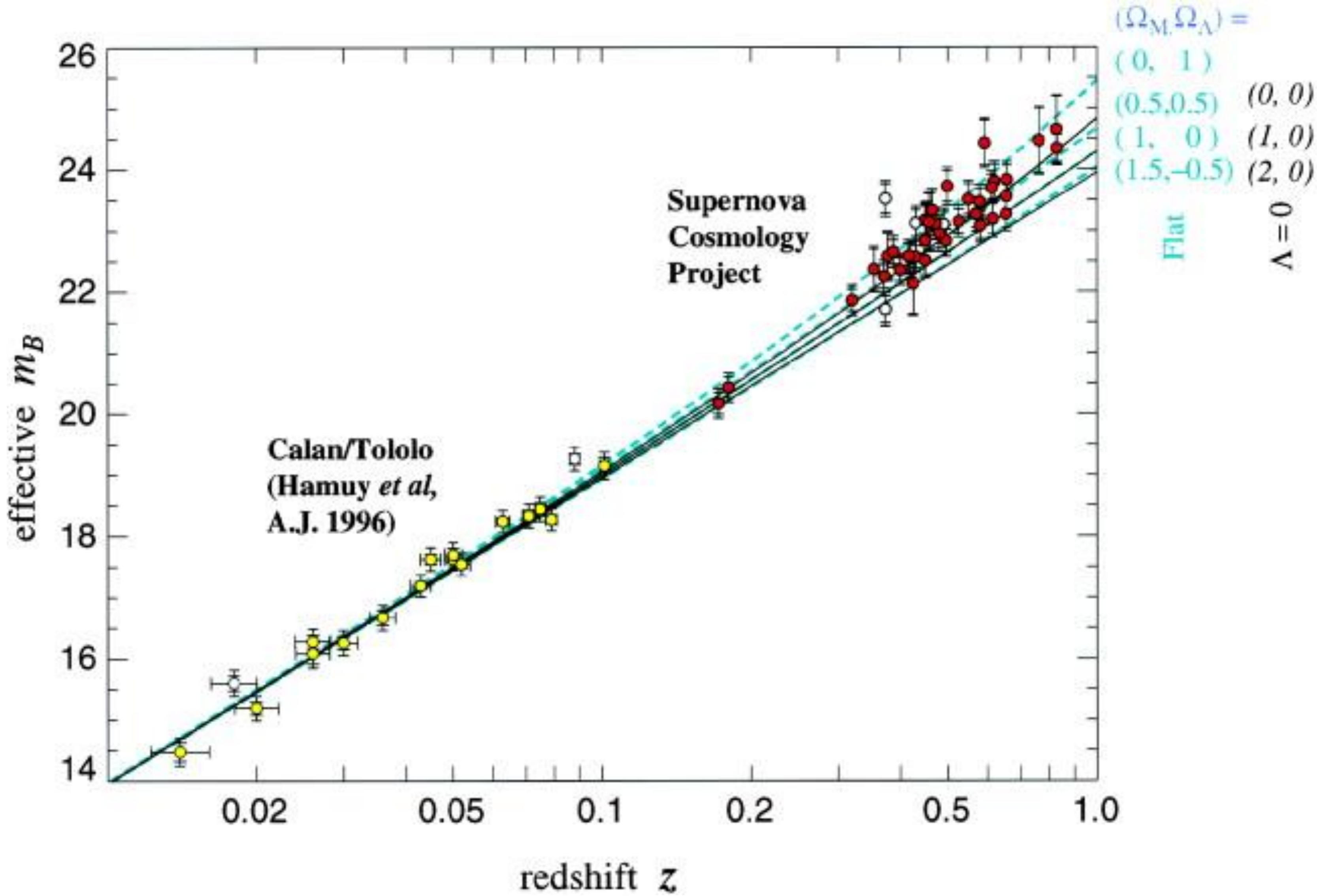
6614 diffuse band as a proxy of extinction towards cepheids



Current determinations of the Hubble parameter

$$70^{+2.4}_{-3.2}\ (\mathrm{km/s})/\mathrm{Mpc}$$





Supernova
Cosmology
Project
Calan/Tololo
(Hamuy et al,
A.J. 1996)
effective m_B
redshift z
$(\Omega_M,\Omega_\Lambda)$ =
(0, 1)
(0.5,0.5)
(1, 0)
(1.5,-0.5)
Flat
(0, 0)
(1, 0)
(2, 0)
$\Lambda = 0$
14
16
18
20
22
24
26
0.02
0.05
0.1
0.2
0.5
1.0

From Perlmutter et al.

Could the faintness of the supernovae be due to intervening dust?

The color measurements that would show color-dependent dimming for most types of dust indicate that dust is not a major factor.

Our SNe Ia distances have the important advantage of including corrections for interstellar extinction occurring in the host galaxy and the Milky Way.

Atypical extinction?

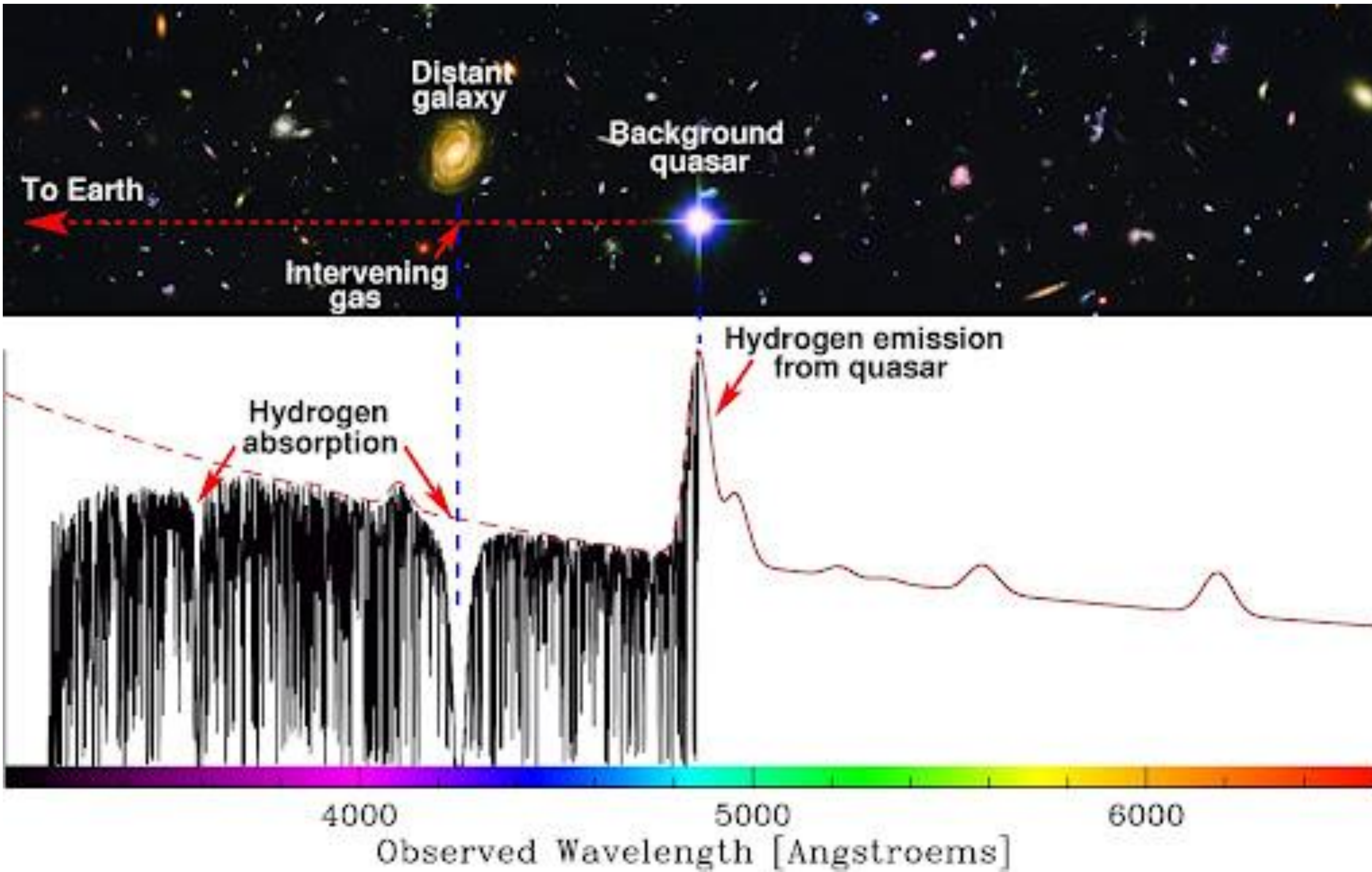
high-redshift SNe with significant extinction were discarded rather than included after a correction for extinction.

Some modest departures from the Galactic reddening ratios have been observed in the Small and Large Magellanic Clouds, M31, and the Galaxy, and they have been linked to **metallicity variations**

Where the observed extinction is originated?

We also employ a refined estimate of the selective absorption to color excess ratio, $R_V = A_V/E_{B-V}$, which has been calculated explicitly as a function of SN Ia age from accurate spectrophotometry of SNe Ia (Nugent, Kim, & Perlmutter 1998a).
This work shows that although R_V is the canonical value of **3.1** for SNe Ia at maximum light or before, over the first 10 days after maximum R_V slowly rises to about **3.4**.
For highly reddened SNe Ia, this change in R_V over time can appreciably affect the shape of the SN Ia light curve .

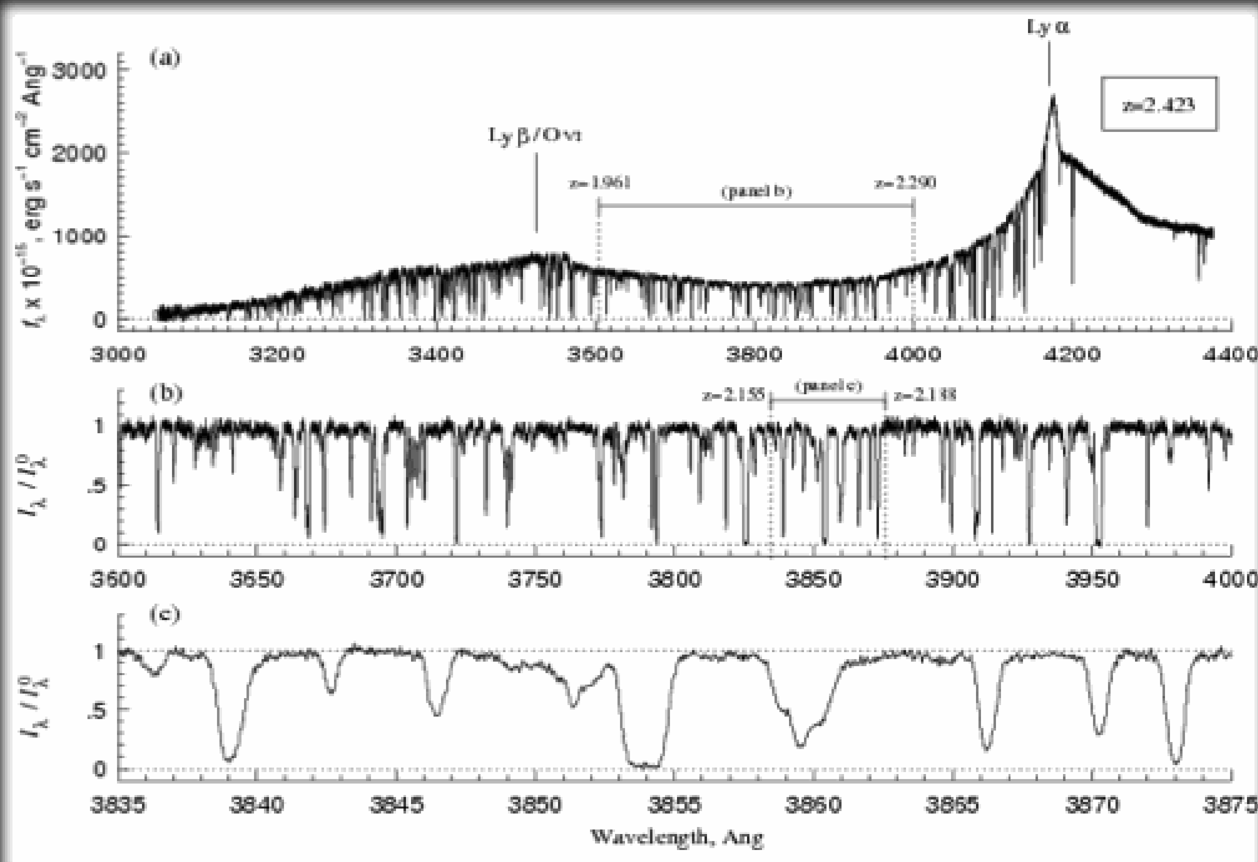
Lyman's forest



„Teen” clouds per a kiloparsec

The Level of Detail- is… just simply awesome!

Resolution = λ/Δλ = c/Δv = 45,000! Δv=6.5 km/s



A typical sample of the Lyα forest lines at z=2

The “velocity” interval sampled per pixel is 2 km/s!

Conclusions

In the estimates of distances to Supernovae Ia the possible intergalactic extinction is neglected

The intergalactic extinction law can be severely changed by the cosmological redshift

The above effects may lead to overestimates of the distances to cosmological objects if SN Ia are used as „standard candles".