

# **Metal Abundance Calibration of Ca II Triplet Lines in RR Lyrae Stars**

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# Metallicity

Metallicity was first discussed by Baade in the 1950's regarding stellar populations

Chamberlain & Allen showed that there were stars had metallicity  $1/100$  of the sun

Birth of study of metal-poor stars

# RR Lyrae

Associated with Globular Clusters and the halo

Considered population II stars

Enter George Preston

# A SPECTROSCOPIC STUDY OF THE RR LYRAE STARS\*

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*Received March 12, 1959*

## ABSTRACT

The possibility that the RR Lyrae stars do not constitute a homogeneous spectroscopic group has been investigated by surveying the spectra of more than one hundred RR Lyrae stars at very low dispersion (430 Å/mm at  $H\gamma$ ).

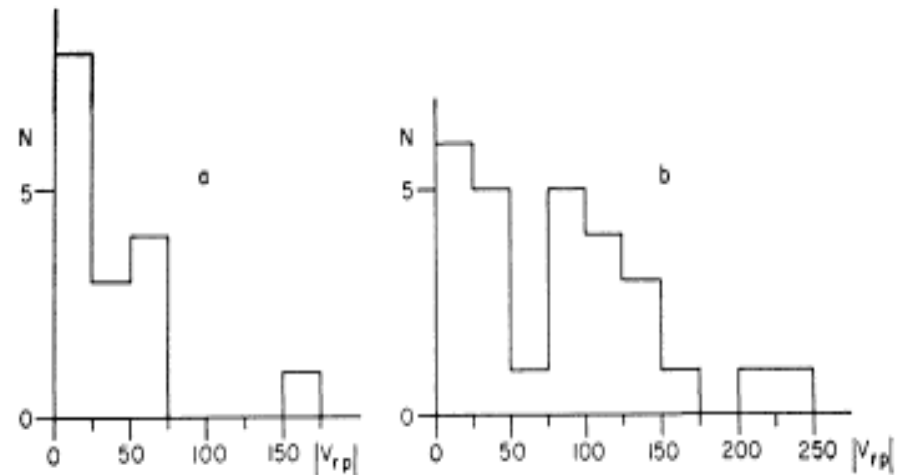
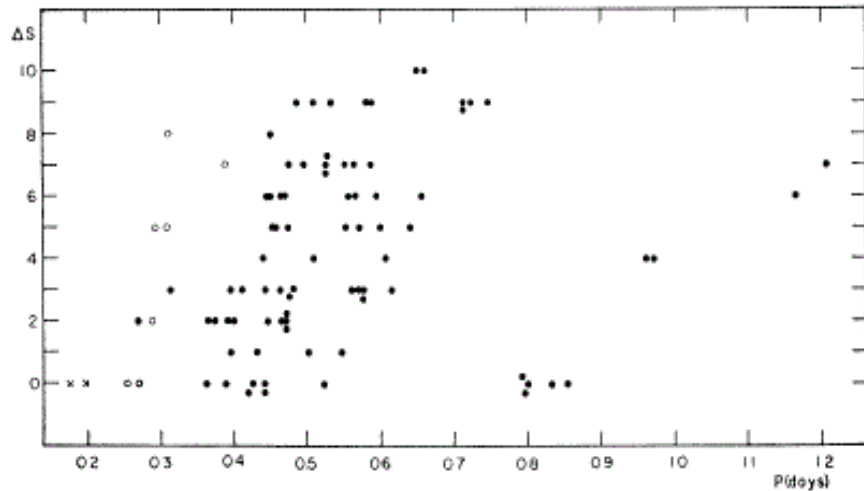
During the quarter of the light-cycle preceding minimum light, all the Bailey type a variables have hydrogen lines of similar strength, the spectral types ranging from F4 to F6. However, the K line of Ca II differs in strength from star to star by an amount that corresponds to about one spectral class, the spectra ranging in appearance from those of normal F-type stars to those of extreme F-type subdwarfs. Intermediate cases are common, and no separation into discrete spectroscopic groups is indicated by the material of this study. The Bailey type c variables have systematically earlier spectral types at minimum light, but they show qualitatively the same spread in spectroscopic peculiarity.

The difference,  $\Delta S$ , between the spectral types derived from the hydrogen lines and from the K line of Ca II at minimum light has been adopted as a parameter to describe the extent of the weak-line characteristic; high-dispersion studies indicate that this characteristic is due to low metal abundances.  $\Delta S$  increases systematically with increasing period,  $P$ , for both the Bailey type c and the Bailey type a variables with  $P < 0^d75$ , the spread in  $P$  for a given  $\Delta S$  among the latter corresponding approximately to the spreads observed in individual globular clusters. A third  $P$  versus  $\Delta S$  sequence appears to exist among the variables with  $P > 0^d75$ .

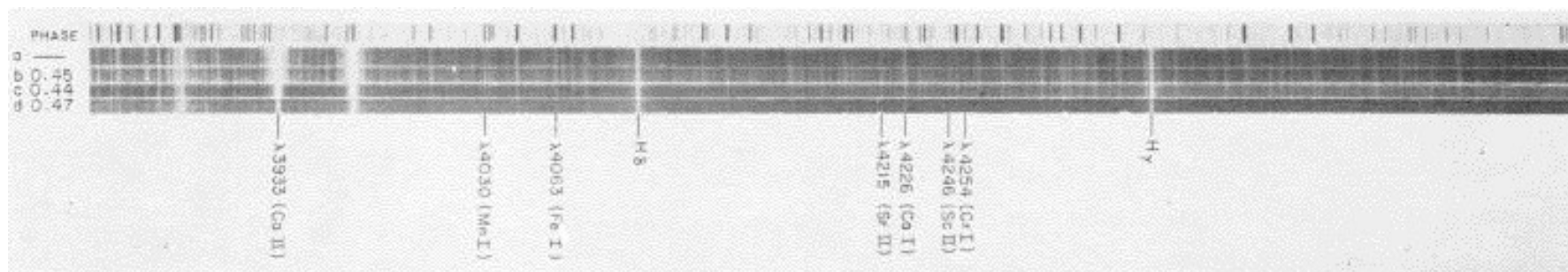
The period-frequency distributions of the strong- and weak-line variables indicate that the RR Lyrae star population near the sun differs from those found in globular clusters and far from the galactic plane, in that it possesses a strong-line (small  $\Delta S$ ) component. The concentration of strong-line variables to the plane is confirmed by the intercomparison of the period-frequency distributions of various regions of the Galaxy. In addition, the strong-line variables appear to be relatively less concentrated toward the galactic center.

The solar motion and mean peculiar radial velocity of the weak-line variables resemble those derived for the globular clusters; those for the strong-line stars are intermediate between the values derived for halo and spiral-arm objects.

# A Spectroscopic Study of the RR Lyrae Stars



# A Coarse Analysis of Three RR Lyrae Stars



LOGARITHMIC RELATIVE ABUNDANCES\*

ELEMENT	LOG $N/N_{\odot}$			
	DX Del	RR Lyr	X Ari	$\alpha$ CMi†
Al.	.	-1 5 (2, 0, <i>b</i> )	-3 0 (2, 0, <i>b</i> )	-0 3
Ca	0 0 (6, 0, <i>b</i> )	-1 0 (5, 0, <i>b</i> )	-2 4 (1, 0, <i>c</i> )	+ 2
Sc	- 5 (0, 2, <i>c</i> )	-1 7 (0, 5, <i>b</i> )	-3 1 (0, 4, <i>b</i> )	- 2
Ti	- 1 (2, 13, <i>a</i> )	-1 3 (2, 18, <i>a</i> )	-2 6 (0, 13, <i>a</i> )	0
V	- 7 (2, 2, <i>c</i> )	-1 8 (0, 2, <i>c</i> )	.	- 2
Cr	0 (6, 5, <i>b</i> )	-1 1 (1, 5, <i>b</i> )	-3 1 (1, 0, <i>c</i> )	+ 1
Mn.	+ 2 (5, 0, <i>b</i> )	-1 5 (2, 0, <i>c</i> )	< -3 2 (2, 0, <i>c</i> )	+ 2
Fe ..	0 (51, 15, <i>a</i> )	-1 2 (62, 15, <i>a</i> )	-2 8 (28, 2, <i>a</i> )	+ 3
Sr . . .	- 6 (0, 2, <i>c</i> )	-2 0 (0, 1, <i>c</i> )	-3 5 (0, 2, <i>c</i> )	- 1
Y : . .	.	-1 2 (0, 2, <i>c</i> )	.	0
Ba :	-0 8 (0, 1, <i>c</i> )	-1 8 (0, 1, <i>c</i> )	.	-0 6
[ <i>m</i> / <i>H</i> ]	-0 05	-1 25	-2 70	+0 2

\* The quantities in parentheses are, in order, (1) no. of neutral lines measured; (2) no. of ion lines measured; (3) a quality estimated: *a* = good, *b* = fair, *c* = poor

† The abundances for  $\alpha$  CMi are taken from Greenstein (1948)

Skip 50 years....

# Hipparcos

$\pi$  to  $\pm 0.001''$

Factor of 2 improvement  
(Van Leeuwen 2007)

Re-Reduction:

$\pi$  to  $\pm 0.0005''$





# GAIA

Factor of 10 improvement over  
Hipparcos + radial velocities

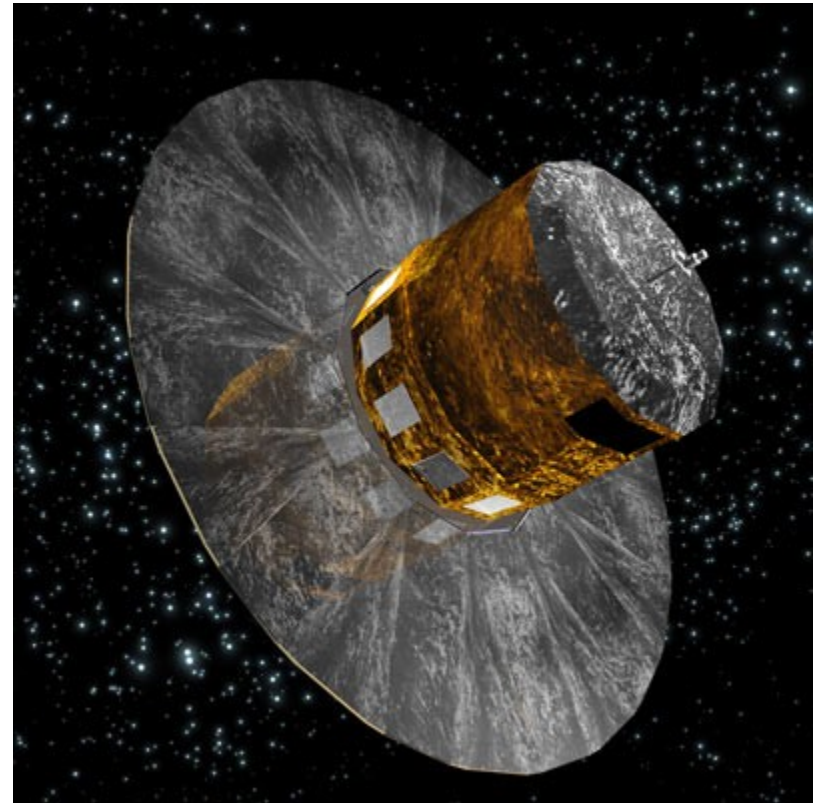
$\pi$  to  $\pm 20 \mu\text{as}$  ( $0.00002''$ ) at 15th  
mag

$\pi$  to  $\pm 200 \mu\text{as}$  ( $0.0002''$ ) at 20th  
mag

Out to 10 kpc

Likely 10's of thousands of RR  
Lyrae

Multiple spectrophotometric  
measurements down to 20th  
magnitude



1/24/11

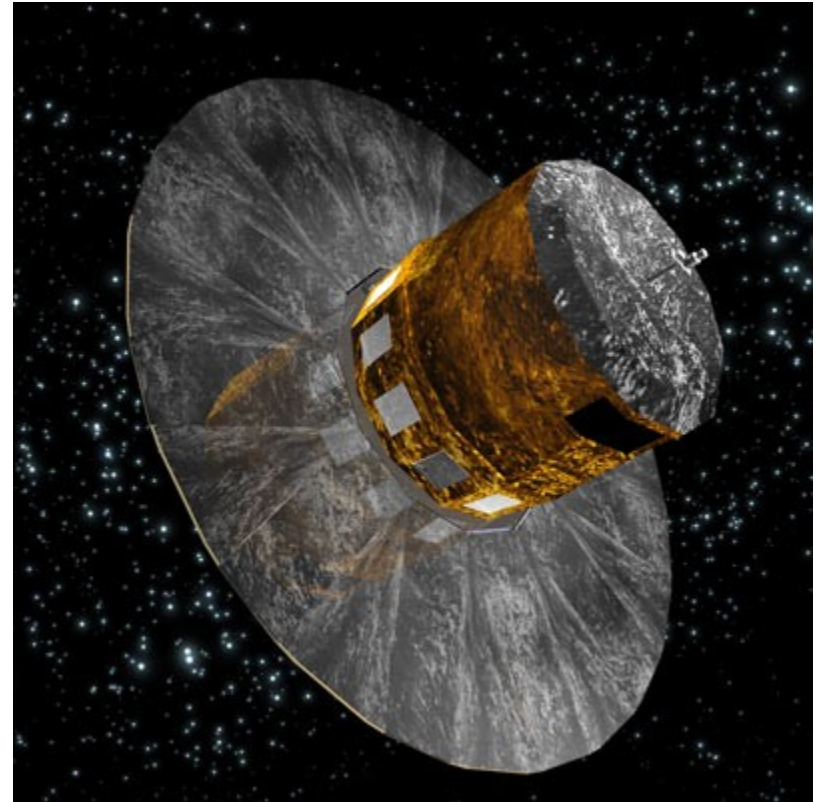
# GAIA spectra

Will measure spectra to get radial velocities.

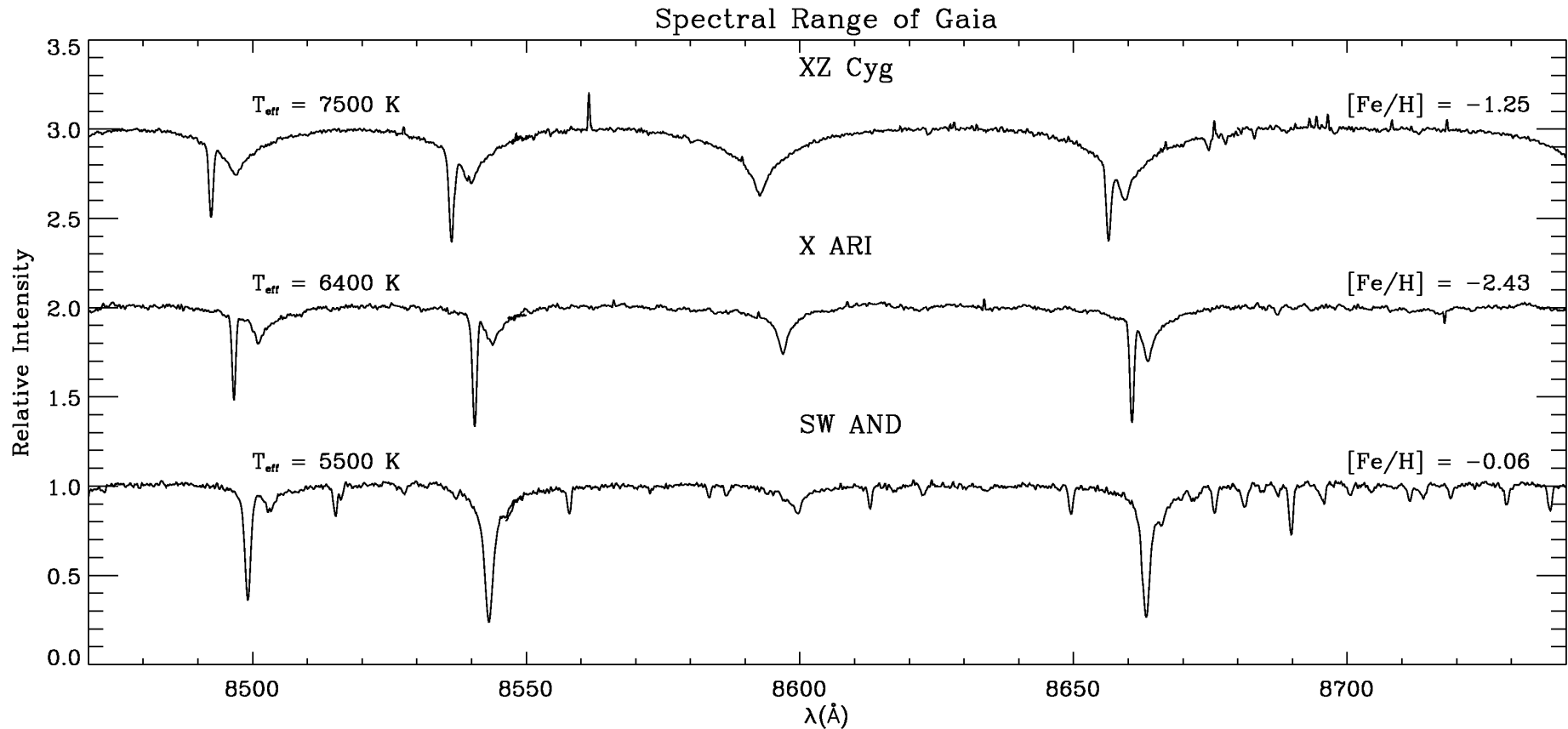
Will measure each star 40 times on average

Spectra window includes Hydrogen Paschen series and the Ca II triplet

Measure spectra at 16.5 mag with S/N of 20 (for RR Lyrae, that's out to 16 kpc)

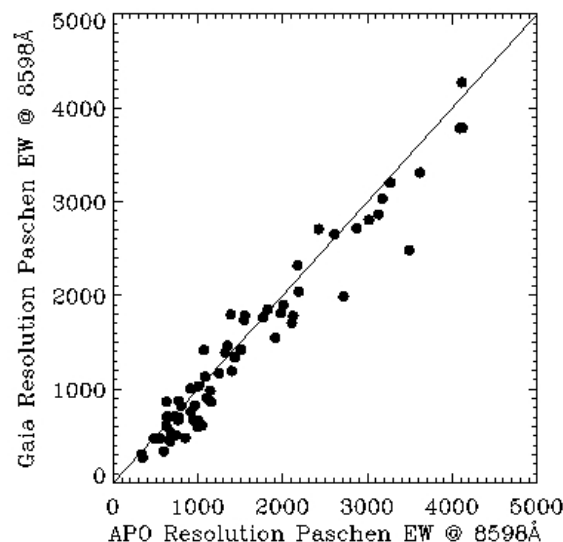
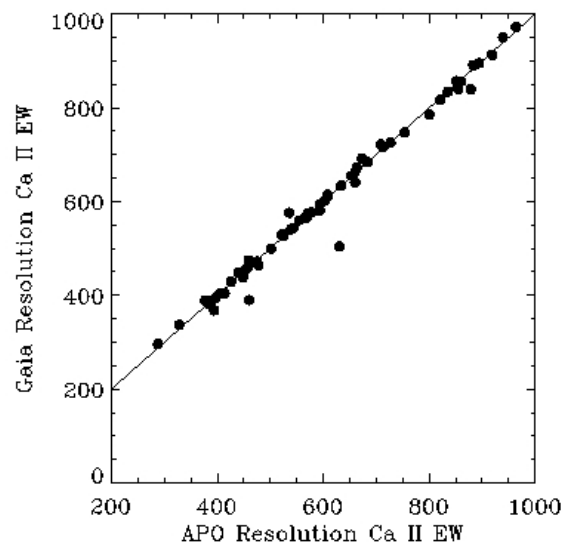


# APO Spectra

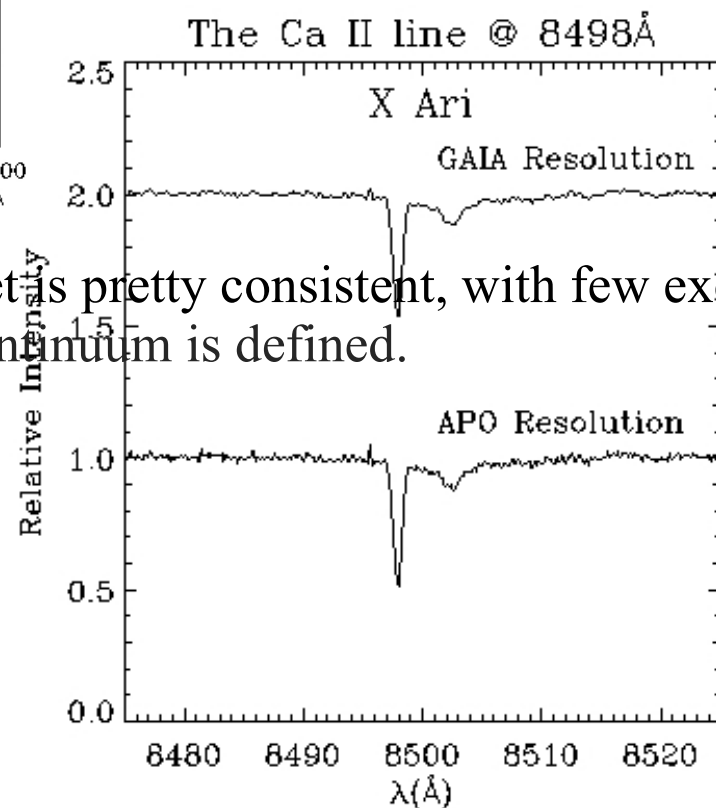


Spectral Range is from 8470Å to 8750Å at a resolution of 11,500.  
Several RR Lyrae stars, showing various temperatures and [Fe/H] values.

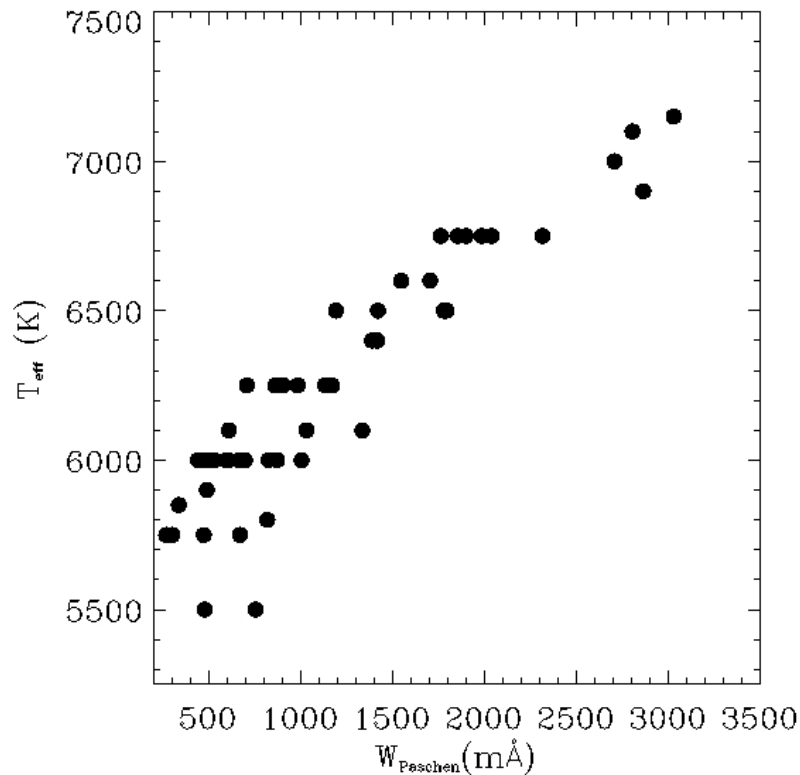
# High Res/Low Res



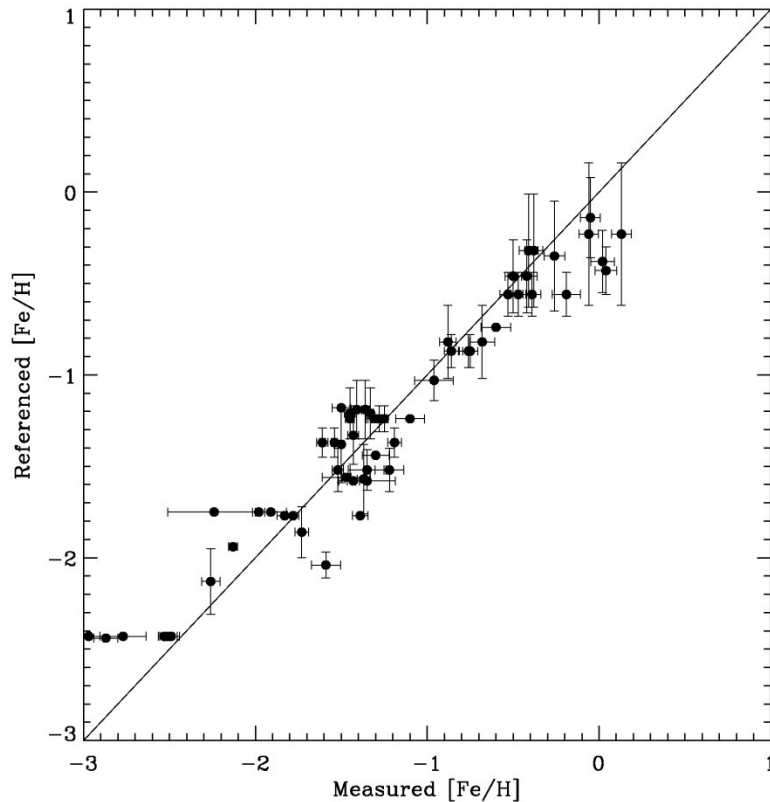
a Gaussian fitting program. Measuring the Ca II triplet is pretty consistent, with few exceptions between low and high resolution due to where the continuum is defined.



# Determining Temperature



# Calculating $[\text{Fe}/\text{H}]$

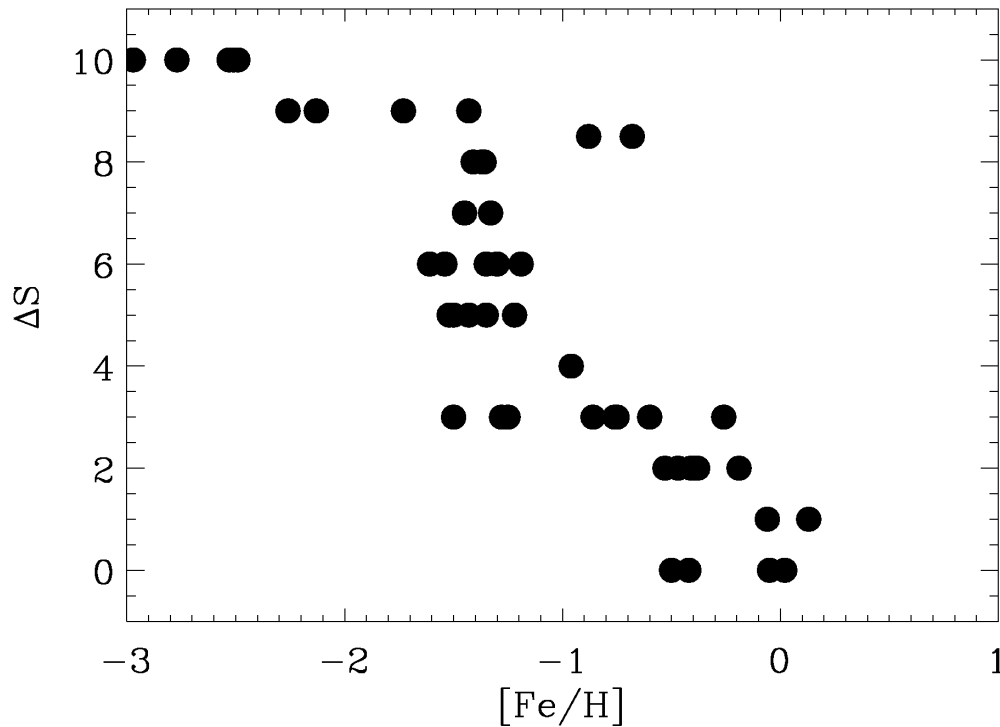


Derived  $[\text{Fe}/\text{H}]$  from  
new MOOG values  
using Fe II

Did not use Fe I due  
to departures from  
LTE

Observations at  
random phases to  
simulate GAIA

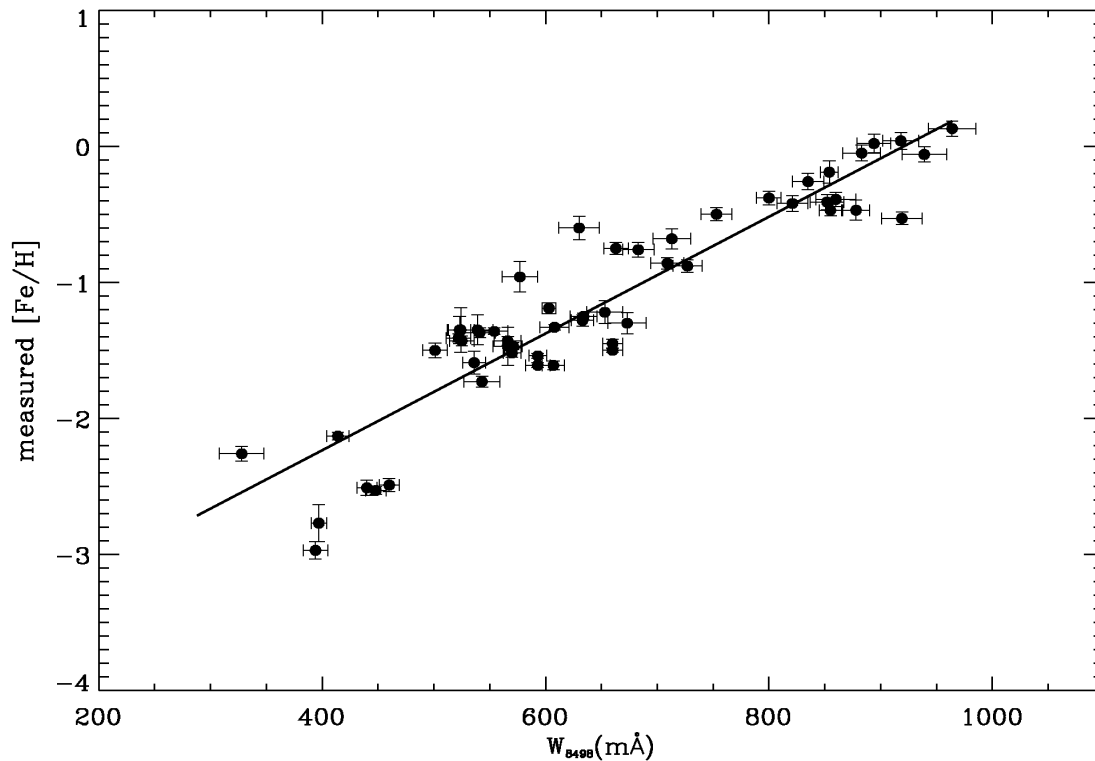
# $\Delta S$ Calibration



$\Delta S$  was used to  
calibrate  $[Fe/H]$  by  
Preston and Layden

Clementini showed  
correlation between  
EW of Ca II K and  
 $[Fe/H]$

# Calibrating $[\text{Fe}/\text{H}]$



There is an (approximately) linear relationship between the Ca II EW and  $[\text{Fe}/\text{H}]$

EW does not vary with phase by more than 10 %



# References

- Clementini, G., Tosi, M. and Merighi, R 1991, AJ 101, 2168
- Cole, A.A, Smecker-Hane, T.A., Tolstoy, E., Bosler, T.L., and Gallagher, J.S., Mon. Not. R. 2004 Astron. Soc. 347, 367
- Feast, M.W., Laney, C.D., Kinman, T.D., Van Leeuwen, F., Whitelock, P.A. 2008 Mon. Not. R. Astron. Soc., 386, 2115
- Layden A., 1994 AJ 108, 3
- Preston, G.W. 1959 AJ 130, 507