F3501--Scientific workflow in astrophysics

Autumn – 2024

Prapti Mondal

Doc. Ernst Paunzen

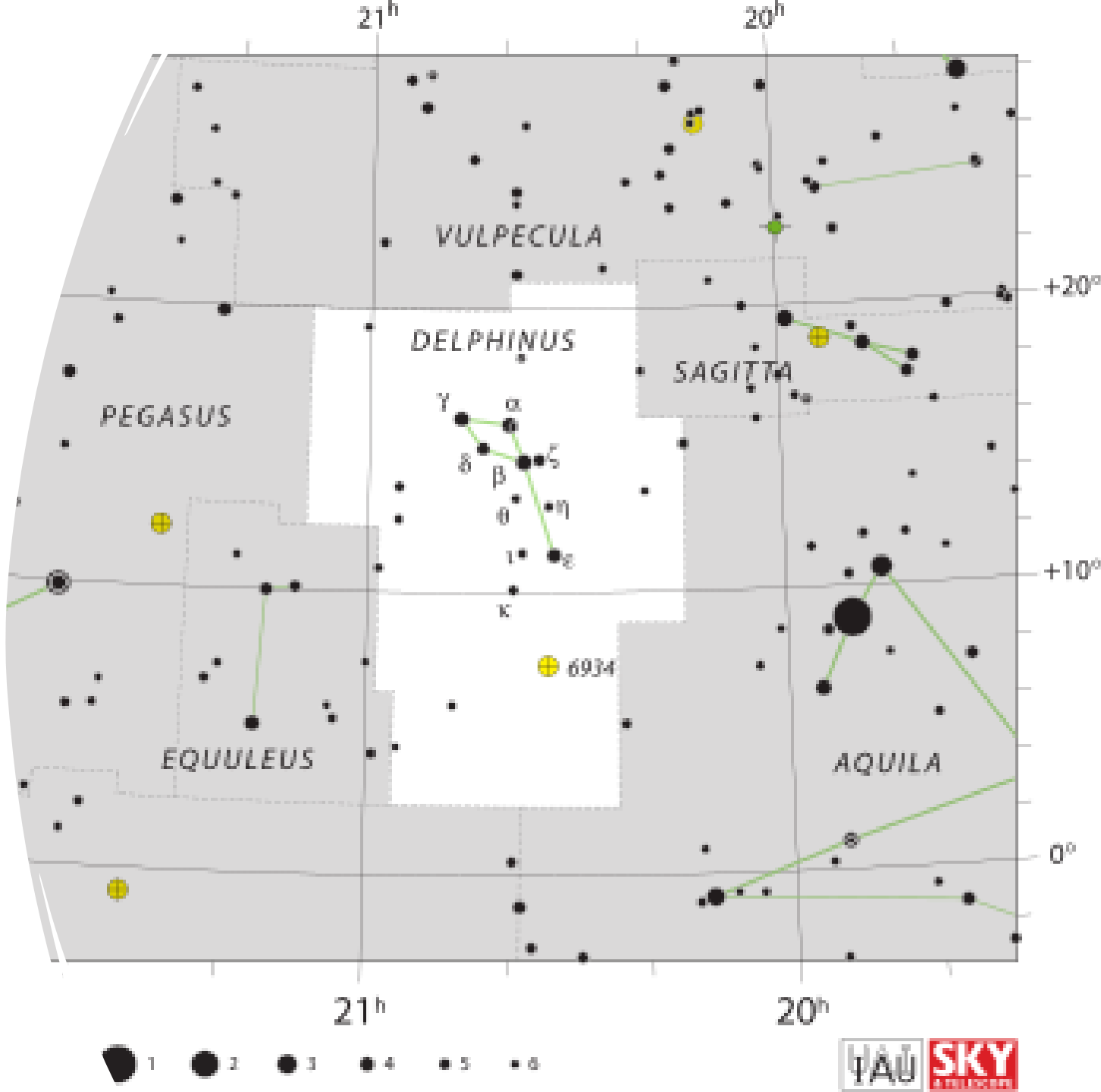
Delta delphini star

- **Introduction to Delta Delphini**

- **Overview:** Delta Delphini (δ Delphini) is a binary star system in the constellation Delphinus.
- **Distance:** Approximately 238 light-years from Earth.
- **Brightness:** Apparent magnitude of 4.43, visible to the naked eye.
- **Objective:** To explore the characteristics, classification, and scientific significance of Delta Delphini.

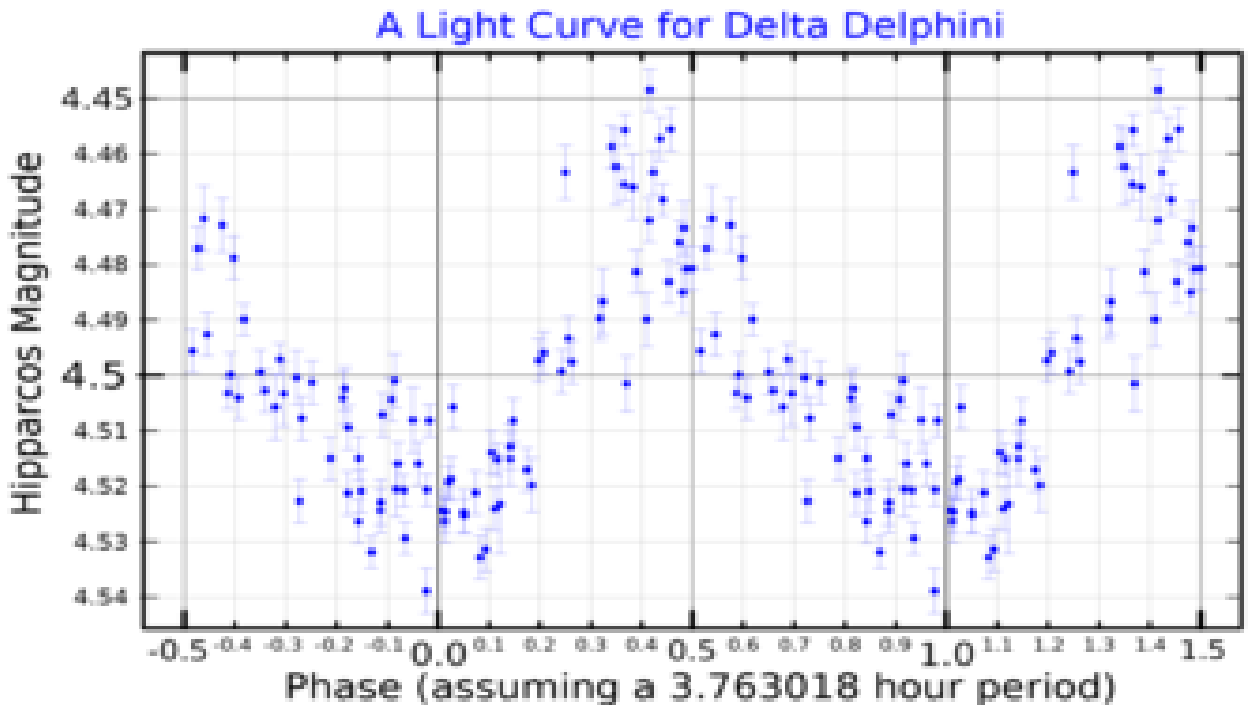
Location in the Sky

- **Constellation**: Delphinus (the Dolphin).
- **Coordinates**: Right Ascension: 20h 39m 38.25s; Declination: +15° 54' 43.9".
- **Observation**: Best viewed in the Northern Hemisphere during late summer.



Delta Delphini – A Binary Star

- **Binary Nature**: Spectroscopic binary with two stars orbiting a common center of mass.
- **Orbital Period**: Around 40.58 days.
- **Components**: Delta Delphini A (primary, brighter) and Delta Delphini B (secondary, fainter).



Spectral Classification of Delta Delphini

- **Type:** Classified as an A7III or A7IV star.
- **A7:** White star, hotter than the Sun with temperatures between 7,500K and 10,000K.
- **III or IV**: Suggests it's in the giant or subgiant phase, having left the main sequence.
- **Significance**: Understanding its stage in stellar evolution.
- **Spectral class :** kA7hF1VmF1pSrEuCr

Delta Delphini as a Chemically Peculiar (CP) Star

- **Am Star**: Classified as an A-type metallic-line (Am) star.
- **Chemical Peculiarities**: Overabundance of certain elements like zinc, strontium, zirconium; underabundance of calcium and scandium.
- **Cause**: Likely caused by slow rotation and diffusion processes that lead to uneven distribution of elements.

Chemically Peculiar Stars (CP Stars)

- **Definition**: Stars with abnormal abundances of specific chemical elements.
- **Types of CP Stars**: Am, Ap (magnetic stars), Bp (peculiar B-type stars), etc.
- **Significance in Astronomy**: Chemically peculiar stars help astronomers understand how stellar rotation and magnetic fields affect the distribution of elements.

Am Stars and Delta Delphini

- **Characteristics of Am Stars**:
- Strong metallic lines in the spectrum.
- Slow rotational velocity.
- Found predominantly in binary systems.
- **Delta Delphini as an Example**: Exhibits these features, making it a key object for studying Am stars.

Walraven VBLUW photometric system

- This photometric system measured light from the visible to the near ultraviolet, with passbands at the effective wavelengths of 542 nm (V), 427 nm (B), 385 nm (L), 362 nm (U) and 323 nm (W). For this reason it is also known as the Walraven VBLUW Photometer.

Type	V	$V-B$	$B-U$	$U-W$	$B-L$	V_J	$(B-V)_J$
		(log intensity)				(mag)	
Am	0.007	0.006	0.007	0.009	0.004	0.018	0.015
δ Del	0.006	0.006	0.006	0.010	0.003	0.015	0.015
δ Sct	0.010	0.005	0.006	0.012	0.004	0.025	0.012

Table 1. The average standard deviation in the photometric parameters for the three types of stars in the $VBLUW$ system and the UBV system (with subscript J)

HR	HD	Name	V	V-B	B-U	U-W	B-L	N	V_J	$(B-V)_J$
421	8829	47 Cet	0.512	0.121	0.358	0.137	0.190	3	5.57	0.307
2094	40292		0.628	0.112	0.380	0.151	0.191	3	5.29	0.285
2255	43760	6 Mon	0.043	0.140	0.459	0.182	0.211	3	6.74	0.354
3228	68703		0.160	0.114	0.426	0.121	0.218	3	6.46	0.290
3649	74198		0.893	0.003	0.422	0.105	0.162	3	4.64	0.004
6492	157919	55 Oph	1.029	0.159	0.389	0.193	0.219	4	4.28	0.400
6561	159876	ζ Ser	1.329	0.105	0.434	0.159	0.210	5	3.53	0.265
8322	207098	δ Cap	1.590	0.110	0.395	0.153	0.197	4	2.88	0.280
8787	218227	θ Gru	1.028	0.167	0.422	0.195	0.240	4	4.28	0.420

Table 2. The photometric parameters of delta delphini star in the VBLUW system (in log intensity scale) and in the UBV system (in mag scale with subscript j)

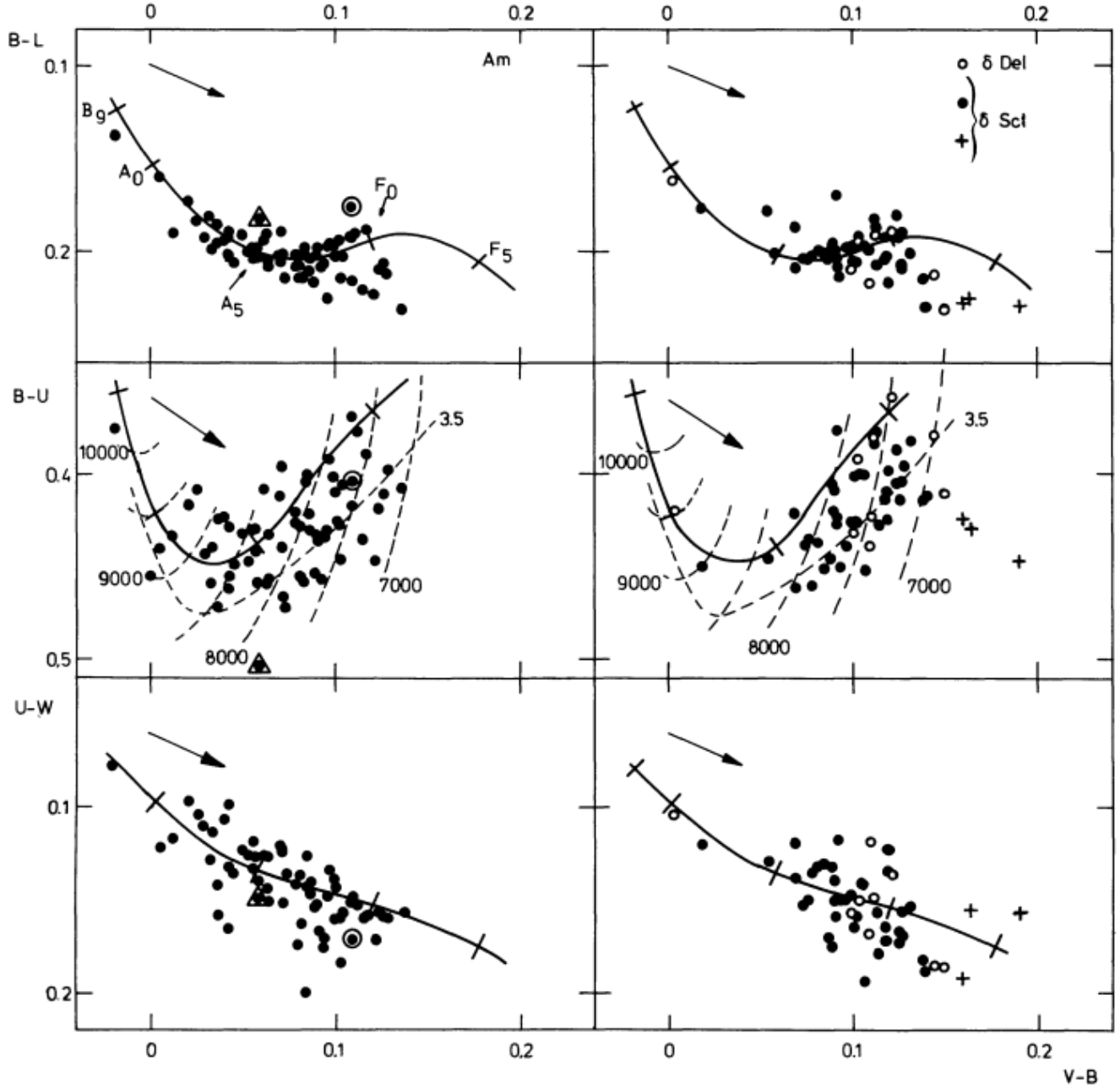


Fig. 1. The two-colour diagrams for the Am Stars (on the left) and δ Del and δ Sct stars (on the right). Sketched are the main sequence (full curve), a number of T_{eff} = const lines and the $\log g = 3.5$ line (dotted curves) in the $V-B/B-U$ diagrams and the reddening trajectories (arrows). Special symbols will be explained in the text

PHOTOMETRY

- Two subgroups based on their apparent visual magnitudes and the source of their spectral-type classifications,
- 1. Bright **δ** Delphini stars with $m_v < 6.7$
- 2. Faint δ Delphini stars with mv >6.7

- A Comparison of the ß and b — y Temperature Indices
- $(b - y)_0 = 2.943 - ß - 0.09\delta c_1 - 0.2\delta c_2$
- $\Delta M_V = 8\ \delta c_1$

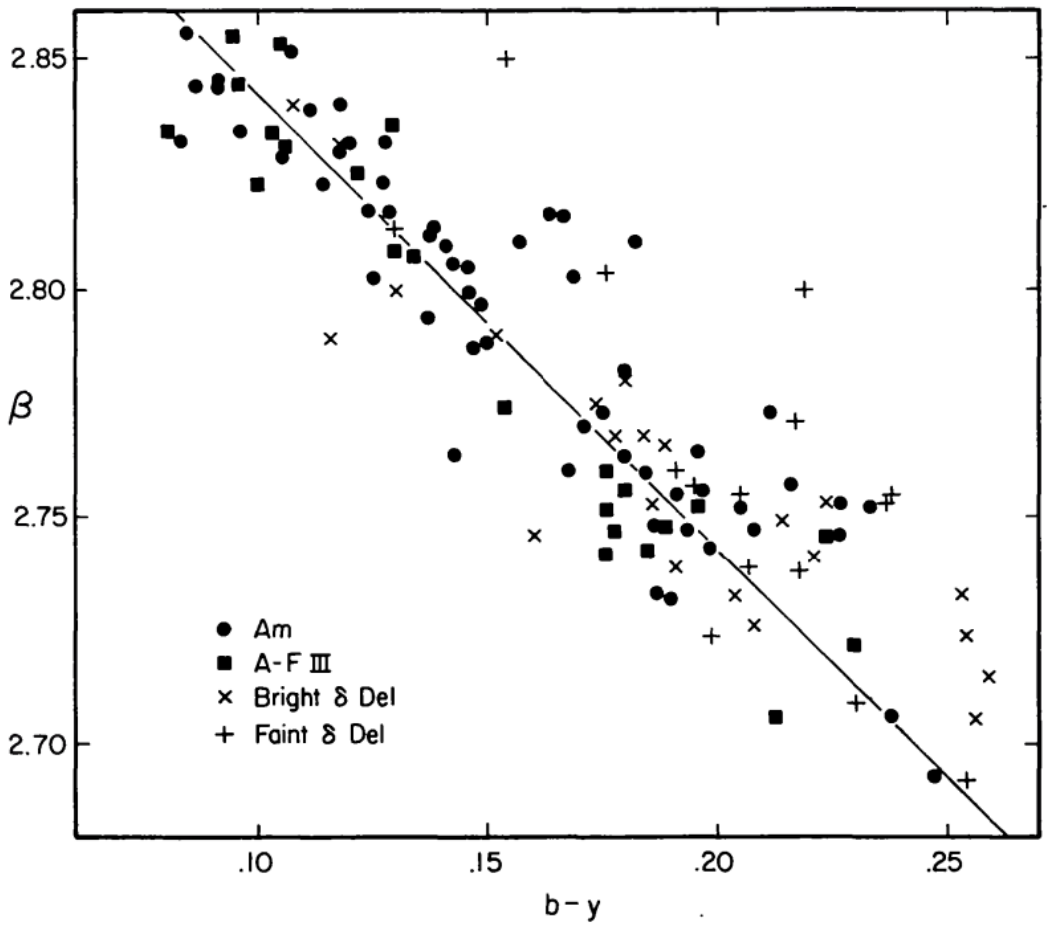


FIG. 2.—Comparison of the β and $b - y$ temperature indicators for the δ Del stars, and for a group of A–F III stars and a group of Am stars taken from Cowley *et al.* (1969). The solid line represents the calibrated (Crawford 1975) relation $b - y = 2.943 - \beta$ without the δm_1 or δc_1 terms.

Variability

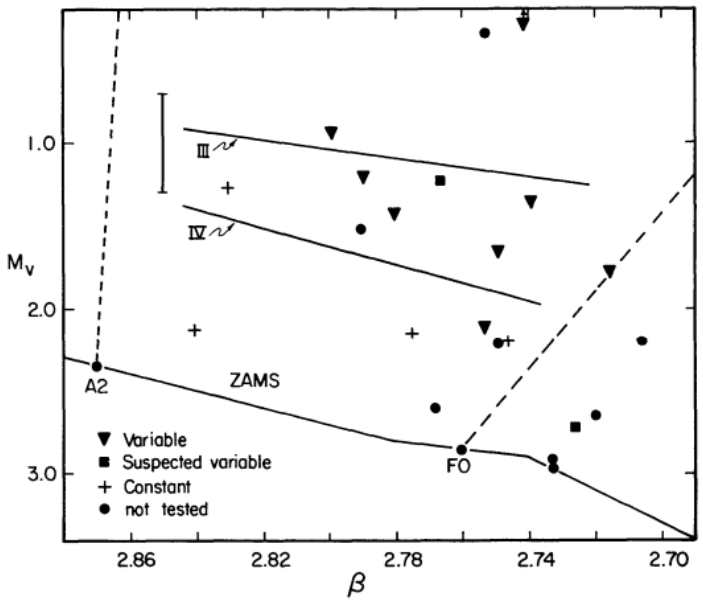


FIG. 5.—The bright δ Del stars, indicating the stars which have been tested for light variability. The dashed and solid lines are delineate the observed instability strip.

TABLE 3

VARIABILITY AMONG DELTA DELPHINI STARS

HR	*P* (day)	AMPLITUDE (mag)	CONSTANCY		SOURCE*	*v* sin *i*	SOURCE*
			mag	hr			
421.....	Var.?	...	...	...	2	...	...
1706.....	0.087	0.080	...	...	1	33	1
1974.....	Const.	...	0.003	2.6	3	80	4
2100.....	0.060	...	...	...	1	70	1
3185.....	0.141	0.100	...	...	1	14	1
3228.....	Const.	...	0.004	3.0	3	80	4
3265.....	0.097	0.040	...	...	1	25	1
4760.....	Const.	...	0.002	4.0	3	93	4
5017.....	0.135	0.35	...	...	1	17	1
7020.....	0.194	0.290	...	...	1	32	1
7928.....	0.153	0.050	...	...	1	41, 25	1, 5
7984.....	Const.	...	0.002	1.3	3	90	...

* (1) Baglin *et al.* 1973, (2) Kukarkin, Efremov, and Kholopov 1958, (3) Breger (private communication), (4) Danziger and Faber 1972, (5) personal estimate.

Variability

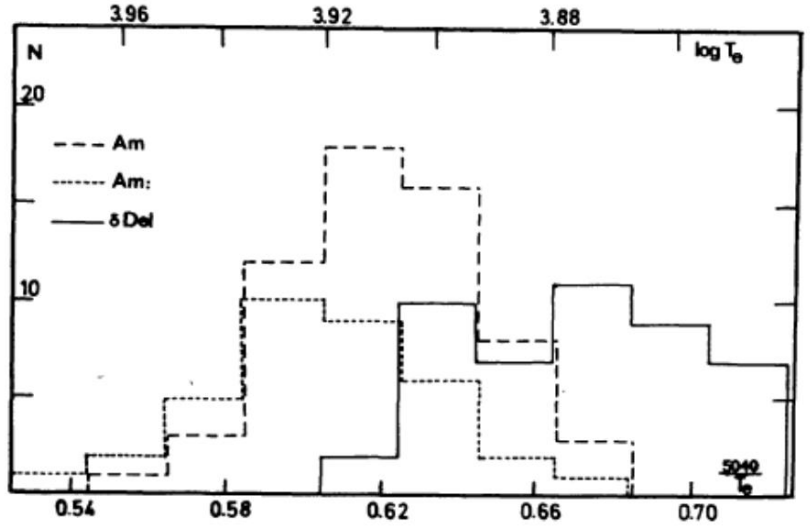


Fig. 1. Temperature histogram for Am, Am: and δ Del stars. Am and Am: are from Cowley et al., 1969; δ Del are from Kurtz, 1976 and 1979, Cowley et al., 1969, Houck and Cowley, 1975 and Jaschek M., 1980. Physical parameters are from Philip-Egret (1980)

Am stars: metallic elements heavier than Fe overabundant and scandium and/or calcium underabundant.

Am mild (Am:): like Am but with less pronounced anomalis.

δ Del stars: overabundances only for metallic elements, heavier than Fe, calcium normal with respect to hydrogen (Bidelman, 1965; Kurtz, 1968).

Rotation

Am stars slow rotators

Normal stars rotate fast

Am: and δ Del rotate faster than Am

	$\langle v \sin i \rangle$
Am	35 ± 3 km s^{-1}
Am:	49 ± 4 km s^{-1}
δ Del	50 ± 6 km s^{-1}

Anomalous-abundance δ Delphini stars

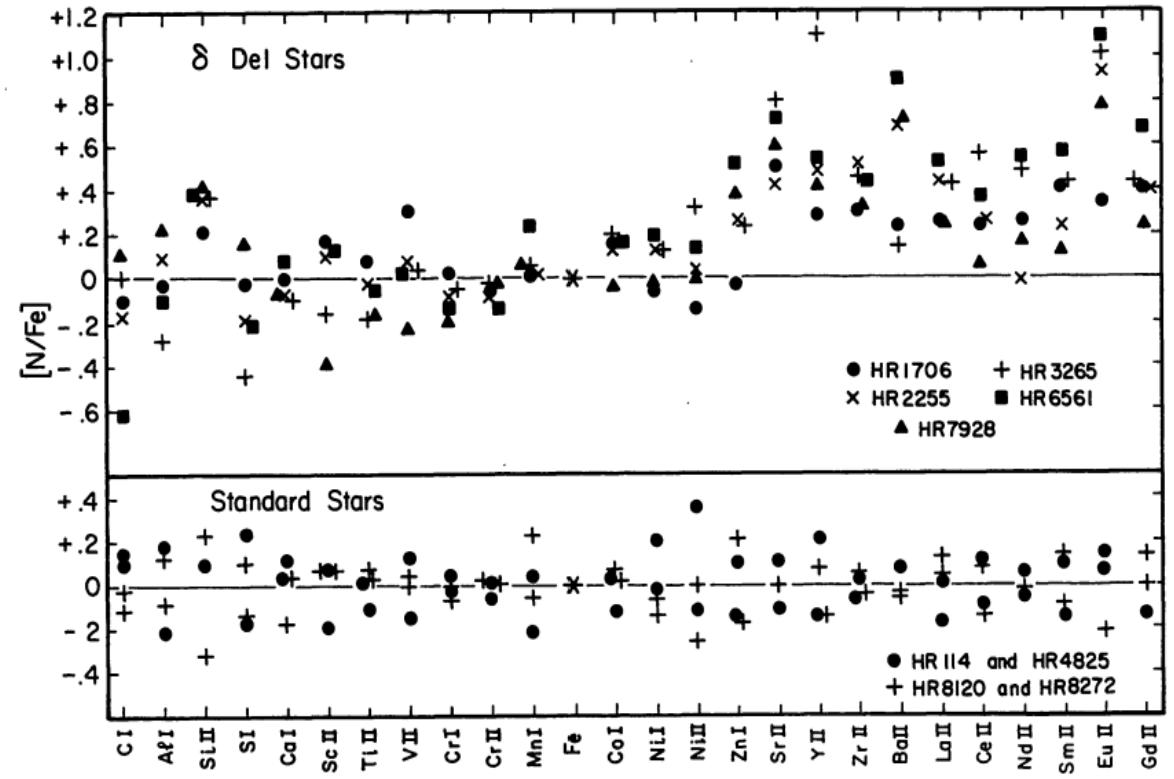


FIG. 7.—The derived abundances normalized to Fe in the anomalous-abundance δ Delphini stars and in the four comparison standard stars. The standards have been separated into two groups according to surface gravity to show that their abundances are not dependent on luminosity.

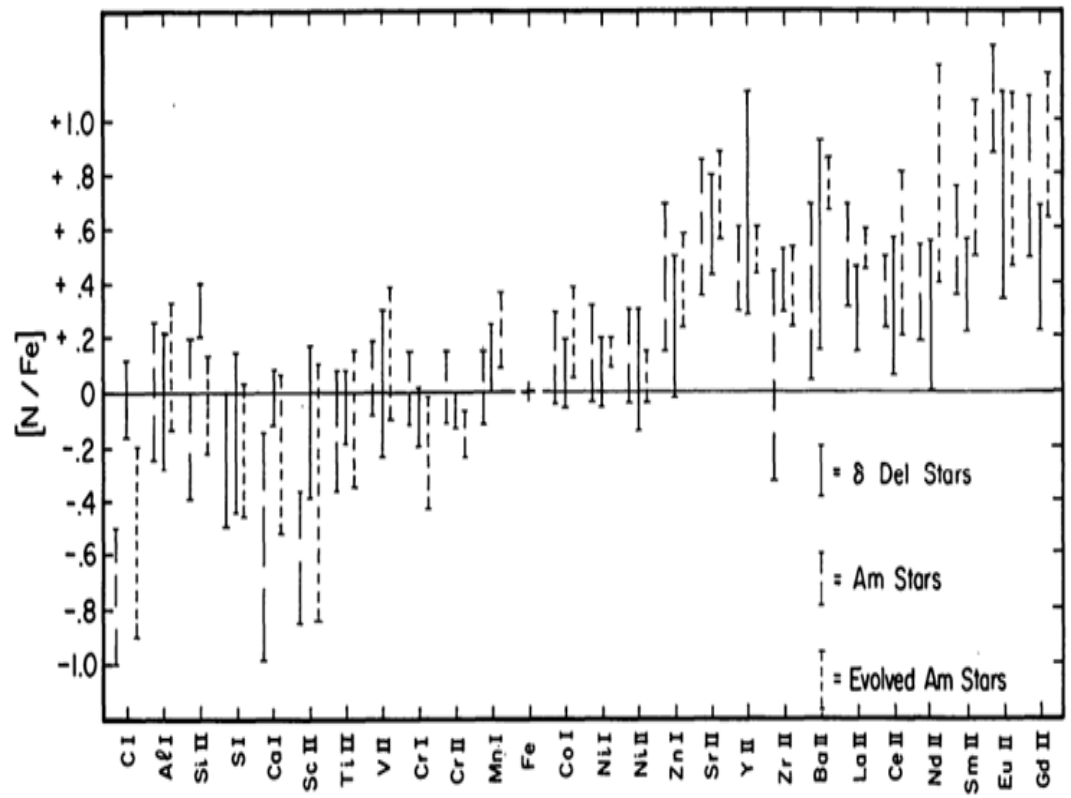


FIG. 8.—A comparison of the abundances normalized to Fe in the anomalous-abundance δ Del stars with those in the Am stars (Smith 1971) and those in five evolved Am stars lying from 1 to 2 mag above the main sequence (Smith, private communication). This diagram shows the anomalous-abundance δ Del stars to be very similar to the evolved Am stars rather than to the main-sequence Am stars. Note especially the Ca I, Sc II, and Zr II abundances.

anomalous-abundance S Del stars and the Ba || stars

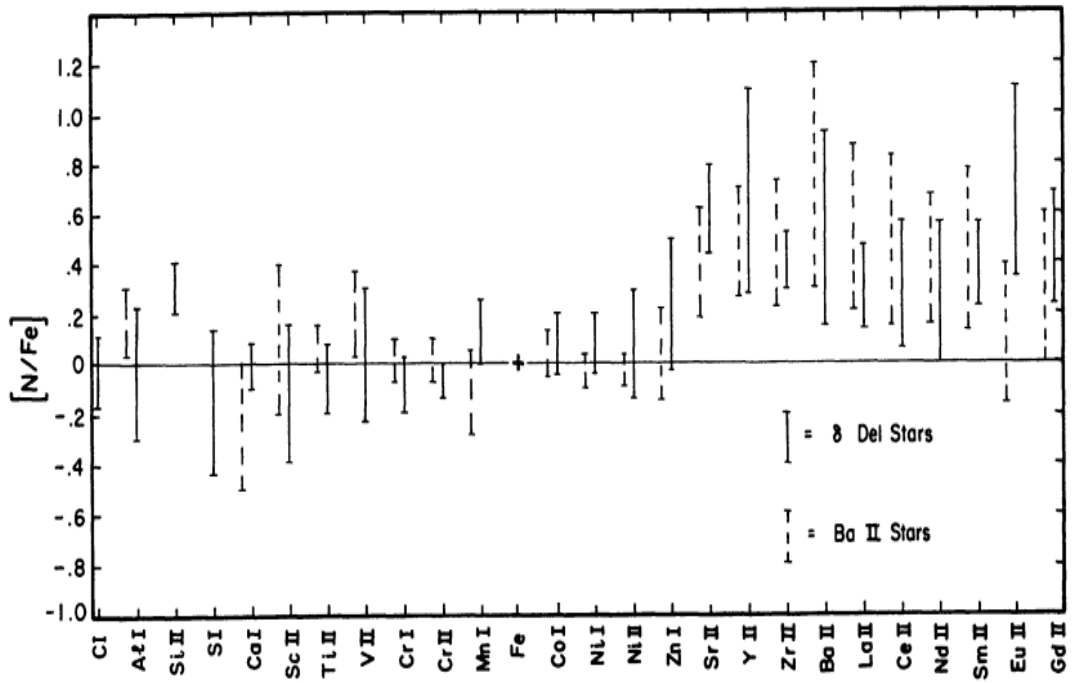


FIG. 9.—Comparison of the abundances normalized to Fe in the anomalous-abundance δ Del stars and the Ba II stars (Warner 1965) showing striking similarities between the two groups. See the text for arguments that the similarities are coincidental.

DISCUSSION

- (i) anomalous-abundance 8 Delphini stars are evolved Am stars may be incorrect
- (ii) each of the pulsating anomalous-abundance 8 Delphini stars may be a binary consisting of an Am star and a 8 Scuti star
- (iii) diffusion and pulsation may be able to coexist in a single star under some conditions
- (iv) the diffusion hypothesis may not be the correct explanation for the abundance anomalies of the metallic-line stars