Journal of Astronomical History and Heritage, 15(3), 246-254 (2012).

SIGURD ENEBO AND VARIABLE STAR RESEARCH: NOVA GEMINORUM 1912 AND THE RV TAURI STARS

Bjørn Ragnvald Pettersen
Department of Mathematical Sciences and Technology, Norwegian University of Environmental and Life Sciences, PO Box 5003, N-1432 Ås, Norway.
E-mail: bjorn.pettersen@umb.no

Abstract: Sigurd Enebo made two important contributions to variable star research in 1912: the serendipitous discovery of Nova Geminorum II and the introduction of RV Tauri stars as a new class of variables. Based on recently-discovered source material and literature sources, we describe Enebo's variable star program from 1903 to 1942 and highlight some results. Enebo was a meticulous observer who contributed extended time series for several types of variable stars. He determined periods for a large number of them, and was the discoverer of 2 eruptive, 7 long period, and 2 Algol variables.

Keywords: variable stars, Nova Geminorum 1912, RV Tauri stars, Sigurd Enebo (Einbu)

1 INTRODUCTION

Sigurd Enebo (Figure 1) was born in rural Lesjaskog, Norway, on 5 November 1866. He was the third child in a flock of eight. He became a teacher and organist. He established himself at Dombås, Norway, in 1896, the same year he opened a lifelong correspondence with the astronomers at the University of Oslo. Jens Fredrik Wilhelm Schroeter, who was First Assistant (*Observator)* from 1890 to 1919 and Professor from 1919 to 1927, became a supervisor and mentor for Enebo's self-education in astronomy, and eventually directed his efforts towards observations of variable stars. Enebo studied Gauss' treatise on motions in the Solar System and quickly realized the need to study more advanced mathematics. In 1902 he borrowed a powerful set of binoculars (magnification 20×) and set out to detect Neptune by recording its motions among the stars.

Schroeter realized that Enebo had determination and talent as an observer and in a letter dated 15 December 1902 suggested that he should begin systematic monitoring of variable stars. In 1903 Enebo borrowed a 7-cm homemade refractor (Figure 2). He made a tripod mounting and began variable star observations in November 1903. From the University Observatory in Oslo he borrowed the *Bonner Durchmusterung* star maps which he copied manually onto transparent paper, including different symbol sizes for the nine different magnitudes shown. He could now identify variable stars and comparison stars for his observing program.

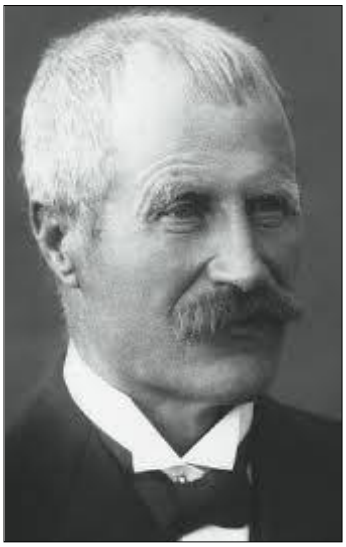

Figure 1: Sigurd Enebo (Einbu), 1866–1946 (courtesy: *Yearbook*, 1947).

At Dombås, Sigurd Enebo became acquainted with a fellow-teacher, Helga Eriksen, and they married in 1905. Two years later he bought the property Brennøygarden from her parents, and outside the house he established an observing site modeled after Tycho Brahe's Stjerneborg. During the first few years Enebo determined the periods of a number of variable stars and he discovered new Algol variables and long period variables. The results were published in *Astronomische Nachrichten*, initially with assistance frrom Schroeter, but from 1906 Enebo submitted his own contributions to the journal. He also collected his observations in a series of 14 papers that were published between 1906 and 1944 in *Archiv for Mathematik og Naturvidenskab* and in the *Publications from the Norwegian Academy of Sciences*. As Enebo's mentor, Schroeter was a scrutinizing reviewer of the observation tables and manuscripts (in German), as well as the facilitator of the printing and its funding. He also applied to the Academy of Sciences to obtain funds from the Fridtjof Nansen Foundation to acquire a larger telescope for Enebo. Upon the advice of Camille Flammarion a 10.8-cm refractor was acquired from Bardou of Paris (see Figure 3). Enebo made his first observations with this new instrument (of RW Aur) on 22 December 1906.

During the summer of 1907 Enebo was visited by astronomy professor Hans Geelmuyden. This led Geelmuyden to submit an application to the Parliament for an annual stipend to Enebo so that he could devote himself entirely to astronomy. The Parliament awarded Enebo an annual grant in 1908. He reduced his amount of teaching and increased his observing program. Two years later the grant was increased considerably. Enebo became a state-supported full-time astronomer, and continued as such for the rest of his life.

A new house at Brennøygarden was completed in 1913, and Enebo established an observing room in the attic, equipped with a rotating conical roof (see Figure 4).[1] He continued his extensive observing program until 1940, with a few stars being observed until 1942. His last paper was published in 1944.

Figure 2: The homemade 7-cm refractor (photograph by the author).

Figure 3: The 10.8-cm Bardou refractor (photograph by the author).

Sigurd Enebo changed his family name to Einbu in 1925, which reflects in his authorship.

Recently a box containing about 2000 postcards and letters addressed to Enebo was discovered in the attic of his abandoned house. This source material allows his astronomical career to be studied in greater detail than before. This paper is partly based on these unpublished sources and partly on the scientific publications by Enebo. We will now review his efforts and results as an observer and discoverer of variable stars between 1903 and 1942.

2 THE INITIAL OBSERVATIONS

In the fall of 1903 Enebo employed Argelander's step method on increasingly fainter stars. During his first winter season 1903/04 (Nordic summer nights are too bright for photometric observations) he had begun monitoring twelve stars relative to sets of nearby comparison stars. Four of the stars showed no immediate variability. He continued to observe them for three seasons, and they proved to be constant.

Figure 4: The house at Brennøygarden with the roof-top observatory. Sigurd Enebo is posing in the foreground (courtesy: Urd 27 March 1915; photographer: H.H. Lie).

Table 1 reveals that the standard deviations of his visual estimates were (slightly) better than 0.1 mag-

Table 1: Non-variable stars observed by Sigurd Enebo.

Star	Year	Instrument	No. of obs.	Magn ± σ
32 Vul	1903-1906	binoculars	45	5.16 ± 0.08
BD+33º4056	1903-1906	7 cm refractor	47	8.66 ± 0.05
BD+49º3239	1904-1906	7 cm refractor	52	9.27 ± 0.03
BD+45º3271	1904-1906	7 cm refractor	101	8.81 ± 0.09
RT Tau	1906-1907	7 cm refractor	22	9.33 ± 0.09
RT Tau	1907-1909	11 cm refractor	91	9.33 ± 0.08

nitude. RT Tau, which he added to his program in 1906, was not detected as a variable by Enebo. It was observed with two of his instruments and may thus serve to check the consistency of his observations. The last two lines of Table 1 yield equal results for both instruments. RT Tau is listed as constant in the *General Catalogue of Variable Stars*.

When Enebo selected comparison stars for a new variable to be added to his program, he carefully compared telescope views to *Bonner Durchmusterung* maps. During such exercises he noted several deviations. He alerted Schroeter that BD+39º1963 was seen much fainter than on the map. Schroeter confirmed that he could just see it with the 19-cm Merz refractor of the University Observatory in Oslo. In April 1905 Schroeter advised Enebo to keep this under surveillance, as it may prove to be a variable star.

Schroeter mailed astronomical journals to Enebo from time to time. He could borrow them for a few weeks before they had to be returned to the Observatory library. Enebo selected variable stars and suspects from journal articles and observing reports. On 16 November 1905 he added BD+41º851 to his program. He monitored it throughout the winter season, sometimes estimating magnitudes several times per night. On four occasions the star was too faint to be detected in his 7-cm refractor. Enebo deduced from his initial data that the period was about 13 days and that the star was an Algol variable (Schroeter, 1906). At the end of the season he refined the period to 13.196 days (Enebo, 1906c), close to the value of 13.199 days obtained later from 301 photographic plates at Harvard College Observatory (Pickering, 1906). Four years later the period was further refined to 13.1989 days (Enebo 1910c). The first variable star that Enebo discovered was named RW Per.

At this time Enebo had about two dozen variable stars on his program. Many were Miras or semi-regulars for which several years would be required to determine the period. Successful period determinations were achieved for Algols, Cepheids, and RR Lyra stars during these initial years. The number of program stars more than doubled in 1907 when his new 11-cm refractor allowed fainter stars to be monitored. Each of the following years would see an annual increase of a dozen stars, bringing the program to 110 stars by 1912.

3 THE CONTRIBUTIONS OF 1912

Nova Geminorum II was discovered on 12 March 1912 by Sigurd Enebo. It was a serendipitous discovery by an experienced variable star observer. He realized immediately what he saw and rushed to alert astronomers at the University Observatory in Oslo. He was advised to telegraph the astronomical central bureau in Kiel which informed observatories worldwide. As it turned out, Enebo had discovered the Nova before it reached maximum luminosity so the object plays the role of the first nova to be studied spectroscopically in all phases of development.

A couple of months later he published three papers where he classified five variable stars as possible members of the RV Tau type. He selected the members of this class (Enebo, 1912b) by a light curve characterized by a periodic β Lyr-like variability, superimposed on a much slower background variation with a time scale of perhaps several years. The periods observed put RV Tau type stars between short period variables and long period variables. Enebo (1908e) had studied RV Tau itself in 1906-1908 and had identified the characteristics and periods of the variability. The β Lyr-like variations showed two unequal minima (0.6 and 0.3 magnitude) with a period of 78.6 days. He attributed the 3-year background variability of 0.8 magnitude to a slow variation of one of the components of what he thought was a β Lyr eclipsing binary. The long term periodicity would later become a distinguishing characteristic between subclasses RVa and RVb.

4 THE VARIABLE STAR PROGRAM

Sigurd Enebo published results for 125 stars throughout his career. Half of them (52%) were observed for 10 years or longer. The majority of these (78%) were irregular or long period variables.

During the first half of the twentieth century the most cited classification scheme for variable stars was due to Edward C. Pickering. It was an observational approach which separated the variables according to the nature of their brightness variations. There were five classes:

1. Novae
2. Short period variables
3. Long period variables
4. Irregular variables
5. Eclipsing variables

The stars on Sigurd Enebo's observing program are compiled in Tables 2-5. We list the modern variable classification in column 2 from the *General Catalogue of Variable Stars* (GCVS) (Samus et al., 2012). Enebo's classification is noted in column 4. The Tables also contain information on the total time span of Enebo's observations (column 3), the periods determined from these observations (column 4), and the literature sources for the data (column 5). The latter are identified by the issue number of *Astronomische Nachrichten* (e.g. AN 4188) and by the running number of Enebo's publication series of original observations, named *Beobachtungen Veränderlicher Sterne angestellt auf Dombaas (Norwegen)* (e.g. B # 2). These designations are attached to the relevant publications in the reference list.

4.1 Novae and Eruptive Stars

Table 2 lists novae and other eruptive stars observed by Enebo. The discovery of Nova Geminorum II = DN Gem is the single one serendipitous discovery that made his name known beyond contemporary variable star observers. At this time he was still observing from the yard outside his home with instant visibility of the entire sky. A year later he had completed a small tower observing room on top of his house, equipped with a revolving conical roof. Enebo later remarked that he would have made earlier detections of other novae (i.e. Cygni 1921 and Herculis 1936) had it not been for the limited sky view through the slit, which prevented easy visual scanning of the skies (Einbu, 1944a).

Table 2: Novae and eruptive stars observed by Sigurd Enebo.

Star Designation	GCVS Type	Observing Interval	Result	Literature sources
RW Aur	T Tau	1906-1939	Irregular behavior, but maxima at P=3,430 d	AN 4188, B # 2, 3, 4, 5, 6, 8, 9, 12
SS Aur	U Gem	1908-1939	Multiple outbursts	AN 4307, 4506, 4596, 4727, 5206, 5521, B # 4, 6, 8, 9, 10, 11, 12
SV Cep	Rapid irregular	1909-1939	Annual outbursts	AN 4497, 4596, 5206, B # 8, 12
SY Gem	U Gem?	1904-1916	Outbursts	AN 4229, B # 9
DN Gem	nova	1912	Discovery!	AN 4562
DQ Her	nova	1934	One observation	AN 6078
X Per	γ Cas	1903-1906		B # 1, AN 4207
UV Per	U Gem	1923-1926	Two outbursts	B # 10, AN 5521

Table 3: Short period pulsating variable stars observed by Sigurd Enebo.

Star Designation	GCVS Type	Observing Interval	Period	Literature sources
SY Aur	C	1907-1939	P=10,140 d	AN 4238, 5521, B # 3, 5, 8, 10, 12
RW Cam	C	1907-1908	P=16,4 d	AN 4223, B # 2
RZ Cam	RR	1909-1916	P=0,480 d; RR	AN 4497, B # 6, 12
RW Cas	C	1906-1907	P=14,80 d confirmed	AN 4207
SW Cas	C	1907-1911	P=5,44 d; C	AN 4223, B # 2, 3, 5
SZ Cas	C	1914-1918	P=13,604 d confirmed	B # 14
XY Cas	C	1922-1923	P=4,50 d confirmed	B # 14
XZ Cyg	RR	1905-1920	P=0,467 d; RR	AN 4094, B # 1, 2, 14
SU Dra	RR	1907-1911	P=0,660 d; RR	AN 4223, B # 5
RZ Gem	C	1908-1914	P=5,530 d; C	AN 4300, B # 3, 5, 13
Z Lac	C	1907-1912	P=10,89 d	AN 4223, B # 2, 3, 6
RR Lac	C	1907-1912	P=6,412 d	AN 4223, B # 2, 3, 6
SV Per	C	1907-1914	P=11,128 d	AN 4223, B # 2, 3, 8
SX Per	C	1907-1911	P=4,290 d; C	AN 4300, B # 5
U Tri	RR	1911-1915	P=0,447 d conf.; RR	AN 4595, B # 14

Another remarkable observation of a potential eruptive star, perhaps a dwarf nova, was made by Enebo in 1904. Upon consulting the *Bonner Durchmusterung* star maps on 4 March 1904 he noted that BD+31°1380 (magnitude 9.2) was not visible in his 7-cm refractor. He informed Schroeter at Oslo University Observatory who subsequently checked the field with larger telescopes. On 20 April 1904 he, too, could not see BD+31°1380. Enebo continued his monitoring for a year, but could never detect it. A letter from Schroeter dated 22 April 22 1905 reports that he saw it on 18 April 1905, slightly fainter than BD+31°1379. He estimated the magnitude at 9.5. Enebo's notebook reports that he saw it as very faint on 24 October and 28 November 1905, and again on 16 March 1906. These observations are reported with question marks in Enebo (1917). On Christmas Eve 1906 Enebo saw the star clearly at magnitude 9.5 in his new 11-cm refractor, 0.1 magnitude fainter than BD+31°1379 (Enebo, 1908a).

Enebo continued monitoring BD+31°1380 = SY Gem for the next ten years. He estimated his detection limit with the new refractor at magnitude 12.5 in the majority of cases, and again and again he noted that the star as invisible. On a few occasions he suspected he saw it very faintly, but recorded the observations as uncertain (Enebo, 1917). Numerous other observers have searched for SY Gem, both visually and photographically, without success. Enebo (1917) suggested that it might be a U Gem star with rare and short-lived flare ups. Meanwhile, a search for a nova remnant did not reveal any candidates (Downes and Szkody, 1989). A mystery remains about the 1856 *Bonner Durchmusterung* observations and later ones. Enebo is listed by Müller and Hartwig (1918) as the discoverer of SY Gem.

Other erupting stars in Table 2 are currently classified as a flaring T Tau-star (RW Aur) and an X-ray pulsar with an IR excess (X Per).

4.2 Pulsating Variables with Short Periods

Table 3 lists the short period variables observed by Enebo. There are eleven Cepheids and four RR Lyr stars, identified as C and RR, respectively, in column 2. He determined the periods in column 4 for eleven of the stars, and confirmed the period determined by other observers for four stars. He was the first to classify the four RR Lyr stars (e.g. see Figure 5)[2] and three of the Cepheids, based on his own light curves. XZ Cyg, which he observed extensively during the winter of 1905/1906, was the first variable star for which he published a light curve (Enebo, 1906b; 1906c).

4.3 Irregular and Long Period Variables

Table 4 lists the irregular and long period variables observed by Enebo. The type in column 2 is from Samus et al. (2012) where M indicates Mira variable, SRA/SRB/SRC/SRD indicate subgroups of semi-reg-

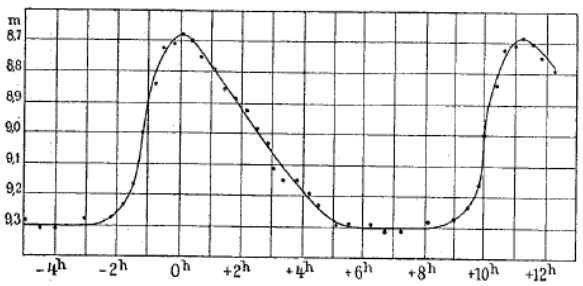

Figure 5: Sigurd Enebo's light curve for the RR Lyr variable XZ Cyg (after Enebo, 1906b).

ular (SR) variables, and RVa/RVb indicate sub-groups of RV Tau stars. LB indicates slow irregular variables. Column 4 lists the periods determined by Enebo. If a period could not be determined, he classified the star as irregular. Table 4 contains twenty-six Mira variables, of which Enebo determined a period for twenty-four stars. For sixteen Mira stars the period values determined by Enebo deviate less than 1% from the modern values listed in the GCVS. Three stars deviate more than 4%, i.e. TT Cas, W Dra, and Z Peg. Table 4 contains forty semi-regular variables, of which Enebo determined periods for thirty. Many of them are reported to show variable or multiple periods in the GCVS, which produces large deviations between current period values and 15 of those determined by Enebo. Two stars, i.e. RV Lac and RX UMa, have had the light curves re-interpreted and the periods revised by an integer number. Table 4 contains four RV Tau stars, of which Enebo determined a period for three. SS Gem later had its period doubled. There are eight irregular variables, in agreement with Enebo except that CY Cyg appeared constant during his (short) observing series. However, Enebo classified a total of seventeen stars in Table 4 as irregular, some no doubt due to the short time intervals over which he observed them.

Enebo persistently monitored forty-four stars for more than two decades and twenty-one stars for more than three decades. Three stars, i.e. RR Cyg, AD Cyg, and SW Gem, were monitored for thirty-five years. This last-mentioned star was the first long period variable discovered by Enebo (1906a) from observations conducted during 1904-1906. It took an additional four years before the period estimate was set at 698 days. This was refined to 680 days only when the observations ended in 1939 (Einbu, 1943). Further discoveries of long period variables were SW Per (Enebo, 1908a), SY Per (Enebo, 1908g), TT Cas (Enebo, 1909a), AI Cyg (Enebo, 1910b), RY Lac (Enebo, 1911b), and AF Peg (Enebo, 1914b).

Table 4: Irregular and long period variable stars observed by Sigurd Enebo.

Star Designation	GCVS Type	Observing Interval	Period	Literature sources
RV And	SRA	1914-1916		B # 13
SZ And	M	1907-1938	P=342 d	AN 4272, 5206, B # 11, 12
TU And	M	1909-1938	P=315 d	AN 4596, 4727, 5206, 5521, B # 8, 10, 12
TV And	SRB	1908-1939	P=115 d	AN 4323, 4506, 4596, 5521,B # 4, 6, 9, 10, 11, 12
TX And	M	1910-1938	P=234 d	AN 4596, 4727, 5206, B # 6, 11, 12
TY And	SRB	1910-1938	P=151 d	AN 4596, 4727, 5206, 5521, B # 6, 11, 12
UW And	M	1911-1938	P=236 d	AN 4596, 4727, 5206, 5521, B # 11, 12
RR Aur	M	1906-1939	P=308 d	AN 4207, 4506, 4596, 5206, 5521, B # 4,9,10,13
RS Aur	SR	1906-1939	P=170 d	AN 4207, 4506, 4596, 4727, 5206, B #2,3,6,11,12
RU Aur	M	1911-1939	P=466 d	B # 12
RV Aur	SRB	1914-1917	Irr. ?	B # 13
TV Aur	SRB	1908-1938	P=183 d	AN 4416, 4506, 4596, 5521, B # 5, 10, 12
TW Aur	SRB	1908-1939	P=148 d	AN 4416, 5206, 5521, B # 5, 9, 10, 12
TX Aur	LB	1911-1925	Irr.	AN 4727, B # 12
UZ Aur	SRB	1908-1916	Irr.?	B # 9
VW Aur	SRB	1911-1936	P=213 d	AN 4595, 4727, 5521, B # 9, 10, 12
ρ Cas	SRD	1903-1908	Irr.?	B #1, 2
Z Cas	M	1907		AN 4207
RV Cas	M	1906-1912	P=333 d	AN 4207, 4596, 4727, B #2
SS Cas	M	1914-1916	P=142 d	B # 14
TT Cas	M	1908-1939	P=372 d	AN4277,4323,4506,4596,4727,5521,B #5,8,10,12
X Cnc	SRB	1904-1910	P=362 d	AN 4207, B # 4
RR Cyg	SRB	1904-1939	Irr.	B # 1, 2, 3, 14, AN 4506
SV Cyg	LB	1904-1906	Irr.	B # 1, 2
AB Cyg	SRB	1907-1931	P=522 d	AN 4272, 4323, 4727, B # 4, 11
AD Cyg	LB	1907-1942	Irr.	AN 4416, 4506, 4596, 4727, 5206, B # 5, 11, 14
AF Cyg	SRB	1910-1913	P=94 d	AN 4596, 4727, 5206, B # 6, 13
AH Cyg	SRB	1909-1932	P=100? d	AN 4497, 4727, B # 8, 11
AI Cyg	SRB	1910-1942	P=141 d	AN 4400, 4497, 4596, 4727, B # 6, 11, 14
AV Cyg	SRD	1910-1940	P=88 d	AN 4595, 4727, 5206, 5521, B # 8, 10, 13
CY Cyg	LB	1904-1906	constant	B # 1
W Dra	M	1906-1927	P=260 d	AN 4207,4506,4596,4727,5206,5521, B #2,3,5,10
X Dra	M	1907-1938	P=257 d	AN 4207, 4506, 4596, 4727,5206,5521,B # 3,5,12
SV Dra	M	1909-1939	P=258 d	AN 4416, 4506, 4596, 5206, 5521, B # 5, 10, 13
TT Dra	SRB	1914-1918	P=95 d	AN 5206
TY Dra	LB	1907-1927	Irr.	AN 4497, 4727, B # 6, 10
UU Dra	SRB	1907-1927	P=234? d	AN 4497, 4596, 5521, B # 8, 10
SS Gem	RVa	1908-1911	P=45 d	AN 4323, 4506, B # 5
SW Gem	SRA	1904-1939	P=680 d	AN 4092, 4272, 4416, 4497, 5521, B #1,2,5,10,13
g Her	SRB	1903-1906	Irr.	B # 9
RY Her	M	1906		AN 4207
U Lac	SRC	1904-1908	Irr.	B # 1, 2
RS Lac	SRD	1908-1926	P=237 d	AN 4323, 4596, 4727, 5206, 5521, B # 4
RU Lac	M	1911-1927	P=203 d	AN 4596, 4727, 5206, 5521, B # 10
RV Lac	SRB	1909-1932	P=137 d	AN 4416, 5521, B # 10, 11
RY Lac	SRB	1910-1932	P=122 d	AN 4473, 4497, 4596, 4727, B # 6, 11

T Lyr	LB	1904-1906	Irr.	B # 9
X Lyr	LB	1904-1909	Irr.	B # 3
SZ Lyr	SRA	1909-1939	P=133 d	AN 4497, 4727, 5206, 5521, B # 6, 9, 10, 13
TX Lyr	M	1913-1939	P=223 d	AN 4715, 5207, 5521, B # 10, 13
Z Peg	M	1905-1911	P=320 d	AN 4207, 4506, B # 3
SS Peg	M	1907-1939	P=419 d	AN 4272,4323,4506,4596,4727,5206,5521, B # 5, 10, 14
ST Peg	SRB	1907-1939	P=101 d	AN 4272, 4727, B # 4, 10, 11, 14
SU Peg	M	1909-1939	P=198 d	AN 4416, 4506, 4596, 4727, 5206, 5521, B # 14
SW Peg	M	1911-1939	P=396 d	AN 4596, 4727, 5206, 5521, B # 10, 14
SX Peg	M	1910-1927	P=306 d	AN 4727, 5206, 5521, B # 9, 10
UY Peg	LB	1907-1914	Irr.	AN 4595, B # 8
AF Peg	SRB	1913-1932	P=52 d	AN 4726, 5206, 5521, B # 10, 11
SW Per	SRB	1905-1932	P=84 d	AN 4229, 4272, 4506, 4596, 4727,B # 2,5,8,10,11
SY Per	SRA	1907-1940	P=472 d	AN 4271, 4323, 5206, 5521, B # 8,10,14
TW Per	M	1911-1927	P=337 d	AN 4727, 5206, 5521,B # 10
TX Per	RVa	1911-1940	P=77 d	AN 4595, 4727, 5206, 5521, B # 8, 10, 11, 14
UZ Per	SRB	1911-1940	Irr. ?	B # 9, 10, 14, AN 5206, 5521
VV Per	SRB	1913-1927	P=220? d	AN 4715, B # 10
VW Per	M	1913-1936	P=278 d	AN 5206, B # 14
R Sge	RVb	1914-1917	Irr. ?	B # 14
RV Tau	RVb	1906-1912	P=78,7 d	AN 4188, 4243, B # 2, 4, 6
TV Tau	SRA	1912-1913	P=120 d	AN 4727
TX Tau	SRA	1911-1940	Irr.	B # 11, 14
S Tri	M	1909-1939	P=248 d	AN 4506, 4596, 4727, 5206, 5521, B # 5, 10, 14
T Tri	M	1911-1940	P=320 d	AN 5206, B # 14
Y UMa	SRB	1906-1909	Irr.	AN 4207, B # 2, 3
Z UMa	SRB	1906-1908	P=206 d	AN 4207, B # 2
RS UMa	M	1906-1939	P=260 d	AN 4207, 4280, 4506, 4596, 4727, 5206, 5521, B # 2, 3, 8, 10, 14
RX UMa	SRB	1907-1919	P=64 d	AN 4272, 4323, 4506, B # 4, 6, 11
RZ UMa	SRB	1908-1913	P=133 d	AN 4323, 4506, 4727, B # 5
SV UMa	SRD	1910-1932	P=76 d	AN 4596, 4727, 5521, B # 10, 11
V UMi	SRB	1910-1913	P=72 d	AN 4497, 4596, 4727, B # 6

Table 5: Eclipsing variables observed by Sigurd Enebo.

Star Designation	GCVS Type	Observing Interval	Period	Literature sources
TT And	EA	1907-1913	P= 2,764 d	AN 4232, B # 14
UU And	EA	1910-1920	P=1,486 d	AN 4502, B # 12
RY Aur	EA	1907-1925	P=2,725 d	AN 4232, B # 7, 13
SX Aur	EB	1907-1939	P=1,210 d conf.	AN 4238, B # 3, 4, 6, 9, 12
TT Aur	EB	1907-1926	P=1,333 d	AN 4272, 4300, B # 3, 9, 13
ε Aur	EA	1903-6; 1928-30	A minimum	B # 1, 13, 14
SS Cam	EA	1909-1936	P=4,824 d	AN 4497, B # 9, 12
SX Cas	EA	1907-1909	P=36,564 d	AN 4238, 4241, B # 3
SX Dra	EA	1909-1913	P=5,169 d	AN 4386, 4502, B # 7
UZ Dra	EA	1907-1925	P=3,261 d	AN 4595, 5206, B # 7, 13
RX Gem	EA	1907-1913	P=12,209 d	AN 4232, 4407, B # 7
SV Gem	EA	1908-1920	P=4,006 d	AN 4386, B # 7, 13
SX Gem	EA	1908-1930	P=1,367 d	AN 4497, B # 7, 13
u Her	EA	1903-1906	P=2,051 d conf.	B # 1, AN 4363
RT Lac	RS CVn	1908-1910	P=5,073 d	AN 4319, 4416, B # 4
RW Lac	EA	1909-1916	P=5,185 d	AN 4400, 4410, 4502, 5206
TT Lyr	EA	1911	P=5,244 d	AN 4497
RV Per	EA	1905-1910	P=1,974 d	AN 4173, 4207, 4407, B # 4
RW Per	EA	1905-1910	P=13,199 d	AN4078,4407,B # 1
ST Per	EA	1907-1910	P=2,648 d	AN 4223, 4407, B # 4
SV Tau	EA	1908-1913	P=2,167 d	AN 4319, 4407, B # 4, 7
RW UMa	EA	1907-1913	P=7,328 d	AN 4272, 4502, B # 7
RR Vul	EA	1907-1908	P=5,051 d	AN 4272, 4300
RS Vul	EA	1908-1909	P=4,477 d	AN 4386

4.4 Eclipsing Variables

Table 5 lists the eclipsing variables observed by Enebo. There are twenty-one Algol variables, two β Lyr type, and one RS CVn star, identified in column 2 by EA, EB, and RS CVn, respectively. Enebo determined the periods in column 4 for twenty-one of the stars, and confirmed the periods determined by other observers for two stars. He classified nineteen Algol stars and one β Lyr star based on his own light curves.

RW Per was the first variable star discovered by Enebo (Schroeter, 1906). Enebo (1906c) classified it immediately as an Algol and determined the period to be 13.196 days. This closely matched the photo-

graphic result of 13.199 days (Pickering 1906) and was further improved by Enebo (1910c) to 13.1989 days.

Enebo also discovered the Algol variable RW Lac. It served initially as a comparison star to RV Lac, but a faint appearance and subsequent rapid rise on 11 December 1909 led Enebo (1910b) to suspect Algol variability. He suggested a period of 5.18 days and refined the value just a month later to 5.1874 days (Enebo, 1910d). Further observations a year later (Enebo, 1911d) and a final minimum in 1915 brought the period to 5.18453 days (Enebo, 1923). The modern value in the GCVS (Samus et al., 2012) is 10.36922 days, due to Martinov (1938) who decided from a photographic light curve that the secondary eclipse did not occur exactly at phase 0.5. Lacy et al. (2005) concluded from photoelectric and spectroscopic observations that RW Lac consists of two very similar main sequence G-stars with masses close to 0.9 solar masses. They confirm a slightly eccentric orbit and suspect synchronous rotation. Comparison with evolutionary models suggests an age of 11 Gyr.

The period determination of some stars would prove challenging. SX Aur initially led to P = 1.53 days but with a growing time series the number of

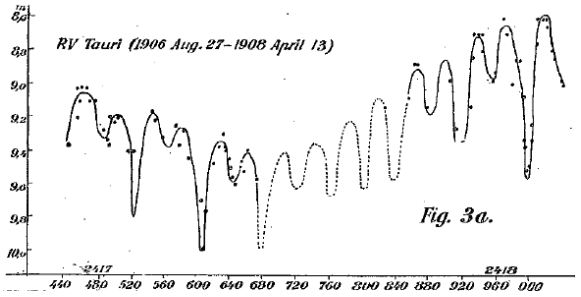

Figure 6: The light curve of RV Tau generated by Sigurd Enebo (after Enebo, 1908f).

outliers increased. A decade of observations did not allow Enebo to determine a definitive period. A letter from Ejnar Hertzsprung at Leiden Observatory dated 19 March 1929 informed Enebo that a reanalysis of his observations has led to P = 1.21 days. This was supported by further observations of SX Aur by P.T. Oosterhoff in Leiden, which revealed primary and secondary minima of different depth. When Enebo concluded his observations in 1936 he confirmed Hertzsprung's value. TT Aur initially revealed a period of 0.67 days but seven more years of observations led to twice that value. The initial observations of SV Tau suggested P = 2.167 days, but continued monitoring revealed minima of different depth and the period value was doubled. However, the star catalogues have retained the initial value pending clarification.

5 VARIABLE STAR SUMMARY

The main event contributing to the present centenary was the discovery of Nova Geminorum II = DN Gem at 20:32 MET on 12 March 1912 (Enebo, 1912a). It was an astrophysically-important discovery because the nova was detected before it reached maximum. This allowed the largest refractor in the world at Yerkes Observatory to obtain time-lapse spectra for the first time of the initial phases of nova developments. Immediately after the discovery the spectrum showed hydrogen lines in absorption, but on 15 March they appeared as strong emission lines. They increased in strength during the next few days as did the ultraviolet continuum (Parkhurst, 1912).3 The blue- shifted lines indicated approaching gas shells at several hundred km/s. Recent high resolution Hα imaging with the Nordic Optical Telescope has revealed remnants of several rings around the current 16th magnitude star (J.E. Solheim, private communication).

Enebo (1912b; 1912c; 1912d) was the first to refer to RV Tau type variables as a separate classification. This designation is still in use today, one hundred years later. Enebo had made a thorough study of RV Tau itself between 1906 and 1910 (Enebo, 1907b; 1908e; 1908f; 1910f), and one of his light curves is reproduced here in Figure 6. His interpretation at the time was governed by the observed β Lyr type light curve with a period of 78.8 days combined with the speculation that one of the components was also a slow variable in its own right with a period of 3 years. Based on light curves in the literature Enebo (1910f) remarked that R Sge and V Vul showed similar behavior.

By 1912 Enebo had recognized similar behavior in stars on his own observing program. TV And was his strongest candidate (Enebo, 1912b; 1912d). He also suggested RW Aur, TY Dra, RY Lac, UY Peg and RX UMa as possible members of the RV Tau class (Enebo, 1912b; 1912c; 1912d). This seems to have gone unnoticed for several years. In the review of variable stars in *Handbuch der Astrophysik*, Ludendorff (1928) referred to Sigurd Enebo as the originator of the term RV Tau type variables. This was pointed out in a note by Zsoldos (1993). Ludendorff's list of RV Tau stars included TV And from Enebo's proposal, but none of the others. It is remarkable that none of Enebo's candidates (except RV Tau itself) is included in the RV Tau class today, but R Sge and V Vul are.

Spectroscopy later revealed that RV Tau type stars are very luminous supergiants. Radial pulsations are thought to cause both volume and temperature fluctuations of the star. The location of RV Tau stars in the Hertzsprung-Russell Diagram suggests them to be in the short-lived post-AGB phase. Some (if not all) are binaries, and mass loss may have taken place during the giant phase of one component. The energy distributions show excesses at infrared and submillimeter wavelengths, indicating stable and extensive dust disks or shells.

During his career Enebo discovered a nova (DN Gem), a possible dwarf nova (SY Gem), seven long period/semiregular variables (SW Gem, SW Per, SY Per, TT Cas, AI Cyg, RY Lac, and AF Peg) and two Algols (RW Per and RW Lac). He determined periods for seven Cepheids, three RR Lyra stars, twenty-four Miras, thirty semi-regular variables, three RV Tau stars, and twenty-one eclipsing binaries. Throughout his career he monitored 125 different variable stars for which he collected 22,403 magnitude values. He had several comparison stars for each variable, so the total number of individual magnitude estimates was 49,783.

Two stars in Enebo's variable star program remain undecided. BD+43º1712 was bright enough to be observed twice in the *Bonner Durchmusterung* program in March 1857 at magnitude 9.5. Enebo reported it missing in 1905. This was confirmed by a visual search with a 19-cm Merz refractor at the University Observatory in Oslo and also by a photographic plate obtained at Harvard Observatory (Schroeter, 1905, Kreutz; 1905). Enebo also suspected a star in Cep to be variable. In his last paper (Einbu, 1944b) he noted that it had still not been designated a variable star, but he maintained that it may be variable.

6 CONCLUDING REMARKS

Enebo was appointed to honorary memberships of astronomical societies in France, Mexico, and Norway. He was elected a member of the Norwegian Academy of Sciences and in 1926 received its Fridtjof Nansen Award for excellent research. Five years later he received the Gunnerus Medal from the Royal Norwegian Society of Science. He became a member of IAU Commission 27 (Variable Stars) in 1933.

In Germany the Astronomische Gesellschaft awarded Enebo their Lindemann Award in 1906 for his discovery of the Algol variable RW Per. He received a reprinting of the complete *Bonner Durchmusterung* star catalogue and atlas. The Sociedad Astronomica de Mexico awarded Enebo the Atenogenes Silva Medal for his discovery of Nova Geminorum II in 1912.

In addition to his scientific efforts described in this paper, Sigurd Enebo was the leading popularizer of astronomy in Norway in the first half of the twentieth century. He contributed monthly articles on the night sky to numerous newspapers throughout the country for several decades. He authored several popular books on astronomy, some written with a particular focus on young readers.

The Enebo family changed their name to Einbu in 1926. This was motivated by their local dialect and also reflected the original name of the family homestead. Sigurd Einbu even changed the written orthography in his later astronomy books, from formal Norwegian to a form strongly reflecting his local dialect.

For several decades Enebo spent the summer months (which were too bright for observing) on lecturing tours throughout the country, presenting astronomy to the general public. Consequently, 'Sigurd Einbu' was a household name in Norway when he died on 10 May 1946, six months short of his 80th birthday. Two generations later he is largely forgotten. His remarkable career from self-taught astronomy studies to a unique, lifelong state stipend, to discoveries of variable stars, and his persistent, extended series of careful observations, should justify his place in the history of variable star astronomy.

7 NOTES

1. The GPS position of the observatory site is: 62º 04′ 22″ N; 09º 05′ 20″ E.
2. Enebo referred to RR Lyra stars as Antalgols. This term 'Antalgol' was first proposed by Hartwig for the short period Cepheids. The light curve is characterized by a constant phase during the minimum and a steep rise to maximum, i.e. the opposite of Algol eclipsing binaries.
3. An anonymous referee has pointed out the career similarities, from amateur to professional employment, for Enebo and Parkhurst, on the basis of careful observations and analyses.

8 REFERENCES

Downes, R.A., and Szkody, P., 1989. CCD observations of old nova fields. *Astronomical Journal*, 97, 1729-1736.

Einbu (Enebo), S., 1927. Observations of variable stars made at Dombås (Norway) – X. *Skrifter utgitt av Det Norske Videnskaps-Akademi. Mat.-Naturv. Klasse 1927*, No. 13, 1-59 (B # 10) [In German].

Einbu, S., 1928. Notes on variable stars. *Astronomische Nachrichten*, 231, 11-14 (AN 5521) [In German].

Einbu (Enebo), S., 1933. Observations of variable stars made at Dombås (Norway) – XI. *Skrifter utgitt av Det Norske Videnskaps-Akademi. Mat.-Naturv. Klasse 1933*, No. 2, 1-38 (B # 11) [In German].

Einbu, S., 1935. Notes on Nova 452. 1934 Herculis. *Astronomische Nachrichten*, 254, 89 (AN 6078) [In German].

Einbu, S., 1940. Observations of variable stars made at Dombås (Norway) – XII. *Skrifter utgitt av Det Norske Videnskaps-Akademi. Mat.-Naturv. Klasse 1939*, No. 9, 1-31 (B # 12) [In German].

Einbu, S., 1943. Observations of variable stars made at Dombås (Norway). *Archiv for Mathematik og Naturvidenskab*, 47(1), 1-19 (B # 13) [In German].

Einbu, S., 1944a. Notes on my astronomical work. *Norsk Populær-Astronomisk Tidsskrift*, 2, 46-50 [In Norwegian].

Einbu, S., 1944b. Observations of variable stars made at Dombås (Norway). *Archiv for Mathematik og Naturvidenskab*, 47(14), 181-214 (B # 14) [In German].

Enebo, S., 1906a. A new variable 40.1906 Geminorum. *Astronomische Nachrichten*, 171, 191-192 (AN 4092) [In German].

Enebo, S., 1906b. Observations of the variable 76.1905 Cygni. *Astronomische Nachrichten*, 171, 219-224 (AN 4094) [In German].

Enebo, S., 1906c. Observations of variable stars made at Dombaas (Norway) – I. *Archiv for Mathematik og Naturvidenskab*, 27(17), 1-50 (B # 1) [In German].

Enebo, S., 1907a. Observations of the variable RV Persei. *Astronomische Nachrichten*, 174, 331-334 (AN 4173) [In German].

Enebo, S., 1907b. Observations of RW Aurigae and RV Tauri. *Astronomische Nachrichten*, 175, 205-206 (AN 4188) [In German].

Enebo, S., 1907c. A note on variable stars. *Astronomische Nachrichten*, 176, 107-110 (AN 4207) [In German].

Enebo, S., 1907d. A note on some new variables, *Astronomische Nachrichten*, 176, 373-374 (AN 4223) [In German].

Enebo, S., 1908a. Two new variable stars. *Astronomische Nachrichten*, 177, 73-74 (AN 4229) [In German].

Enebo, S., 1908b. Three Algol stars. *Astronomische Nachrichten*, 177, 121-122 (AN 4232) [In German].

Enebo, S., 1908c. Notes on variable stars. *Astronomische Nachrichten*, 177, 221-222 (AN 4238) [In German].

Enebo, S., 1908d. On the Algol star 142.1907 Cassiopeiae. *Astronomische Nachrichten*, 177, 269-270 (AN 4241) [In German].

Enebo, S., 1908e. On the light variability of RV Tauri. *Astronomische Nachrichten*, 177, 313-316 (AN 4243) [In German].

Enebo, S., 1908f. Observations of variable stars made at Dombaas (Norway) – II. *Archiv for Mathematik og Naturvidenskab*, 29(11), 1-60 (B # 2) [In German].

Enebo, S., 1908g. New variable 17.1908 Persei. *Astron-*

omische Nachrichten, 178, 381-382 (AN 4271) [In German].
Enebo, S., 1908h. Confirmation of variability for some newly discovered variables. *Astronomische Nachrichten*, 178, 395-398 (AN 4272) [In German].
Enebo, S., 1909a. New variable 142.1908 Cassiopejae. *Astronomische Nachrichten*, 179, 83-84 (AN 4277) [In German].
Enebo, S., 1909b. A note on RS Ursae Majoris. *Astronomische Nachrichten*, 179, 131-132 (AN 4280) [In German].
Enebo, S., 1909c. Confirmation of variability for some newly discovered variables. *Astronomische Nachrichten*, 180, 63-64 (AN 4300) [In German].
Enebo, S., 1909d. A note on SS Aurigae. *Astronomische Nachrichten*, 180, 183-184 (AN 4307) [In German].
Enebo, S., 1909e. Improved elements for two new Algol stars. *Astronomische Nachrichten*, 180, 367-368 (AN 4319) [In German].
Enebo, S., 1909f. Confirmation of variability for some newly discovered variables. *Astronomische Nachrichten*, 181, 47-48 (AN 4323) [In German].
Enebo, S., 1909g. On the star u Herculis. *Astronomische Nachrichten*, 182, 309-312 (AN 4363) [In German].
Enebo, S., 1909h. Observations of variable stars made at Dombaas (Norway) – III. *Archiv for Mathematik og Naturvidenskab*, 30(4), 1-60 (B # 3) [In German].
Enebo, S., 1910a. Three Algol stars. *Astronomische Nachrichten*, 183, 287-290 (AN 4386) [In German].
Enebo, S., 1910b. Two new variables. *Astronomische Nach-richten*, 184, 141-142 (AN 4400) [In German].
Enebo, S., 1910c. Improved elements for an Algol star. *Astronomische Nachrichten*,184, 253-256 (AN 4407) [In German].
Enebo, S., 1910d. A note on 34.1910 Lacertae. *Astronomische Nachrichten*, 184, 303-304 (AN 4410) [In German].
Enebo, S., 1910e. Confirmation of variability for some newly discovered variables. *Astronomische Nachrichten*, 184, 393-398 (AN 4416) [In German].
Enebo, S., 1910f. Observations of variable stars made at Dombaas (Norway) – IV. *Archiv for Mathematik og Naturvidenskab*, 30(12), 1-60 (B # 4) [In German].
Enebo, S., 1911a. Observations of variable stars made at Dombaas (Norway) – V. *Archiv for Mathematik og Naturvidenskab*, 31(10), 1-58 (B # 5) [In German].
Enebo, S., 1911b. New variable 5.1911 Lacertae. *Astronomische Nachrichten*, 187, 137-140 (AN 4473) [In German].
Enebo, S., 1911c. Confirmation of variability for some newly discovered variables. *Astronomische Nachrichten*, 188, 147-150 (AN 4497) [In German].
Enebo, S., 1911d. On four Algol stars. *Astronomische Nachrichten*, 188, 247-248 (AN 4502) [In German].
Enebo, S., 1911e. Observations of long period variables. *Astronomische Nachrichten*, 188, 311-314 (AN 4506) [In German].
Enebo, S., 1912a. Discovery of Nova Geminorum 2. *Astronomische Nachrichten*, 191, 65 (AN 4564) [In German].
Enebo, S., 1912b. Observations of variable stars made at Dombaas (Norway) – VI. *Archiv for Mathematik og Naturvidenskab*, 32(12), 1-52 (B # 6) [In German].
Enebo, S., 1912c. Confirmation of variability for some newly discovered variables. *Astronomische Nachrichten*, 192, 185-186 (AN 4595) [In German].
Enebo, S., 1912d. Observations of long periodic variables. *Astronomische Nachrichten*, 192, 201-204 (AN 4596) [In German].
Enebo, S., 1913. Observations of variable stars made at Dombaas (Norway) – VII. *Archiv for Mathematik og Naturvidenskab*, 33(8), 1-63 (B # 7) [In German].
Enebo, S., 1914a. Confirmation of variability for two newly discovered variables. *Astronomische Nachrichten*, 197, 183-184 (AN 4715) [In German].
Enebo, S., 1914b. New variable 14.1914 Pegasi. *Astronomische Nachrichten*, 197, 365-366 (AN 4726) [In German].
Enebo, S., 1914c. Observations of long periodic variables. *Astronomische Nachrichten*, 197, 375-376 (AN 4727) [In German].
Enebo, S., 1914d. Observations of variable stars made at Dombaas (Norway) – VIII. *Archiv for Mathematik og Naturvidenskab*, 34(4), 1-50 (B # 8) [In German].
Enebo, S., 1917. Observations of variable stars made at Dombaas (Norway) – IX. *Archiv for Mathematik og Naturvidenskab*, 35(2), 1-50 (B # 9) [In German].
Enebo, S., 1923. A note on variable stars. *Astronomische Nachrichten*, 217, 439-442 (AN 5206) [In German].
Kreutz, H., 1905. A note by the editor.-180 *Astronomische Nachrichten*, 169, 47-48 [In German].
Ludendorff, H., 1928, The variables of the RV Tauri-class. In (Eberhard, G., Kohlschütter, A., and Ludendorff, H. (eds.). *Handbuch der Astrophysik. Band VI*. Pp. 173-180 [In German].
Martinov, D.Y., 1938. *Publications of the Engelhardt Observatory*, 20.
Müller, G., and Hartwig, E., 1918. *Geschichte und Literatur des Lichtwechsels Veränderliche Sterne*. Leipzig, Poeschel und Trepte [In German].
Parkhurst, J.A., 1912. Changes in the early spectrum of Enebo's nova in Gemini. *Popular Astronomy*, 20, 236-238.
Pickering, E.C., 1906. The Algol variable, +41º 851. *Harvard Circular*, No. 114 (also, The Algol variable 29.1906 Persei, 041342. *Astronomische Nachrichten* 171, 281-284, 1906).
Samus, N.N., Durlevich, O.V., Kazarovets, E.V., Kireeva, N.N., Pastukhova, E.N., and Zharova, A.V., 2012. *General Catalogue of Variable Stars* (internet version; downloaded 4 June 2012).
Schroeter, J.F., 1905. A note on stars of the Bonner Durchmusterung. *Astronomische Nachrichten*, 169, 47-48 (AN 4035).
Schroeter, J.F., 1906. A new variable star of the Algol type, 20.1906 Persei. *Astronomische Nachrichten*, 170, 357-358 (AN 4078).
Zsoldos, E., 1993. On the origin of the term "RV-Tauri-type". *The Observatory*, 113, 305.

Dr Bjørn R Pettersen is Professor of Geodesy at the Norwegian University of Environmental and Life Sciences, and an Adjunct Professor of Astronomy at the University of Oslo. He has published 180 research papers and has edited proceedings from IAU symposia and other international conferences. His main research interests include observational astronomy, space geodesy, gravimetry, and the history of science. He has served on the Committee of the IAU Working Group on Historical Instruments.