ART. VII.—*On the Transit Instrument as a substitute for the Zenith Telescope in determining Latitude, and on the Latitude of New Haven ;* by Prof. C. S. LYMAN.

THE method of determining latitude by measuring micrometrically the difference of meridional zenith distances of stars on opposite sides of the zenith, known commonly as Talcott's method, strongly commends itself to observers, both by its beautiful simplicity, and the very great accuracy of its results. It is the method of late years exclusively used in the operations of the United States Coast Survey, and may properly be regarded as one of the many excellent incidental fruits of that great National work. A special instrument, however, the zenith telescope, has been required for making the necessary observations, and sup-

* It may be stated in connection with this subject that the geodetic surveys of two arcs, one in the New England States, the other on the Chesapeake Bay, are already completed and the astronomical part of the former is nearly so, promising an important result derived from the labors of the U. S. Coast Survey at no distant time.

posed to be indispensable for this purpose. It indeed admirably answers the end for which it was invented, and in respect to simplicity, convenience, and efficiency, leaves almost nothing to be desired. But being expensive, and of limited use, it is likely to be in the hands of but few observers. The suggestion, therefore, of additional instrumental facilities for using this method of latitude, so as to render it more widely available, may not be considered as without value.

At the recent meeting of the American Association, at Springfield, the writer, in a brief communication, pointed out the facility and efficiency with which a transit instrument may be used as a substitute for the zenith telescope, in such observations. The object of the present article is, in part, to exemplify further the same point, and at the same time to place on record the results of a more careful determination, astronomically, of the latitude of New Haven, than, so far as appears, has heretofore been attempted.

The essential parts of the zenith telescope, as an instrument for determining latitude by Talcott's method, are its level and micrometer. And the superiority of the method itself rests mainly on the fact that its results depend on these simple and efficient instrumental means, instead of on graduation. It is obvious, that a transit instrument with a declination micrometer and a suitable level attached to its finding circle, is, at the same time, essentially a zenith telescope, and is capable of performing the whole work of that instrument—as accurately, if of corresponding size and quality, and as conveniently, if furnished with a reversing apparatus. The advantages of such a use of the transit instrument, in a multitude of cases, scarcely need to be pointed out. Where both latitude and longitude are to be determined at the same station, as is usually the case, a single instrument will suffice for both, and thus half the ordinary equipment for the purpose may be dispensed with. The corresponding diminution of expense will be a consideration of weight where pecuniary means are limited, as will also the saving of transportation, in the case of boundary and other surveys in remote and uninhabited districts. The observer who has at command such an instrument, even of very moderate size, will have it in his power to fix his latitude with a degree of precision scarcely surpassed even in first class observatories.

The transit instrument with which the observations were made, the results of which are given in this article, has an object glass (by Fitz) of two and six-tenths inches aperture, and thirty-five and a half inches focal length; a filar-micrometer, so constructed as to be used with equal facility either in the plane of the meridian or perpendicular to it; and a twelve inch circle, graduated on the new and excellent engine of Messrs. E. & G. W.

Blunt, of New York,) reading by two verniers to $10''$. The level attached to the alidade of the circle has a run of one-thirteenth of an inch for $5''$; and this being the smallest division of the scale, single seconds and fractions have to be estimated by the eye—a defect which will be further noticed in another connection.

The graduation of the circle is very accurate. The difference between the readings of the opposite verniers seldom amounts to $15''$, and from its law of variation, it is manifestly due, in the main at least, to a very slight excentricity in centering the circle on the graduating engine, not to imperfection in the engine itself.

The micrometer-screw has 75 threads to the inch, or one revolution of the head equal to $78''\cdot74$.

The optical performance of the instrument is very satisfactory. Transits of Polaris are readily taken at midday, and in favorable states of the atmosphere, at that hour, even by reflection in mercury. Transits of Aldebaran have been taken when the star was within 6° of the sun's center. The eye-piece commonly used is a diagonal one of four lenses, with prismatic reflector,—the magnifying power about 190.

The method of observing for latitude with the transit instrument is of course essentially the same as with the zenith telescope. A pair of stars having been selected, which culminate within a few minutes of each other, but on opposite sides of the zenith, and having their zenith distances nearly equal, the instrument is set for the star first to culminate, the level clamped, the bubble brought to zero by the slow-motion screw which turns the whole instrument, the star bisected with the micrometer wire, and the readings of the level and micrometer noted. The axis is then reversed, the bubble brought to zero as before, and the other star observed in the same manner.

The pairs for the observations now to be considered, were taken from the Catalogue of the British Association. The stars are to the sixth magnitude, and mostly within 25° of the zenith, the difference of zenith distances of the stars of a pair being usually less than $25'$ —averaging about $12'$.

The individual results of 92 pairs are exhibited in the following table, which includes, with two exceptions, all the observations made, whether in favorable or unfavorable states of the atmosphere. In a few cases where the B. A. C. differs widely from other catalogues, the B. A. C. results are enclosed in brackets [] and are omitted in computing the mean. That the fault is in the B. A. C., is obvious from the accordance of the corresponding results from other catalogues with the general average.

The contents of the table are as follows:

Col. 1 and 2. The numbers from the British Association Catalogue designating the stars of a pair.

3. The dates of the observations.

4. The mean results for latitude from each pair, using the positions of the B. A. C.; the seconds of the individual results, where the same pair was observed on different evenings, being placed at the left hand side of the column, and connected with their mean by a brace.

5. The differences, Δ , between these mean results of pairs and the mean of the whole.

6. The results for latitude from the same observations, the position of one or both the stars of the pair being taken from some other catalogue than the B. A. C.; the arrangement as in column 4.

7. The names of these other catalogues; G. standing for Greenwich Twelve Year Catalogue; B. that of the British Association; R. the catalogue in Radcliffe Observations for 1856; and A. the English Nautical Almanac. A. G., for example, signifies that the position of the first star of the pair is from the Nautical Almanac, and that of the other from the Twelve Year Catalogue; etc.

8. The differences between the results in column 6 and the mean of the whole.

Number of each Star in B. A. C.		Date of observation.	Lat. by B. A. C.		Δ	Lat. by other catalogues.	Name of catalogue.	Δ
			41° 18'			41° 18'		
121	164	1858, Nov. 8	43"·4 }	43"·7	+1·3	42"·3 }	42"·6	B. G. +0·2
"	"	" " 11	44 ·1 }			43 ·0 }		
155	219	" " 10		40·0	-2·4		39·8	G. B. -2·6
245	334	" " 11		42·1	-0·3		42·0	B. G. -0·4
267	314	" Dec. 16		45·3	+2·9		45·3	B. G. +2·9
334	487	" Nov. 10	42·1 }	42·5	+0·1	41·7 }	42·2	G. G. -0·2
"	"	" 11	43·0 }			42·7 }		
1083	1123	1859, Jan. 20		45·0	+2·6		43·0	R. G. +0·5
1175	1214	" " "		40·7	-1·7		42·1	B. R. -0·3
1313	1367	" " "		43·5	+1·1		42·0	R. R. -0·4
3523	3777	" Oct. 21		41·0	-1·4		40·2	A. A. -2·2
3742	3767	" May 6		42·6	+0·2		42·4	B. G. 0·0
3767	3809	" " "		42·6	+0·2		42·4	G. B. 0·0
3856	3913	" " "		41·8	-0·6		42·2	G. R. -0·2
3968	3995	" " "		40·8	-1·6		40·5	B. G. -1·9
4112	4151	" " "		43·9	+1·5		43·0	G. G. +0·5
4216	4240	" " "		42·7	+0·3			
4351	4371	" " "		42·8	+0·4			
4371	4406	" " "		42·9	+0·5		42·1	B. G. -0·3
4789	4823	" June 30		42·8	+0·4		45·2	G. R. +2·8
4980	5036	" " "		44·0	+1·6		43·9	G. R. +1·5
5131	5181	" July 5		41·5	-0·9			
5245	5285	" June 30	40·5 }	40·3	-2·1	41 0 }	40·8	R. A. -1·6
"	"	" July 5	40·1 }			40·6 }		
5285	5309	" June 30		40 9	-1·5		40·8	A. B. -1·6
5336	5388	" " "		43·1	+0·7		44·2	B. R. +1·8
5406	5490	" July 5		41·5	-0·9			
5417	5460	" " 6		40·7	-1·7			
5460	5523	" June 30		43·7	+1·3		42·8	B. G. +0·4

Number of each star in B. A. C.		Date of observation.	Lat. by B. A. C.		Δ	Lat. by other catalogues.	Name of catalogue.	Δ
5449	5604	1859, June 30	$41^{\circ} 18'$ $43^{\circ} 4'$	$43^{\circ} 7'$	+1.3	$41^{\circ} 18'$ $43^{\circ} 6'$	B. G.	+1.5
"	"	" July 5	$44^{\circ} 1'$	43.8	+1.4	$44^{\circ} 3'$	R. R.	+0.2
5525	5560	" " 6				42.6		
5643	5703	" June 30	40.7					
"	"	" July 5	41.9	41.5	-0.9			
"	"	" " 6	41.9					
5703	5752	" June 30		[47.2]	+ [4.8]	42.7	B. R.	+0.3
5747	5776	" July 5	40.8	40.2	-2.2	40.5	G. B.	-2.5
"	"	" " 6	39.5			39.2		
5776	5842	" " 5	41.4	41.9	-0.5			
"	"	" " 6	42.4					
5841	5887	" Aug. 16		40.5	-1.9			
5951	6021	" July 5		42.9	+0.5	42.4	G. A.	0.0
6033	6079	" Aug. 16	[56.1]			43.8		
"	"	" " 29	[57.2]	[56.7]	+ [14.3]	44.9	R. R.	+2.0
"	"	" Sept. 1	[56.7]			44.4		
6150	6185	" Aug. 29		42.3	-0.1	41.9	G. B.	-0.5
6162	6193	" Sept. 1		43.1	+0.7			
6178	6246	" Aug. 16		43.1	+0.7	41.7	G. G.	-0.7
6185	6238	" " 29		41.5	-0.9			
6223	6289	" Sept. 1	40.7	40.8	-1.6	41.5	G. G.	-0.8
"	"	" " 9	40.9			41.7		
6289	6322	" Aug. 29	43.0	43.5	+1.1	43.2	G. G.	+1.3
"	"	" Sept. 7	44.1			44.3		
6404	6473	" Aug. 16	41.2	41.2	-1.2			
"	"	" Sept. 9	41.2					
6427	6470	" Aug. 29		43.8	+1.4			
6520	6556	" " 16	43.6			41.9		
"	"	" " 29	45.4	44.4	+2.0	43.7	R. B.	+0.3
"	"	" Sept. 1	44.3			42.6		
6583	6637	" Aug. 16	42.4	43.6	+1.2	42.3	G. B.	+1.1
"	"	" Sept. 9	44.8			44.7		
6623	6648	" " 1	41.0			41.9		
"	"	" " 26	43.2	41.7	-0.7	44.0	G. G.	+0.2
"	"	" Oct. 4	41.0			41.9		
6662	6744	" Sept. 7		43.2	+0.8	43.7	G. B.	+1.3
6674	6712	" Aug. 29	[51.5]			43.7		
"	"	" Sept. 9	[50.1]	[50.8]	+ [8.4]	42.3	G. R.	+0.6
6690	6748	" Aug. 16	42.5	42.5	+0.1	42.0	G. B.	-0.4
"	"	" Sept. 26	42.5			42.0		
6709	6737	" " 1		41.6	-0.8			
6731	6765	" Oct. 4		44.5	+2.1			
6741	6784	" Aug. 29				43.8		
"	"	" Sept. 9	[38.5]	[37.8]	- [4.6]	42.3	R. R.	+0.6
6779	6849	" " 26	[37.0]	41.5	-0.9	42.2	G. B.	-0.2
6799	6851	" " 7	42.1	41.6	-0.6			
"	"	" Oct. 7	41.1					
6827	6867	" Aug. 29	43.2			43.4		
"	"	" Sept. 9	43.1	43.1	+0.7	43.3	B. R.	+0.9
"	"	" Oct. 3	43.4			43.5		
"	"	" " 4	42.8			42.9		
6858	6930	" Sept. 1	42.4	42.5	+0.1			
"	"	" Oct. 6	42.6					
6893	6936	" Sept. 7	42.7	42.7	+0.3	41.2	G. B.	-1.2
"	"	" " 26	42.6			41.2		
6926	6952	" Aug. 29	41.4	41.3	-1.1	41.6	G. B.	-0.9
"	"	" Oct. 4	41.2			41.4		
6932	6975	" " 3		42.7	+0.3	42.4	R. B.	0.0
6937	6965	" " 7		45.3	+2.9	43.2	G. G.	+0.8

Number of each star in B. A. C.		Date of observation.	Lat. by B. A. C.	Δ	Lat. by other catalogues.	Name of catalogue.	Δ
6965	6997	1859, Sept. 1	$41^{\circ} 18'$ $42^{\circ} 6'$		$41^{\circ} 18'$ $42^{\circ} 2'$		
"	"	" " 9	$44^{\circ} 0'$	$+1^{\circ} 1'$	$43^{\circ} 6'$	G. B.	$+0^{\circ} 7'$
"	"	" Oct. 7	$43^{\circ} 8'$		$43^{\circ} 4'$		
6959	7029	" Sept. 7	$45^{\circ} 4'$	$+3^{\circ} 0'$			
6963	7022	" " 26	$44^{\circ} 4'$	$+2^{\circ} 0'$	$44^{\circ} 6'$	B. G.	$+2^{\circ} 2'$
6996	7041	" Oct. 3	$40^{\circ} 8'$	$-1^{\circ} 6'$			
7037	7107	" Aug. 29	$40^{\circ} 9'$	$-1^{\circ} 5'$	$40^{\circ} 3'$	B. G.	$-2^{\circ} 1'$
7041	7114	" Oct. 3	$39^{\circ} 8'$	$-2^{\circ} 6'$			
7067	7153	" Sept. 7	$40^{\circ} 5'$	$-1^{\circ} 9'$			
7088	7124	" Oct. 4	$40^{\circ} 3'$	$-2^{\circ} 3'$	$39^{\circ} 8'$	G. B.	$-2^{\circ} 8'$
"	"	" " 7	$39^{\circ} 9'$		$39^{\circ} 4'$		
7119	7174	" Sept. 9	$40^{\circ} 7'$	$-1^{\circ} 7'$			
7246	7281	" " 7	$42^{\circ} 4'$	$+0^{\circ} 6'$	$42^{\circ} 5'$	B. G.	$+0^{\circ} 7'$
"	"	" " 9	$43^{\circ} 6'$		$43^{\circ} 7'$		
7253	7313	" " 26		$+0^{\circ} 3'$	$42^{\circ} 9'$	G. B.	$+0^{\circ} 5'$
7377	7437	" " 9	$43^{\circ} 1'$		$43^{\circ} 8'$		
"	"	" Oct. 4	$42^{\circ} 1'$	$+0^{\circ} 2'$	$42^{\circ} 7'$	G. B.	$+0^{\circ} 9'$
"	"	" " 7	$42^{\circ} 7'$		$43^{\circ} 4'$		
7437	7476	" Sept. 9	$42^{\circ} 0'$				
"	"	" Oct. 4	$42^{\circ} 7'$	$+0^{\circ} 2'$			
"	"	" " 7	$43^{\circ} 0'$				
7554	7593	" Sept. 26	$40^{\circ} 3'$				
"	"	" Oct. 3	$41^{\circ} 6'$	$-1^{\circ} 2'$			
"	"	" " 4	$42^{\circ} 5'$				
"	"	" " 7	$40^{\circ} 3'$				
7607	7642	'58, Nov. 22	$40^{\circ} 0'$	$-2^{\circ} 4'$	$40^{\circ} 8'$	B. R.	$-1^{\circ} 6'$
7627	7683	'59, Sept. 26	$41^{\circ} 4'$		$42^{\circ} 7'$		
"	"	" Oct. 3	$40^{\circ} 3'$	$-1^{\circ} 7'$	$41^{\circ} 5'$	A. B.	$-0^{\circ} 4'$
"	"	" " 4	$41^{\circ} 1'$		$42^{\circ} 4'$		
"	"	" " 7	$40^{\circ} 0'$		$41^{\circ} 3'$		
7627	7749	" Sept. 26	$40^{\circ} 0'$		$41^{\circ} 5'$		
"	"	" Oct. 3	$40^{\circ} 1'$	$-2^{\circ} 4'$	$41^{\circ} 6'$	A. G.	$-0^{\circ} 9'$
"	"	" " 4	$40^{\circ} 3'$		$41^{\circ} 7'$		
"	"	" " 7	$39^{\circ} 8'$		$41^{\circ} 2'$		
7699	7807	'58, Nov. 22	$40^{\circ} 1'$	$-2^{\circ} 3'$			
7777	7800	" " 18	$41^{\circ} 6'$		$41^{\circ} 5'$		
"	"	'59, Oct. 4	$43^{\circ} 1'$	$-0^{\circ} 2'$	$43^{\circ} 0'$	B. G.	$-0^{\circ} 3'$
"	"	" " 7	$42^{\circ} 0'$		$41^{\circ} 9'$		
7843	7888	'58, Nov. 18	$[49^{\circ} 0']$		$43^{\circ} 8'$		
"	"	" " 22	$[46^{\circ} 7']$	$+ [5^{\circ} 7']$	$41^{\circ} 5'$	R. G.	$+0^{\circ} 5'$
"	"	'59, Oct. 4	$[48^{\circ} 7']$		$43^{\circ} 5'$		
7856	7902	" Sept. 26	$41^{\circ} 7'$	$-0^{\circ} 7'$	$42^{\circ} 6'$	R. G.	$+0^{\circ} 2'$
7961	8032	'58, Nov. 18	$43^{\circ} 6'$	$+1^{\circ} 1'$	$42^{\circ} 7'$	B. G.	$+0^{\circ} 2'$
"	"	'59, Oct. 4	$43^{\circ} 4'$		$42^{\circ} 5'$		
7962	8023	" " 18	$43^{\circ} 1'$	$+0^{\circ} 7'$	$42^{\circ} 6'$	G. G.	$+0^{\circ} 2'$
7994	8023	" " 3	$43^{\circ} 9'$	$+1^{\circ} 1'$	$42^{\circ} 9'$	B. G.	$+0^{\circ} 1'$
"	"	" " 18	$43^{\circ} 1'$		$42^{\circ} 1'$		
7990	8169	'58, Nov. 8	$43^{\circ} 6'$	$+1^{\circ} 2'$	$43^{\circ} 4'$	G. A.	$+1^{\circ} 0'$
8079	8158	" " 18	$44^{\circ} 2'$	$+1^{\circ} 8'$	$42^{\circ} 9'$	B. R.	$+0^{\circ} 5'$
8177	8238	'59, Oct. 13	$43^{\circ} 0'$	$-0^{\circ} 1'$	$43^{\circ} 3'$	G. G.	$+0^{\circ} 3'$
"	"	" " 18	$41^{\circ} 6'$		$42^{\circ} 0'$		
8212	8237	'58, Nov. 18	$42^{\circ} 9'$	$+0^{\circ} 5'$	$43^{\circ} 4'$	G. G.	$+1^{\circ} 0'$
"	"	" " 22	$42^{\circ} 9'$		$43^{\circ} 4'$		
8282	8324	" " 18	$41^{\circ} 7'$	$-0^{\circ} 7'$			
8355	8	'59, Dec. 30	$45^{\circ} 5'$	$+3^{\circ} 1'$			
α Cyg.	61^1 Cyg.	" Oct. 3 to Nov. 25, 20 obs.	$42^{\circ} 7'$	$+0^{\circ} 3'$	$42^{\circ} 5'$	A. A.	$+0^{\circ} 1'$
γ Cep.	ω Pisc.	" Oct. 3 to Dec. 24, 21 obs.	$41^{\circ} 8'$	$+0^{\circ} 4'$	$41^{\circ} 7'$	A. A.	$-0^{\circ} 7'$

If we divide these 92 pairs into four sets of 23 each, as indicated in the table by the lines after Nos. 5336, 6623, and 7119, the mean of each set respectively, and of the whole, will be as follows: column 1, giving the number of the set; col. 2, the number of results of pairs in the set by B. A. C.; col. 3, the mean of these results; col. 4, the number of results of pairs by other catalogues; col. 5, the mean of these; col. 6, the number of results by both B. A. C. and other catalogues taken together; col. 7, the mean of the same; col. 8, the probable error, E , of this mean; col. 9, the probable error, E' , of a single result for latitude.

Set	By B. A. C.		By other Catalogues.		By both B. A. C. and others.		E.	E'.
	Prs.	Mean.	Prs.	Mean.	Num. of results.	Mean Lat.		
1	23	41° 18' 42''·46	20	41° 18' 42''·34	43	41° 18' 42''·40	± 0''·15	± 0''·97
2	21	42 ·35	14	42 ·60	35	42 ·45	± 0 ·14	± 0 ·82
3	21	42 ·32	14	42 ·36	35	42 ·34	± 0 ·17	± 1 ·02
4	22	42 ·35	18	42 ·53	40	42 ·43	± 0 ·12	± 0 ·76
All	87	41 18 42 ·37	66	41 18 42 ·45	153	41 18 42 ·41	± 0 ·07	± 0 ·88
	E	± 0 ·10		± 0 ·10		Mean of the whole.		
	E'	± 0 ·97		± 0 ·80				

We may regard 41° 18' 42''·41, then, as a close approximation to the latitude of the point in New Haven, where the observations were made, the probable error of this result, as given by the observations, being less than a tenth of a second. In taking the arithmetical mean of the results for the several pairs, we assume, of course, for each of these results equal weights—no discrimination having been attempted between errors of observation and of star-places, or between different catalogues. Such discrimination, however, in so large a number of independent pairs, would not have materially changed the result.

It will be seen, from the above table, that any one of the four sets would have given a latitude almost identical with the mean of the whole—in no case differing from it so much as a tenth of a second, or ten feet on the earth's surface. That this extremely close accordance, however, of results from sets composed of so few pairs, is in a measure accidental, may be inferred from the larger probable errors of these results as given in column E . Had there been three sets, instead of four, the differences would have been somewhat greater, though still not exceeding a few tenths of a second.

The probable error of a single result for latitude, as given in the last column, (about nine-tenths of a second on an average), includes, it will be understood, the accidental error of observation, (depending on observer, instrument, state of the atmosphere, etc.), together with the error of the stars' places, as given in the catalogues. The experience of the observers of the Coast

Survey with the zenith telescope, as stated by the superintendent, shows that usually the latter error very much exceeds the former, or that the catalogues are less reliable than the instruments. The same is apparent from our own results. While the probable error of a single result (including both error of observation and of catalogue) amounts, on an average to $\pm 0''.88$, the probable error of observation, as distinct from that of catalogue, is found by comparing the repetitions on the same pairs in our first table, to be only $\pm 0''.48$. A similar value of this error is given by a comparison of the longer series of repetitions on the last two pairs of that table (α and 61^1 Cygni, γ Cephei and ω Piscium) as given below. Twenty observations were taken of the former pair, and twenty-one of the latter. The star-places used are those of the English Nautical Almanac.

Date of Obs.	α Cygni and 61^1 Cygni.	Δ	Date of Obs.	γ Cephei and ω Piscium.	Δ
1859.			'58, Nov. 8	41° 18' 41''.2	-0''.5
Oct. 3	41° 18' 42''.9	+0''.4	11	41 .4	-0 .3
4	42 .0	-0 .5	'59, Oct. 15	42 .4	+0 .7
7	41 .9	-0 .7	18	42 .1	+0 .4
10	41 .9	-0 .7	21	41 .3	-0 .4
11	43 .7	+1 .2	27	43 .2	+1 .5
15	41 .8	-0 .8	29	40 .8	-0 .9
18	42 .7	+0 .2	Nov. 1	42 .0	+0 .3
21	42 .3	-0 .2	3	41 .4	-1 .3
23	42 .9	+0 .3	14	43 .3	+1 .6
25	42 .2	-0 .4	15	40 .6	+1 .1
28	43 .6	+1 .0	23	42 .4	+0 .6
29	42 .8	+0 .2	28	41 .7	0 .0
Nov. 2	42 .8	+0 .2	Dec. 8	43 .0	+1 .3
3	43 .4	+0 .9	10	40 .2	-1 .5
4	43 .0	+0 .5	12	41 .6	-0 .1
9	43 .2	+0 .7	15	41 .0	-0 .7
14	43 .0	+0 .4	16	41 .9	+0 .2
17	41 .7	-0 .9	21	41 .2	-0 .5
19	42 .0	-0 .6	23	41 .6	-0 .1
25	41 .3	-1 .2	24	41 .9	+0 .2
Mean	41 18 42.55	$\pm 0''.10$	Mean	41 18 41.73	$\pm 0''.12$
Prob. Er. of single result		+ 0 .47			$\pm 0 .55$

We have, then, for the probable accidental error of *observation*, from the repetitions on the same pairs in our first table, $\pm 0''.48$; from α and 61^1 Cygni, $\pm 0''.47$; from γ Cephei and ω Piscium, $0''.55$; from all these combined, $\pm 0''.50$. This compared with the average probable error of a single result for latitude, $\pm 0''.88$, in which it is included, gives for the probable error depending on the catalogues used, $\pm 0''.72$. The relative accuracy, therefore, of instrument and catalogues, in the present case, may be represented approximately by the ratio of 5 to 7. That the Twelve Year and other catalogues used are, on the whole, more accurate than that of the British Association, appears from the values of E' in the last line of the table on page 58; viz. $\pm 0''.97$ for B. A. C., and $\pm 0''.80$ for the other catalogues; although in the column for

the latter, as may be noticed, many of the positions for one of the stars of a pair, are also from B. A. C. If we separate from these values the probable error of observation, $\pm 0''.50$, before stated, we shall have for error depending on the catalogues, $\pm 0''.82$ for B. A. C., and $\pm 0''.63$ for the others. This result accords well with the remark of Prof. Bache, in a paper published in the 12th volume of the Proceedings of the American Association, that "the probable error of the result by a single pair of stars as depending on the catalogue errors of the stars' places, will range from $\pm 0''.60$ to $\pm 1''.00$."

In the same paper it is stated also, that "a probable error in observing of from $\pm 0''.25$ to $\pm 0''.80$ may be expected for one observation, according to the size and quality of the instrument and the ability of the observer." The average value of this error for some 300 pairs of stars, observed with the excellent instruments and by the experienced observers of the Coast Survey, is, according to the same paper, $\pm 0''.47$ —ranging from $\pm 0''.25$ to $\pm 1''.14$. The value of the corresponding quantity in our own results, is, as we have seen, $\pm 0''.50$, ranging from $\pm 0''.47$ to $\pm 0''.55$. A considerable portion of this is due, doubtless, to the want of sufficient sensitiveness in the alidade level of the instrument; the run of which, as before stated, is only one thirteenth of an inch for 5", smaller portions of the scale than this being measured by the eye. This level, we may remark, was intended originally only to be used in the ordinary way, in connection with the graduated circle, and is sufficiently sensitive for that purpose; but not enough so to correspond, in point of accuracy, with the micrometer,* or for the delicacy required in observations for latitude with the zenith telescope. The use of the instrument for such observations was wholly an after thought, and no change was made to adapt it to its new functions. It is of smaller size also than the zenith telescopes of the Coast Survey, and it may be proper to add, that, being of the observer's own make, and a first attempt of the kind, some allowance is due in a comparison of its results with those of more finished instruments in the hands of trained observers.

In order to compare the latitude, thus determined astronomically, with the geodetical determination of the Coast Survey, a survey was made with theodolite and chain connecting the writer's observatory with three points in the city, the positions of which are given in the Coast Survey Report for 1851, viz., "Brewster's Factory Cupola" at the foot of Wooster street, "Episcopal church," which means the west spire of St. Paul's,

* Sixty successive bisections of Polaris, near culmination, with the micrometer wire, gave for probable error of a single bisection, $\pm 0''.30$; which would make the probable error of a single result for latitude (involving two bisections) as depending on the micrometer alone, $\pm 0''.21$.

and "College Spire," which is that of the Lyceum, or middle spire. The results are as follows.

	Lat. by Talcott's method.	By Coast Survey.	Diff.
Observatory of the writer,	41° 18' 42''·41		
Factory Cupola, East Street,	3·29	41° 18' 7''·10	3''·81
St. Paul's Church, W. Spire,	7·52	11·32	3·80
College Observatory, (Athen. Tower),...	22·36		
"College Spire," (Lyceum),	23·90	27·74	3·84
Chapel Spire,	25·49		

Mean excess of geodetic over astronomical lat. 3''·82.

It may be added that a series of observations made in 1850, with an excellent Pistor and Martins' Patent Sextant, on northern and southern stars, and also a series of observations made in 1858, in the usual way, with the circle of the Transit instrument before described, on Polaris and other stars, both direct and by reflection, and in reversed positions of the instrument, gave results differing but about half a second from the above determinations, the former minus, the latter plus.

The differences among results for latitude, depending on differences of catalogues, are often considerable, even when the best authorities only are trusted; as will be seen by comparing the mean results, given below, of the observations on α and 61^1 Cygni, and γ Cephei and ω Piscium, according as the declinations are taken from the several catalogues named.

	α and 61^1 Cygni.	γ Cephei, ω Piscium.
English Nautical Almanac,	41° 18' 42''·5	41° 18' 41''·7
Twelve Year Catalogue,	42·6	41·4
B. A. C.,	42·7	41·8
Greenwich, 1850,	42·8	41·6
Washington, 1845-1850,	42·7	
Radcliffe, 1856, '57,	41·9	40·3
Bradley,		40·7
Piazzi,		41·1
Argelander,		41·8
Mädler,		41·4

It will be noticed, also, in respect to these two pairs, that there is a greater difference between their respective mean results, than we should expect from well determined nautical almanac stars. This difference between the means of the twenty and twenty one observations respectively on the two pairs, using the nautical almanac declinations, amounts to 0''·8, an amount difficult to attribute to any errors of instrument or of observation, and equally difficult, perhaps, to ascribe to errors of stars' places, especially as the several catalogues so well agree with each other. From whatever source it may arise, it seems to be constant, and will receive further investigation.