

Teleskoppraktikum

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Abstract

Contents

0.1	Imaging of open clusters	3
0.1.1	Determination of cluster membership using Gaia	3
0.1.1.1	M34	5
0.1.1.2	Teutsch 55	12
0.1.1.3	Stock 19 (C0001+557)	19
1	References	26

0.1 Imaging of open clusters

0.1.1 Determination of cluster membership using Gaia

In order to determine the membership of the imaged stars to a cluster, we followed the following procedure shown in the flowchart (figure 1). It and the followed procedure will be quickly summerized in the following:

1. We make as many light sources visible as possible. It turned out that the red filter was in every case the filter with the most sources visible; blue was always the worst one.
2. Check if the light source of our observation is also visible in the the Digitized Sky Survey (DSS2) on Aladin [?].
3. If it is visible on both images, put a number on this star (cf. 2 and 3).
4. Use Aladin in order to find the corresponding Gaia DR2 source IDs (SIDs) to those stars. However, if there were multiple sources very close to each other, this source was not used.
5. Insert those SIDs in the ESA Gaia archive ([?], [?]).
6. Extract valuable properties like: right ascension, declination, the proper motion in those directions, the Gaia magnitude, the parallax and the errors of those values.
7. Using the position and magnitude of every light source we can reconstruct our observation image (cf. 4). The proper motion can also be illustrated by arrows originating from the corresponding star.
8. Now we can take a look at the distribution of distances and proper motions using a histogram (cf. 5). We can exclude outliers in distance and the proper motions using an iterative three sigma clipping procedure. Meaning, we removed all stars outside the three sigma regime with respect to the median. This eliminated outliers with high or low distances or proper motions. This clipping was repeated until nothing was 'clipable' anymore. Notice that having the right distance is not enough; you also need the right proper motion. Using an gaussian fit on the remaining stars, which will be called cluster members (CMs) from here on, gives us our guess for the distance and the proper motion of this cluster.
9. As an independent check we also have a look at the radial velocities of our CMs (cf. 6). We expect to not see CMs as outliers here.
10. As additional information, we also provide a histogram of our extracted sources and our CMs.
11. Followed by a new reconstruction of our observation just containing the CMs (cf. 9).
12. Finally we show the distribution of proper motions including the proper motion of the cluster extracted from the gaussian fit.

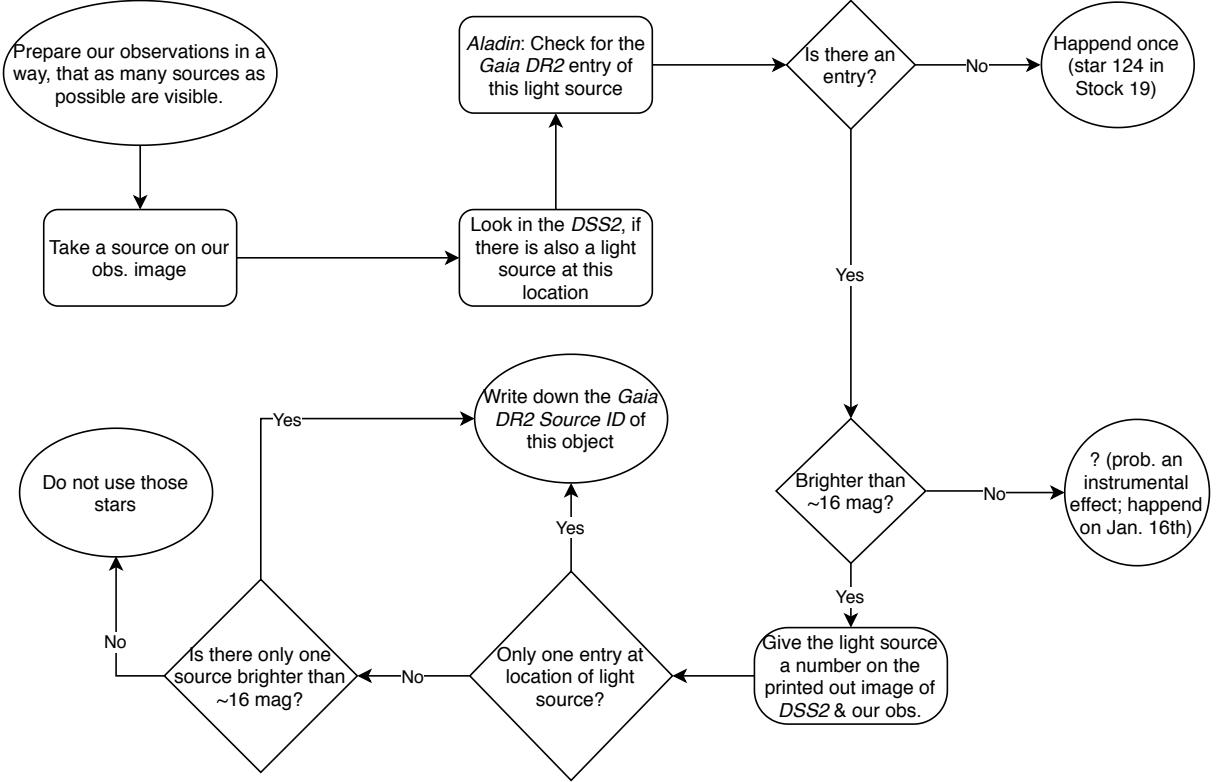


Figure 1: This flowchart summarized the procedure, which was used in order to extract the sources from our observation.

Table 1: **Num. stars:** Number of extracted sources from our observations for every cluster. **Not used:** Number of sources not used, because the existence of two or more *Gaia DR2* entries very closeby. **Two parameter sol.:** Some stars are missing the full five parameter solution (position on the sky in RA and Dec, proper motions and parallax), but only have a two parameter sol. (RA and Dec). **Neg. parallax:** Stars with negative parallaxes were excluded from the analysis. **Analysed stars:** The final number of analysed stars. **RV stars:** Only a small number of stars also had a radial velocity value.

	M34	Teutsch 55	Stock 19
Obs. date	Jan. 16 th	Jan. 16 th	Jan. 22 nd
Filter	R	R	R
Exposure time (s)	150	300	200
Num. stars	195	191	208
No Gaia DR2 entry	0	0	1
Not used	6	5	0
Two parameter sol.	3	3	2
Neg. parallax	2	0	2
Analysed stars	185	184	203
RV stars	28	33	37

In the appendix one finds the Gaia Source IDs of all extracted stars.

0.1.1.1 M34

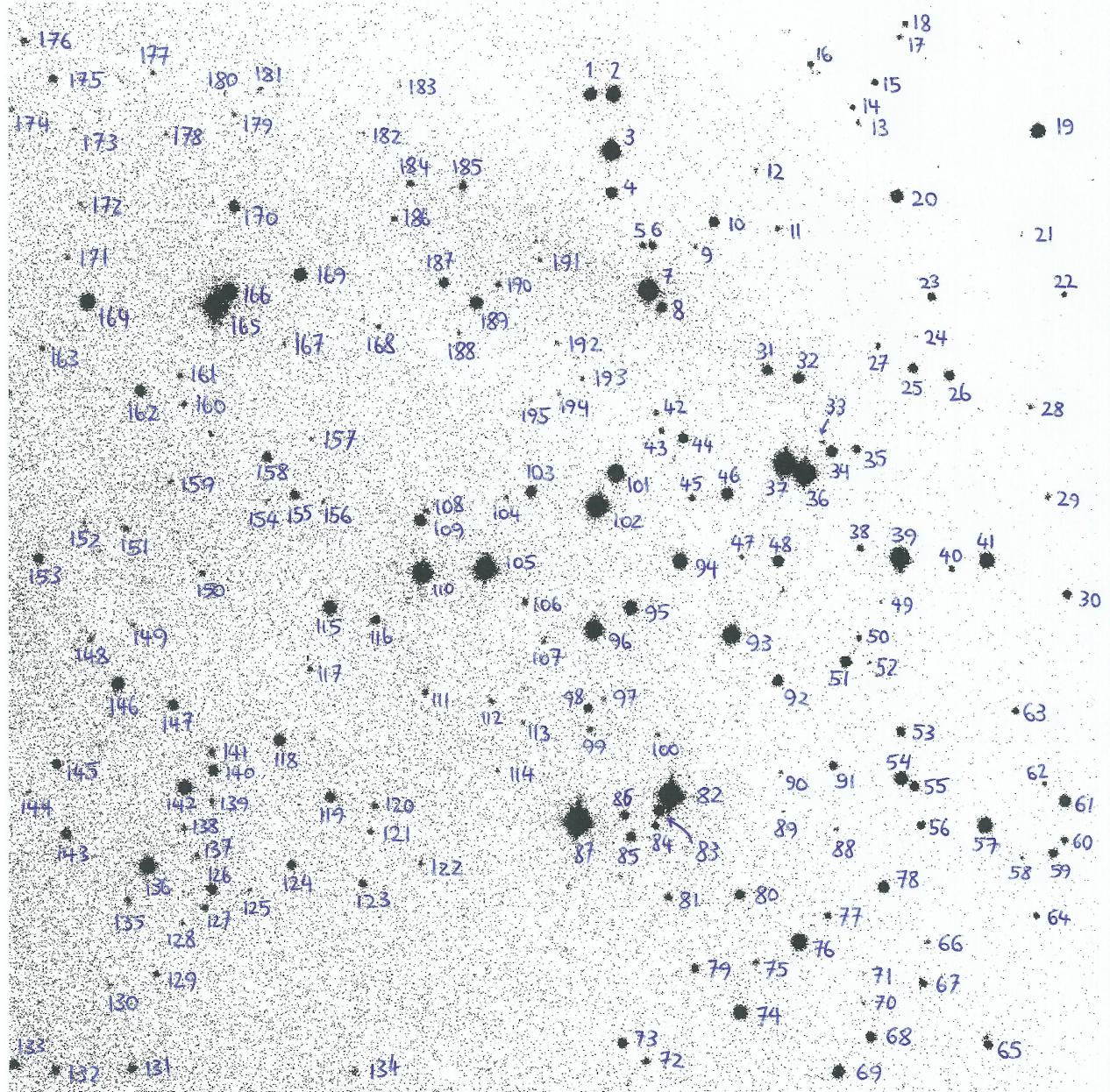


Figure 2: Our observation of M34 in the red filter with an exposure time of 150 seconds. The numbers are in correspondence with those in image 3.

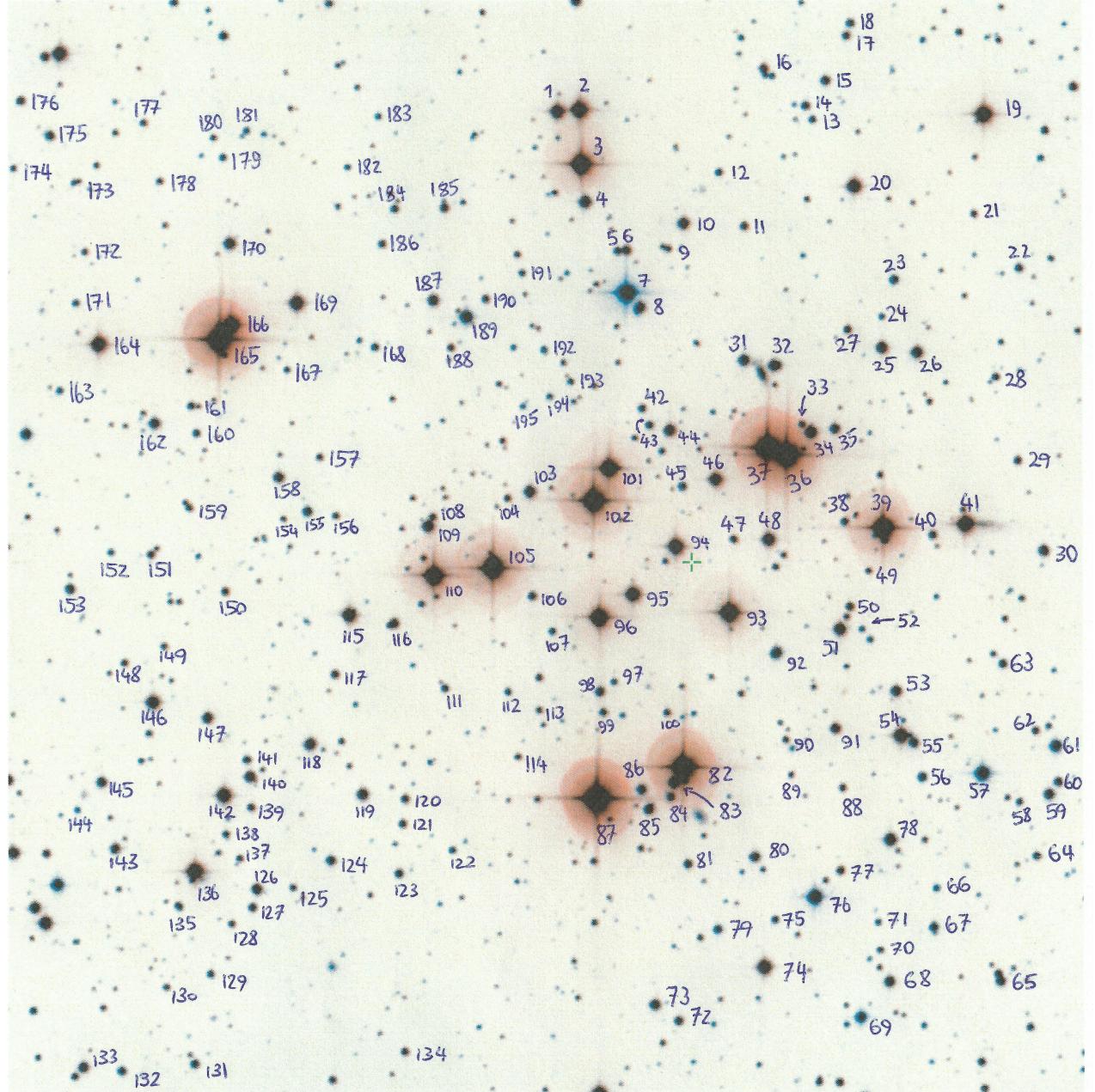


Figure 3: The negative of the observation of M34 by the DSS2. This picture was extracted from *Aladin*. The numbers are in correspondence with those in image 2.

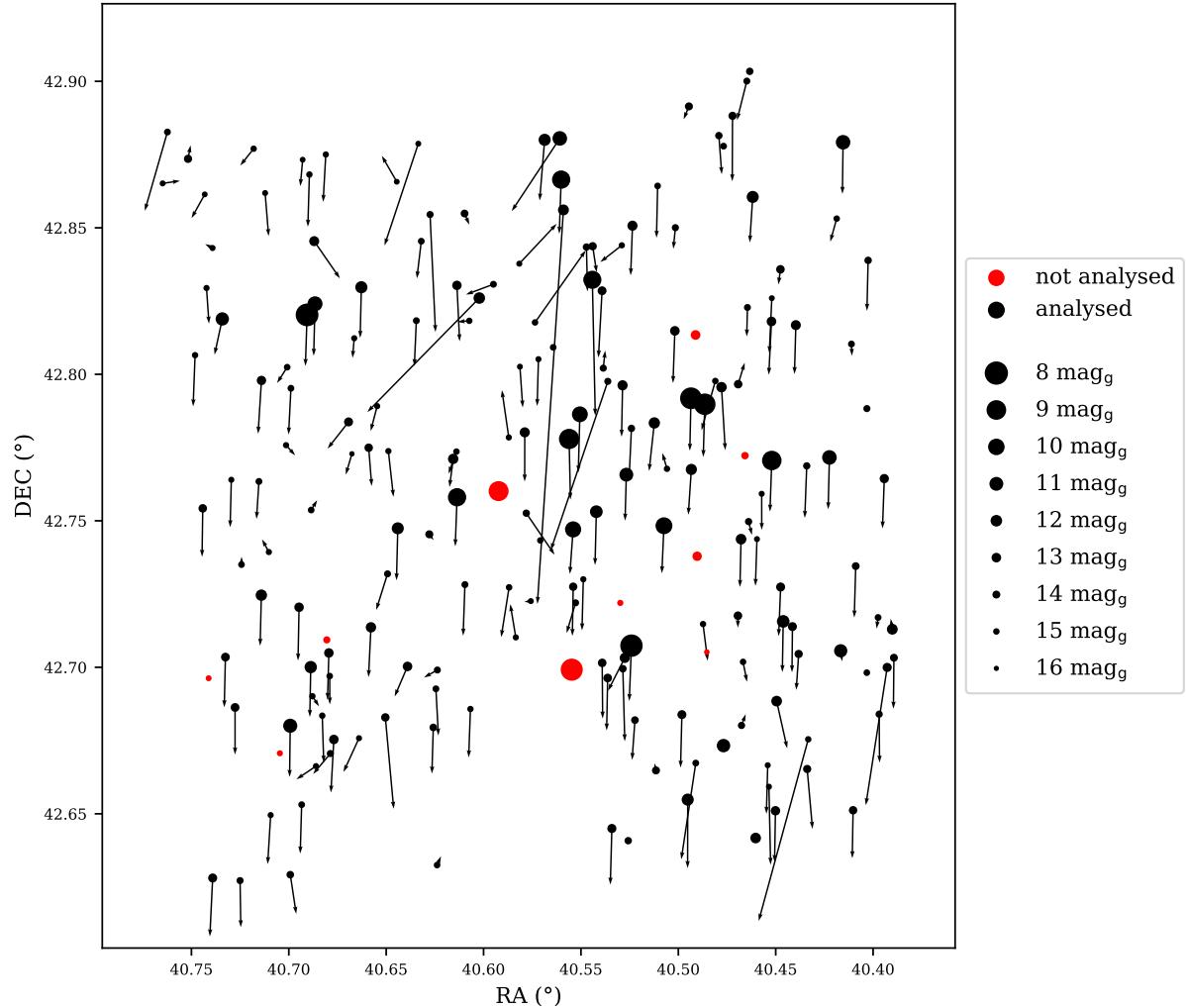


Figure 4: Every point is an extracted source. The size corresponds to the Gaia magnitude. The arrows illustrate the direction of the proper motion. A star was for example not analysed if the proper motions were missing.

Figure 4 already illustrates that most stars are moving in the negative declination direction. One can also see some high proper motion stars.

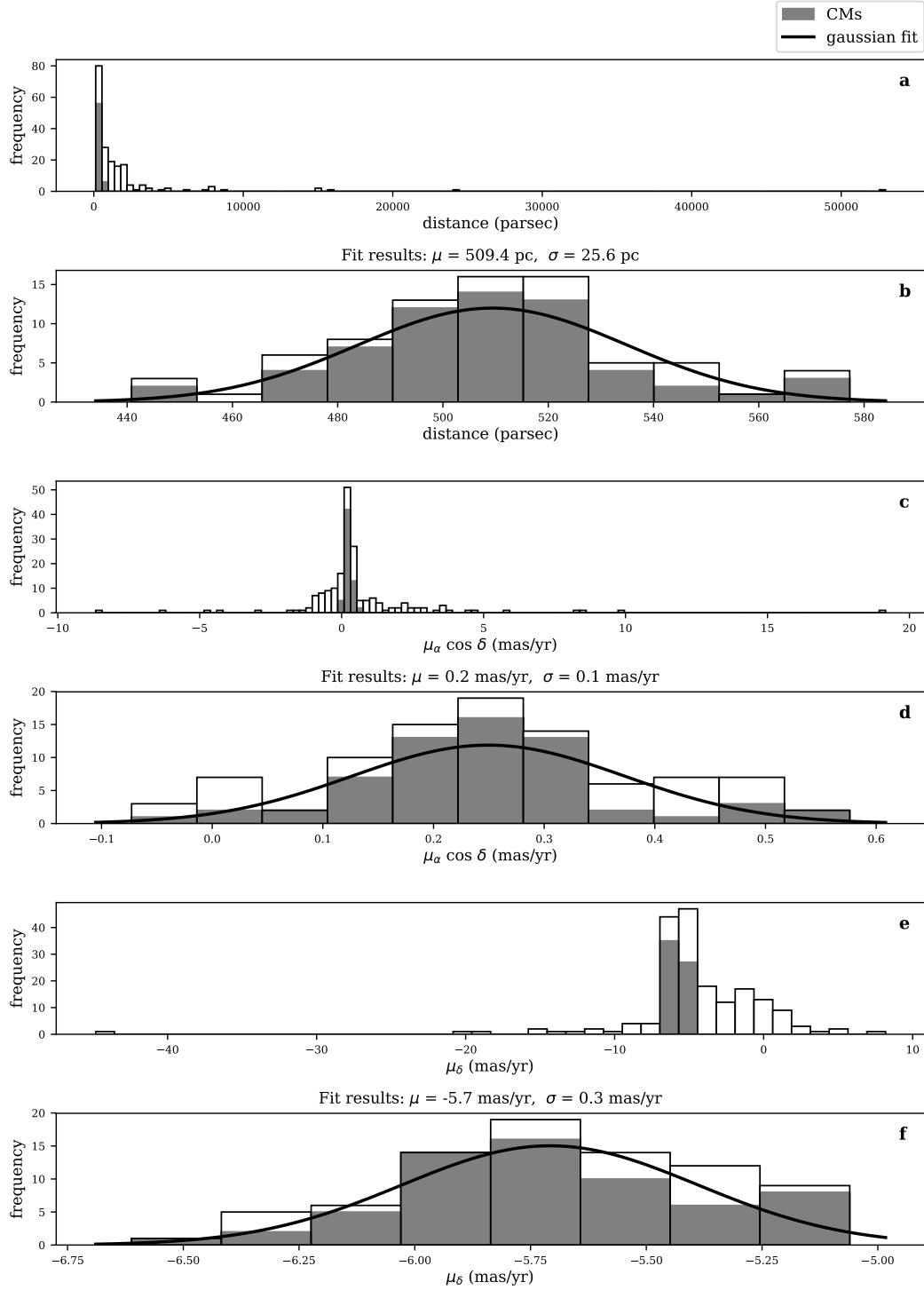


Figure 5: Histogram of the analysed stars. In order to determine the Cluster members (CMs) an iterative sigma clipping procedure was applied (see beginning of 0.1.1). **a, c, e:** The distances and proper motions for all stars and the CMs (in gray). **b, d, f:** This zoom-in also includes a gaussian fit of the CMs. Above those plots the mean and sigma of this gaussian.

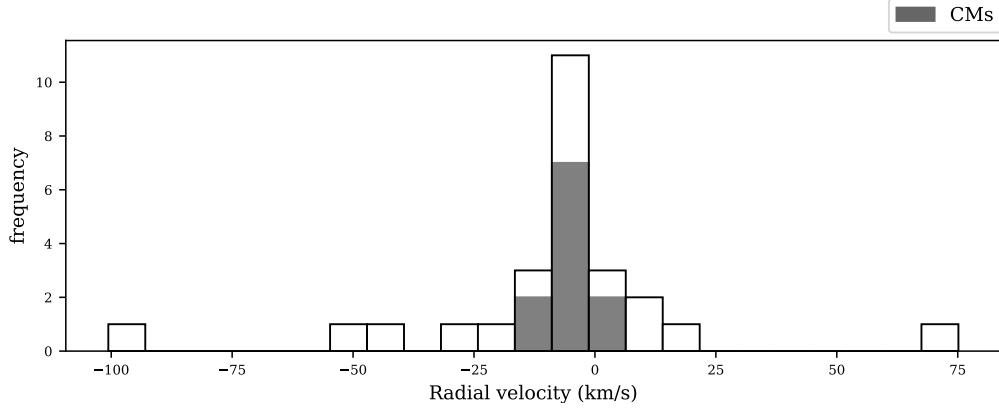


Figure 6: An histogram of the radial velocities. In gray our cluster members determined with figure 5. We see that none of the outliers are also CMs. This is what we would expect.

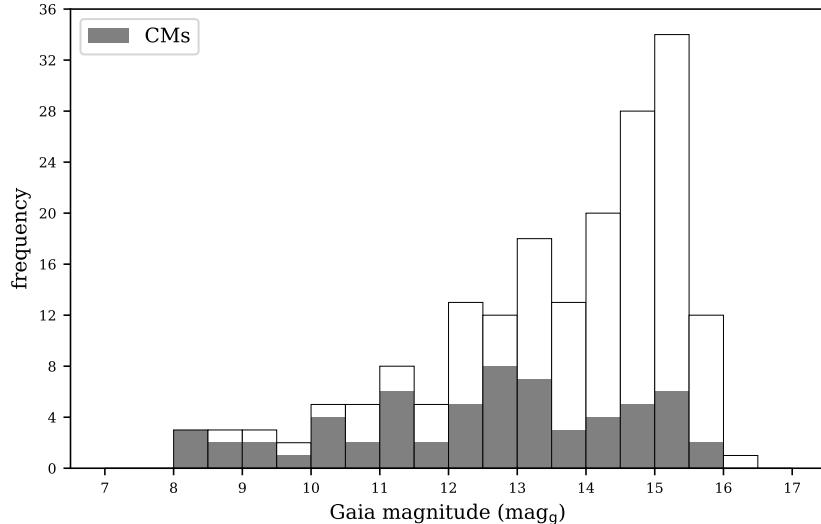


Figure 7: The distribution of Gaia magnitudes of the analysed stars.

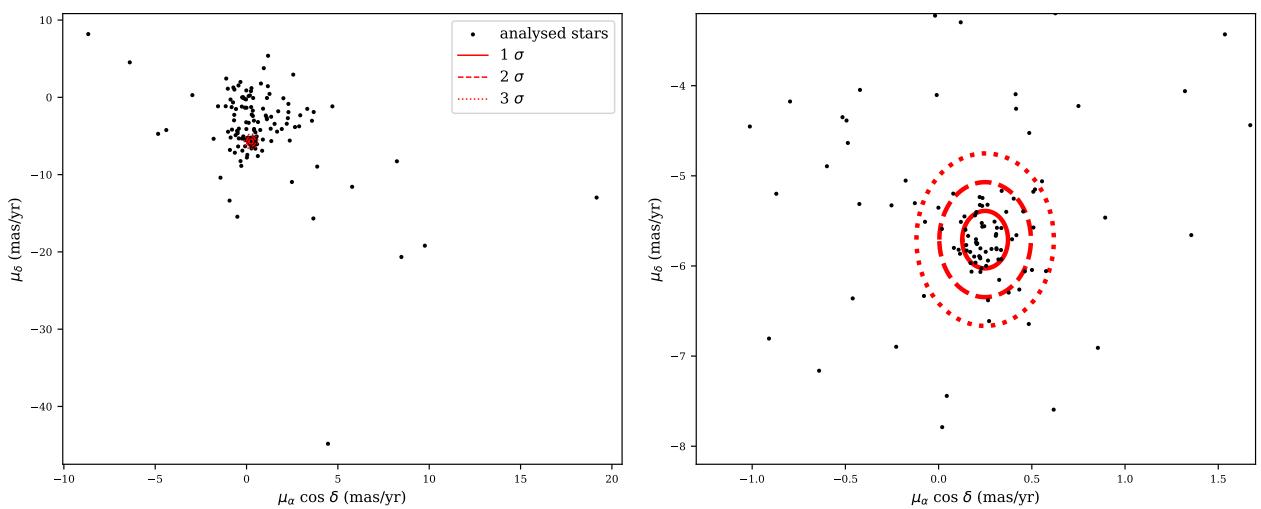


Figure 8: The proper motions of all analysed stars including the proper motion of the cluster (red) extracted in figure 5. The right side is a zoom-in of the left side.

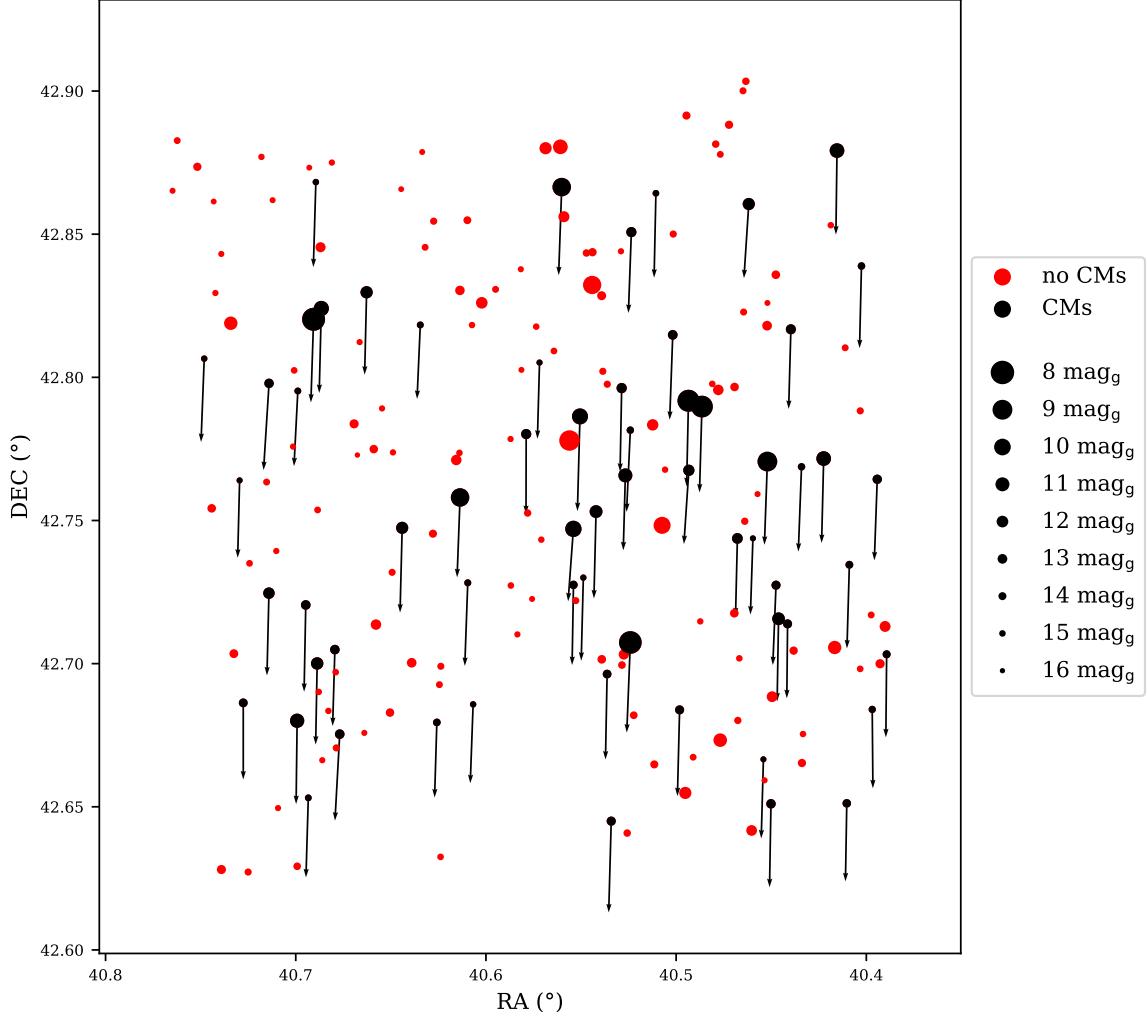


Figure 9: Similar to figure 4 yet just including our cluster members (CMs).

Those last few plots clearly shows us that those stars really make us a cluster. Our cluster distance of (509 ± 26) pc agrees with the literature value of 513 pc. We want to bring up that SIMBAD incorrectly classifies some stars as member stars of M34. E.g. *Gaia DR2 337177889338182400*¹ - this star has an distance of (126 ± 1) pc according to *Gaia*. This would be about 400 parsec away from the core of the cluster.

Table 2: All *Gaia Source IDs* of our identified cluster members (CMs) of M34.

337189979669777024	337165657269539712	337151604138401024	337176446229194752	337173663090374272
337189640368700416	337154215478462720	337151707217611520	337176240070775424	337174006687749504
337189842231829632	337154146758992000	337152153894211712	337176377509719424	337175415437021824
337167370961929600	337154073743193088	337153184686353280	337149783072247424	337175346717538304
337167066020594304	337153631361117952	337153322125297408	337149748712509440	337178439093990656
337167169099820416	337165378097895424	337152561914712320	337172975895643648	337178503517166208
337166134011354624	337165275017903744	337154112399259008	337172112606444672	337177167783677056
337165584255547008	337153493924213888	337153837521355520	337172323060610944	337177236503146624
337165966508978688	337153493923993344	337153837521356928	337173147694323968	337178851410839040
337165829070036608	337163698766294784	337152978527902592	337173078974848000	337177545740806656
337165932149250176	337164038067322368	337153081607118080	337172288701093632	
337165481176331008	337163630046824064	337177408301862784	337173525651437568	
337165652975852160	337151840360210688	337177373942124672	337173113334580224	

¹<http://simbad.u-strasbg.fr/simbad/sim-basic?Ident=Gaia+DR2+337177889338182400&submit=SIMBAD+search>

Table 3: *Gaia Source IDs* of the non CMs of M34.

337190014029514240	337177614460287360	337152566211055744	337172219981402496	337175552875962368
337190018325811456	337177614460290048	337152944168176640	337171945103720832	337175651659849856
337177850682133760	337154181118730752	337153425204519040	337171910743987968	337176033912291456
337177820618702848	337154078039521536	337153356485035904	337171876382612992	337176063976748160
337189571649224832	337165416753189760	337153459564251520	337124936685069824	337176068272026368
337177820618707712	337165382393453056	337153974960313344	337149302035925248	337176171351238656
337177717539493504	337152012158896256	337152978527905664	337172975895640064	337178679612144128
337189567352918400	337163733124237824	337177404005543552	337173078974851584	337178640957119744
337189743447917696	337163698766295808	337176618028304128	337173078974849664	337178847115567360
337190568081631488	337163698766295936	337176583668152448	337172662361656320	337178920130314112
337190568081630464	337164003707585920	337153115966851328	337173525651433344	337179538605845248
337190563785327232	337164008003935744	337176652387618432	337173525651432832	337179607325083520
337190666871477760	337151913376040704	337176648091300736	337173800529335680	337178026777124736
337190632505871744	337151810296828288	337152841089175168	337173697450114176	337178091200302592
337190636801101312	337151638498142464	337153012887641600	337172907176365824	337178022481798912
337167203459553280	337151702921857536	337152806729441664	337176824184478080	337177923697917696
337167031660864640	337152119534475136	337176377509721088	337176789826567424	337177889338184576
337166172667408512	337152394412380032	337173422572224768	337176785531080576	337177889338182400
337166172667412096	337153150326620928	337173353852753280	337176892905777536	337177958057657344
337166207027147136	337153146030266752	337173216413805312	337176824186301440	337178159920736128
337166516264801920	337153219046094464	337149817431979264	337173903608540800	337177541445409664
337166378825857664	337151943439422208	337149817431981568	337174006687747968	337177545740805504
337165897789510528	337152424475762432	337173005959042432	337175552875965824	337177472725904512
337165893493188096	337152531851323776	337172941535906432	337176995984984960	
337165897789512064	337152566211055104	337172219981401856	337178537876901888	

0.1.1.2 Teutsch 55

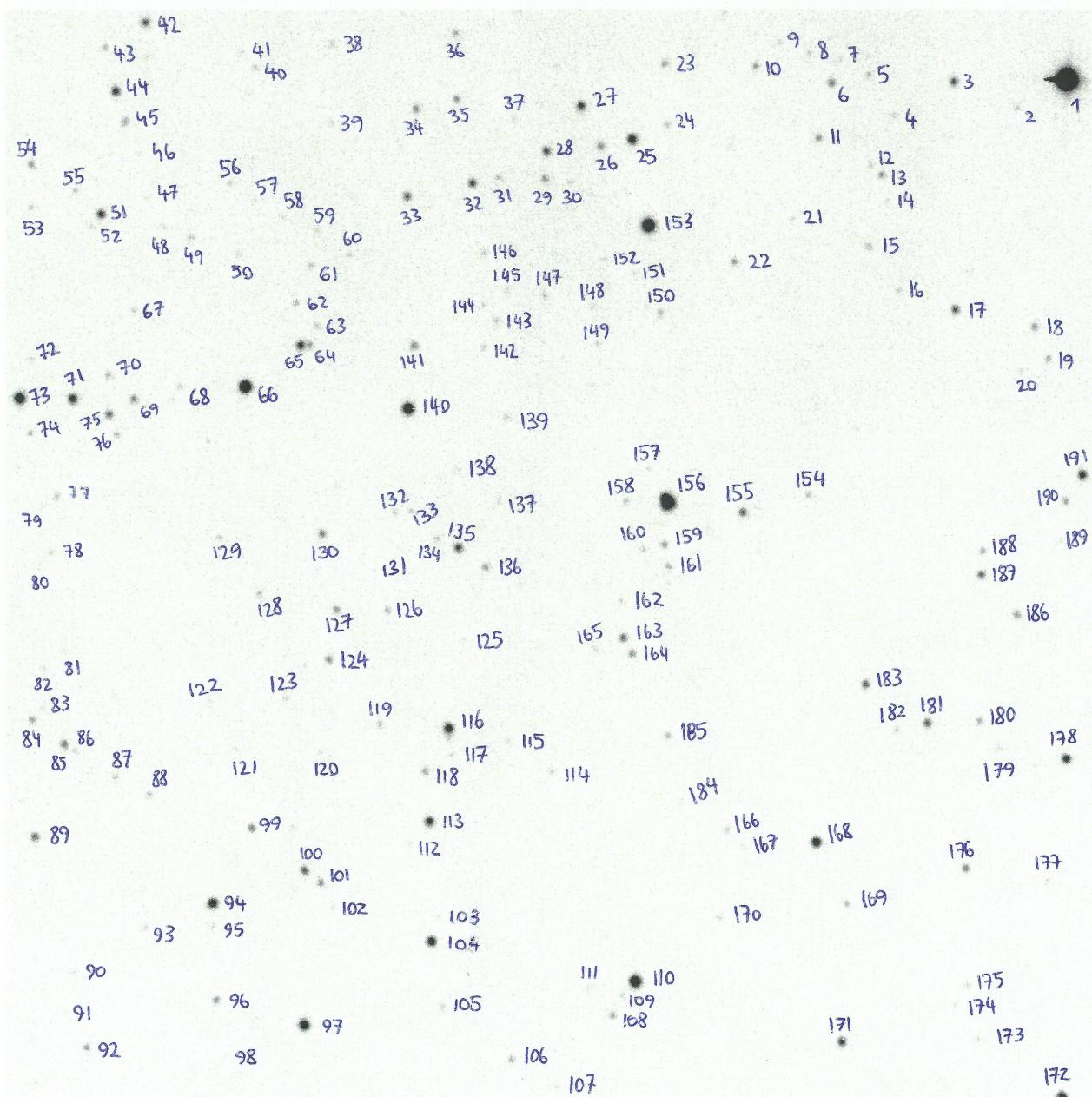


Figure 10: Our observation of Teutsch 55 in the red filter with an exposure time of 300 seconds. The numbers are in correspondence with those in image 11.

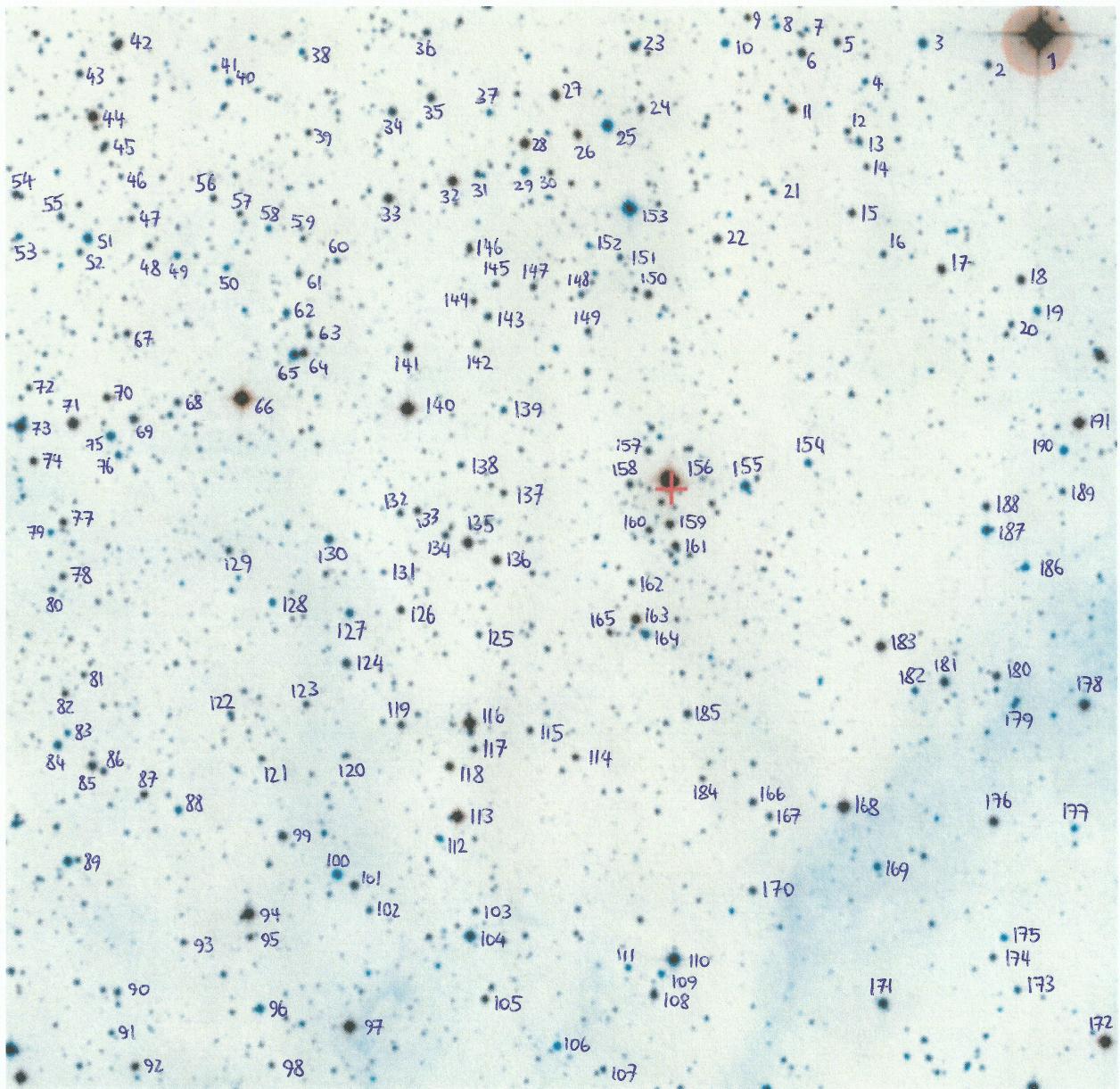


Figure 11: The negative of the observation of Teutsch 55 by the DSS2. This picture was extracted from *Aladin*. The numbers are in correspondence with those in image 10.

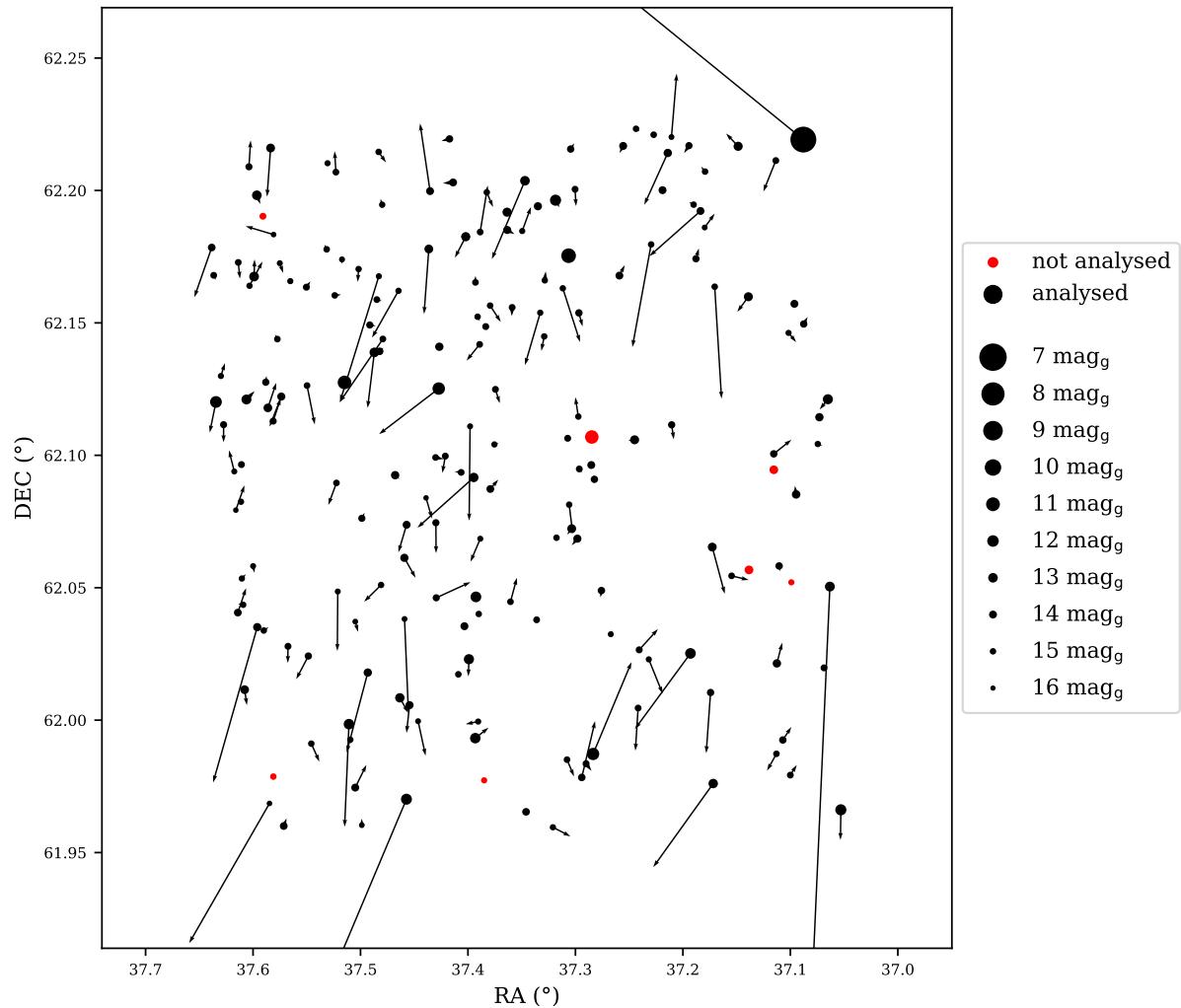


Figure 12: Every point is an extracted source. The size corresponds to the Gaia magnitude. The arrows illustrate the direction of the proper motion. A star was for example not analysed if the proper motions were missing.

Notice the high proper motion stars in figure 12.

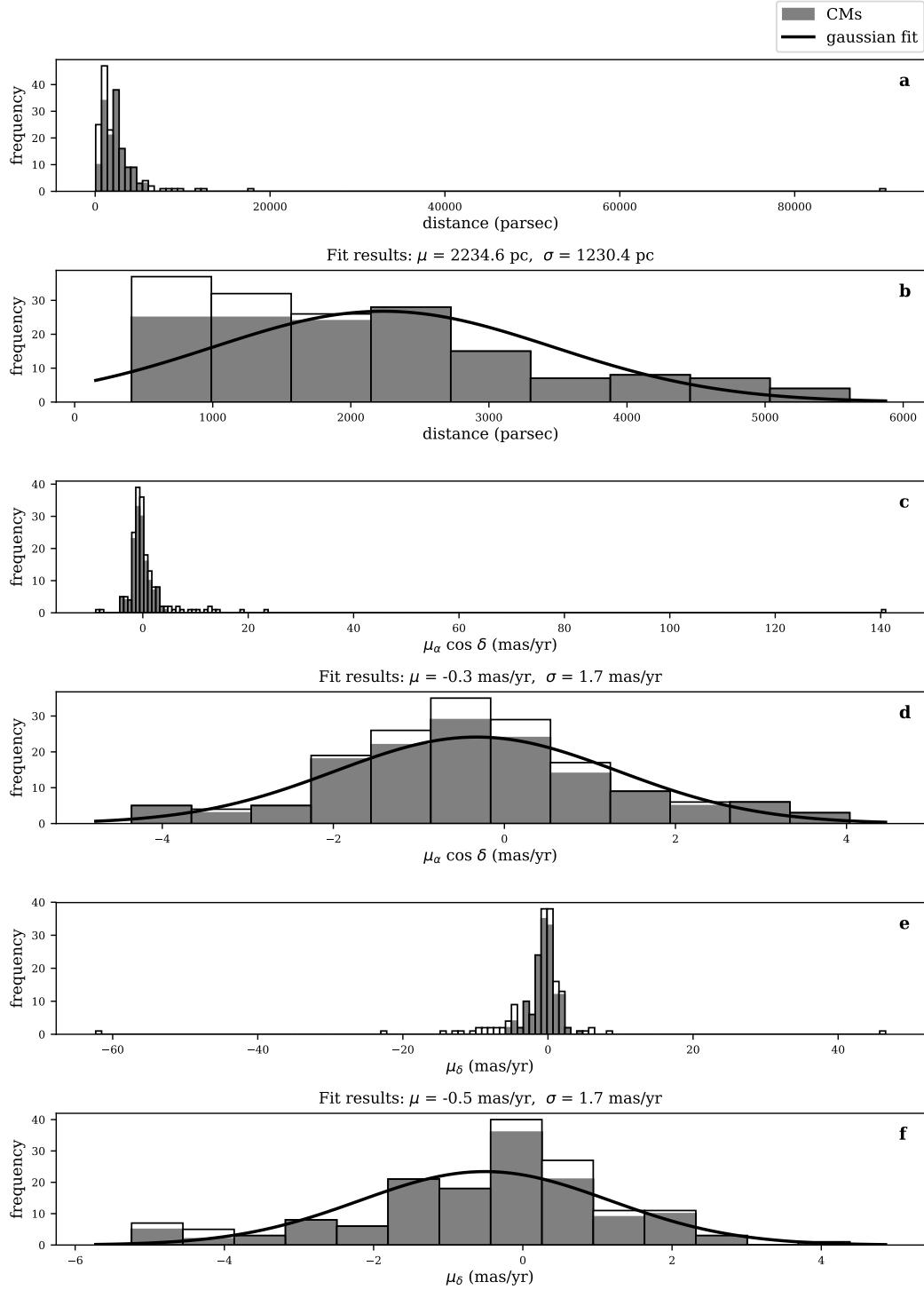


Figure 13: Histogram of the analysed stars. In order to determine the Cluster members (CMs) an iterative sigma clipping procedure was applied (see beginning of 0.1.1). **a, c, e:** The distances and proper motions for all stars and the CMs (in gray). **b, d, f:** This zoom-in also includes a gaussian fit of the CMs. Above those plots the mean and sigma of this gaussian.

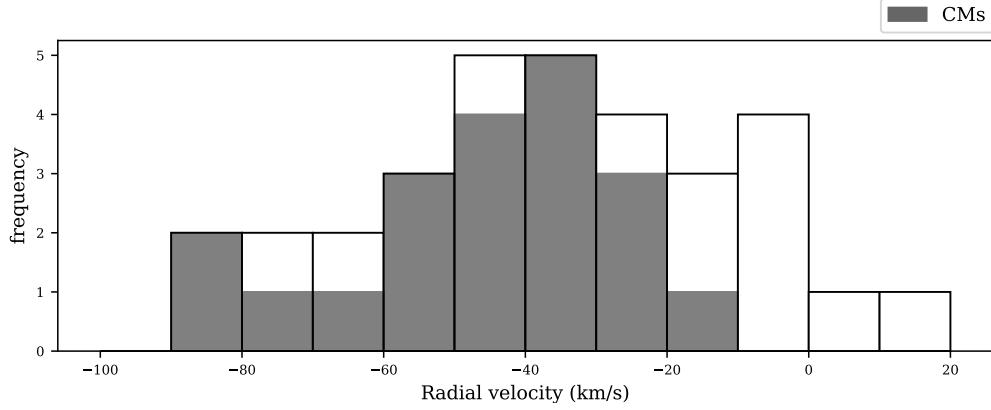


Figure 14: An histogram of the radial velocities. In gray our cluster members determined with figure 13. We see that non of the outliers are also CMs. This is what we would expect.

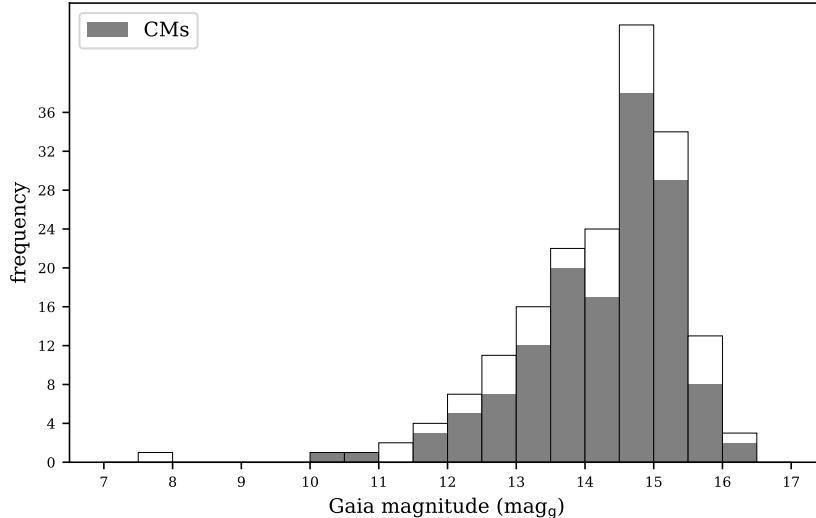


Figure 15: The distribution of Gaia magnitudes of the analysed stars.

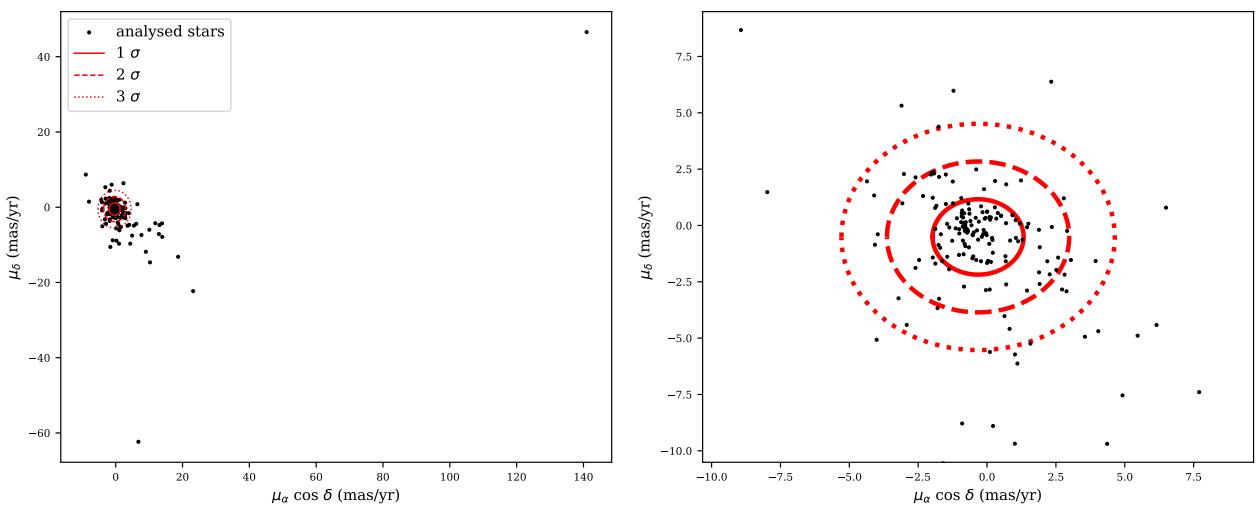


Figure 16: The proper motions of all analysed stars including the proper motion of the cluster (red) extracted in figure 13. The right side is a zoom-in of the left side.

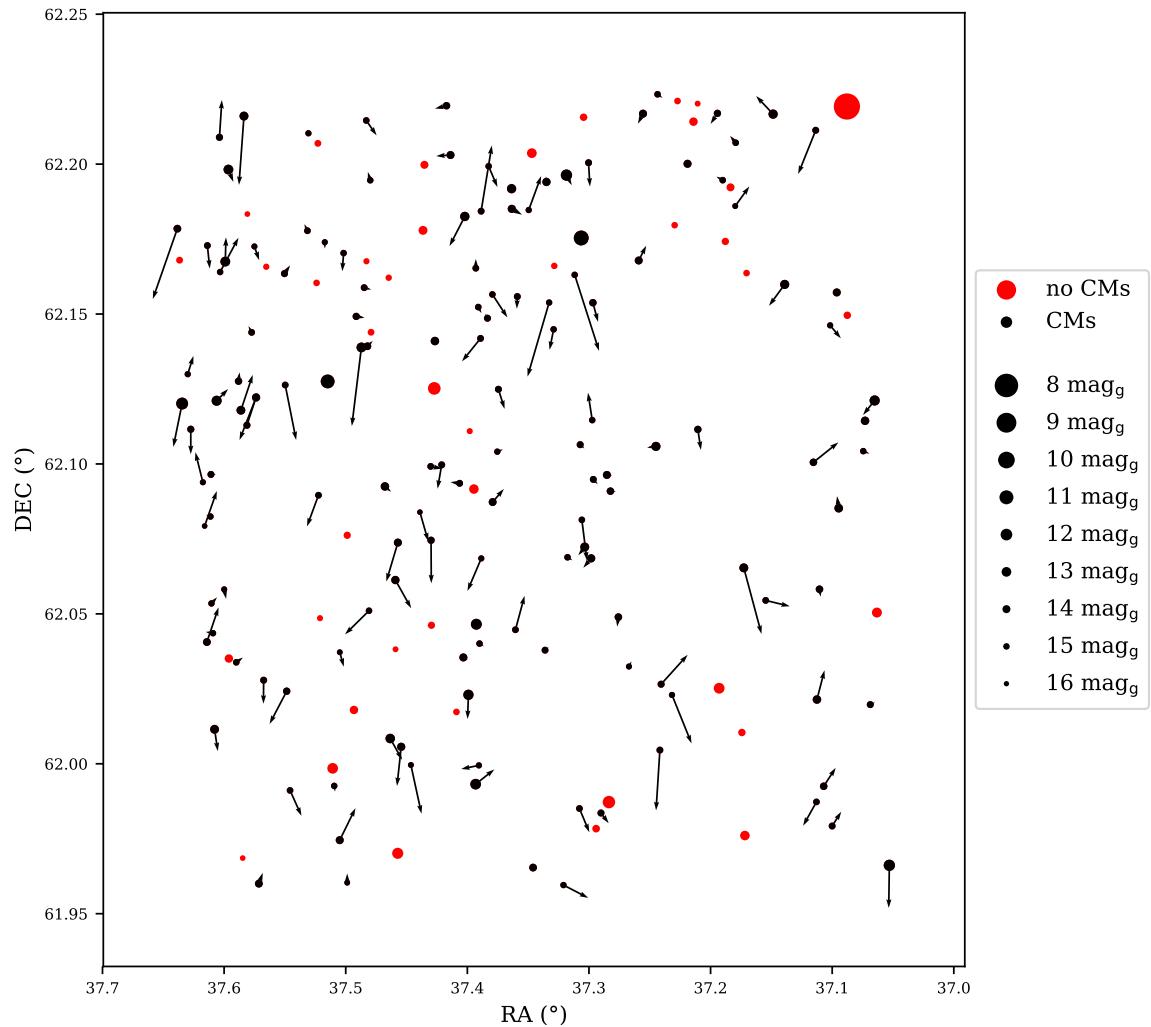


Figure 17: Similar to figure 12 yet just including our cluster members (CMs).

In contrast to figure 9 we do not see, that those stars are moving as a group in one direction. We also see this very broad distribution in distances and proper motions in figure 13. So we cannot really confirm this cluster.

Table 4: All *Gaia Source IDs* of our identified cluster members (CMs) of Teutsch 55.

513620643419170048	513991522438846080	513603356171236864	513603188672284544	513616039214263808
513620471620472576	513991041402525952	513602604556727168	513603257391604352	513614561745676160
513620402900999680	513991007042793856	513602604556729856	513615145861079808	513614561745520896
513620505980209280	513979320431655168	513602600256983168	513614974062383360	513614527385939584
513620162382821376	513979324731745408	513602570196995840	513615008422120832	513614458666310784
513620093663346560	513979702688856704	513602192239875712	513603704068348800	513614458666314624
513619750065972608	513979324731738624	513602913794383360	513615042781850112	513614458666316800
513619646986761600	513991213200956800	513602119220208384	513615077141594880	513613702752071168
513619612627027200	513991208901147648	513601745563300096	513615317659755776	513613908910524288
513618100798551680	513991178841219200	513602020441196416	513615283300017536	513613904611707648
513618822353389184	513615867415543552	513602776355441024	513615283300021760	513613049917218560
513618719273849216	513615867415546624	513600508612716032	513615180220811264	513607655438172544
513619372108862720	513615833055812864	513600508612723200	513615248940279936	513607999035549056
513619887504920576	513615622598206336	513601367606164864	513616107933729664	513608033395284480
513619814486284416	513615558173884544	513601573764596096	513615798696076544	513608033395282304
513616898207875200	513979187292805760	513601539400829568	513616520250583680	513608205193962752
513616898207683584	513603841507296768	513601505044977920	513616588970057344	513611052753420160
513616829488210688	513979152933080192	513601466386006016	513616520250578944	513617134427177216
513616898207688576	513979084213598720	513601058368394752	513616588970054272	513614149428684288
513616932567425024	513979084213601792	513612706319704320	513616623329788928	513614252507894016
513616726408994944	513979015494118784	513612775039173760	513616588970055552	513613938971458176
513616966927154560	513978912414908416	513612878118387456	513616417171365632	513614321227373184
513992278352841600	513978912414914560	513613359154704128	513616382811631488	513617379244080640
513616928269018368	513979084213604992	513613530953392896	513616451531105920	513617482323287552
513992140913887360	513603772787821056	513613427874173440	513616485890839552	513617447963853184
513992037834676096	513603566629392128	513613457934694272	513619440828334464	513618306957312512
513991419359381376	513603497909917952	513613462233912576	513617654121970176	513618306957002368
513991762957004416	513603497909915776	513613393514437120	513614802263686912	
513991556798575616	513603497909918720	513602982513857024	513616245372852736	

Table 5: *Gaia Source IDs* of the non CMs of Teutsch 55.

513619234669893120	513619917573669120	513615936135015552	513612981197602688	513616485890837504
513619784425703936	513616996987737216	513615936135019776	513601608124185216	513613870251555328
513620540339946112	513616692049256832	513615833055811072	513614870983181696	513607964675796864
513619784425700992	513992067894589056	513602565896806656	513603119952661248	513607861596594176
513619646986763264	513991384999644672	513601745563294976	513603016873591936	513611435009360000
513619612627031680	513991075762257792	513602772055238016	513603291751491072	
513618135158287360	513991041402529664	513601157147534976	513615175921610752	
513618787993324288	513990972682789376	513602840774713984	513615352019490432	
513619578267289216	513979633969386368	513612775039175808	513615764332333184	

0.1.1.3 Stock 19 (C0001+557)

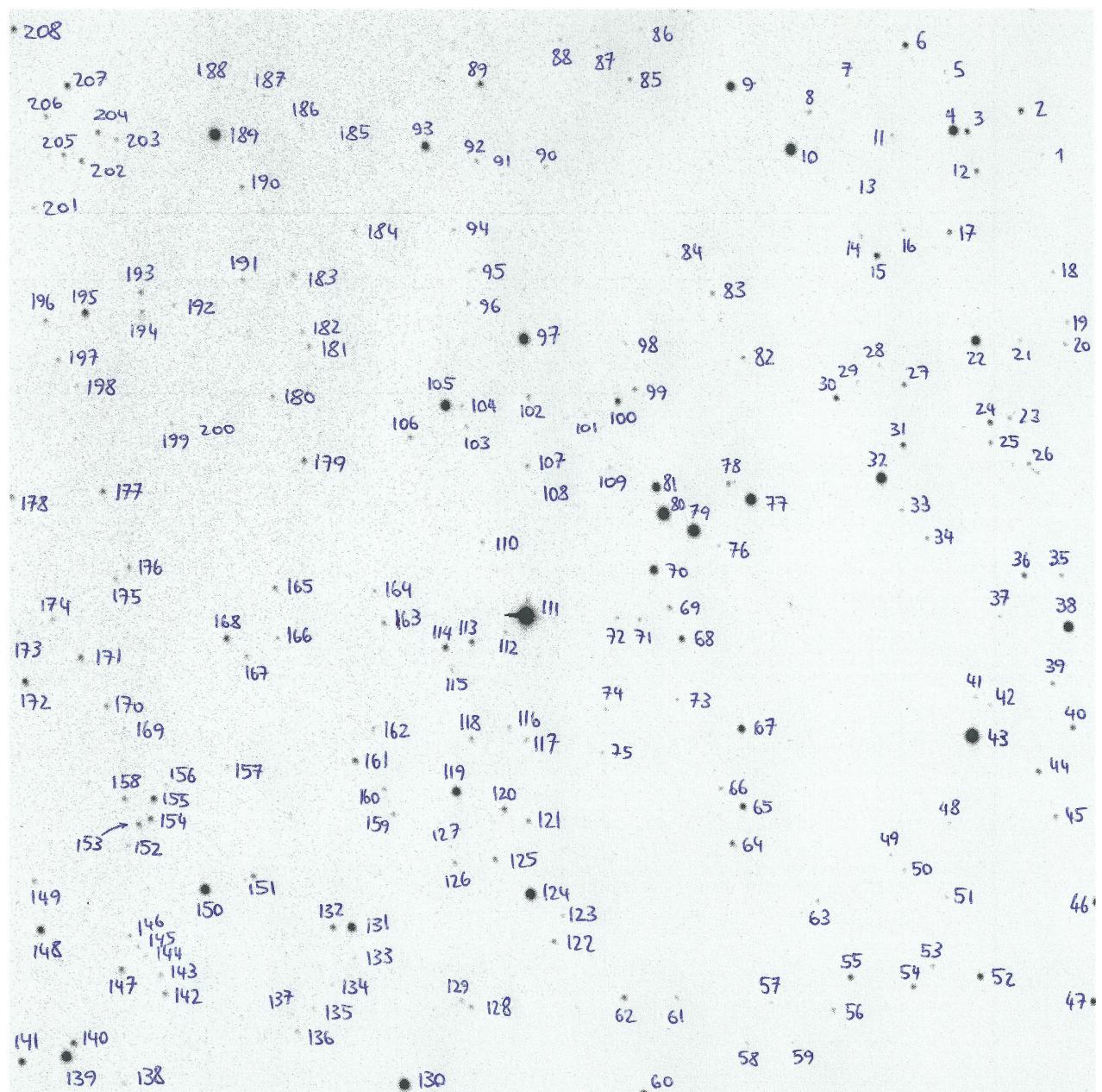


Figure 18: Our observation of Stock 19 in the red filter with an exposure time of 200 seconds. The numbers are in correspondence with those in image 19.

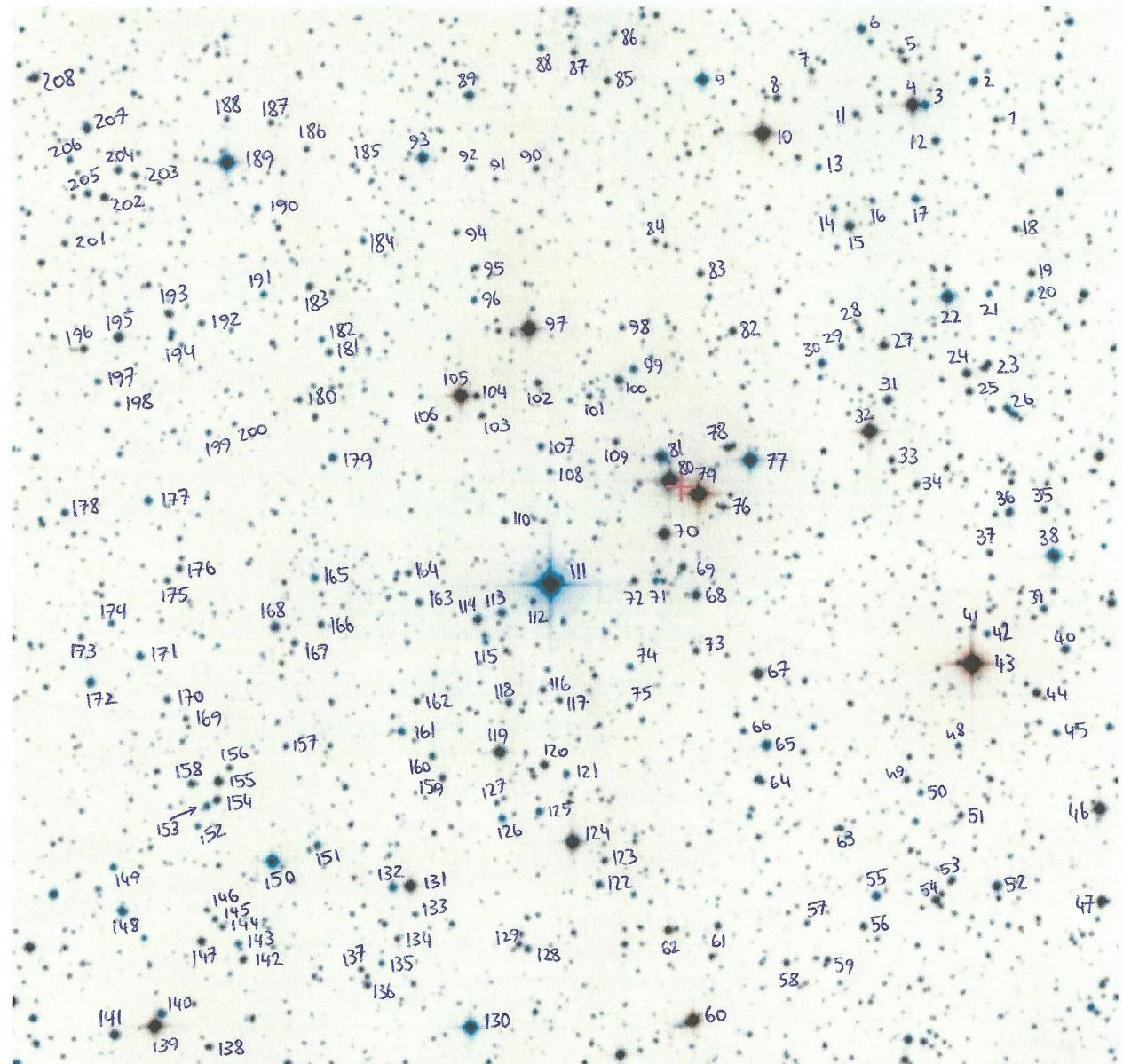


Figure 19: The negative of the observation of Stock 19 by the DSS2. This picture was extracted from *Aladin*. The numbers are in correspondence with those in image 18.

The only light source we observed - of the about 600 - without a Gaia DR2 entry is star 124 (in the lower middle of 18 and 19) known as TYC 3656-465-1.

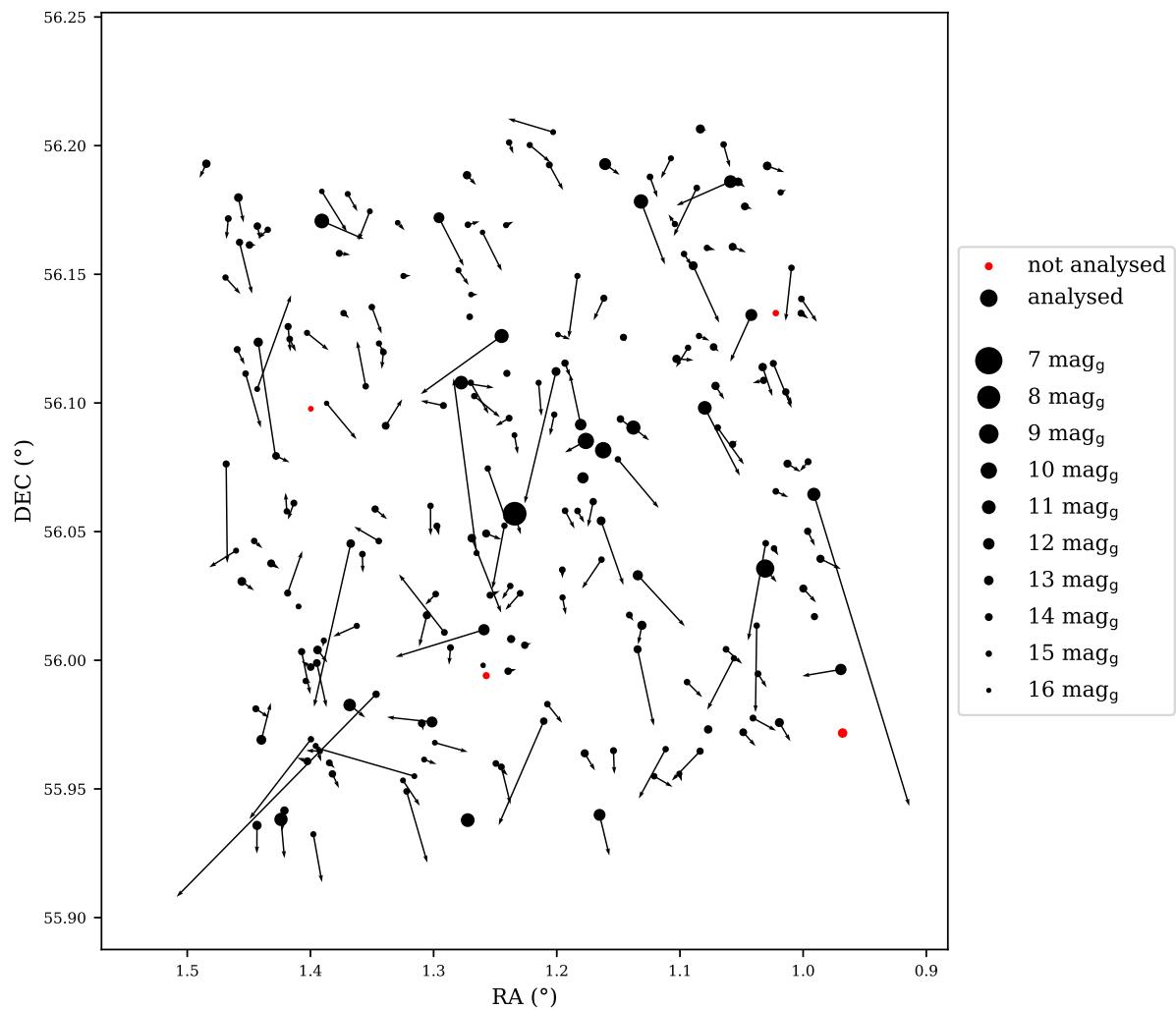


Figure 20: Every point is an extracted source. The size corresponds to the Gaia magnitude. The arrows illustrate the direction of the proper motion. A star was for example not analysed if the proper motions were missing.

In contrast to figure 4, a preferred direction of the stars we observed is not directly apparent.

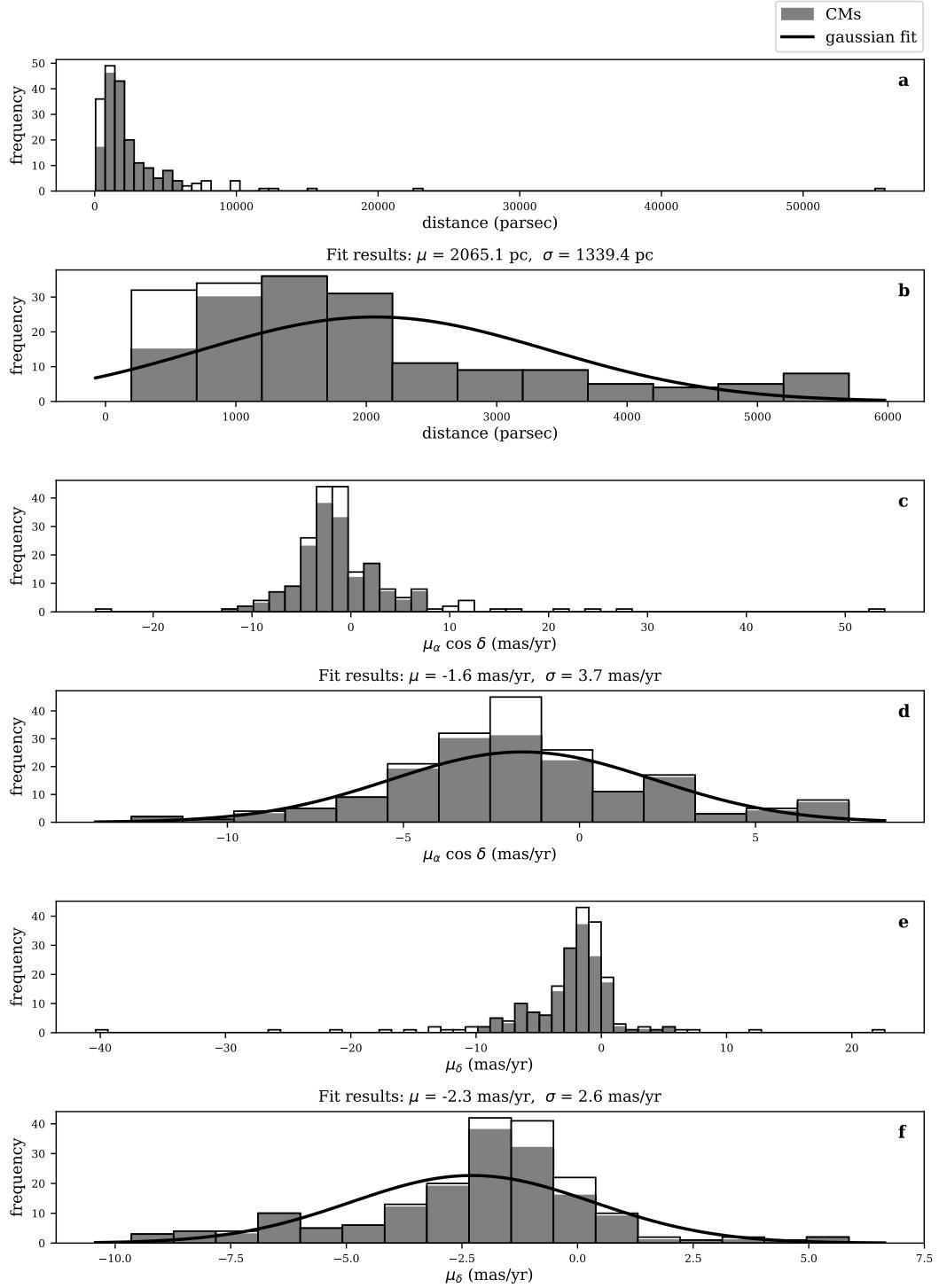


Figure 21: Histogram of the analysed stars. In order to determine the Cluster members (CMs) an iterative sigma clipping procedure was applied (see beginning of 0.1.1). **a, c, e:** The distances and proper motions for all stars and the CMs (in gray). **b, d, f:** This zoom-in also includes a gaussian fit of the CMs. Above those plots the mean and sigma of this gaussian.

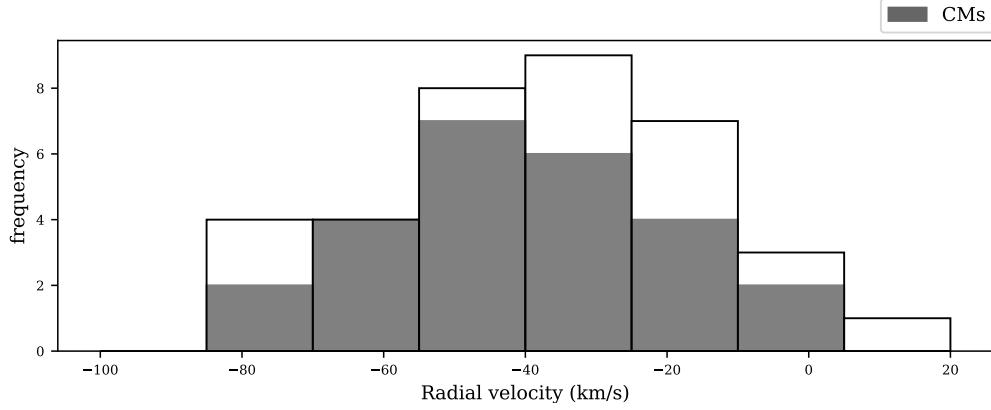


Figure 22: An histogram of the radial velocities. In gray our cluster members determined with figure 21.

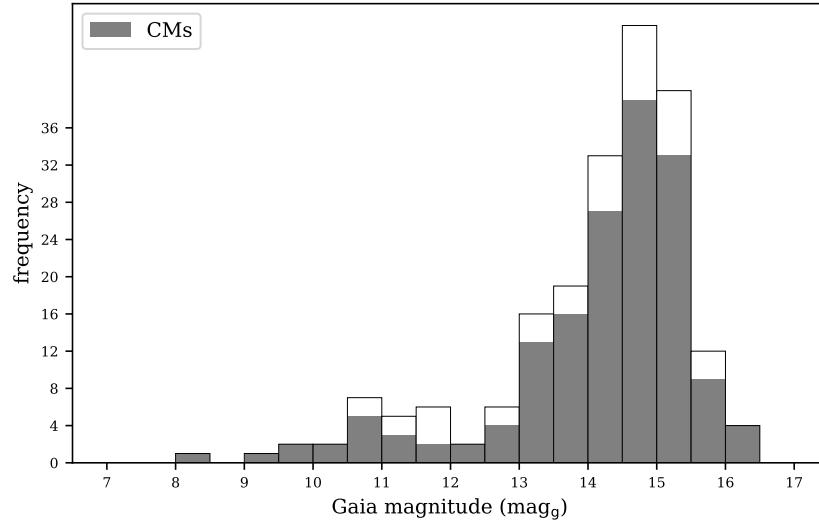


Figure 23: The distribution of Gaia magnitudes of the analysed stars.

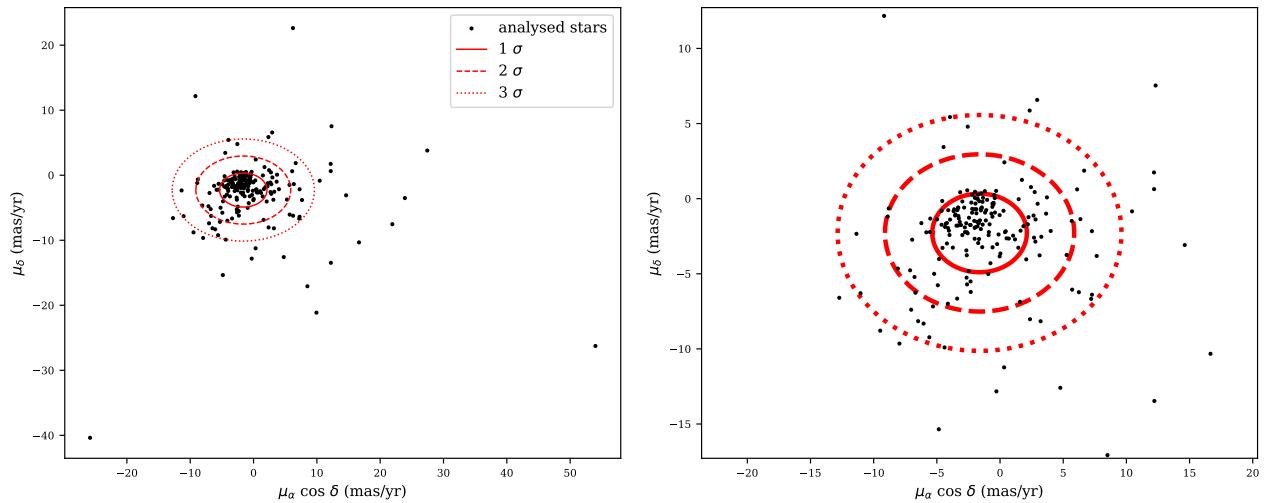


Figure 24: The proper motions of all analysed stars including the proper motion of the cluster (red) extracted in figure 21. The right side is a zoom-in of the left side.

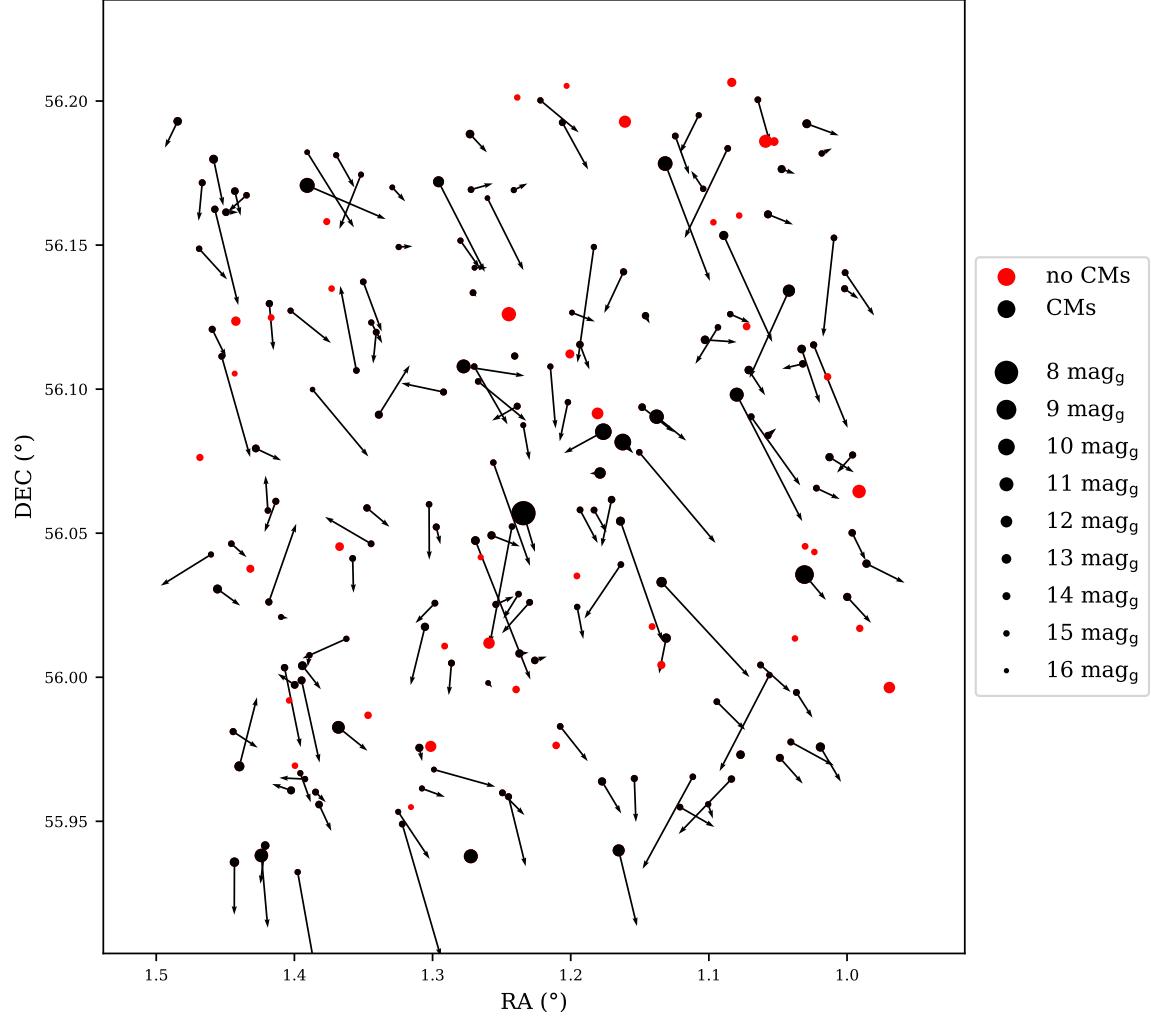


Figure 25: Similar to figure 20 yet just including our cluster members (CMs).

Similar to 17, but in contrast to figure 9 we do not see, that those stars are moving as a group in one direction. We also see this very broad distribution in distances and proper motions in figure 21. So we cannot really confirm this cluster.

Table 6: All *Gaia Source IDs* of our identified cluster members (CMs) of Stock 19.

420874776035616512	420866220460820480	420964970347766400	420862131652010752	420869072319131008
420875188352476160	420866014302391680	420964901628291584	420868007167254656	420869415916515968
420875016553783936	420865876863445504	420964901628292608	420867972807519616	420869450276248320
420875050913525376	420865979942662016	420964935988030848	420867972807524096	420869450276244992
420874290700505600	420865773784235392	420964759890587648	420867801008840960	420869518995713408
420874294999283584	420865739424500096	420964798549079552	420867801008838272	420869725154141056
420874947834311168	420865705064765696	420870962104679296	420867079454351232	420869656434657024
420874810395357440	420864983510262784	420870962104682112	420866903351769600	420870549787844096
420874913474575232	420864983510269568	420873882682440960	420867285612779520	420869931312547712
420874501157717504	420865700763485696	420873504725321856	420867212591948544	420964523671177088
420874569877191040	420864708632374784	420873436005849344	420867487469889280	420964523671176960
420874707316144256	420865327107652352	420870859025472768	420867491771196544	420964558030914304
420873195487658496	420865120949224704	420870790306001280	420867526130932864	420964725531434624
420873195487659648	420866151741352704	420870790305998976	420867526130932096	420964695469863552
420873161128172160	420871408781519232	420870824658830336	420867526130937472	420965107786724096
420873023688973184	420871541916442880	420870790306005504	420867418747843072	420964454951694592
420873019387938560	420871924177379072	420870446708618752	420868866160725888	420964386232348928
420873023688975360	420871718018945024	420870446708621696	420867594843854208	420964386232219648
420874363718770048	420871821098157696	420873294265833856	420869141038619136	420963836476410112
420874363718771840	420871718019163904	420870343629413376	420867663569868288	420963664677718528
420874363718773632	420871821098164608	420868831800928640	420869141038616448	420963973915527168
420872920609763200	420871511860522624	420868831800930560	420869141038614016	420963595958408448
420872748811076224	420871305702102144	420868831800933632	420869209758084992	420963699037458048
420872778869755776	420872027256582656	420868763081458816	420869141038617344	420964111354467584
420872783170817280	420872130335792256	420868694361987968	420868591282790016	420964145714196992
420872538350177664	420872061616314752	420868660002250368	420868522563308928	420964214433667456
420872542652648320	420872061616320384	420868694361991168	420868556923042304	420964214433667712
420872473933176192	420871855457889792	420868282045138432	420870068751517184	420964145714334464
420866632777656704	420873676524006400	420871236982638336	420870167529611392	420965623182941824
420866594115318400	420874088840863616	420871065183955840	420870137470996224	420965623182937344
420866564058188672	420873917042170496	420868213325668480	420870103111263488	420954009591365248
420866495338712576	420967856565786112	420862234731211264	420869347197023616	
420866220460819072	420967959645000448	420868105945182336	420869278477562624	

Table 7: *Gaia Source IDs* of the non CMs of Stock 55.

420874982194047872	420872508292912512	420871683659218688	420871065183959936	420869347197022720
420874982194048128	420866564058185344	420873328622834432	420868247685405824	420869484635986048
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420874604236930816	420866426619243648	420873436005847168	420868350764636544	420963664677718656
420873058048713984	420865533266258560	420868763081461376	420867659268629504	420963664677878784
420872954969497600	420871374421576320	420868586978944768	420868419484095360	420963630318149504

1 References