PACS

Sky Fields and Double Stars for Spatial Calibration

	Name	Function	Date	Signature
Prepared by	D. Lutz, B. Ali		16-Oct-03	
Checked by				
Approved by				
Approved by				
Approved by				
Authorized by				
Authorized by				

DOCUMENT CHANGE RECORD

Issue / Rev.	Date	Change Notice Number	Modified Pages or Paragraphs	Remarks / Nature of Change
Draft 0.1	08-Jul-02	Initial draft		
Draft 0.2	24-Jun-03	Rev 1	Section 3	Included 2MASS K-band search results
Draft 0.3	29-Jul-03		All 3.2 3.4.1 5.2	Small changes, fixed typos etc. Added coordinates to table Added discussion of Herbig AeBe stars Added discussion of Condon et al. BGS double galaxies
Draft 0.4	13-Aug-03		All	Minor text changes
			6.2	More info on Saturn satellites
Draft 0.5	14-Oct-03		All, Appendix	Added HIRES/2MASS quicklook, minor changes in text
Issue 1.0	16-Oct-03		Appendix	Changed HIRES/2MASS images for stars to correctly contoured ones.

Table of Content

1 Scope and Assumptions

This document summarizes the status of the search for fields with multiple far-infrared objects that are suited for spatial calibration of PACS. In addition to tasks requiring single point sources, the PCD (AD-1) identifies a need for fields containing binary or multiple point sources or clusters of sufficient brightness over scales of typically a few arcminutes (Requirements 2.6.3, 3.1.2, 3.1.3). The purposes of these requirements are accurate verifications of pixel scales, optical distortions, and of chopper throw. The use of multiple sources with accurate far-infrared positions could bypass the errors induced by multiple pointings of the satellite on a single source. Ideally, these multiple sources all should have *far-infrared* positions accurate to the sub-arcsecond level. This document describes the results of several approaches to this problem, including unsuccessful ones.

As an indication for the required fluxes, we follow PCD 3.1.2 asking for 160mJy in the PACS bands to achieve S/N 20 in 1 min. PCD 2.6.3 asks for yet brighter objects. The local far-infrared background has to be checked in all cases to avoid disturbances. As a working assumption, we searched for multiplicity roughly on the 0.5’ to 5’ scale. It is important to cover several position angles since the PACS chop angle cannot be varied freely – only for objects near the ecliptic poles all angles are accessible, by repeated observations over a one year period.

This document does not address the fallback options of using for some spatial calibrations bright and heavily structured fields that do not have a priori positional information, and of stepping over single point sources at the expense of including satellite positioning errors.

2 Applicable and Reference Documents

AD-1 PACS-MA-GS-001 PACS Calibration Document Draft 7 (PCD)

RD-1 Potential ISOCAM fields for PACS spatial calibration, B. Ali, 17-May-2002
RD-2 Solar System Objects as Calibrators for Herschel, T. Müller, e-mail, 05-Jul-2002

3 Stars

Stars are excellent candidates because of usually accurate positions, and pointlike nature. The second property implies that objects with structure spatially resolved by PACS, e.g. large dust shells or WR star ejecta, have to be avoided. Assuming photospheric emission, the required brightness of an object with 160mJy at 75µm can be estimated using the formula of Engelke (AJ 104, 1248 (1992)) which is valid for late type stars. The resulting requirement of $K \leq 1.8$ implies severe limitations for the use of 'normal' well-behaved stars as PACS spatial calibrators.

3.1 Optical Star Clusters

Globular cluster stars are too faint and too densely packed. Some open clusters match the desired spatial structure but stars are too faint, again. The brightest stars of an amateur's open cluster like Praesepe, for example, are around V=7 and intermediate spectral types, i.e. clearly out of reach.

3.2 Bright Binaries (V-band search)

Bright Binaries with V<5 mag (for both components) and separations between 30" and 300" were searched by (1) direct query of the Washington Visual Double Star Catalogue in Vizier and (2) searching for V<5 objects with such separations in the Bright Star Catalogue. After weeding out a few objects where one or both components are double themselves on the arcsecond scale, the following three candidate pairs remain:

Name	Sep.	J2000 coordinates	Type	V	K
	arcsec			mag	mag
HR 3206 Gam1Vel	42.9	08 09 29.33 –47 20 43.0	B1IV	4.27	4.87
HR 3207 Gam2Vel		08 09 31.95 –47 20 11.7	WC8+O9I	1.78	1.98
HR 4618	269.1	12 08 05.22 –50 39 40.6	B6IIIe	4.47	4.92
HR 4621 Del Cen		12 08 21.50 –50 43 20.7	B2Ivne	2.60	2.49
HR 6554 Nu1Dra	61.2	17 32 10.57 +55 11 03.3	A6V	4.88	4.24
HR 6555 Nu2Dra		17 32 16.03 +55 10 22.7	A4m	4.87	4.16

Given their magnitudes, even those few bright objects are at best marginally suited for PACS. The local FIR background has not yet been verified! There may be disturbing diffuse far-infrared emission.

3.3 Bright Binaries (K-band search)

The 2MASS all-sky catalog was searched based on the following two criteria: (i) both components must have 2MASS K-short magnitudes less than 3 mag. (ii) The total separation between the components must be less than 5 arc-minutes. A total of 33 fields qualified both criteria. These are listed below. The 2MASS gif images of the tiles on which the first star (Star 1 below) appears are shown in Appendix A (the star is not centered on the tile).
As already mentioned in Section 3, the optimal flux limit for PACS spatial calibration purposes is K<1.8 mag. Fields 15 and 30 are the only ones with both stars (roughly) qualify under this flux limit. These two fields should probably be given first priority for any follow-up work. Note, however, that for the bright stars considered here the 2MASS photometric uncertainty is ~20%.
Subsequent analysis of the fields shows some duplication, which has been noted in the table below.
The color-color plot for the stars is shown in the Figure below. Stars labelled in blue are those listed as Star 1 in the table. Stars labelled in red are those listed under Star 2 in the table. For comparison, the colors of the normal dwarfs and giants are shown as solid black lines. The dashed black lines show the effects of extinction on the colors of dwarfs and giant stars.
We additionally obtained HIRES images of the 2MASS fields discussed here. The HIRES technique uses IRAS (InfraRed Astronomical Satellite) data but employs Maximum Correlation Method (MCM, Aumann et al. 1990, AJ, 99, 1674) to produce images with better than the nominal resolution of the IRAS data. The resulting IRAS/HIRES images are shown as contour overlays on the 2MASS fields in Appendix B. We selected the IRAS 60 µm band for these images. For each IRAS/HIRES image, 10 contour levels were drawn between the mininum and the maximum value.

No.	Star 1	Star 2	δ RA	δ Dec	K1	K2
			(')	(')	(mag)	(mag)
1	20012749+5002325, Z Cyg,	20012157+5006167, e Cyg, IRAS 19599+4957, BD+49 3158D	1.48	-3.74	2.557	2.607
2	20110615+3606488 V429 Cyg	20110744+3607510	-0.32	-1.04	2.777	2.869
3	20314523+3231213, AI Cyg	20313652+3233524, AD Cyg	2.18	-2.52	1.510	2.051
4	21065341+3844529, PPM 86045, V1803 Cyg	21065473+3844265, NSV 13546	-0.33	0.44	2.248	2.544
5	20473679+3552184, IRAS 20456+3541	20472904+3553289, IRAS 20455+3542, V375 Cyg	1.94	-1.18	2.737	2.475
6	19122126+4118133,	19121741+4114156,	0.96	3.96	2.906	1.940

No.	Star 1	Star 2	δ RA	δ Dec	K1	K2
			(')	(')	(mag)	(mag)
	RU Lyr	V552 Lyr				
7	22065167+4827557, IRAS 22049+4813, AP Lac	22063991+4827068, CT Lac, LEE 346	2.94	0.82	2.763	2.722
8	02232409+5712430, V403 Per	02231106+5711579, V439 Per	3.26	0.75	2.985	2.690
9	01555447+3716400, HD 11727, IRAS 01529+3702 BD+36 349	01560933+3715066, 56 And, IRAS 01531+3700	-3.71	1.56	1.618	2.949
10	13235563+5455292, ZI 1000, IRAS 13219+5511?	13235629+5455183, IRAS 13219+5511?	-0.16	0.18	1.603	2.821
11	06471981+0802143, 17 Mon	06470582+0800535, ST Mon	3.50	1.35	1.584	2.820
12	04075574+4303113, HD 25892	04075741+4300475, IY Per	-0.42	2.40	2.741	1.683
13	05301775+6303195, BD+62 760	05301020+6304017, NSV 2003	1.89	-0.70	2.913	1.203
14	12193788-1915218, R Crv	12194260-1911560, UW Crv	-1.18	-3.43	2.027	2.186
15	16202077-7841448, del01 Aps	16202690-7840031, HD 145388	-1.53	-1.70	-0.775	1.913
16	17260749-5041059, CGCS 3822	17260004-5038004, kap Ara, IRAS 17220-5035	1.86	-3.09	2.248	2.804
17	16470309-4552189, Westerlund 1 BKS B	16470468-4551238, IRAS 16434-4545, Hen 3-1250, Westerlund 1 BKS D	-0.40	-0.92	2.177	2.610
18	05285171+3225223, V400 Aur	05285288+3228391, V401 Aur, BD+32 996B, HD 243918	-0.29	-3.28	1.987	0.911
19	18111163-2630028	18112756-2629324, OH 5.0 –3.8, HD 315326	-3.98	-0.51	2.442	2.360
20	04195087+4107417, GM Per	04200316+4103500, IR Per	-3.07	3.86	2.990	0.095
21	06451737+1253438, ZI 572	06452314+1251504, AT Gem	-1.44	1.89	1.688	2.856
22	13220982-6413078, UX Cen	13220842-6408188, IRAS 13188-6352	0.35	-4.82	1.948	2.345
23	23080938+5815581, IRAS 23060+5759	23075597+5814423, IRAS 23057+5758	3.35	1.26	2.996	2.907
24	17411041-3020537, CD-30 14574, GH20 358.29+00.08	17405413-3022380, IRAS 17376-3021	4.07	1.74	2.263	2.266
25	Duplicate of 24					

No.	Star 1	Star 2	δ RA (')	δ Dec (')	K1 (mag)	K2 (mag)
26	17101368-4046145, IRAS 17067-4042	17100497-4042276, IRAS 17065-4038	2.18	-3.78	2.049	2.726
27	17385481-3459283, IRAS 17355-3457, SCHB 94, Terz V 1847	17384548-3457177, V492 Sco	2.33	-2.18	2.273	1.541
28	17353314-1419286, IRAS 17327-1417	17353776-1416088, IRC -10372	-1.16	-3.33	2.360	2.217
29	14064732-6222274, NSV 20034, CD-61 4219	14063742-6219408, IRAS 14029-6205	2.48	-2.78	2.481	2.888
30	12472467-5941409, C* 2031	12474326-5941194, bet Cru IRAS 12448-5925	-4.65	-0.36	1.601	1.978
31	07474521-1600519, NSV 3741	07473853-1559263, QY Pup	1.67	-1.43	1.965	2.702
32	17140992-1459593, IRC -10360	17142723-1459209, IRAS 17116-1455	-4.33	-0.64	2.165	2.977
33	17070146-4055380, IRAS 17035-4051	17065791-4053524, IRAS 17034-4049	0.89	-1.76	2.822	2.831

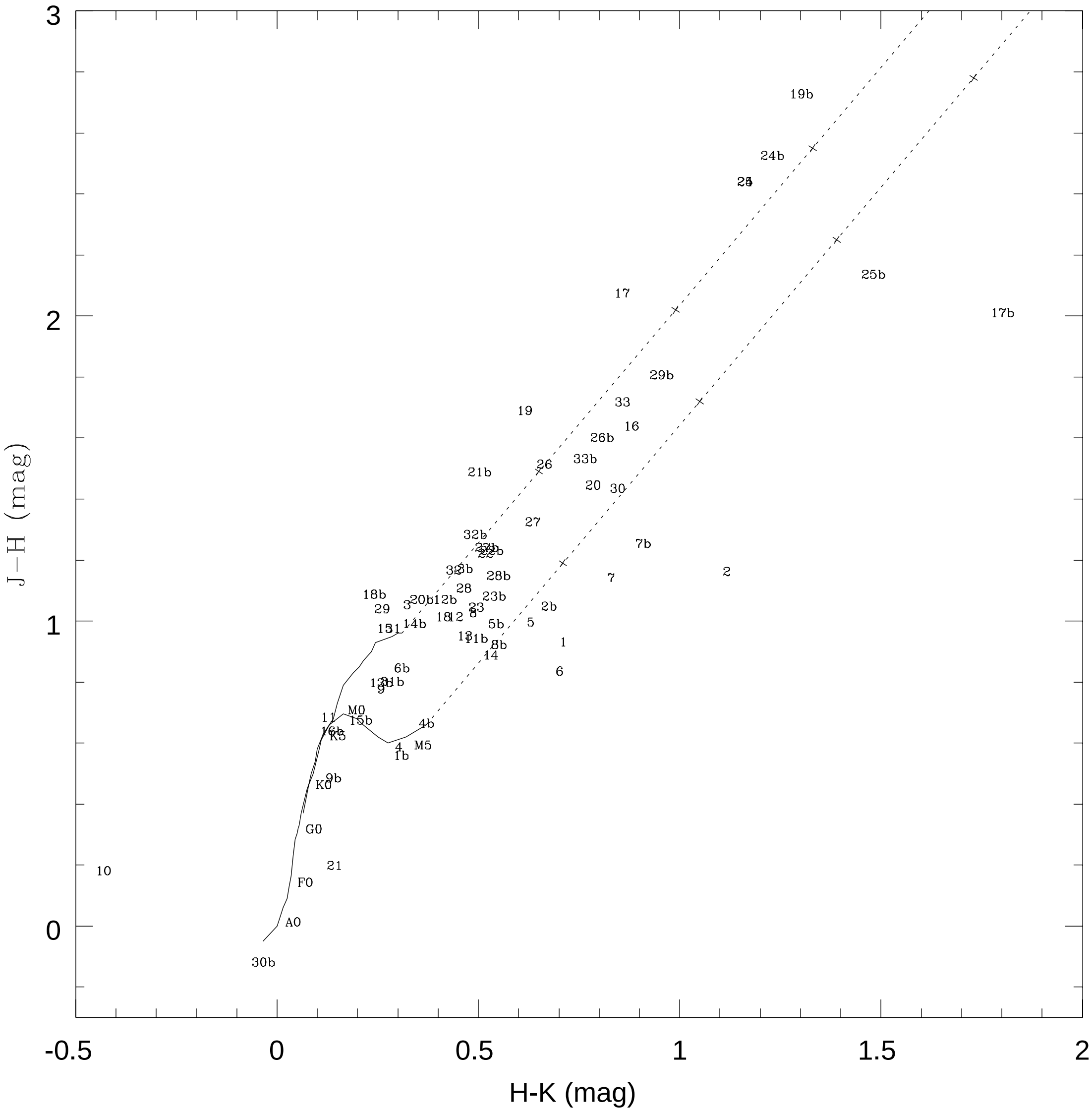


Figure 1: 2MASS color-color diagram for bright binaries from the K-band search

3.4 Other stellar sources

3.4.1 Herbig Ae/Be stars observed with ISOPHOT

Ábrahám et al. A&A 354, 965 (2000) present ISOPHOT data for a number of Herbig Ae/Be stars, including two pairs with interesting spacings (36 and 104 arcsec) . The young stellar nature and complex environment calls for some caution about the far-infrared morphology. Indeed there is evidence for a third mid-infrared source in the LkHα198/V376Cas pair (Lagage et al. 1993), extended emission in the PACS wavelength regime (Natta et al. 1992), and yet another source in the mm (Henning et al. 1998). Extended FIR emission is also seen in the BD+65 1637/LkHα234 region, with the FIR peak likely offset from the optical star LkHα234. While both pairs are FIR bright and scientifically interesting, the prerequisite for use as spatial calibrators (accurately predictable FIR morphology at PACS resolution) appears insufficiently met.

4 Galactic ISOCAM fields

We have searched the ISO archive for ISOCAM rasters with low diffuse background but a large number of point sources, with the hope of then using 2MASS astrometry and the ISOCAM photometry to extrapolate to FIR sources. The main advantage offered by this approach is that non-photospheric emission from the program stars (e.g. dust shells, outflows, etc.) is more easily detected at mid-IR wavelengths than near-IR or shorter wavelengths. Knowledge about such emission sources is needed to ensure that the point-source assumption is not invalidated at PACS wavelengths. RD-1 describes this search. Fields with large source densities are indeed identified, but typical 15µm fluxes are <1Jy with few objects above 3Jy, i.e. too faint for PACS if a photospheric extrapolation is assumed. If objects are dusty (HII regions, YSOs, late stars with dust shells) fluxes would be higher but the applicability of 2MASS positions would need more critical investigation for individual objects. This approach is not considered to be as useful as simply obtaining the results from 2MASS and searching for additional information on the 2MASS selected targets with IRAS/ISO data.

5 Galaxies

There is a large number of galaxies sufficiently bright for PACS, some of them conveniently placed in pairs or groups. Inferring the FIR position/structure from other wavelengths is a problem, however, which may be solved easily for compact or distant objects with radio counterparts but not so easily for more normal nearby galaxies.

5.1 Quasars and AGN from Veron catalogue

Bright Quasars are pointlike for PACS and often have accurately known positions. Assuming the mean quasar energy distribution of Elvis et al. ApJS 95, 1 (1994), quasars with V<15.5 are needed to get >160mJy at 75µm. We have searched the merged lists of quasars, active galaxies, and BL Lac candidates from the 10^{th} edition of the Veron catalogue (from Vizier) for V<15.5, z>0.01 objects with separations between 30" and 300''. Three pairs are found, all formed of inconspicious nearby Seyfert2 or Liner NGC objects (NGC 70/71, NGC 833/835, NGC7679/7682). For the purpose of PACS spatial calibration these objects are likely no better than other galaxy pairs. Real quasar pairs are found only at fainter magnitudes or larger separations. For test purposes, we also searched for V<17.5, z>0.1 pairs and found 11 candidates. Only one QSO in one of these pairs has an IRAS FSC counterpart, however. Sufficient far-infrared brightness is hence not ensured.

5.2 Galaxy pairs

The Arp-Madore catalogue or other catalogs of interacting galaxies could provide a long list of galaxy pairs for which total IRAS fluxes can be retrieved, but the issue of flux distribution over the two objects and of precise FIR centroids is difficult to solve accurately without additional information.

Objects with interferometric radio continuum data are worth consideration, in case the radio mapping is good enough to (i) estimate accurate centroids for the two components, (ii) estimate a rough FIR brightness ratio by assuming FIR flux ratio = radio flux ratio and (iii) filter out objects which are dominated by off-nuclear regions which have hard to predict morphologies (like the Antennae NGC 4038/39). The following subsection provides a first such list from VLA-observed IRAS BGS sources.

Additional literature search could probably enlarge the sample significantly, by starting from interacting Galaxy samples and then introducing IRAS and radio information. The NVSS, e.g., may often give a first indication of the radio emission in a galaxy pair but is not well matched in spatial resolution to PACS.

5.2.1 Galaxy pairs from the IRAS Bright Galaxy Sample with VLA radio observations

Condon et al. ApJ Suppl. 73, 359 (1990) and ApJ Suppl. 103, 81 (1996) published a VLA 1.4GHz atlas of the IRAS Bright Galaxy Sample. With $S_{60\mu m}$>5.24Jy these are very bright sources at PACS sensitivities, even if several components contribute. The following preliminary list is from a first visual inspection of this atlas. To be listed, an object had to fulfil the following criteria:

1. Mapped in VLA B or C configuration or both (sometimes also A), i.e. at spatial resolution 24arcsec FWHM or better. Objects with only D configuration data were not considered.
2. Double radio source, with each component dominated by a single unresolved or slightly resolved component. Component separation 30arcsec<d<300arcsec.
3. Double radio morphology similar to optical or near-IR (2MASS) double morphology, to include double galaxies but exclude unrelated background radio sources (or double lobe radio galaxies), for which the radio morphology is a bad guess of the far-infrared morphology.

Name	Alias	S60	cz	RA	DEC	Sep	PA	S(1.4GHz)
		Jy	km/s	B1950 !!!	B1950 !!!	arcsec	Deg	mJy
NGC 317A		9.28	5293	00 54 49.8	+43 31 51	35	154	2.4
NGC 317B				00 54 51.2	+43 31 20			44.5
NGC 633		7.82	5137	01 34 10.3	-37 34 34	67	173	20.6
ESO 297-G012				01 34 11.0	-37 35 40			11.4
MCG+05-06-036	Mrk 1034	6.74	10083	02 20 20.9	+31 57 43	49	52	3
				02 20 23.9	+31 58 13			32.8
NGC 2342		7.96	5276	07 06 20.4	+20 43 04	151	-144	26.9
NGC 2341				07 06 14.1	+20 41 02			
IRAS09111-1007		7.19	16231	09 11 10.7	-10 07 04	37	74	24.2
				09 11 13.1	-10 06 54			13.7
NGC 2993	Arp 245	10.8	2420	09 43 24.1	-14 08 13	177	-32	46.7
NGC 2992				09 43 17.73	-14 05 42.8			205
IC2810	UGC 06436	5.6	10243	11 23 08.58	+14 57 05.6	71	114	17.2
				11 23 13.06	+14 56 36.7			8
NGC 3994	Arp313	8.26	3118	11 55 02.5	+32 33 20	107	57	43.4
NGC 3995				11 55 09.6	+32 34 19			8.8
UGC 08335	Arp 238	12	9230	13 13 37.54	+62 23 34.4	34	119	7.8

				13 13 41.83	+62 23 17.9			41
IC 4518A		7.7	4875	14 54 24.1	-42 55 53	40	89	120
IC 4518B				14 54 27.7	-42 55 52			9.7
UGC 09618	Arp 302	6.68	10103	14 54 47.8	+24 48 24	40	9	4.4
				14 54 48.24	+24 49 03.9			46.4
NGC 5953	Arp 091	11.6	1965	15 32 13.2	+15 21 35	47	60	17.1
NGC 5954				15 32 16.0	+15 21 58			3.6
NGC 6285	Arp 293	9.87	5691	16 57 37.4	+59 01 50	90	139	6
NGC 6286				16 57 45.0	+59 00 42			61.3
NGC 7253A	Arp 278	6.97	4718	22 17 10.0	+29 08 39	41	131	25.2
NGC 7253B				22 17 12.4	+29 08 12			2.2
NGC 7465		5.5	1968	22 59 32.0	+15 41 45	142	-65	11.7
NGC 7463				22 59 23.1	+15 42 46			1.9
NGC 7469	Arp 298	27.7	4892	23 00 44.4	+08 36 16	79	26	145
IC 5283				23 00 46.7	+08 37 27			9.2
NGC 7674	Arp 182	5.28	8671	23 25 24.41	+08 30 12.6	32	66	162
NGC 7674A				23 25 26.4	+08 30 26			2.2

This list needs individual verification and transformation of all (1950!) coordinates before use in actual calibrations. The sources are not ideal ‘double point sources’. Some extended radio emission at PACS resolution may still be present for many objects despite rejecting the most complex objects.

The accuracy of the offset extrapolation to the FIR will depend on morphology/compactness and on the VLA configuration used and has to be estimated for each object individually. It is probably unrealistic to expect many systems with sub-arcsecond accuracy.

Appendix C shows overlaps of 2MASS K-band and HIRES IRAS 60µm images for the objects listed in the table. The far-infrared morphology is consistent with the radio information listed above – small separations and high contrast systems are of course unresolved in the IRAS data. The plot showing the NGC3994/3995 system has an associated third far-infrared source related to NGC 3991, itself an interacting system for which a far-infrared centroid is not easily specified.

6 Solar system objects

6.1 Asteroid conjunctions

Asteroids provide a large number of effectively pointlike FIR sources slowly moving across the sky. This makes them potential spatial calibrators, pending positive answer to two questions: (1) Is there a sufficient number of >0.16mJy asteroids, so that conjunctions on <5arcmin scales are reasonably frequent? (2) How good are their orbits? <1arcsec accuracy is needed. See RD-2 for some initial numbers. A crude estimate based RD-2 is: Assume there are ~2000 sufficiently bright asteroids in a ±5 deg strip around the ecliptic. The Herschel visibility zone is one third of that – 666 objects in 1200 square degrees or one object per about 2 square degrees. Assuming a ‘cross section’ radius for a conjunction of 5’ around an object and guessing a relative apparent movement of 0.5’/hour, an individual asteroid has a ~20h

long conjunction about every 1500 hours, i.e. there may be a good chance for useful conjunctions at any given period of time.
A prerequisite for using this option will be a tool to obtain accurate Herschel-centric positions for a large number of asteroids.

6.2 Planetary satellites

An inventory of approximate angular separations from the planet, and of FIR fluxes (RD-2) suggests that at least the Galilean satellites of Jupiter and perhaps Titan/Japetus are possible objects. The Galilean satellites are so bright that they should easily stand out of Jupiter straylight. Possible limitations for bolometer operations, from the presence of nearby extremely bright objects, have to be verified.

One disadvantage has to be noted: Position angles of any Jupiter satellite pairs or multiples will always be close to the plane of the Ecliptic. The PACS chopping direction will be approximately orthogonal to the Ecliptic while viewing the Ecliptic. This makes Jovian satellites difficult to use for chop throw calibration. The inclination of the Saturn satellite system during the actual Herschel Mission changes. Using the Saturn Ephemeris Generator 2.2 (http://ringmaster.arc.nasa.gov/tools/ephem2_sat.html), the Saturn ring opening angle towards Earth is:

Date	Ring opening angle (degree)
01-Jan-2007	-12.6
01-Jan-2008	-6.7
01-Jan-2009	-0.8
01-Jan-2010	4.9

For the nominal Herschel launch, first such observations might occur in mid to late 2007. Then, suitable configurations of the bright moons like Titan and Iapetus may still be found (see example in Figure 2 from the Saturn viewer from the same web site). The situation will get worse with time because of the decreasing inclination of the ring system.

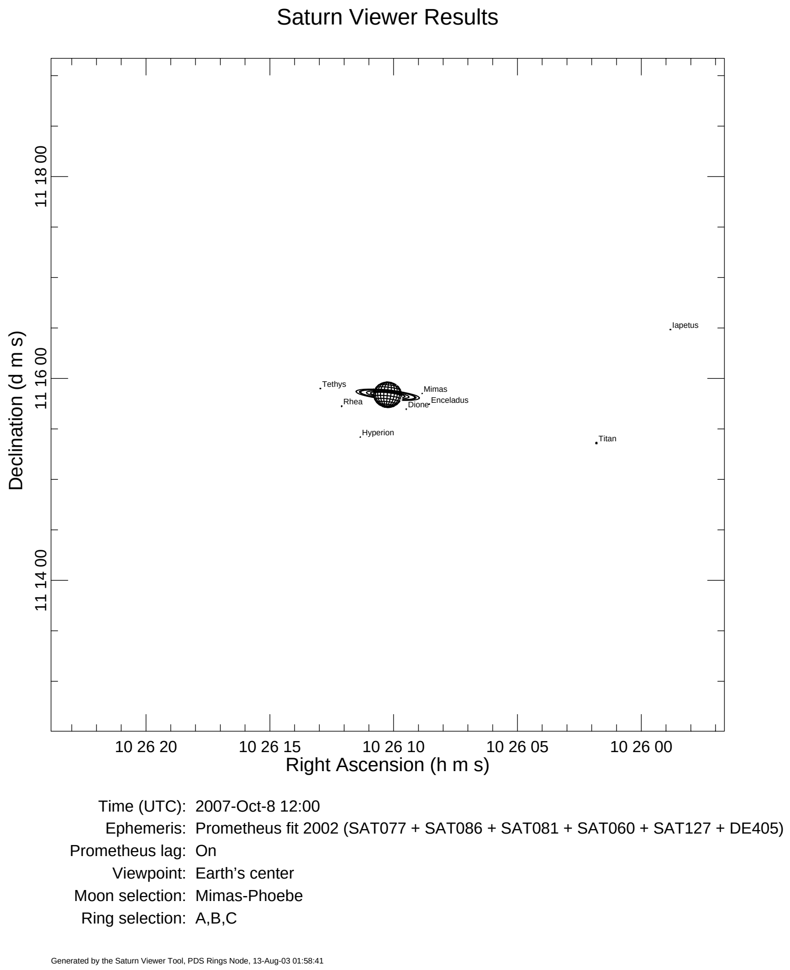
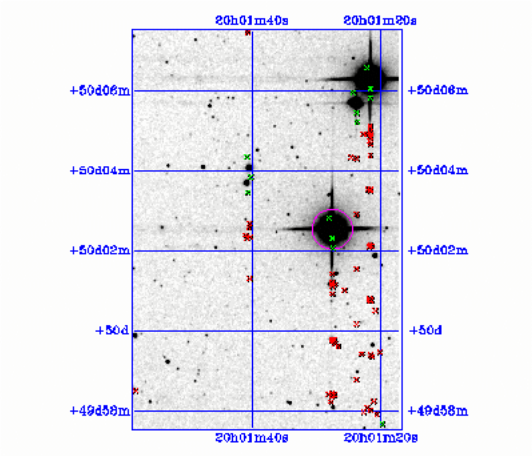
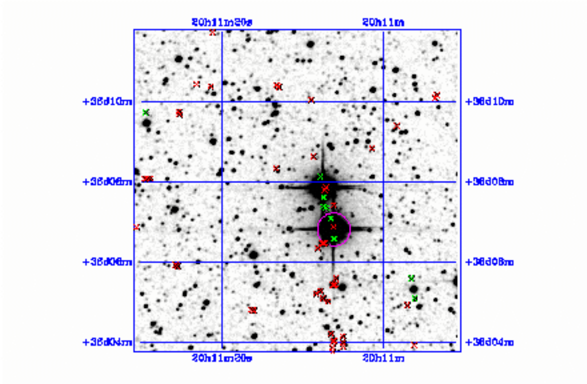


Figure 2: Example view of the Saturn satellite sytem in late 2007

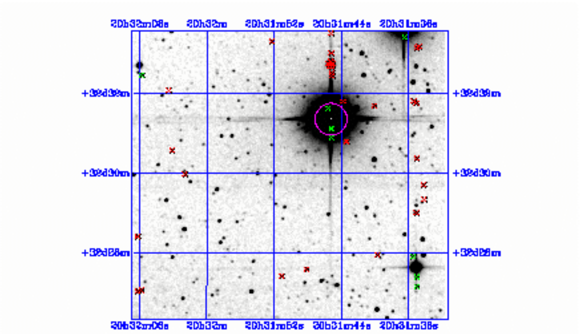
Appendix **A**: 2MASS **images of** fields **with suitable double stars from K-band search**



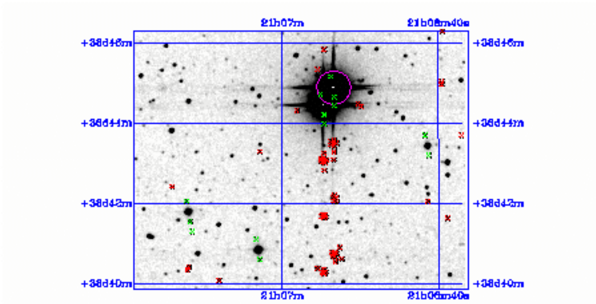
Field 1



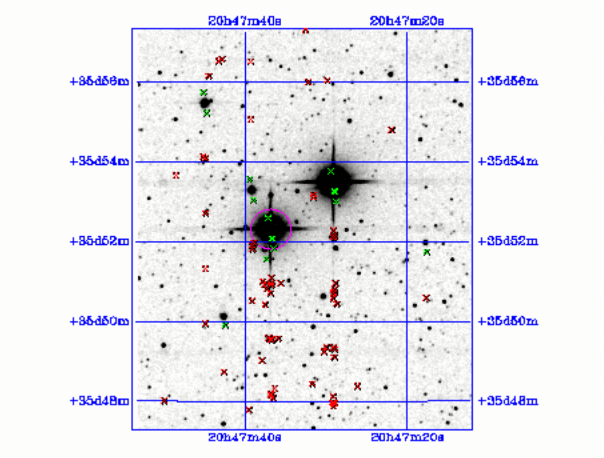
Field 2



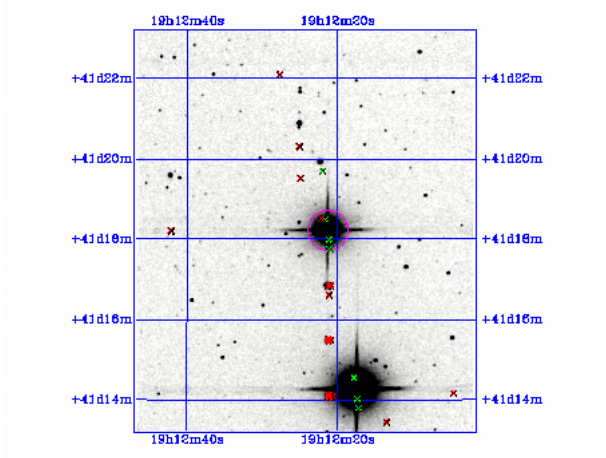
Field 3



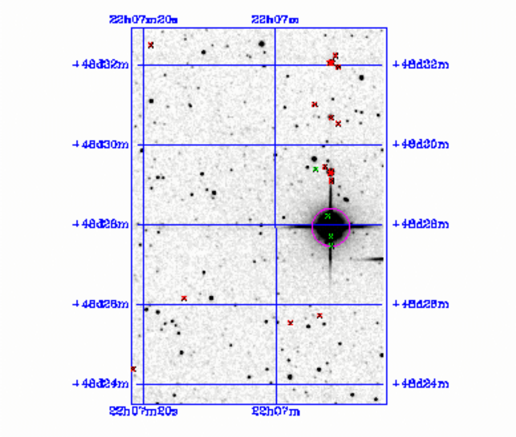
Field 4

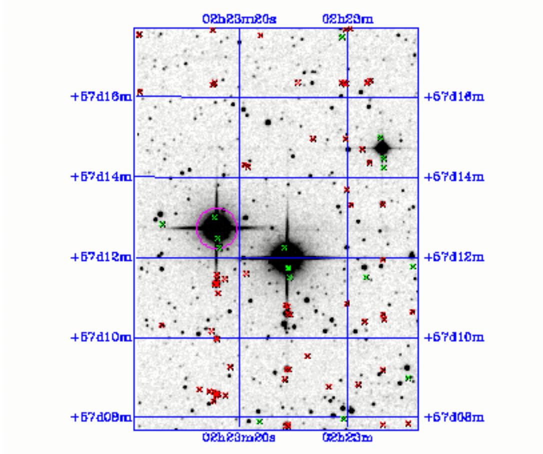


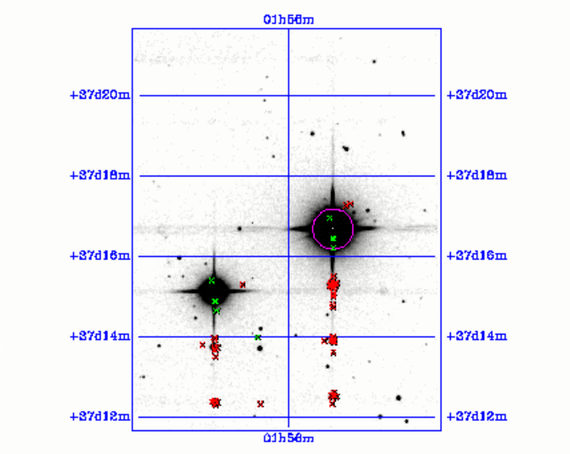
Field 5

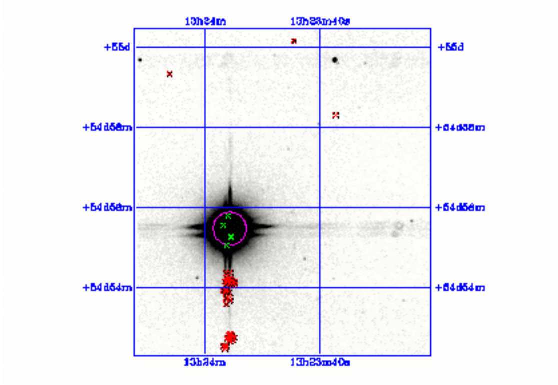


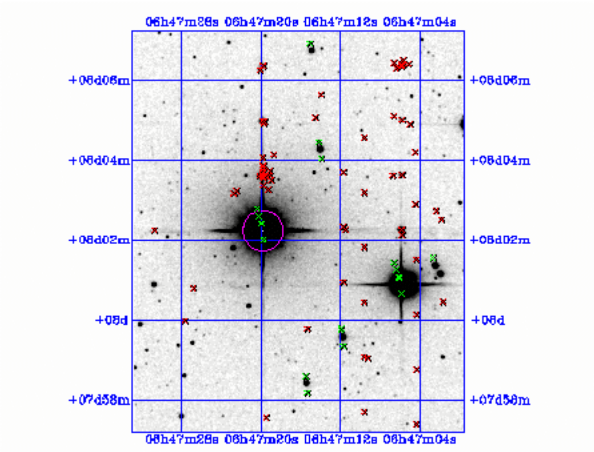
Field 6

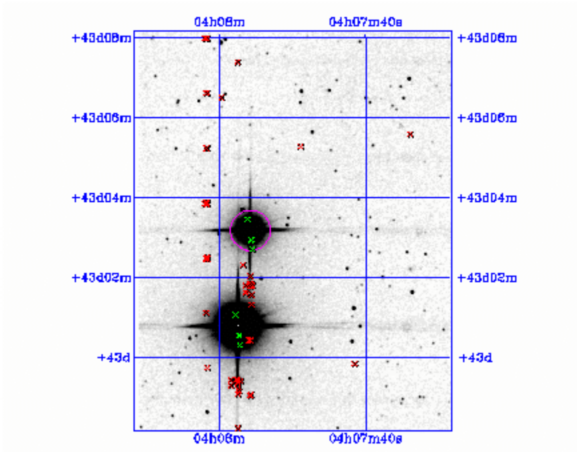

Field 7

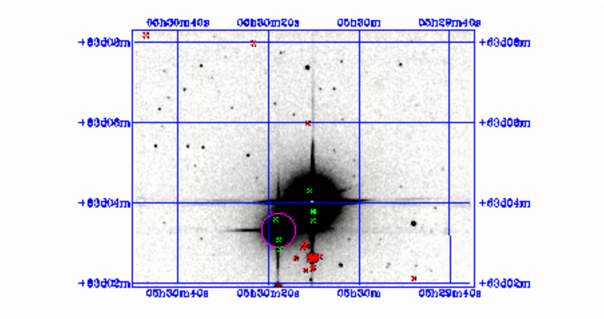

Field 8


Field 9

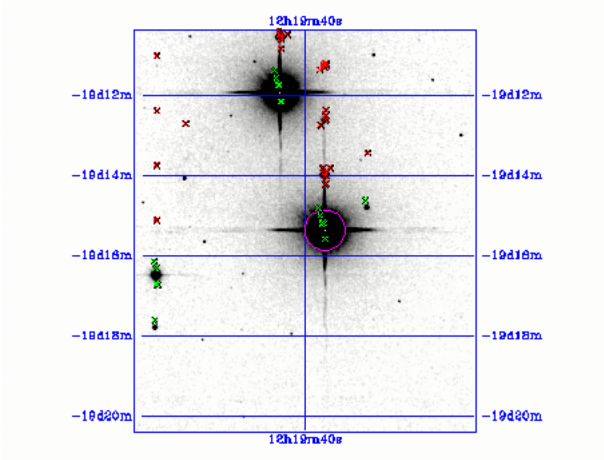

Field 10


Field 11

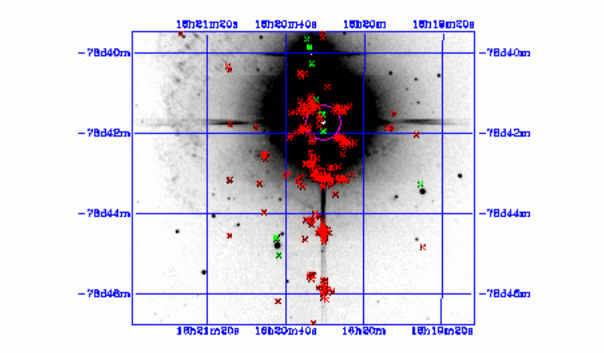

Field 12



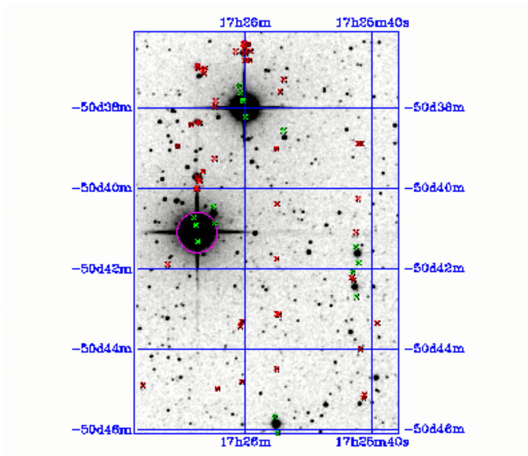
Field 13



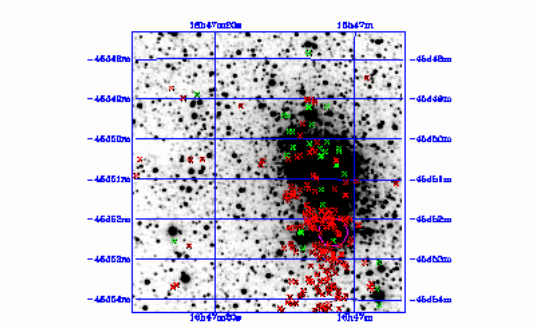
Field 14



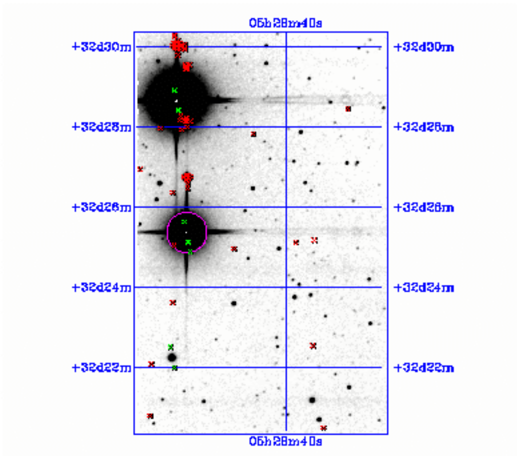
Field 15



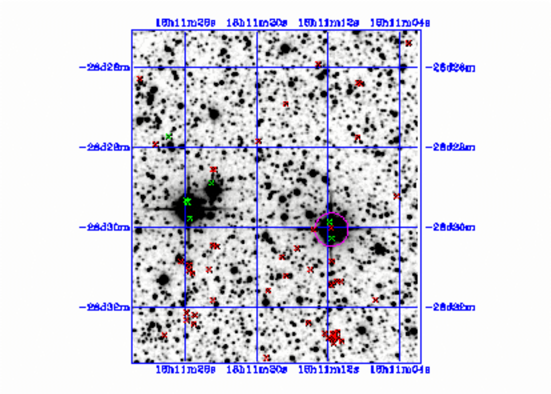
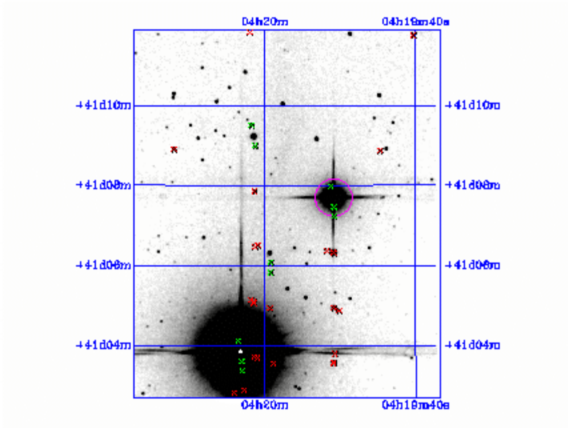
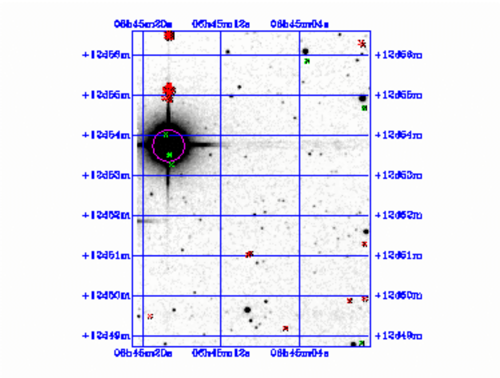
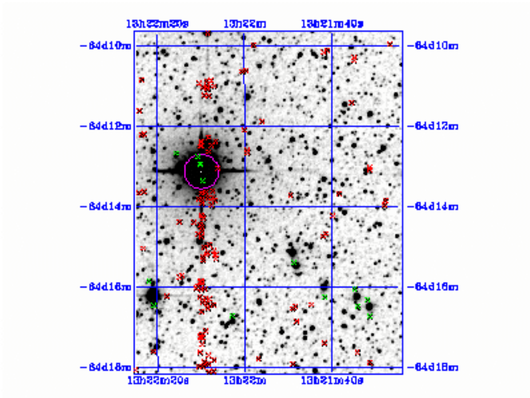
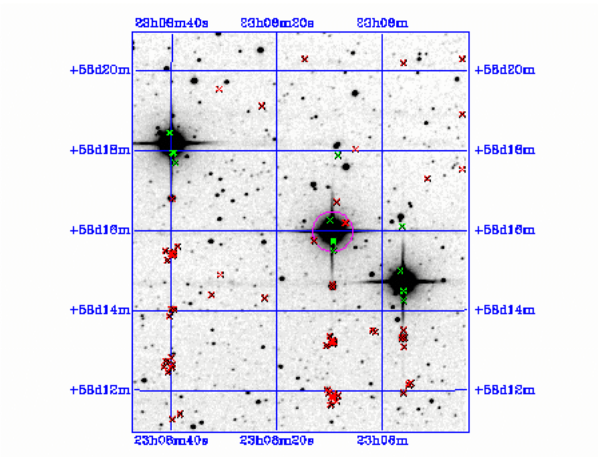
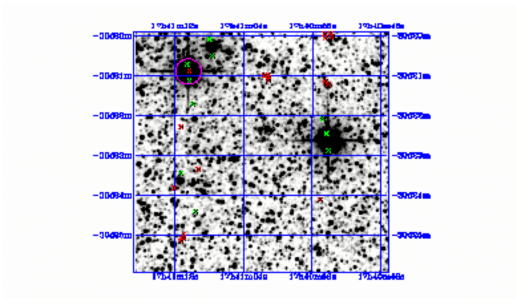
Field 16



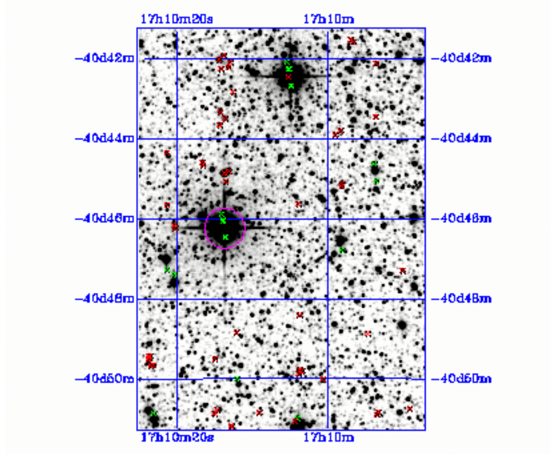
Field 17



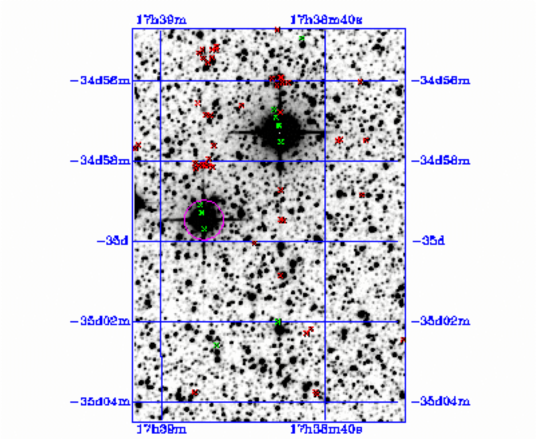
Field 18

	
Field 19	Field 20
	
Field 21	Field 22
	
Field 23	Field 24

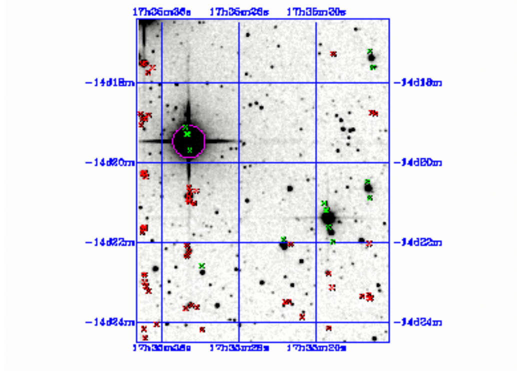
Field 25



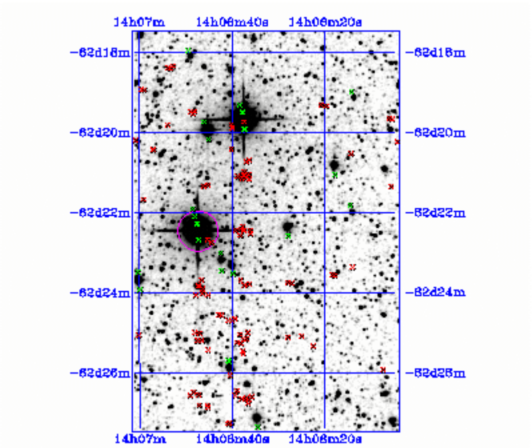
Field 26



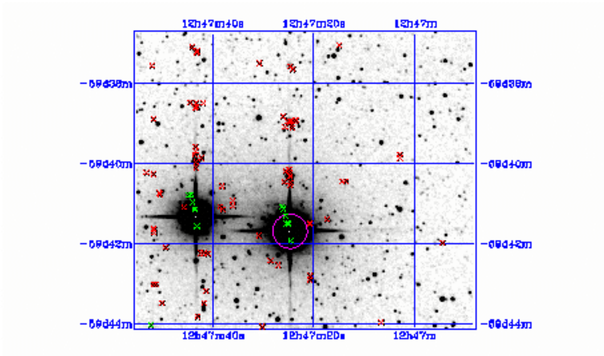
Field 27



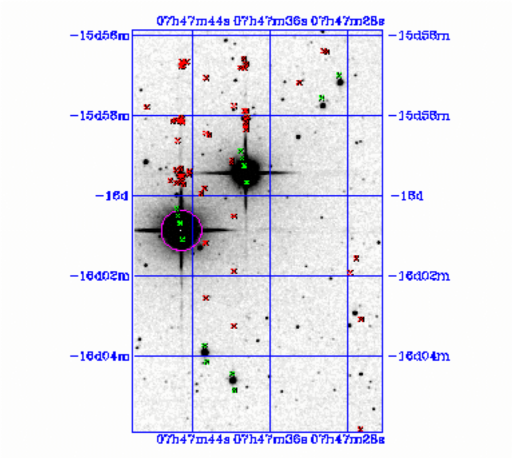
Field 28



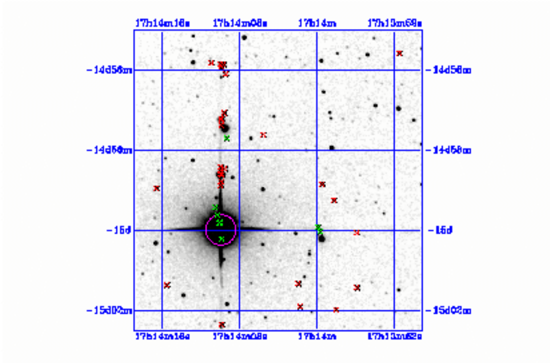
Field 29



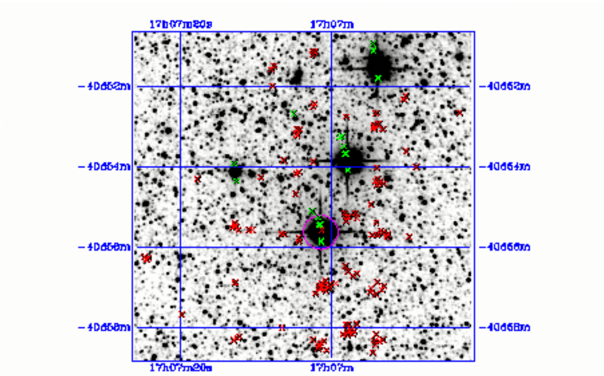
Field 30



Field 31

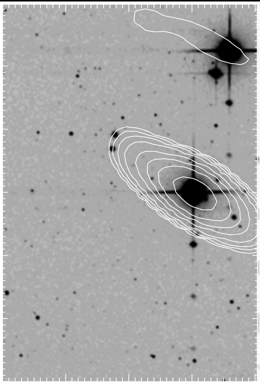
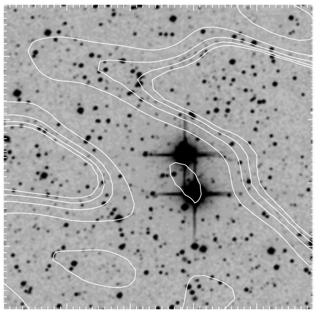
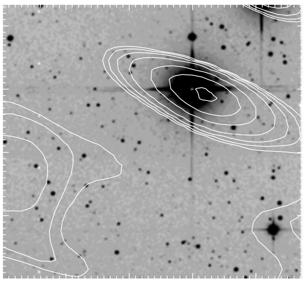
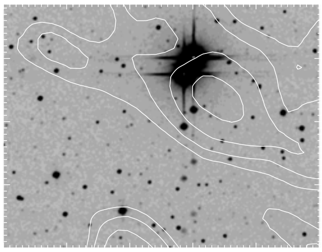
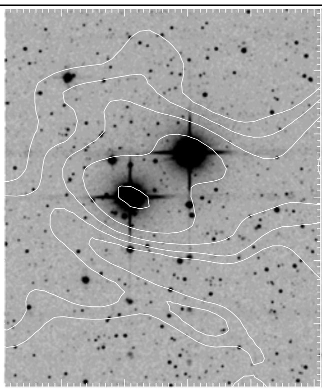
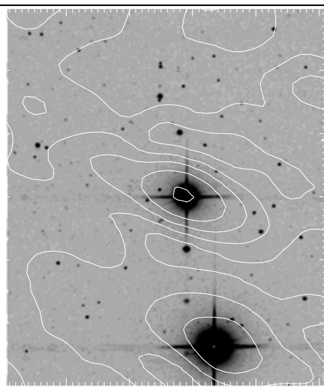


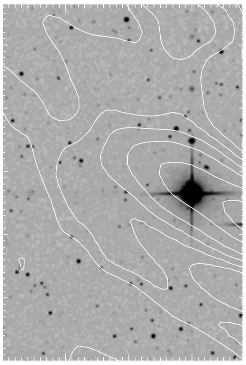
Field 32

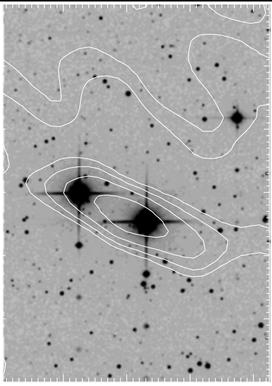


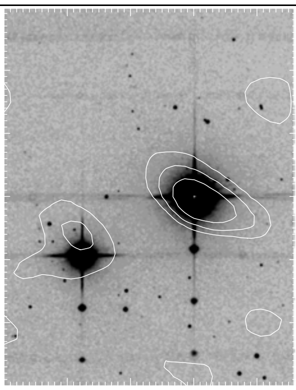
Field 33

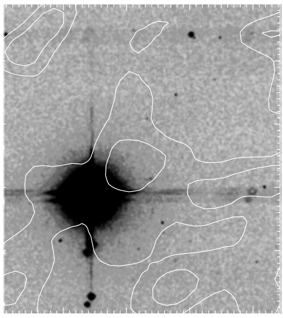
Appendix B: HIRES/2MASS overlays for double stars from K-band search

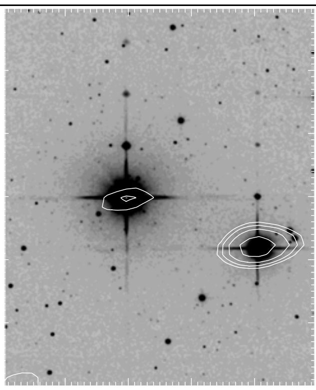
	
Field 1	Field 2
	
Field 3	Field 4
	
Field 5	Field 6

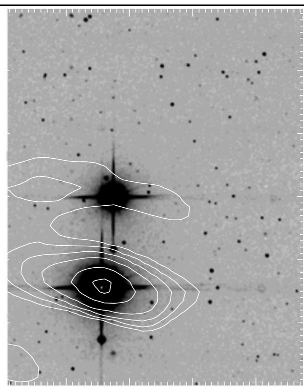

Field 7

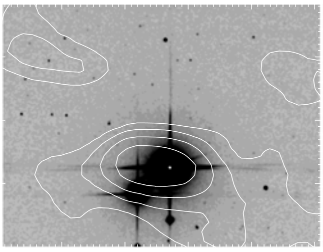
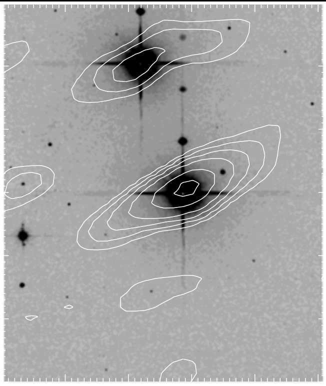
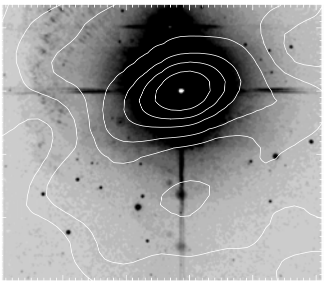
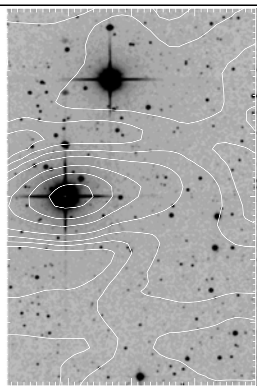
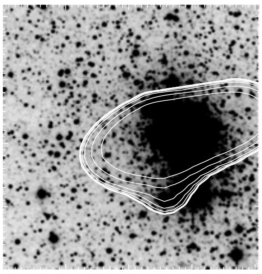
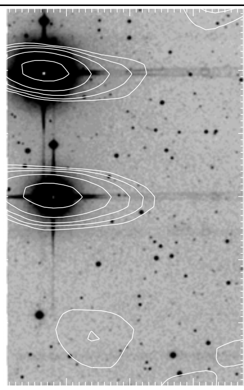

Field 8

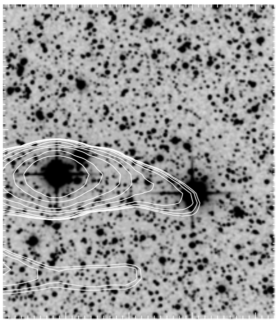
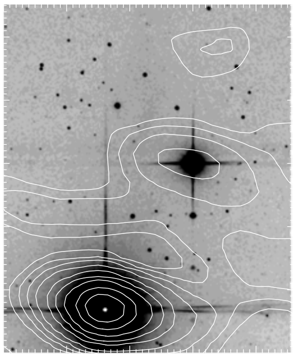
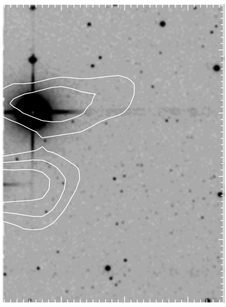
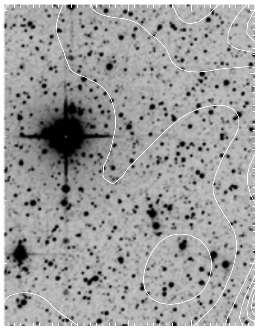
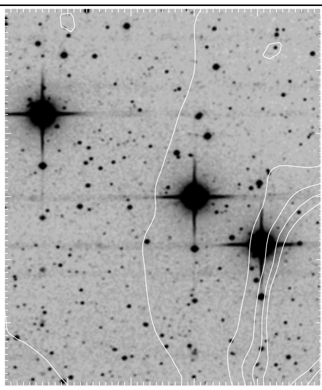
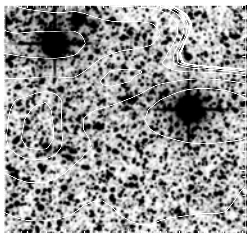

Field 9

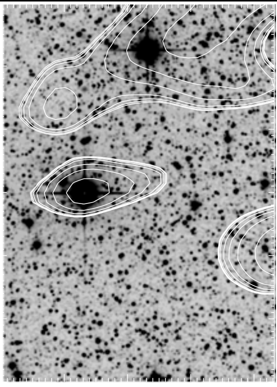
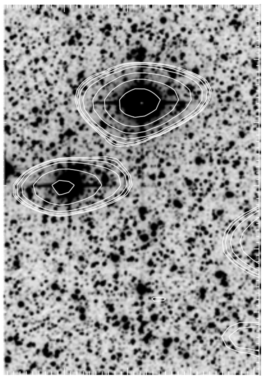
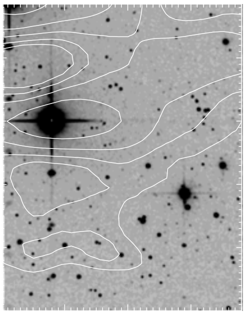
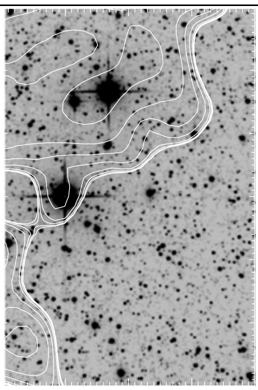
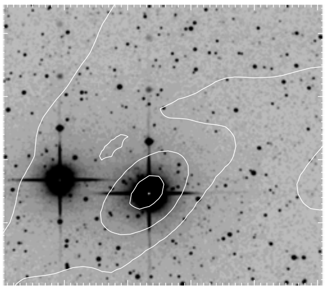

Field 10

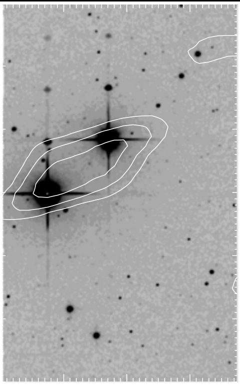
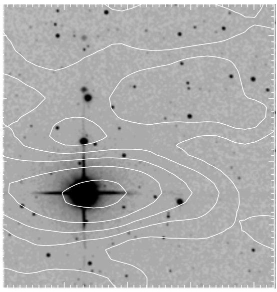
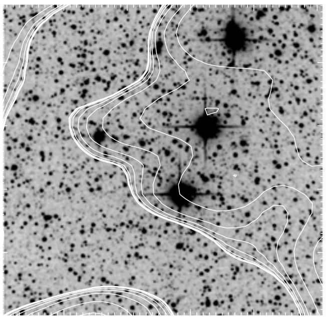

Field 11


Field 12

	
Field 13	Field 14
	
Field 15	Field 16
	
Field 17	Field 18

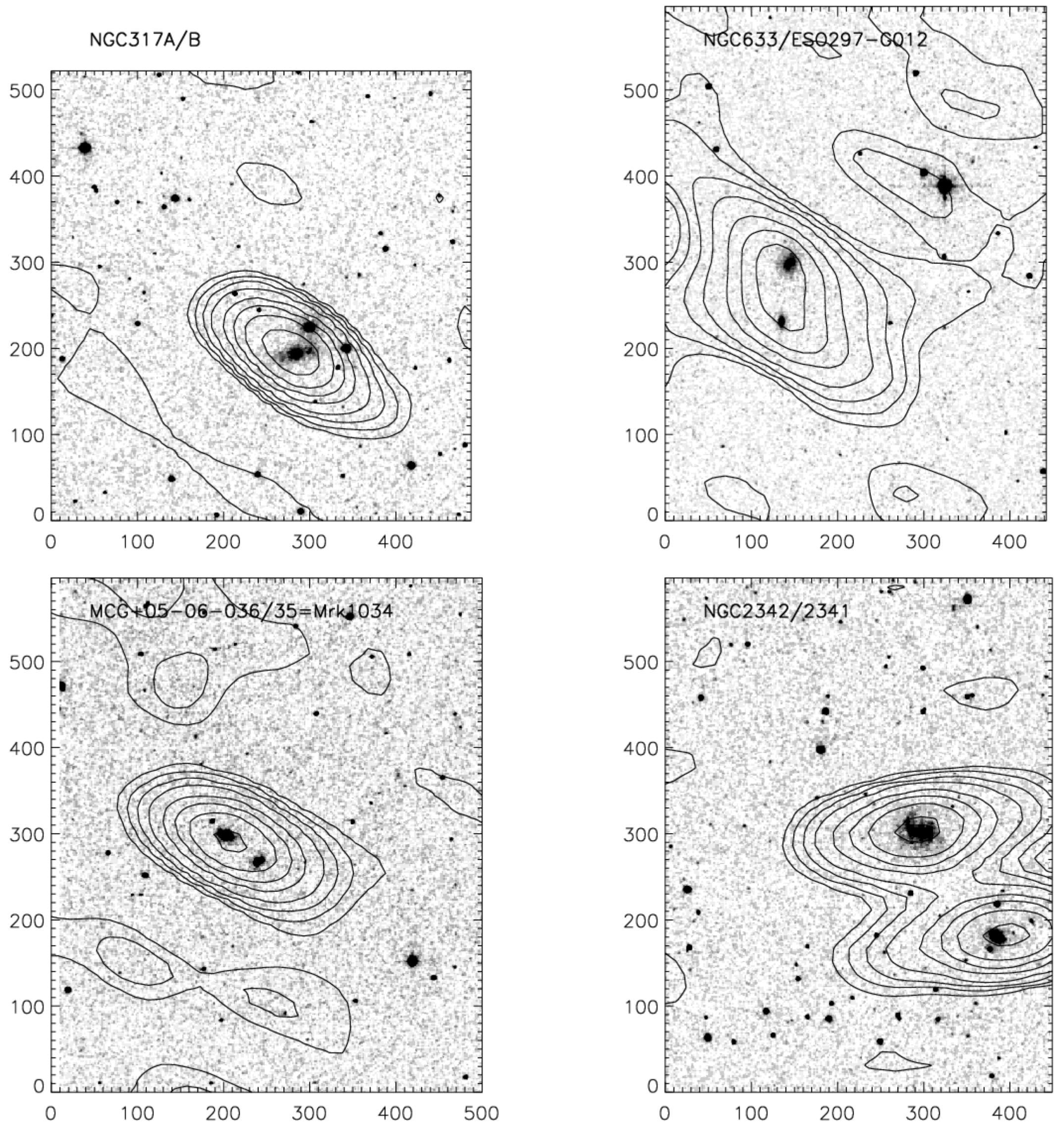
	
Field 19	Field 20
	
Field 21	Field 22
	
Field 23	Field 24

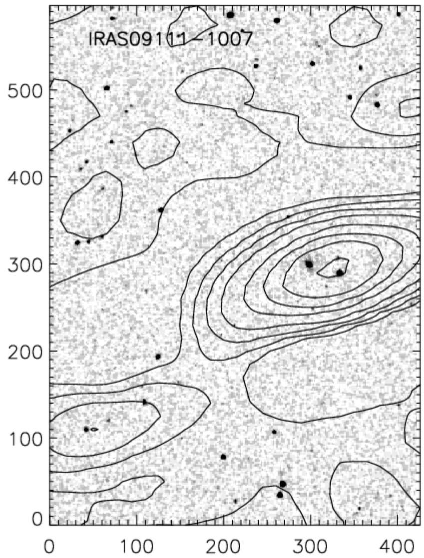
	
Field 25	Field 26
	
Field 27	Field 28
	
Field 29	Field 30

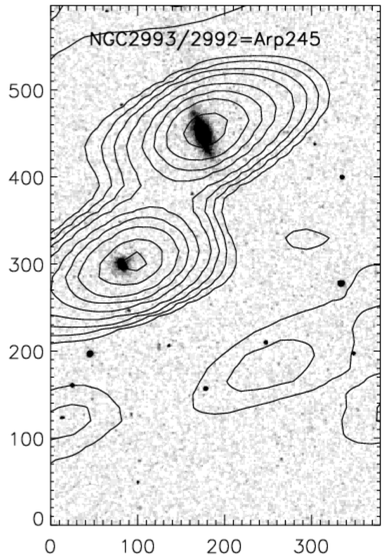
	
Field 31	Field 32
	
Field 33	

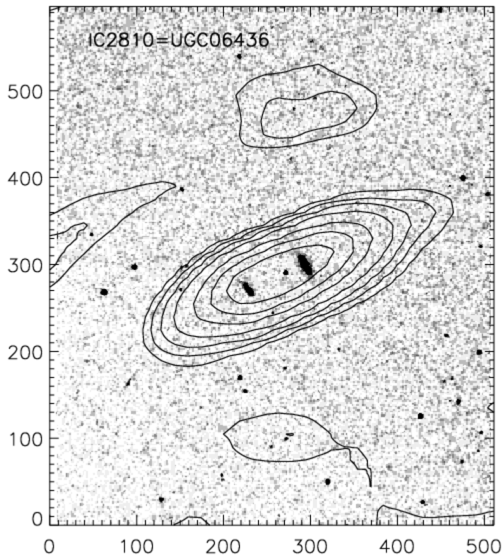
Appendix C: HIRES/2MASS overlays for double galaxies

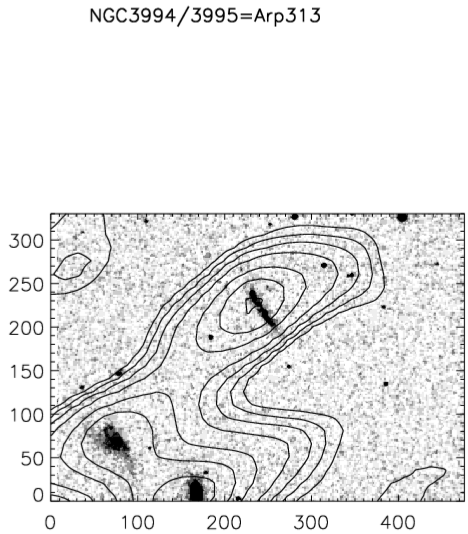
The displays are overlays of 2MASS Ks-Band (grayscale) and IRAS 60µm HIRES processed images (contours 0.2, 0.5, 1, 2, 5 etc. MJy/sr). Scale shown is in arcsecond. Because of limited size of the 2MASS image tiles obtained from NED, the size of the panels changes and the object of interest is often not centered on the panel.

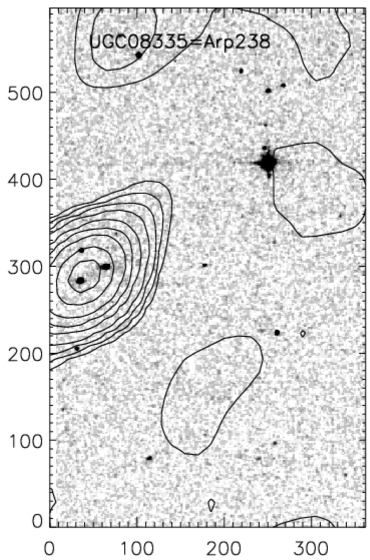


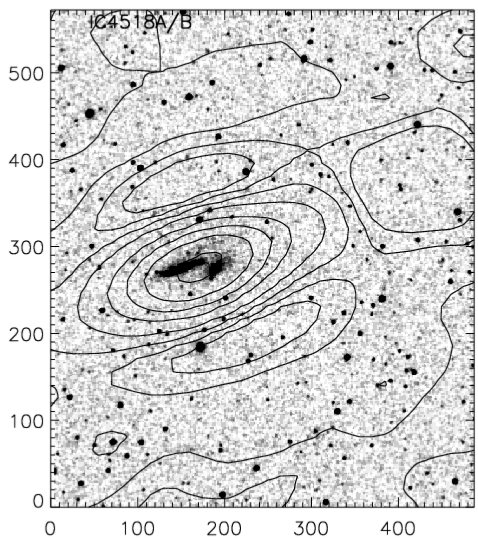

IRAS09111−1007
0
100
200
300
400
500
0
100
200
300
400

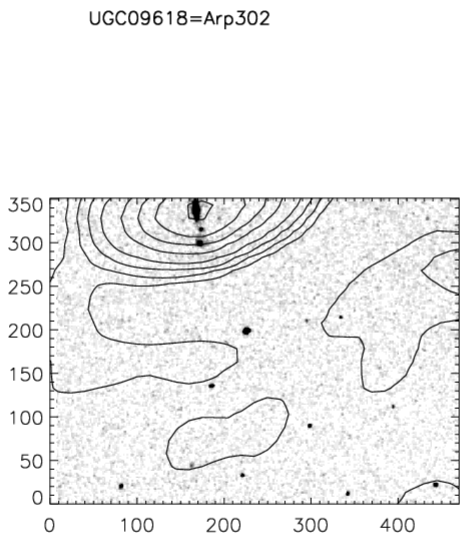

NGC2993/2992=Arp245
0
100
200
300
400
500
0
100
200
300

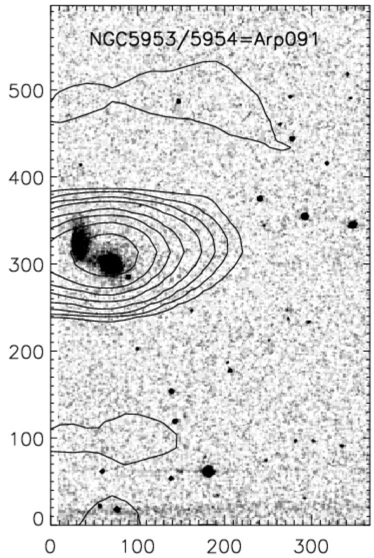

IC2810=UGC06436
0
100
200
300
400
500
0
100
200
300
400
500

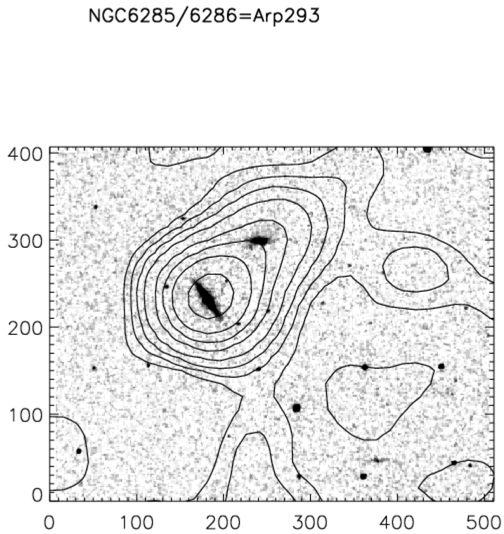

NGC3994/3995=Arp313
0
50
100
150
200
250
300
0
100
200
300
400

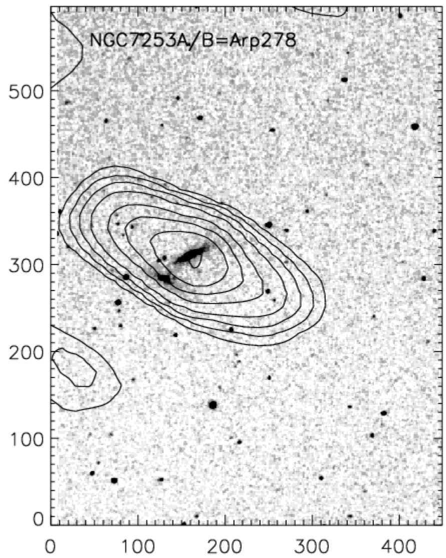

UGC08335=Arp238
0
100
200
300
400
500
0
100
200
300

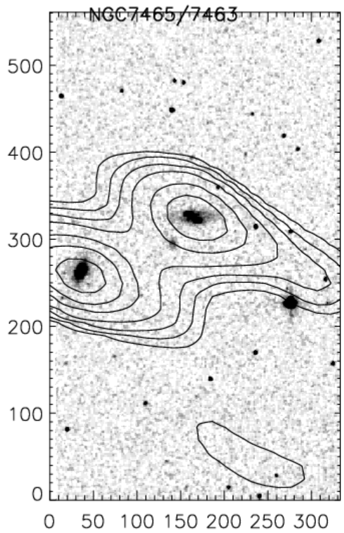

IC4518A/B
0
100
200
300
400
500
0
100
200
300
400

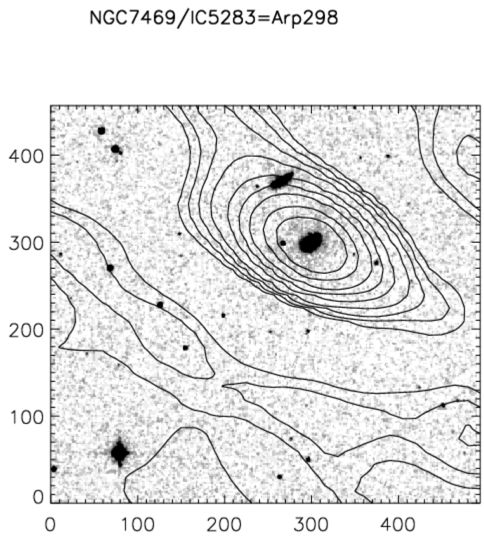

UGC09618=Arp302

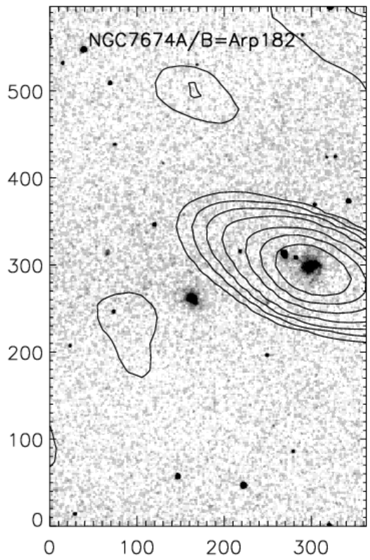

NGC5953/5954=Arp091


NGC6285/6286=Arp293


NGC7253A/B=Arp278


NGC7465/7463


NGC7469/IC5283=Arp298


NGC7674A/B=Arp182
500
400
300
200
100
0
0
100
200
300