Absolute Proper Motions from the Digitized Sky Surveys

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Catalogue of Objects and Measured Parameters from All-Sky Surveys (COMPASS)

Source ^a	Survey ^b	Decl.	Epoch	Emulsion	Band	Depth	Fields	In GSC
code		range		+ filter		(mag)		2.2/2.3
N ^c	Pal-QV	$\delta \geqslant 0^{\circ}$	1983-85	IIaD + W12	<i>V</i> ₁₂	19.5	616	N/Y
S ^d	SERC J	$\delta < -15^{\circ}$	1975–87	IIIaJ + GG395	B_J	23.0	606	Y/Y
S ^d	SERC EJ	$-15^{\circ} < \delta \leqslant 0^{\circ}$	1979–88	IIIaJ + GG395	B_J	23.0	288	Y/Y
XE ^e	POSS-I E	$\delta \geqslant -30^{\circ}$	1950–58	103aE + red plexiglass	E	20.0	935	N/N
XO	POSS-I O	$\delta \geqslant -30^{\circ}$	1950–58	103aO unfiltered	0	21.0	935	N/Y
XJ	POSS-II J	$\delta \geqslant 0^{\circ}$	1987–00	IIIaJ + GG385	B_J	22.5	897	Y/Y
XP	POSS-II F	$\delta \geqslant 0^{\circ}$	1987–99	IIIaF + RG610	R_F	20.8	897	Y/Y
XI	POSS-II N	$\delta \geqslant 0^{\circ}$	1989–02	IV-N + RG9	I_N	19.5	897	N/Y
XS	AAO-SES	$\delta < -15^{\circ}$	1990–00	IIIaF + OG590	R_F	22.0	606	Y/Y
ER	SERC ER	$-15^{\circ} < \delta \leqslant 0^{\circ}$	1990–98	IIIaF + OG590	R_F	22.0	288	Y/Y
IS	SERC I	$\delta \leqslant 0^{\circ}$	1990–02	IV-N + RG715	I_N	19.5	731	N/Y
IS	MW Atlas	$\delta \leqslant 0^{\circ}$	1978-85	IV-N + RG715	I_N	19	173	N/Y
$\mathbf{X}\mathbf{V}^{\mathrm{f}}$	SERC-QV	$-70^\circ < \delta \leqslant 0^\circ$	1987–88	IIaD + GG495	V_{495}	14	94	N/Y
GR ^g	AAO-SR	$-70^\circ < \delta \leqslant 0^\circ$	1996–99	IIIaF + OG590	R_F	20	118	Y/Y

Plate Material Utilized for the Construction of the GSC-II



GSC2.3 export catalogue released in 2007, ~ 1 billion objects, complete to $R_F \sim 20$



0 10000 20000 30000 40000 50000 60000



Schmidt Plates Astrometric Deficiencies



Calibration Methods

- Subplate
- Mask
- Local Filters







BUT:

Need of faint, dense reference catalogues to probe plate-to-plate variations of astrometric residuals

Tycho 2 ~ 2.5 million objects, lim mag V ~ 13 (2000) UCAC4 ~ 113 million obhects lim mag R ~ 16 (2012)



Question: is UCAC4 adequate to probe position- and magnitude/colordependent systematic residuals?

Answer: Yes

Question: Can it be *safely* used?

Answer: No

Reason: Proper motions are correlated with astropysical parameters!



Use of Galaxies as Fiducial Reference Points

- No measurable proper motions on plate
- Wide range of colours/magnitudes
- Pretty uniform distribution on plate



- Must be affected by same magnitude/color dependent systematics as stellar objects
- Only available at relatively high galactic lattitudes (interstellar extinction)



Star/Non-star Distribution on plates XP003/XE003





First-epoch plates magnitude equation



Second-epoch plates magnitude equation



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First-epoch plates colour equation



Second-epoch plates colour equation



BITHION astro

All plates at $|b| > 27^{\circ}$ reduced. Total sky area of 22,525 deg²





Two main calibration steps:

a) Rectification of plate-to-plate geometric + mag/col distorsions



- Cubic polynomial fitting + local filter (w/UCAC4)
- Magnitude/Colour equation (w/Galaxies)
- b. bucciarelli prague, villa lanna, march 18-21 2014



b) Absolutization of proper motions



Finds local scale + rotation from measured $(\mu_{x'}\mu_y)$ on reference plate to equatorial $(\mu_{\alpha'}\mu_{\delta})$ (w/UCAC4)



Principle Equations (1)

$$\Rightarrow \quad \Delta x_s = \quad \mu_x \times \Delta t + D(x_2, y_2) + E(m_2, c_2, x_2, y_2)$$

$$\Delta x_g = D(x_2, y_2) + E(m_2, c_2, x_2, y_2)$$

Δx_s star displacement between overlapping plates Δx_g galaxy object displacement between overlapping plates

D is the geometric distorsion function *E* is the magnitude/colour equation



Principle Equations (2)

$$\Delta x'_{s} = \Delta x_{s} - (D + \bar{\mu}_{x} \times \Delta t) = d\mu_{x} \times \Delta t + E$$
$$\Delta x'_{g} = \Delta x_{g} - (D + \bar{\mu}_{x} \times \Delta t) = -\bar{\mu}_{x} \times \Delta t + E$$

Scale: 200 mas

20

18

14

18 20

16

pseudo-proper motion is injected on galaxies and then removed

$$\Delta x_s'' = (d\mu_x + \bar{\mu}_x) \times \Delta t = \mu_x \times \Delta t$$

Mean formal errors of absolute proper motions ($\mu_{\alpha'}\mu_{\delta}$) and positions





376,490 GIQC QSOs cross-matched with plate data





Proper motion distribution of QSOs as function of magnitude





Proper motion distribution of QSOs as function of colour





Ongoing Work

- continuing checks of *local* solutions
- extension of method to low galactic latitudes



Full details in Zhaoxiang et al., APOP, in preparation

