REGATTA–ASTRO PROJECT:
ASTROMETRIC STUDIES FROM SMALL SPACE LABORATORY

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ABSTRACT. The REGATTA–ASTRO project provides a great set of astrometric and photometric measurements from Small Space Laboratory (SSL). SSL is a special spacecraft being designed at the Space Research Institute, USSR Academy of Sciences. The main feature of this spacecraft is the attitude control by solar light pressure. The main objective of the project is to compile precise global catalogues of star positions, parallaxes and proper motion containing stars with magnitude up to 8-9 and a position accuracy of 0.″01. The astrometric concept of the project is based on a highly deterministic spacecraft angular motion and numerous observations of each star using wide-angle TV cameras with CCD detectors. The SSL computer provides measurement data pre-processing, photometric referencing and data compression. Ground-based computers process the data statistically. The estimated vector includes star coordinates, SSL angular motion parameters and generalized distortion of the instruments used.

1. REGATTA Project

Milestones

- Design, manufacturing and testing of Small Space Laboratory (SSL)
- Interplanetary plasma studies based on SSL (REGATTA–PLASMA project)
- Astrometrical investigation by SSL onboard instruments (REGATTA–ASTRO project)
- Remote sensing of minor bodies of the Solar System (long-term plans)

2. Small Space Laboratory

- Attitude and (sometimes) orbit control by solar light pressure
- No jet propulsion units
- No pressurised compartment
- Passive thermal control

Return

- Ecologic cleanliness
- Payload/total mass ratio up to 50%
- Highly deterministic angular motion and hence accurate instruments' pointing data

J. H. Lieske and V. K. Abalakin (eds.), Inertial Coordinate System on the Sky, 361–366.

3. REGATTA–PLASMA Project

3.1. Primary Goals

- Solar activity mechanisms
- Ways of transmission of the solar influence via the interplanetary medium
- Response of near-planetary medium to the solar perturbations

3.2. Study Method

- Satellite net for multi-probe high temporal and space resolution measurements in collaboration with CLUSTER and SOHO spacecraft

3.3. Design Peculiarities

- Deployable booms carrying electric and magnetic field sensors
- Spinning platform with autonomous power supply, thermal control and data acquisition subsystems

3.4. Project implementation

- REGATTA–E (1993). Studies in near-equatorial region of the Earth magnetosphere. Orbit inclination is 15°, $R_{MIN} = 5\ R_E$, $R_{MAX} = 12\ R_E$
- REGATTA–A (1995). Investigation of the auroral regions of the Earth magnetosphere and near tail; interaction with CLUSTER project. Polar orbit, $R_{MIN} = 3\ R_E$, $R_{MAX} = 20\ R_E$
- REGATTA–D (1996). Studies in "middle tail" of magnetosphere. Near-ecliptical orbit, $R < 70\ R_E$, resonant with periodic Moon flybys
- REGATTA–B (1996). Unperturbed solar wind investigations. Halo orbit around *L* point of the Sun-Earth system
- REGATTA–C (1996). Distant region of magnetosphere. Halo orbit around *L* point of the Sun-Earth system

4. REGATTA–ASTRO Project

4.1. Primary Goals

- Measurements of the star positions, proper motions, parallaxes and magnitudes in UBVRI spectral bands
- Catalogue compilation

4.2. Instrumentation

- Astrometric TV cameras
- Slit photometers

4.3. Scanning mode

- Longitudinal axis of SSL (Z-axis) pointing to the Sun
- Spacecraft rotation around Z-axis with angular rate of 1 rev/day
- Auxiliary cameras inclined by an angle of 160 deg with respect to Z-axis

4.4. Metrologic concept of the experiment

- Multiple observations of every star and following statistical filtering
- Highly deterministic spacecraft angular motion
- High thermal stability

4.5. Design Pecularities

- No moveable parts
- Dynamic symmetry
- Optimal geometrical and optical parameters of the solar stabilizer to minimize the influence of random external perturbations

4.6. Orbit

• Quasi-satellite in the Sun-Earth system	
• Maximum geocentric distance	12 million km
• Synodic period	11 months
• Ecliptical inclination	10 deg

4.7. Registration of stars by TV cameras

• Number of exposures during the star passage across a field of view	600
• Minimum number of consecutive passages per camera	5

4.8. Onboard Processing

- Data correction based on ground and onboard calibration
- Star image extraction
- Calculation of averaged moments of brightness distribution
- Star identification
- Calculation of star track parameters

4.9. Ground Processing

- Data correction to chromatic aberrations
- Computation of coordinate residuals
- Statistical appraisals of star coordinates
- Double star decomposition and magnitude determination
- Determination of parallaxes and proper motions
- Reduction of star positions to the unique epoch
- Transfer to the standard coordinate frame

4.10. Possible ways of future ASTRO Project development

- Observation of quasars to determine star catalogue attitude with respect to inertial frame
- Observations in different spectral bands, including IR and microwave

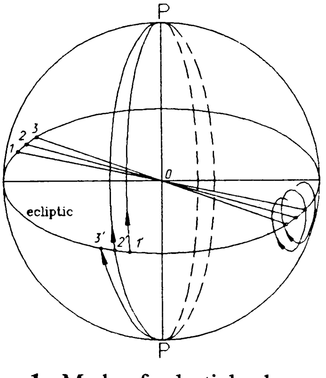

Figure 1. Mode of celestial sphere scanning

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Table 1. Comparative parameters of REGATTA–ASTRO and HIPPARCOS projects.

	REGATTA–ASTRO	HIPPARCOS
Launch year	1993–1994	1989
Star position accuracy (after filtering)	0.″01	0.″002
Magnitudes	8-9	up to 13
Spectral bands	UBVRI	U
f/D, *meters*	0.1 / 0.07	1.4 / 0.29
Field of view, *deg*	5.3×8.0	0.9
Duration of total sphere survey, *years*	0.5	> 2
Number of observations of a specified star	> 10000	650
Single measurement error (*μm / arc sec*)	0.3 / 0.6	0.3 / 0.05
Number of stars being under observation simultaneously	up to 300	up to 4
Variations of angular position of an instrument with respect to the Sun direction, *deg*	0.1	40
Thermal stability of an instrument, *deg*	0.1	?

Table 2. Onboard Astrometric Complex (Main parameters)

TV cameras:	
Number of cameras	4 (astrometry) + 2 (photometry)
Focal length, *mm*	100
D / f ratio	1 : 1.4
Mean number of stars inside field-of-view	80
Lens transparency in 480-800 *nm* band	> 70%
Detector CCD array	
Number of pixels	520×580
Pixel size, *μm*	18×24
Exposure, sec	0.01-2.0
Shooting frequency, 1/*sec*	0.2-0.25
Photometers:	
Number of photometers	2
Photometer type	slit camera
Action mode	continuous
Optic axes	directed orthogonally with respect to the spin axis

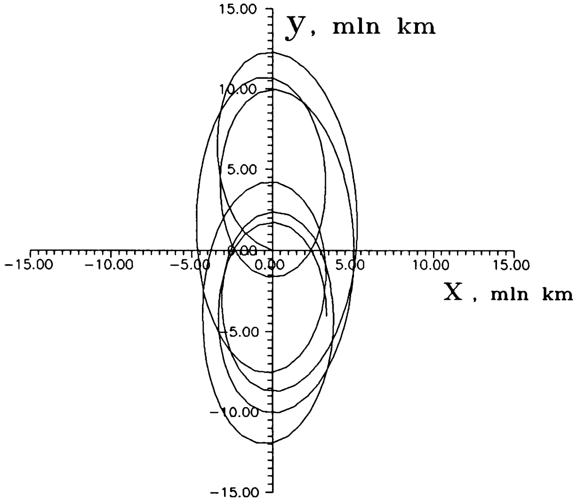

Figure 2. Quasi-satellite orbit of the REGATTA–ASTRO spacecraft. Synodical frame.

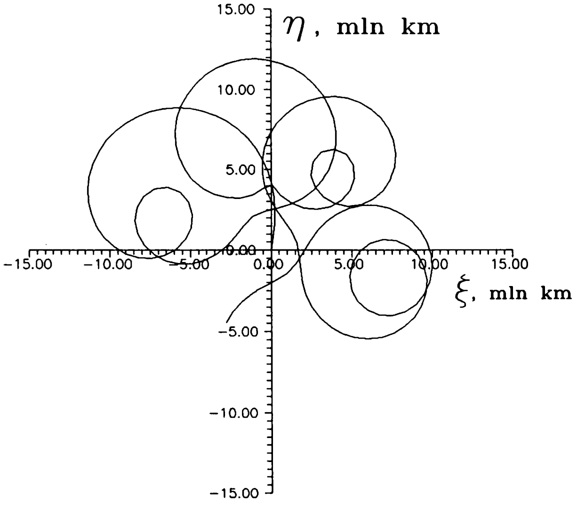

Figure 3. Quasi-satellite orbit of the REGATTA–ASTRO spacecraft. Inertial frame.

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Table 3. Main sources of measurement errors

Source	*Compensation method*
Asymmetry of geometric and inertial parameters	Addition of asymmetry parameters to the list of quantities to be statistically determined
Instrumentation errors	Addition of "generalized distortion" parameters to the list of quantities to be statistically determined
Solar wind pressure variations	Special design of solar stabilizer. Onboard measurement of solar wind parameters
Micro-meteoric bombardment	Oscillation suppressing by hydraulic damper

Discussion

RÖSER: Are REGATTA-ASTRO and LOMONOSOV competitive projects?
KOGAN: No, I hope not.

HUGHES: (1) You have a very large field of view. Can you describe the optical system in a little more detail? (2) With a complex system it will be necessary to very carefully evaluate the systematic optical effects if the accuracy you mention is to be achieved.
KOGAN: (1) The lens transparency in the 480–800 *nm* band is greater than 70%. The other parameters are given in Table 2. The CCD matrix is cooled to –70°C. (2) We are going to describe the optical distortion of the error in the focal plane into a Fourier series expansion and detemine its coefficients statistically together with the star positions. Proper analysis shows that these coefficients may be evaluated from the same data array as the star positions.

HØG: HIPPARCOS uses only one wide band. TYCHO uses B and V, but not U. Are the photometric results in five colours your main mission goal? It seems that the expected astrometric results in the second phase are very similar to HIPPARCOS with respect to accuracy and to the number of stars.
KOGAN: As far as the accuracy in the star positions is concerned, we are going to achieve the accuracy of 10 mas, instead of the 1 mas of HIPPARCOS. The second phase is not yet developed to the necessary level. The figures presented in the table demonstrate only the upper limit of accuracy achievable on the same technological basis.

KOPEJKIN: I think that you cannot obtain an accuracy on the order of one msec because of relativistic corrections. The orbit of the satellite in your project is heliocentric and cannot be determined very accurately.
KOGAN: It's not clear what effects you have in mind. Relativistic corrections are susceptible to detailed calculations and that is being done for quite some time while defining the position of the spacecraft in deep space.

XU: If the total duration of observations of your project will be only one-half year, it would seem to be too short for determining the parallax and proper motions of stars.