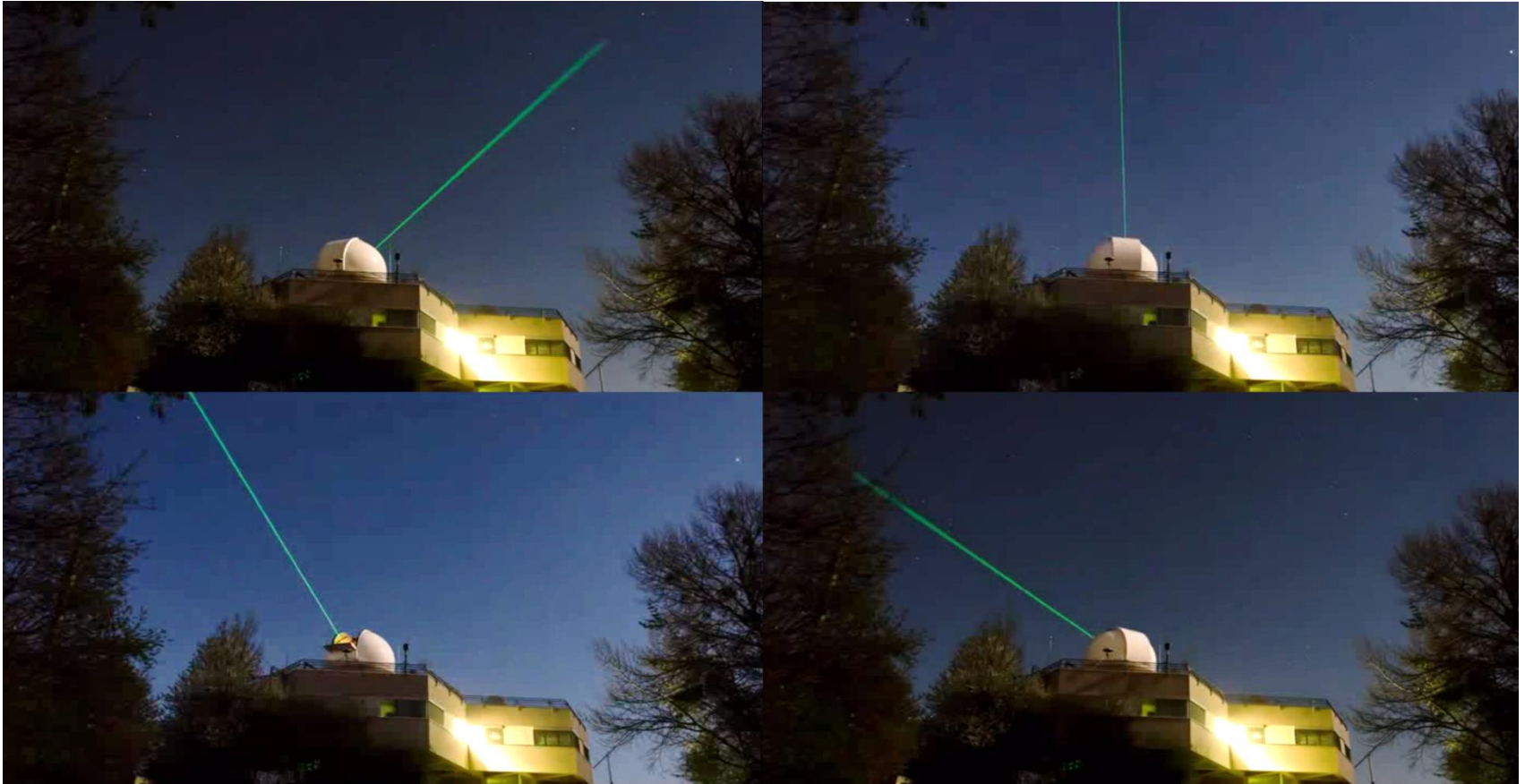


# STARE AND CHASE



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# OUTLINE - STARE AND CHASE

## STARE



- STARE: Camera --> fixed, arbitrary direction of sky
- Field of view:  $7^\circ \times 5^\circ$ , Live-Video of stars analyzed
- Stellar plate solving --> Coordinates of image center
- Sunlit space debris (uncoop.) target passes through image
- Automatic target detection algorithm
- X/Y position on sensor --> Equatorial coordinates (DEC/RA)
- CPF-file generated from data [GMV]
- No a priori orbit information

## CHASE



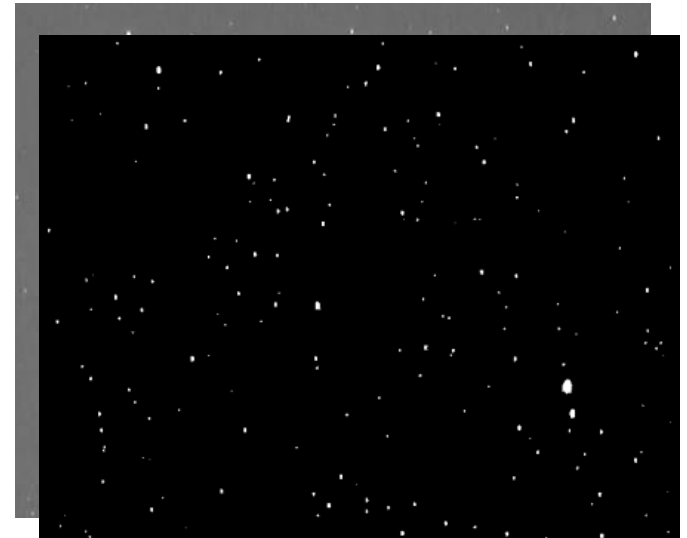
- CHASE: Target tracked with new CPF
- Laser ranging with space debris laser
- 20 W @ 100 Hz, 3 ns pulse width

# CAMERA SETUP

- Analog CCD camera (Watec®: 752 x 582 pixels)
- F/1.4,  $f = 50$  mm, photo objective, COTS
- Piggyback mounted on Graz 50 cm SLR telescope
- Video output: Frame grabber, 25 frames / second
- Stars up to magnitude 9 visible

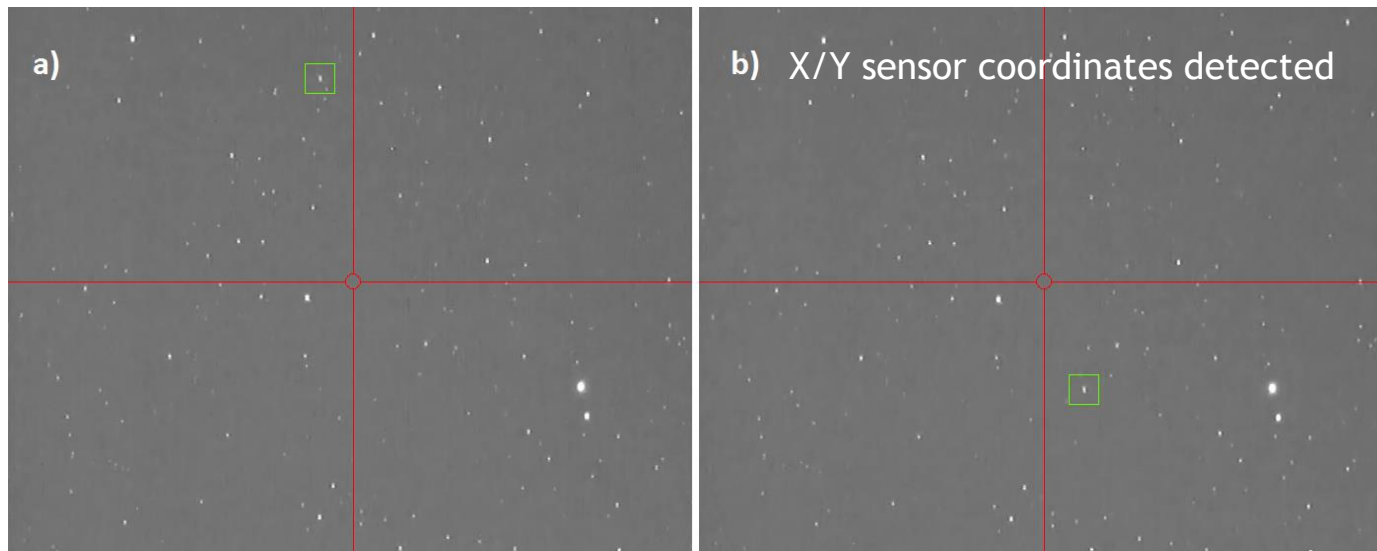


Sky background subtraction



# PLATE SOLVING

- Every 2 seconds: Image of stellar background --> FITS file generated
- Star positions compared with star catalogue via software tool (Pinpoint)
- Equatorial coordinates (Dec/RA) of image center
- Solve accuracy: 15 - 20 arc seconds
- Space debris target passes through field of view (30 - 60 sec)



# POINTING DATA ACQUIRED



- Declination, Right ascension, Julian date --> Stored to file
- CPF generated only from Pointing data --> GMV
- Track File uploaded to our Tracking PC
- SLR tracking procedure started (Chase)
  
- Time from first target detection to tracking --> less than 2 minutes

# EXPERIMENTAL PROCEDURE

Space debris / uncooperative targets chosen with known TLE CPFs

1. **Reference:** Tracking and space debris ranging with standard TLE CPFs
2. **Stare:** Pointing angles to targets acquired, new CPFs calculated
3. **Chase:** Tracking and space debris ranging with new Stare and Chase CPFs

Observation Date	Satellite name	NORAD ID
2016-06-28	Topex	22076
2016-06-29	GlobalStar M001	25162
2016-06-29	SL-14 R/B	33505
2016-06-29	Iridium 61	25263

# RESULTS: OBSERVED - CALCULATED

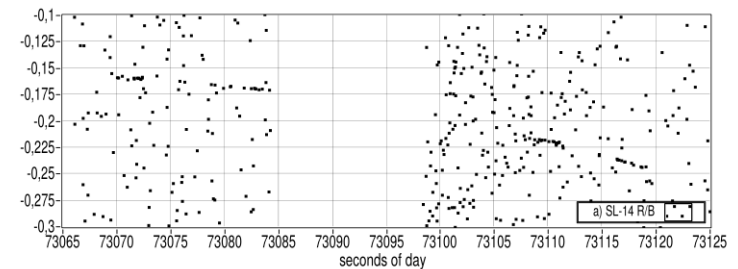
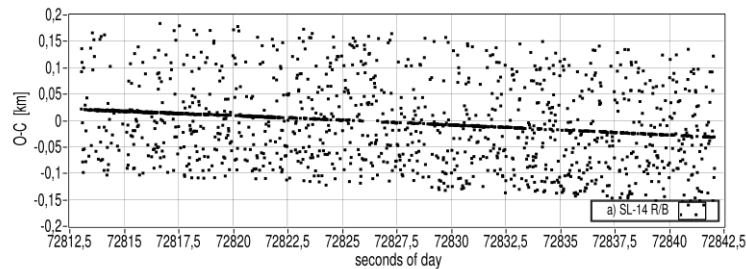
y - axis: Observed-Minus-Calculated Residuals [km]

x - axis: seconds of day: 2016-06-29

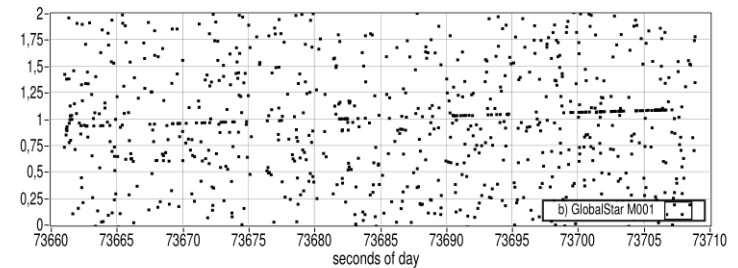
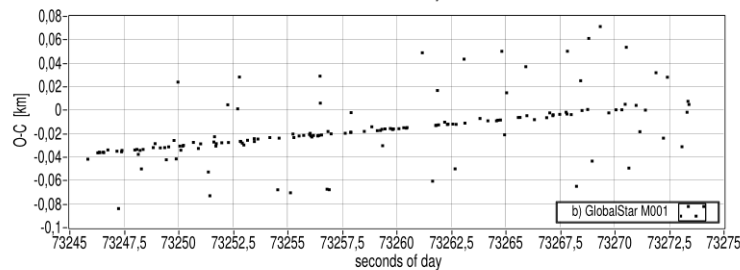
## TLE – CPF

## Stare & Chase – CPF

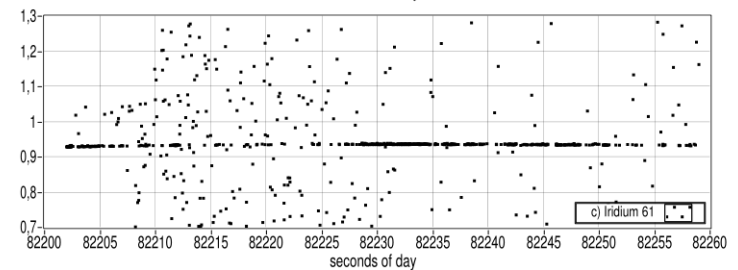
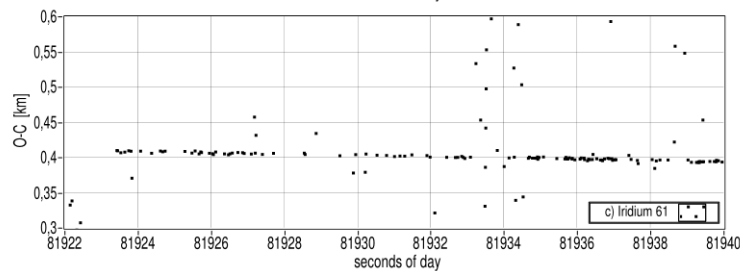
SL14-R/B



GS M001



Iridium 61



# ALL OBSERVATIONS WITHIN ONE PASS

## Observations occurred within a single pass

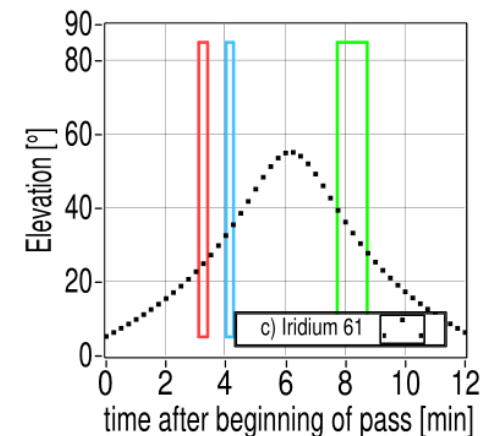
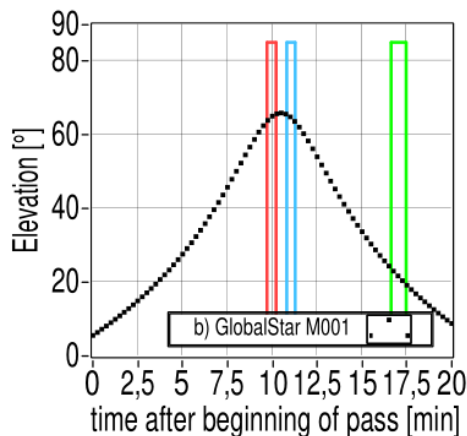
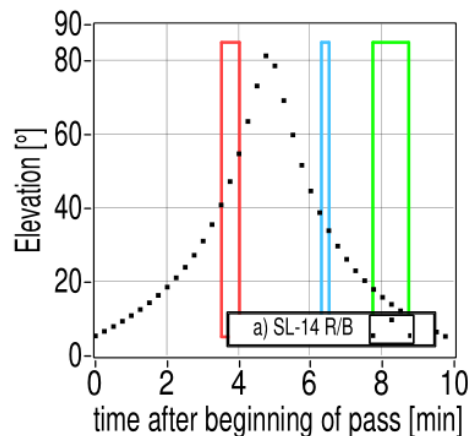
y - axis: Satellite Elevation [°] according to CPF

x - axis: time after beginning of pass [minutes]

**Red:** Space debris laser ranging with TLE - CPFs

**Blue:** Stare observations

**Green:** Space debris laser ranging with Stare and Chase - CPFs





# TIME BIAS AND RANGE BIAS COMPARISON

Comparison of space debris time and range bias

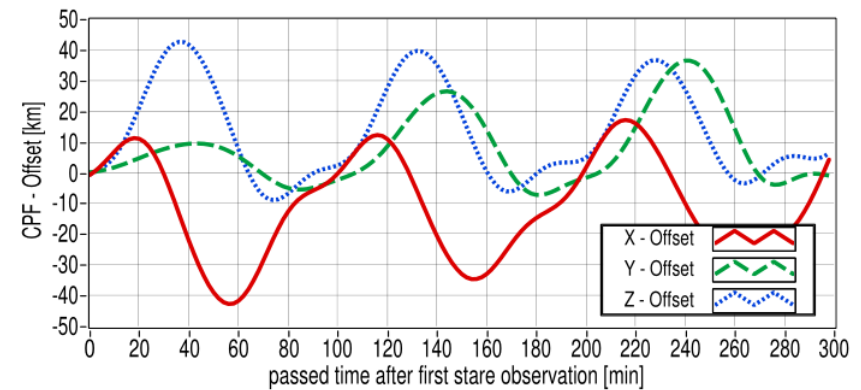
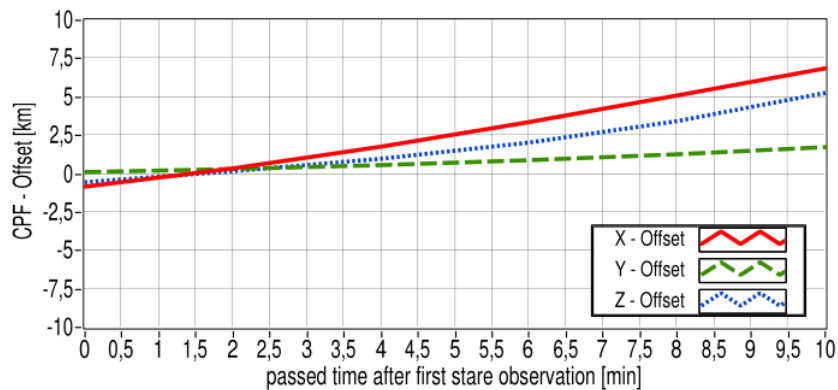
- $t_b$  ... Time bias [ms]
- $r_b$  ... Range bias [m]
- TLE ... Standard Two Line Element - CPF
- SNC ... Stare And Chase - CPF

Satellite name	TLE - CPF		SNC - CPF	
	$t_b$ [ms]	$r_b$ [m]	$t_b$ [ms]	$r_b$ [m]
SL-14 R/B	-23	144	-54	-700
GlobalStar M001	71	-33	336	1750
Iridium 61	-73	2	108	-764

# CPF COMPARISON

## CPF X/Y/Z - Earth Centered / Earth-Fixed Coordinates (SL-14 R/B)

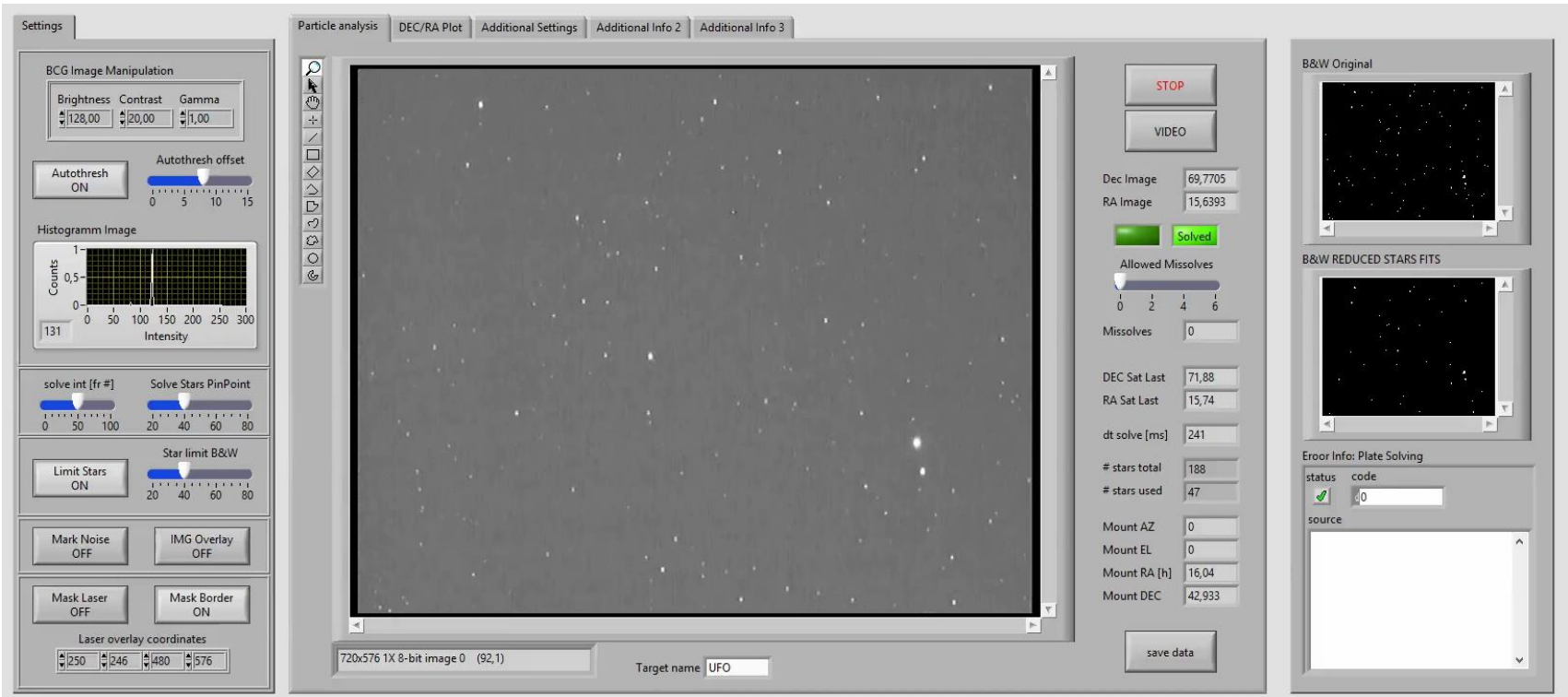
- y - axis: CPF (TLE) - CPF (SNC) [km]
- x - axis: time after first entering of target into field of view
- Offsets: Less than 7.5 km after 10 minutes



## SUMMARY

- Camera records arbitrary part of sky: FOV  $7^\circ \times 5^\circ$
- Automatic space debris target detection
- Plate solving --> Pointing angles to space debris
- CPFs calculated from pointing angles only
- Space debris ranging without a priori orbit information
- CPF - Offsets to TLE CPFs: less than 7.5 km for 10 minutes

# !!! Thank you !!!



The screenshot displays the Starlink software interface, which is used for star identification and tracking. The main window shows a grayscale image of a star field. The interface is divided into several panels:

- Settings Panel (Left):** Contains controls for BCG Image Manipulation (Brightness: 128.00, Contrast: 20.00, Gamma: 1.00), Autothresh (ON), Histogramm Image (Counts vs Intensity), solve int [fr #], Solve Stars PinPoint, Limit Stars (ON), Star limit B&W, Mark Noise (OFF), IMG Overlay (OFF), Mask Laser (OFF), Mask Border (ON), and Laser overlay coordinates (250, 246, 480, 576).
- Particle analysis Panel (Top):** Includes tabs for DEC/RA Plot, Additional Settings, Additional Info 2, and Additional Info 3.
- Control Panel (Right):** Features a STOP button, VIDEO button, Dec Image (69,7705), RA Image (15,6393), a green SOLVED button, Allowed Missolves (0), Missolves (0), DEC Sat Last (71,88), RA Sat Last (15,74), dt solve [ms] (241), # stars total (188), # stars used (47), Mount AZ (0), Mount EL (0), Mount RA [h] (16,04), Mount DEC (42,933), and a save data button.
- Image Panels (Right):** Shows B&W Original and B&W REDUCED STARS FITS images.
- Error Info: Plate Solving (Bottom Right):** Displays status (green checkmark), code (40), and source.

The main image area shows a star field with a target name 'UFO' at the bottom. The image is labeled '720x576 1X 8-bit image 0 (92,1)'.

All studies were performed within the framework of the ESA project:  
4000112734/14/D/SR „Space debris stare and chase“