Characterization of hidden defects of an original XVI Century painting on wood by Electronic Speckle Pattern Interferometry

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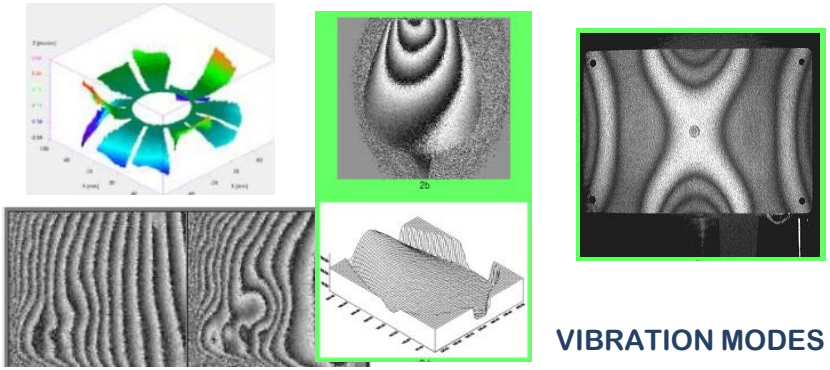
ESPI

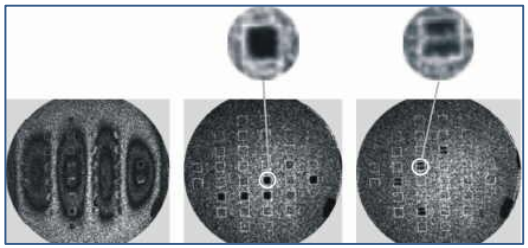
Electronic Speckle Pattern Interferometry

NON CONTACT - NON DESTRUCTIVE
HIGH SENSITIVITY

NDT OPTICAL INTERFEROMETRY
FOR INDUSTRIAL DIAGNOSTICS

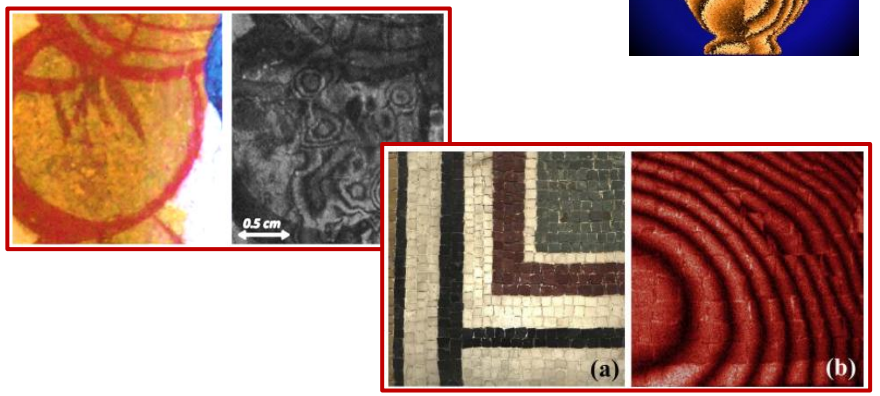


VIBRATION MODES



QUALITY TESTING

DEFORMATIONS



INCREASINGLY UTILIZED

AS DIAGNOSTIC TOOL
IN THE CULTURAL HERITAGE FIELD

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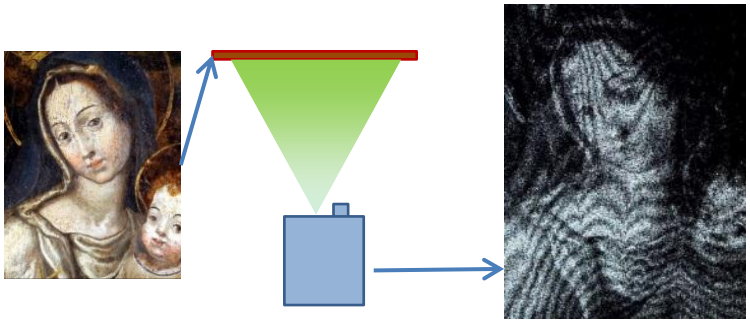
ESPI - IDEAL TOOL FOR CULTURAL HERITAGE DIAGNOSTICS

HIGH SENSITIVITY (AT SUB MICROMETRIC SCALE)

NON CONTACT (THE OBJECT UNDER TEST IS SIMPLY ILLUMINATED BY A LOW INTENSITY LASER LIGHT)

NON DESTRUCTIVE (NO HANDLING - NO COLLECTION OF SAMPLES FROM THE ARTWORK)

REAL-TIME MEASUREMENTS



- MICRO-CRACKS
- DETACHMENTS
- STRUCTURE DEFORMATIONS
- STRESS CONCENTRATIONS

INTERFERENCE FRINGES OVERLAY THE IMAGE OF THE OBJECT

EASY INTERPRETATION OF FRINGES

LOCALIZATION OF DEFECTS

QUANTITATIVE RESULTS

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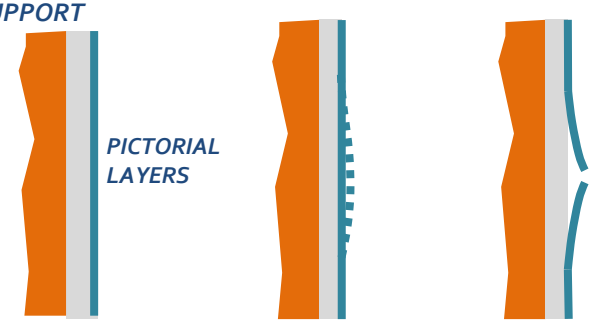
WOODEN ARTWORKS

WHOLE STRUCTURE DEFORMATION

TYPICAL DAMAGES INDUCED BY MICRO-CLIMATE VARIATIONS



INITIAL STAGE DETACHMENT

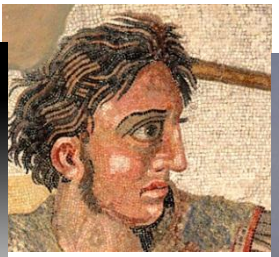
FINAL RESULT: CRACK

LOCAL DAMAGES

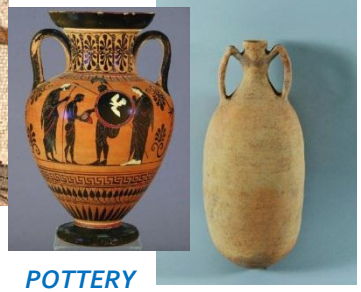
Interferometric analysis is applicable on almost any typology of artwork

FRESCOES

WOODEN SCULPTURES



MOSAIC



POTTERY

. . . . .

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ESPI

Electronic Speckle Pattern Interferometry

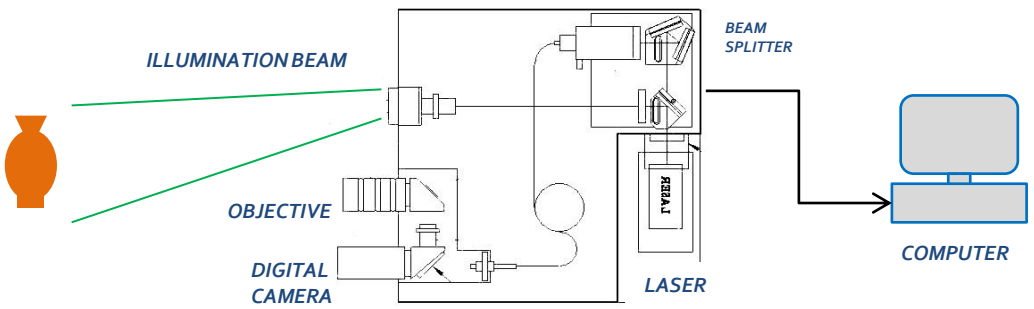
Utilizing Digital Technologies

- COMPACT SELF-CONTAINED OPTICAL SET-UP
- FAST DATA PROCESSING BY DEDICATED SOFTWARE
- *REAL TIME MEASUREMENT*
- *LONG TIME MONITORING*
- *OBJECT SIZE FROM FEW MILLIMETERS UP TO METERS*
- *NO NEED OF OBSCURED LABORATORY*

SYSTEM MAIN FEATURES

- 500 mW – 532nm Laser
- CCD SENSOR
- 30 ftg/sec. (Acqusition + Numerical Processing + Visualization.)
- Size: 450x450x160 mm

MOVABLE FOR IN-SITU UTILIZATION



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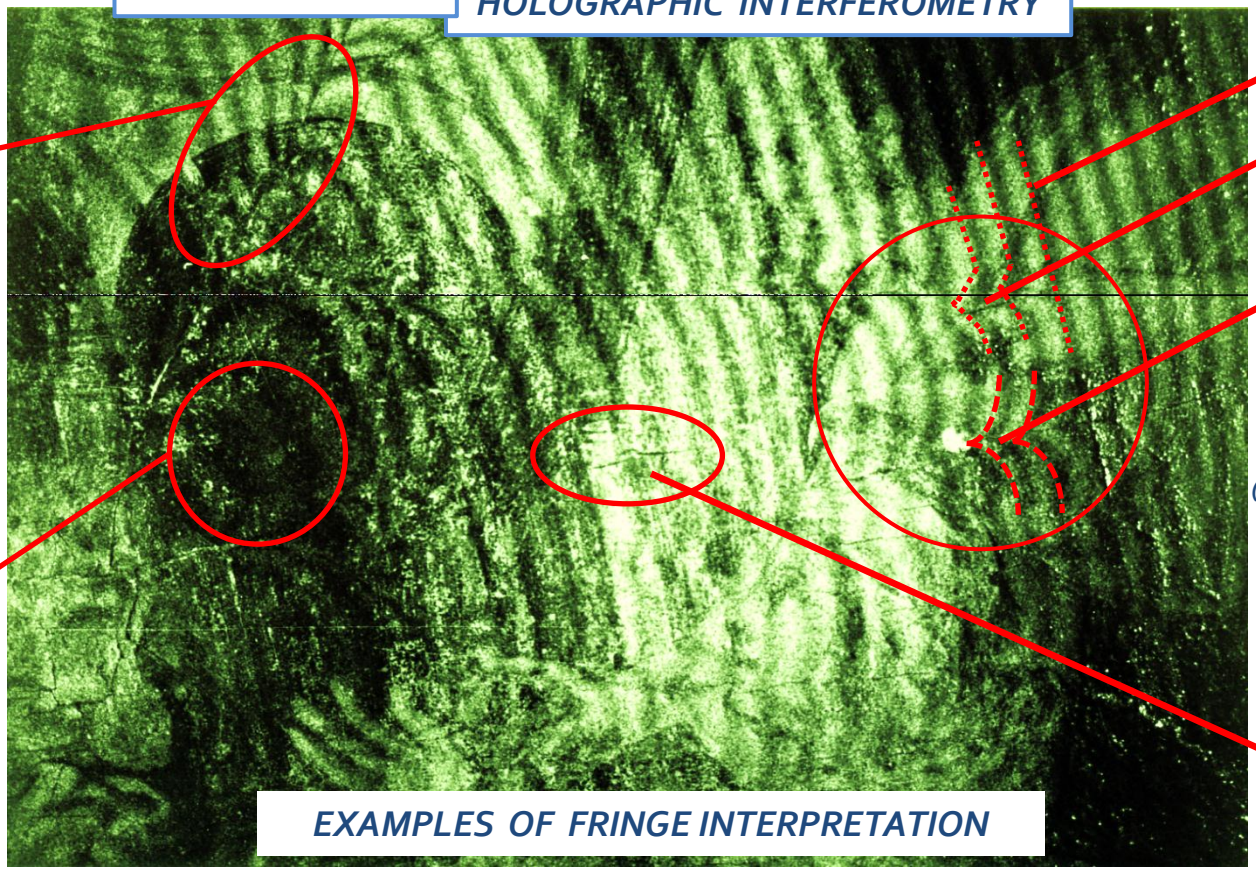
BACKGROUND

HOLOGRAPHIC INTERFEROMETRY



Real-time holographic interferometry for painting conservation and restoration - S. Aurisicchio, A. Finizio and G. Pierattini
Arch. Pol. vol. 18:1977 http://www.iaepan.edu.pl/archaeologia-polona/article/275

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ESPI SURVEY
ON A WOODEN PAINTING

«MADONNA CON BAMBINO E SAN GIOVANNINO»
XVIth CENTURY - AUTHOR UNKNOWN.

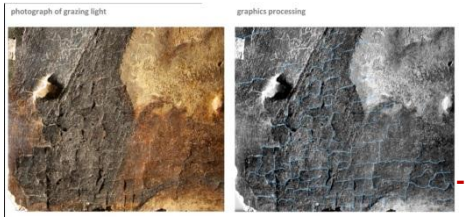
Painting on wood - Size: 72x80 cm

Collection
SUOR ORSOLA BENINCASA University
Naples

TRADITIONAL ART CONSERVATORS SURVEY METHODS ON PICTORIAL LAYERS

QUALITATIVE RISK MAP

- uprisings of the paint film
- gaps of the pictorial film
- uprising characterized as vertical craks

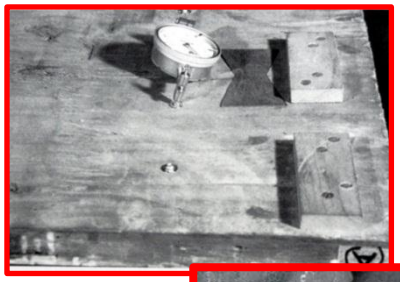


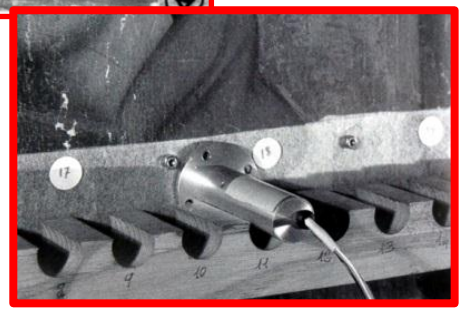
- RAKING-LIGHT IMAGING

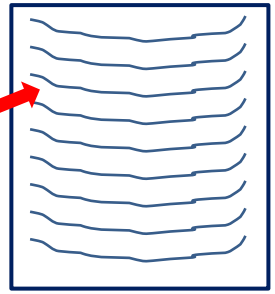
- VISUAL INSPECTION BY "EXPERIENCED" UNAIDED EYE OR WITH OPTICAL MICROSCOPE

- ACOUSTIC METHOD BY "EXPERIENCED" EAR (GENTLE TAPPING ON THE SURFACE)

TRADITIONAL SURVEY METHODS FOR WOODEN SUPPORTS DEFORMATION







DEFORMATION PLOT

- *DISPLACEMENT SENSORS CONSECUTIVELY APPLIED ON DIFFERENT POINTS*
- *MEASUREMENT TAKEN AT DISTINCT TIMES*
- *TIME-CONSUMING PROCEDURE*

M. Ciatti, C. Castelli, A. Santacesarea. "Dipinti su tavola, la tecnica e la conservazione dei supporti" -- EDIFIR - 1999

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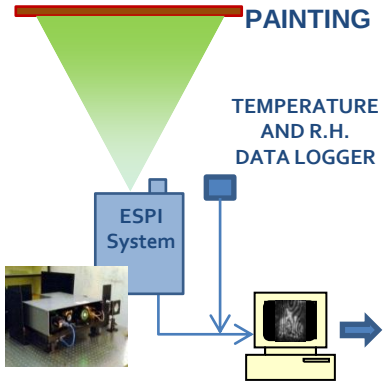
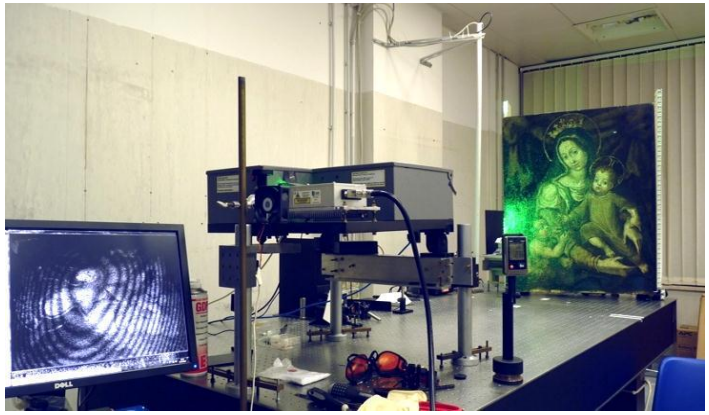
LONG TERM REAL-TIME DISTORTIONS MONITORING OF THE WHOLE STRUCTURE



REAL TIME MOVIE OF FRINGES PROGRESSION



ROOM TEMPERATURE INCREMENT: + 2,2 °C

TOTAL MEASUREMENT TIME: 50 min

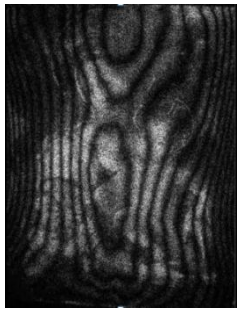
TOTAL SURFACE: 5740 cm^2

FRAMES EXTRACTED FROM THE REAL TIME MOVIE

0 min.

1 min.

10 min.


20 min.

30 min.

48 min.

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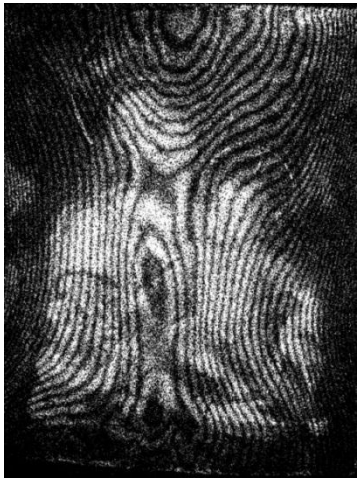
«FULL-FIELD» MEASUREMENTS ON THE WHOLE STRUCTURE

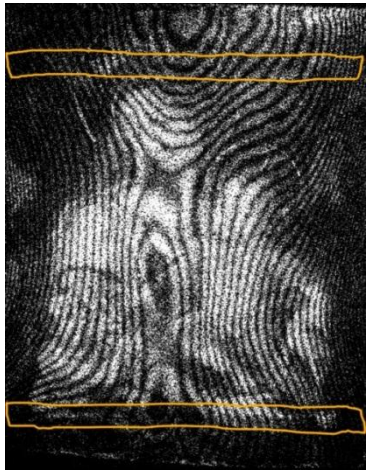


FRINGES SHAPES
SUGGEST
AN INHOMOGENUOUS
STRUCTURE.....

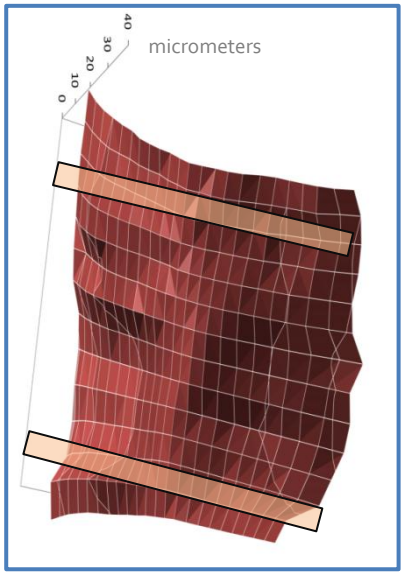
.....ACTUALLY IT IS

TWO REINFORCING BARS
ARE APPLIED ON THE BACK

RESULTS



PROFILES OF
BACK CROSS-BARS



WHOLE STRUCTURE
DISTORTIONS

THE CROSS-BARS APPLIED ON THE BACK
ARE INEFFECTIVE
IN REINFORCING THE ENTIRE PAINTING

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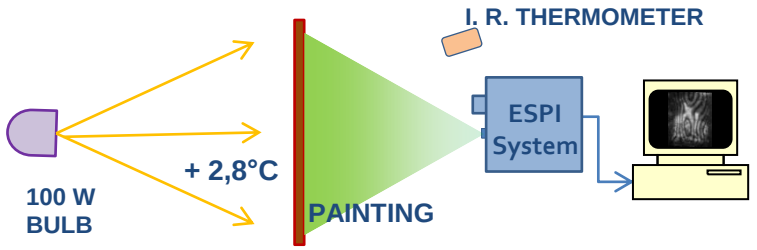
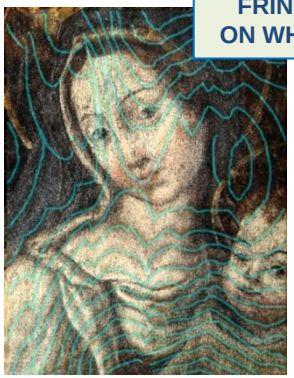
EXPERIMENTAL PROCEDURE

THERMAL LOAD INDUCES MICROMETRIC DISPLACEMENTS REVEALED BY ESPI



ESPI EVIDENCE OF WHOLE STRUCTURE DEFORMATION AND LOCAL CRACKS



FRINGES DELINEATION ON WHITE LIGHT PICTURE

CRACKS DETECTED BY ESPI

VISIBLE

NOT VISIBLE

(BY VISUAL INSPECTION)

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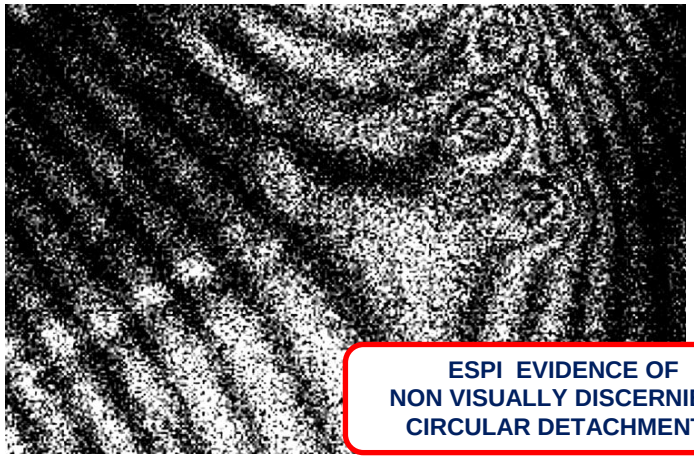
HIDDEN DETACHMENTS OF PICTORIAL LAYERS

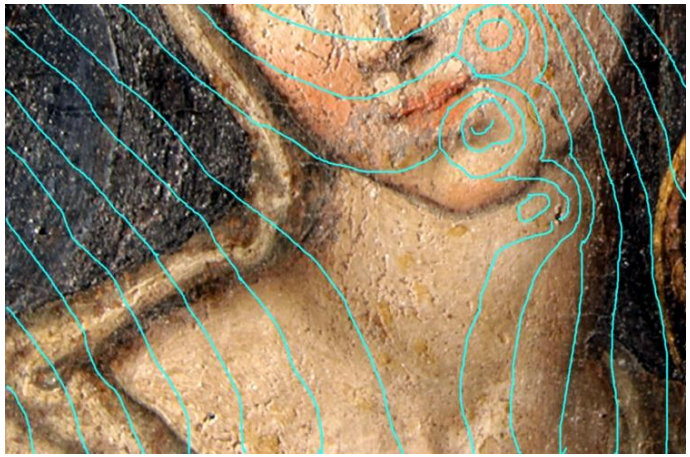
WHITE LIGHT PICTURE



INTERFEROGRAM

ESPI EVIDENCE OF NON VISUALLY DISCERNIBLE CIRCULAR DETACHMENTS

OVERLAY OF FRINGES AND WHITE LIGHT PICTURE



FRINGES DELINEATION ON WHITE LIGHT PICTURE

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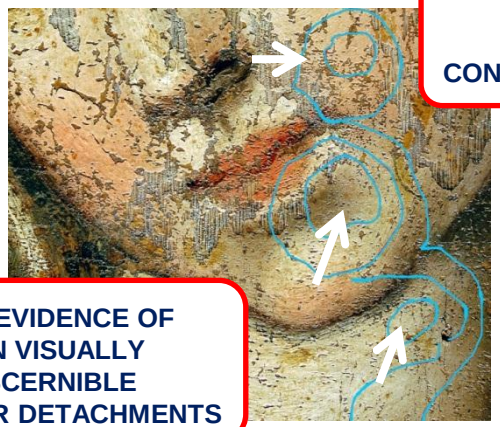
photograph of grazing light

graphics processing

PROBLEMATIC AREA ON THE PAINTING DETECTED BY TRADITIONAL CONSERVATION VISUAL ANALISYS

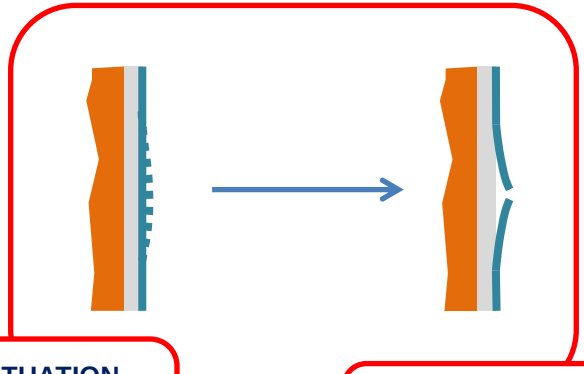
MAP OF DAMAGES REVEALED BY RAKING-LIGHT METHOD

(*VISIBLE FAULTS IN YELLOW*)



NOT DETECTED BY TRADITIONAL CONSERVATION ANALISYS

ESPI EVIDENCE OF NON VISUALLY DISCERNIBLE CIRCULAR DETACHMENTS



PRESENT SITUATION

«BUBBLE» DETACHMENTS ON EXTERNAL LAYER

HIGHLY PROBABLE… FUTURE EVOLUTION

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IN THE LABORATORY PRACTICE
A LONG TIME IS REQUIRED
FOR REACHING MECHANICAL STABILITY
AND THERMAL EQUILIBRIUM
OF THE PAINTING

HOURS TO OBTAIN ACCURATE INTERFEROGRAM ON A LARGE AREA

SPEEDING-UP MEASUREMENTS

LOCAL HEATING INSTEAD OF GLOBAL HEATING

REAL-TIME FRINGE RECORDING DURING THE COOLING STEP

50 W BULB

REAL-TIME MOVIE

FRINGE RECORDING DURING THE COOLING STEP

«TRAVELLING» FRINGES TRACE THE PATH OF DAMAGES

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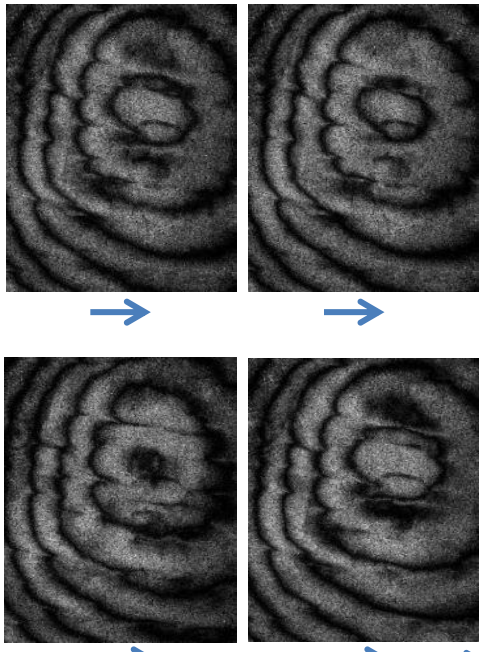
50 W
LIGHT BULB

10 SECONDS
IRRADIATION

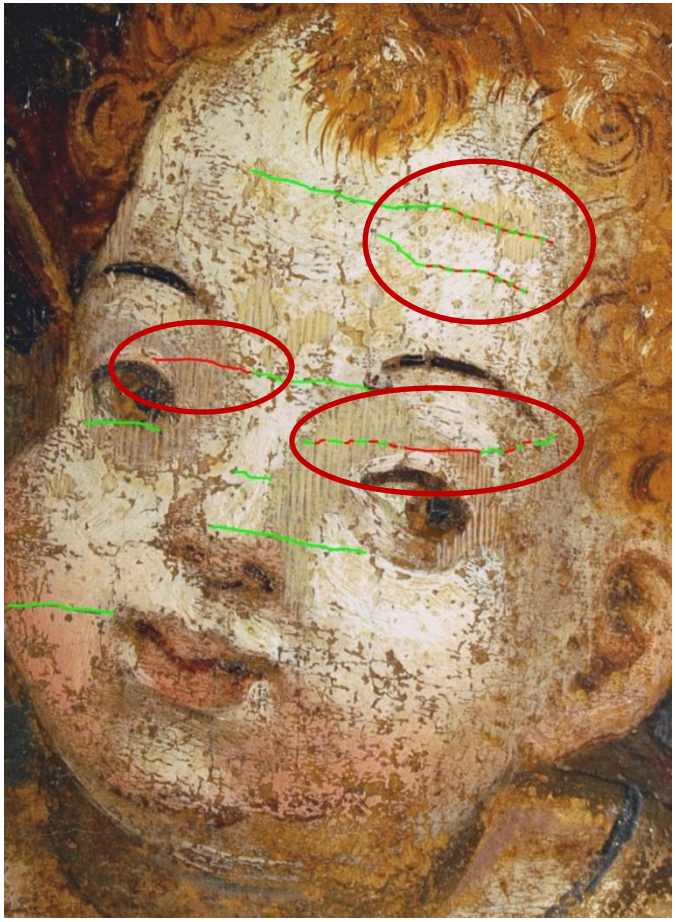
LOCAL
TEMPERATURE
INCREMENT
2,4 °C

REAL-TIME
MOVIE

FRAMES EXTRACTED FROM THE
REAL TIME MOVIE



«TRAVELLING» FRINGES
TRACE THE PATH OF CRACKS
ON THE PICTORIAL LAYER



CRACKS
DETECTED
BY ESPI

PARTIALLY VISIBLE
VISIBLE
NOT VISIBLE

(BY VISUAL INSPECTION)

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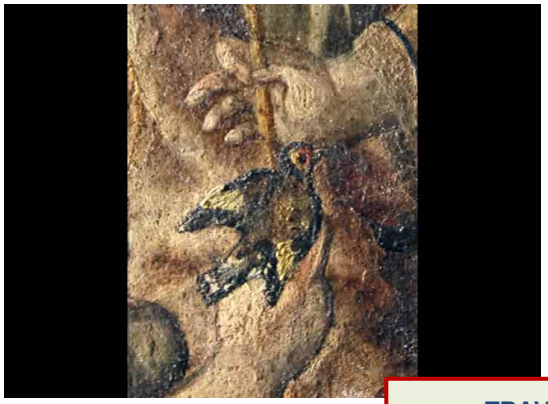
COLLIMATED LIGHT BEAM

50 W LIGHT BULB

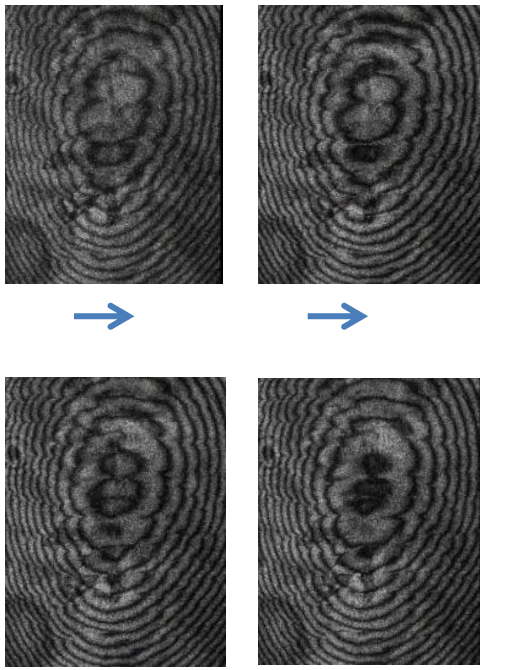
5 SECONDS IRRADIATION

LOCAL TEMPERATURE INCREMENT 2,1 °C



REAL-TIME MOVIE

FRAMES EXTRACTED FROM THE REAL TIME MOVIE



«TRAVELLING» FRINGES TRACE THE PATH OF CRACKS ON THE PICTORIAL LAYER

VISIBLE

NOT VISIBLE

(BY VISUAL INSPECTION)

CONCLUSIONS

ESPI IS A HIGH VALUABLE DIAGNOSTIC TOOL FOR ART DIAGNOSTICS

IN CHARACTERIZING DAMAGES OR REVEALING HIDDEN DEFECTS

AT THE MOMENT THIS TECHNIQUES NEEDS AN EXPERT IN OPTICS.

IT IS ESSENTIAL A CLOSE CO-OPERATION

BETWEEN ART CONSERVATORS AND SCIENTISTS

FOR ART CONSERVATORS IT IS PARTICULARLY IMPORTANT TO PERFORM ITERATIVE ANALYSIS AT REGULAR TIME INTERVALS TO ASSESS THE DAMAGE EVOLUTION.

REDUCTION OF THE COST AND SIMPLIFICATION OF MEASUREMENT METHOD…

COULD ALLOW FOR A ROUTINELY UTILIZATION BY ART CONSERVATORS