

INVESTIGATION OF THE PHENOMENON OF ERUPTING MICRO-PROTUSIONS ON THE SURFACE OF OIL PAINTINGS BY GEORGIA O'KEEFFE



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Introduction

Background

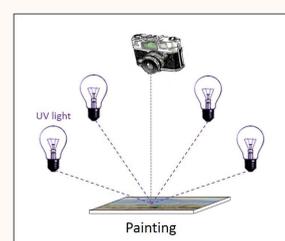
- Abundant micro-protusions have developed on a significant number of oil paintings by the American artist Georgia O'Keeffe (1887-1986).
- In 1947 correspondence with her conservator Caroline Keck, O'Keeffe expressed her concerns about small pinpoint losses starting to appear in one of her 1928 painting,
- Since a couple of years, the hypothesis formed that the development of protusions in O'Keeffe's paintings might be related to metal soaps formation and that the high occurrence of protusions might originate from her use of a specific type of commercial primed canvas.

Objectives of the collaborative research project

- Investigate the nature and origin of protusions in O'Keeffe's paintings
- Develop a quantitative approach to mesoscale surface shape measurements
- Innovate a time lapse approach to monitor the protusions at the scale of the entire painting

Photometric stereo under UV light set-up

- Series of pictures are taken under different angles of illumination.
- UV light is used to excite a fluorescence response on the painting. Fluorescence, by definition, is the light self-emitted from the painting materials and thus displays ideal Lambertian scattering behavior (= isotropic diffusion of light), a necessary condition to accurately extract the surface shape.
- Photometric stereo allows to capture and to separate color and shape features of an object surface.



Schematic representation of photometric stereo acquisition under UV light.



Photometric stereo acquisition under UV light of O'Keeffe's painting *Pedernal*.

Surface shape and color information

Visible image

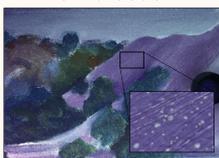


Photometric stereo acquisition + Resolution of a linear system of equations

$$I_i = k(n \cdot l_i)$$

I intensity
 k albedo
 n normal vector
 l illumination

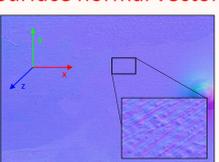
UV-albedo



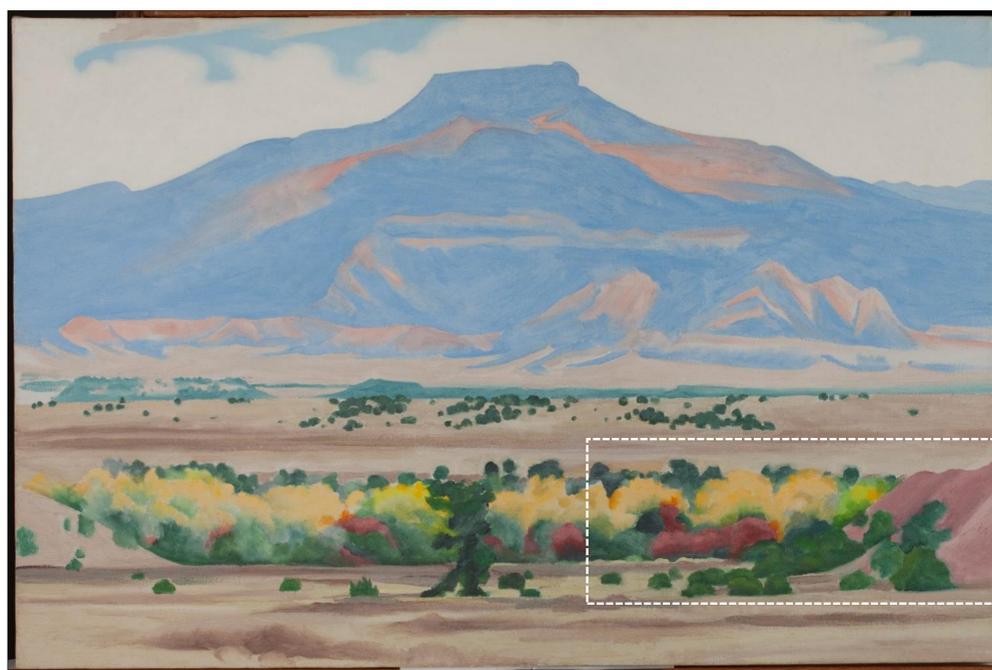
= only color information

+

Surface normal vector



= only surface shape information



Georgia O'Keeffe, *Pedernal*, 1941-1942. Oil painting on canvas, 51.1 x 76.8 cm. Georgia O'Keeffe Museum, Santa Fe, NM.

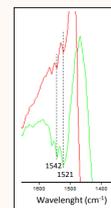
Compositional information



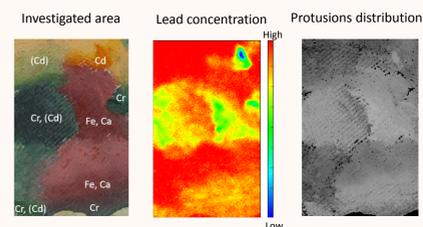
△ Spots of FTIR analysis in reflectance □ Area of XRF mapping

Presence of metallic soaps in **all painted areas** analyzed by in-situ FTIR (△).

- ▲ Red hill area = abundant protusions
- ▲ Green foliage area = very few protusions



Elementary distribution from XRF mapping: possible correlation between the protusions distribution and areas with the highest concentration of lead?



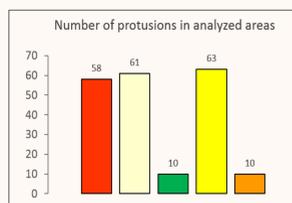
Selective distribution of protusions

Manual extraction of details from the UV-albedo image = information on the protusions occurrence, size and morphology



Manual basic protusions counting

- 1) Extracted detail
- 2) Optimized visualization using threshold
- 3) Protusions counting

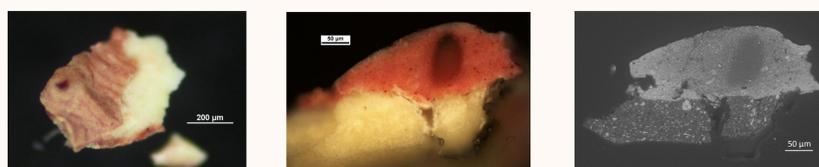


Conclusions and perspectives

- Innovated UV light photometric stereo under UV light
- Selective distribution of protusions in the different colors
- Metallic soaps detected in all colors as determined by FTIR in reflectance
- Protusions seem to be linked to lead concentration and thickness of paint

Future directions

- Monitor surface changes using photometric stereo
- Develop an automatic computer-based approach for protusions extraction algorithms using SIFT (Scale Invariant Feature Transform)
- Investigate the protusions at the microscopic scale



Investigation of a paint fragment (red hill of *Pedernal*) including an erupting protusion: unmounted fragment (left), optical (center) and backscattered electron (right) images of the cross-section.