REDEFINING LIMITS

The (Invisible) Future of Archaeological Aerial Reconnaissance

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Behind the Scenes
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OVERVIEW

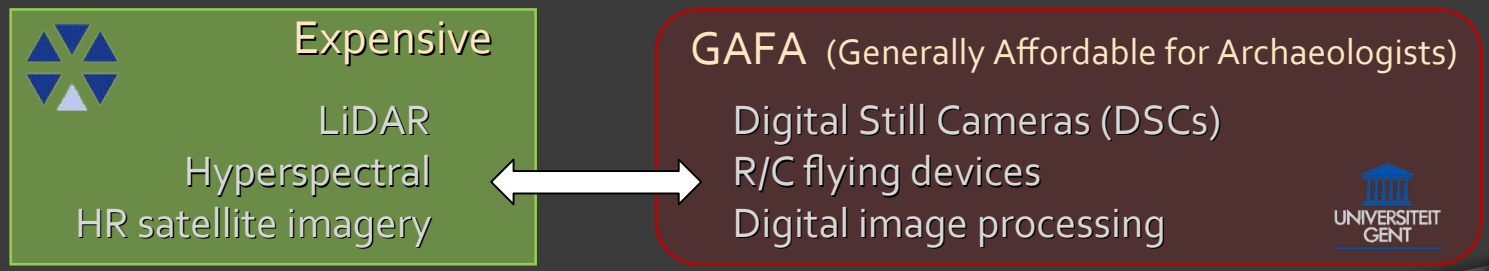
- Aerial archaeology
- Theoretical background
- Approach 1: low-cost
- LBI
- Approach 2: more expensive
- Future
- Conclusion

AERIAL ARCHAEOLOGY – WHAT'S IN A NAME ?

- Aerial archaeology
  - Acquisition of data
  - Data inventory
  - Mapping
  - Interpretation
  - Comparison
- Data acquired from a certain altitude
  - (Spy)satellites
  - RADAR and LiDAR data
  - Airborne multi/hyperspectral scanning
  - Vertical (high-altitude) aerial photography
  - Oblique (low-altitude) aerial photography

AERIAL ARCHAEOLOGY – 21ST CENTURY

- New sensing devices
  - Digital cameras (still and video)
  - Hyperspectral sensors
  - LiDAR
  - Satellite sensors (< 0.5 m GSD)
- Alternative acquisition & processing approaches
  - Strip flying - total coverage (LiDAR, RADAR, hyperspectral, verticals) active archaeological reconnaissance → observer directed
  - Drones or R/C flying devices
  - Digital Image Processing (SFM, auto-orthorectification)



AERIAL ARCHAEOLOGY – FEATURES

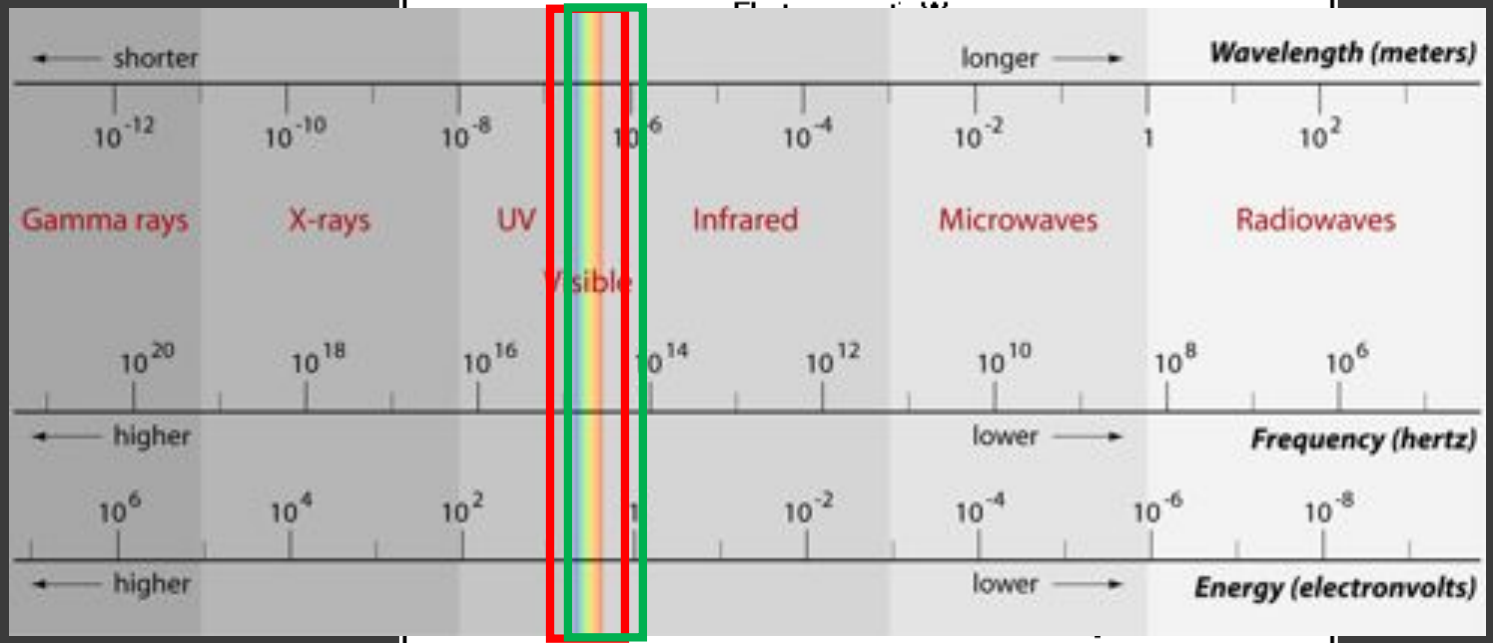
- Crop marks
  - Positive
  - Negative
- Soil marks
- Shadow marks
- Snow marks
- Water marks
- Visible material remains

→ indirect indication of possible archaeological remains

→ *contrast*

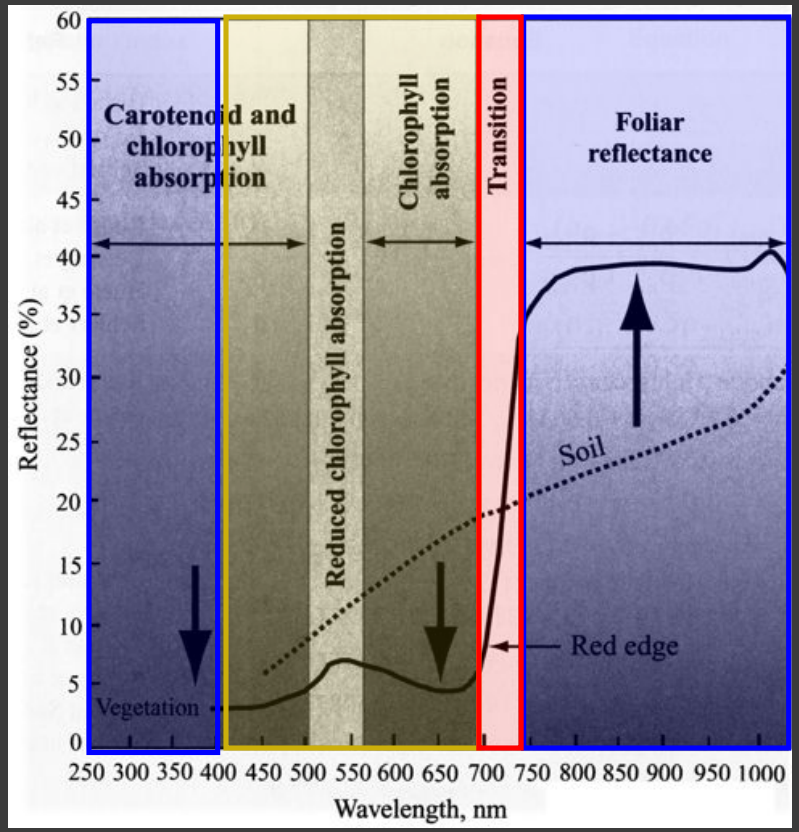
THEORETICAL BACKGROUND (I)

- Invisible spectral radiation
- Recording media
  - Digital cameras: Near-UltraViolet (NUV) – Near-InfraRed (NIR)
  - Hyperspectral sensors: visible – NIR



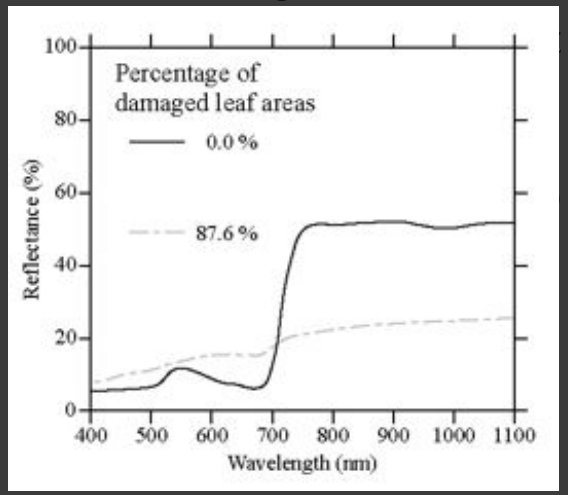
THEORETICAL BACKGROUND (II)

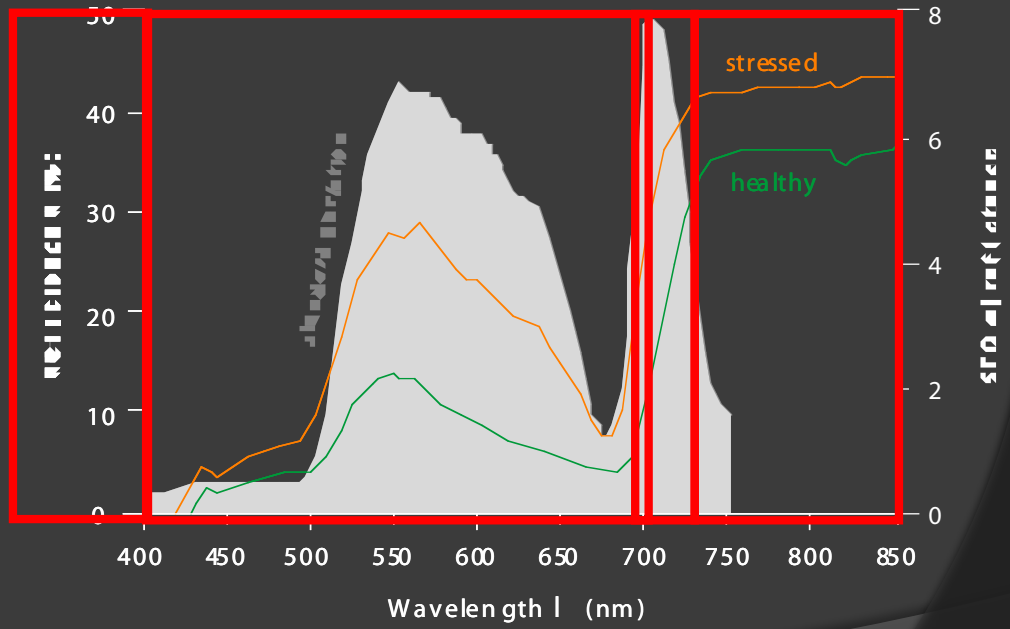
- Healthy green vegetation
  - EM waves are absorbed, reflected and transmitted
  - Visble range → pigments
  - ↓ absorptivity of chlorophyll around 550 nm → green
  - NIR → leaf's internal cellular structure
  - 50 % NIR versus 5 % VIS
  - Red edge: edge between visible spectrum and NIR spectrum
  - Most prominent reflectance characteristic
  - Lack of NUV data



THEORETICAL BACKGROUND (III)

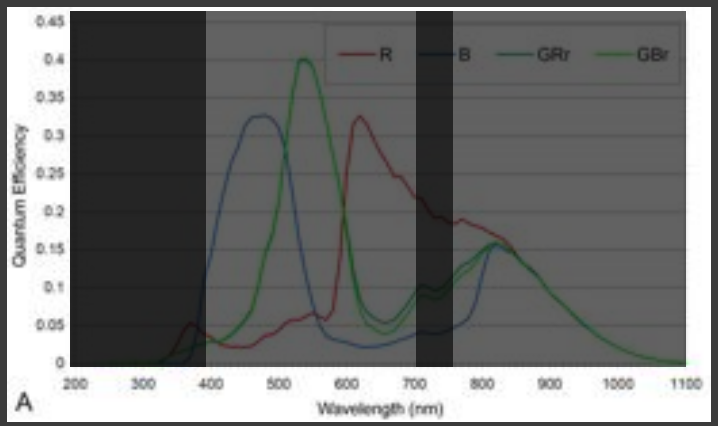
- Stressed vegetation
  - NIR → less straightforward
  - Altered internal structure and/or water content
  - short-term, acute stress: ↑ NIR reflectance
  - chronic stress: NIR reflectance ↓
  - Red edge→ most consistent stress response
  - Often ignored

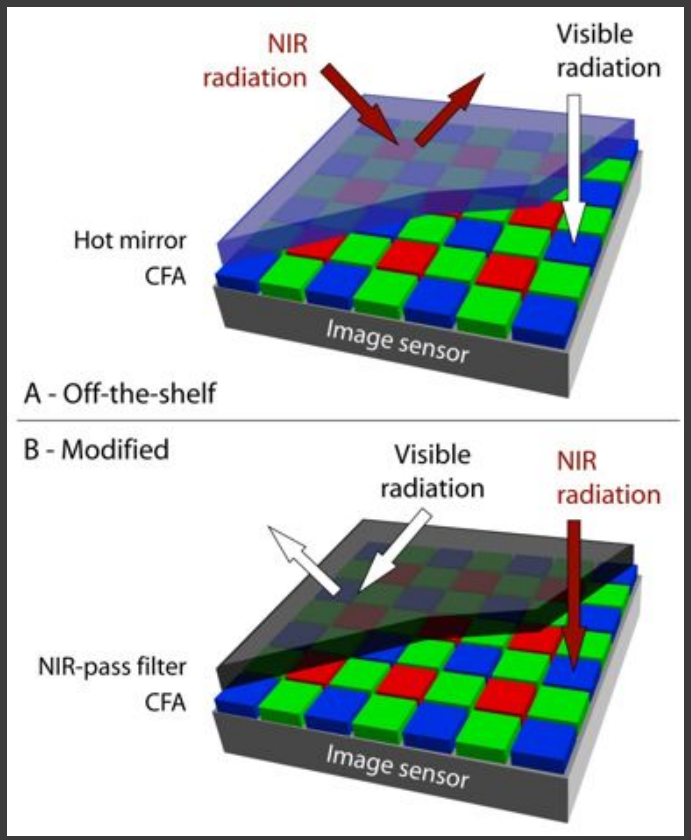




APPROACH 1 – TOOLS

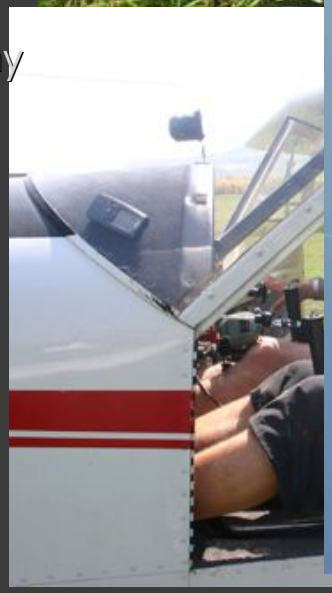
- Digital still cameras
  - Silicon sensor
  - Sensitive to NUV, visible, and NIR
  - NUV-NIR block filter on the sensor
  - Remove filter
  - New filter in front of the sensor





APPROACH 1 – DATA ACQUISITION

- RAW
  - Most pristine sensor data
  - JPEG or TIFF → scientifically unjustifiable
- Two (later three) DSCs
  - Simultaneously operated
  - Comparison with visible
  - Doorless aircraft
  - Helikite Aerial Photography



APPROACH 1 – NEAR-INFRARED (I)

- Visible versus pure NIR
- Negative crop marks
  - *Chlorosis* → difficult
  - Long-term stress → better
  - Low-density vegetation
- Positive crop marks

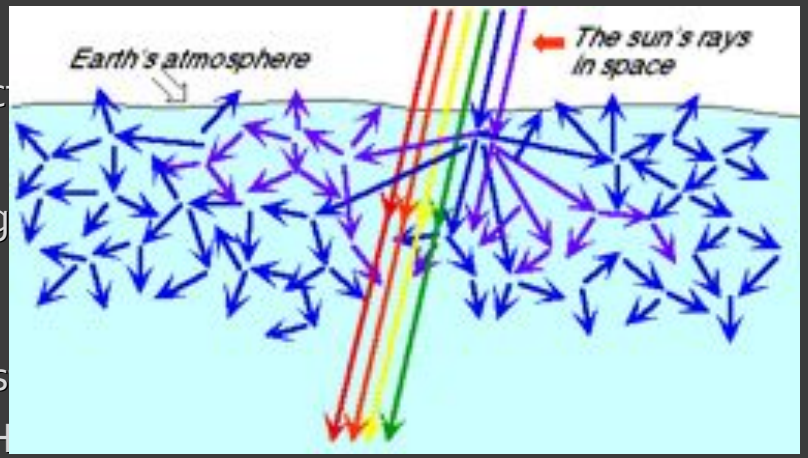
APPROACH 1 – NEAR-INFRARED (II)

APPROACH 1 – RED EDGE

- Best results: R_{700} / R_{800}

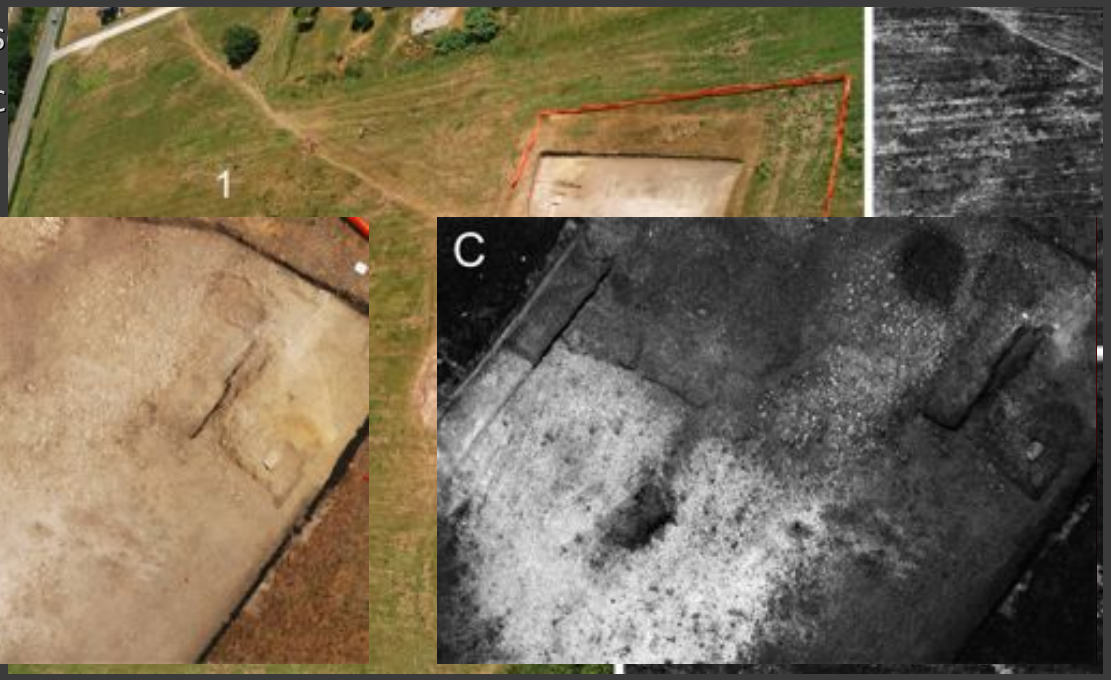
APPROACH 1 – NEAR-ULTRAVIOLET (I)

- Straightforward Red edge & NIR aerial imaging
  - Aeroplane + DSC + lens (any) + filter
- Problematic NUV photography
  - Small amount of terrestrial NUV (ozone layer)
  - Rayleigh scattering (haze, reduced sharpness) → low altitude imaging
  - Low reflectance (< 5 %)
  - Low DSC sensitivity
  - Glass severely blocks NUV
- Consequences
  - Rarely employed (oil spill detec
  - Never used with aerial DSCs
  - Never used in aerial archaeolog
- Solutions
  - DSC + very old, simple lens + as
  - Very stable aerial platform → H



APPROACH 1 – NEAR-ULTRAVIOLET (II)

- Crop marks
  - Visible, but not better
  - Soil instead of crop stress
- Soil Marks
  - Increase in soil contrast
  - Increased res
  - Archaeologic

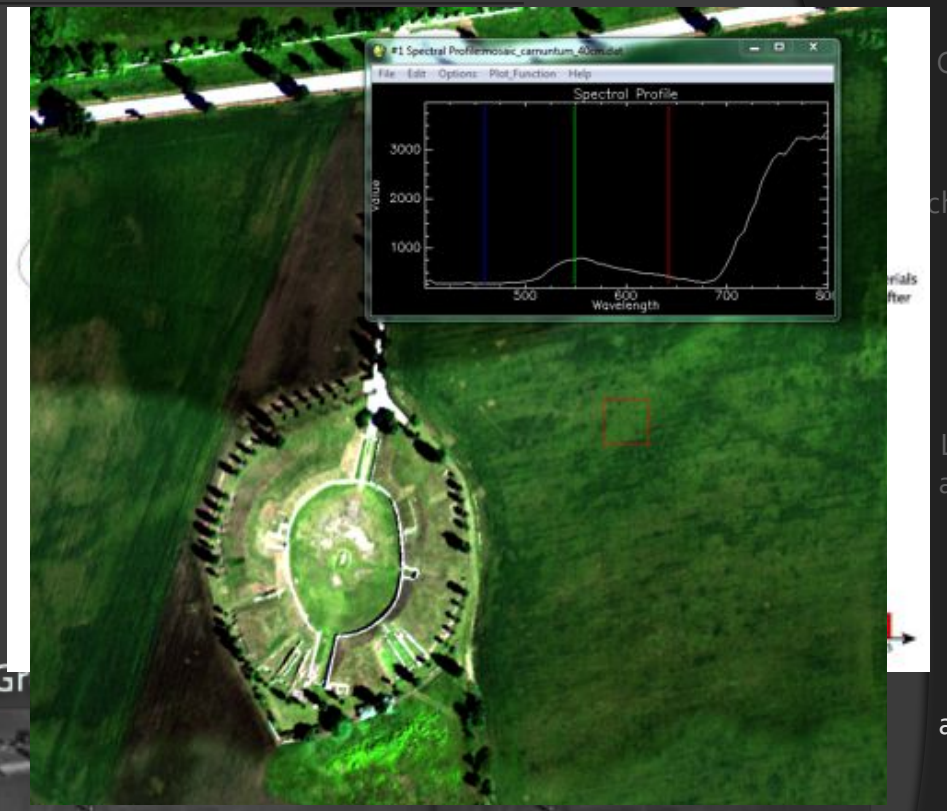


LBI

- LBI for Archaeological Prospection & Virtual Archaeology
  - Air- and spaceborne remote sensing
  - Ground-based remote sensing
  - Data integration, GIS-analyses and VR
- LBI PL 1 -3 key areas
  - LiDAR
  - Aerial reconnaissance
  - Imaging spectroscopy

APPROACH 2 – IMAGING SPECTROSCOPY (I)

- Imaging spectroscopy
  - hyperspectral imaging
  - spectroscopic remote sensing
  - imaging spectrometry
- Principle
  - Conventional image
    - 3 broad bands
    - 3D datacube
      - 2 spatial dimensions: X - Y
      - 1 spectral dimension: Z
  - Extend this concept for Z axis
    - > 100 bands
    - bandwidth = few nanometers
    - spectrally contiguous bands
  - each image = reflectance in specific band (e.g. 680 - 690 nm; 690 - 700 nm)
  - a complete reflectance spectrum / pixel → **spectral signature**



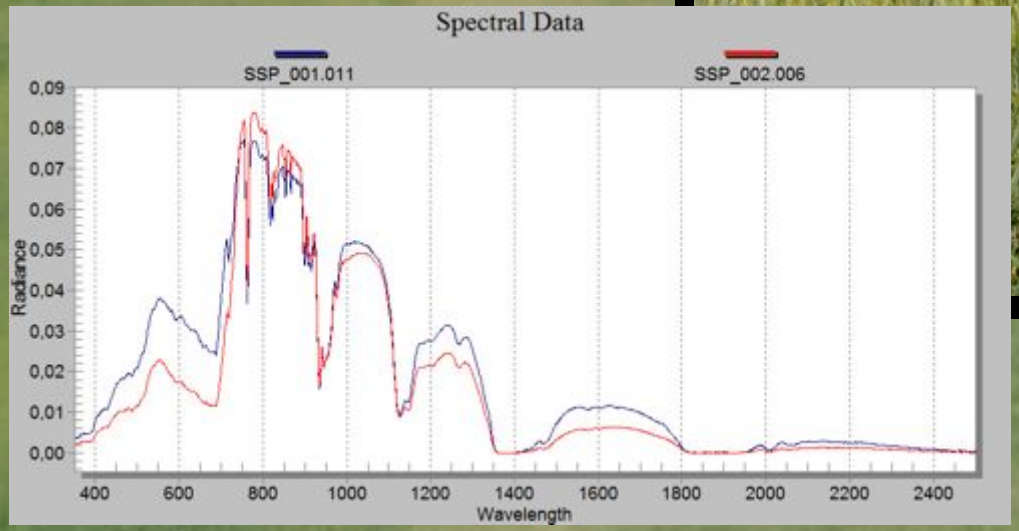
APPROACH 2 – IMAGING SPECTROSCOPY (II)

- Problems
  - Archaeological data acquisition
    - when?
    - how many bands?
    - spectral resolution (FWHM)
    - spatial resolution (GSD)
  - Archaeological data processing
    - which bands?
    - indices?
- LBI approach
  - Intensive spectral sampling programme
  - Data sets with small GSD (i.e. small limit of resolution)

APPROACH 2 – SAMPLING PROGRAMME

- Create a spectral library
- Collection spectral signatures
  - Soils & plants
  - Archaeologically influenced and untouched
  - # conditions
  - # seasons
  - UV (!) to NIR

APPROACH 2 – SAMPLING PROGRAMME



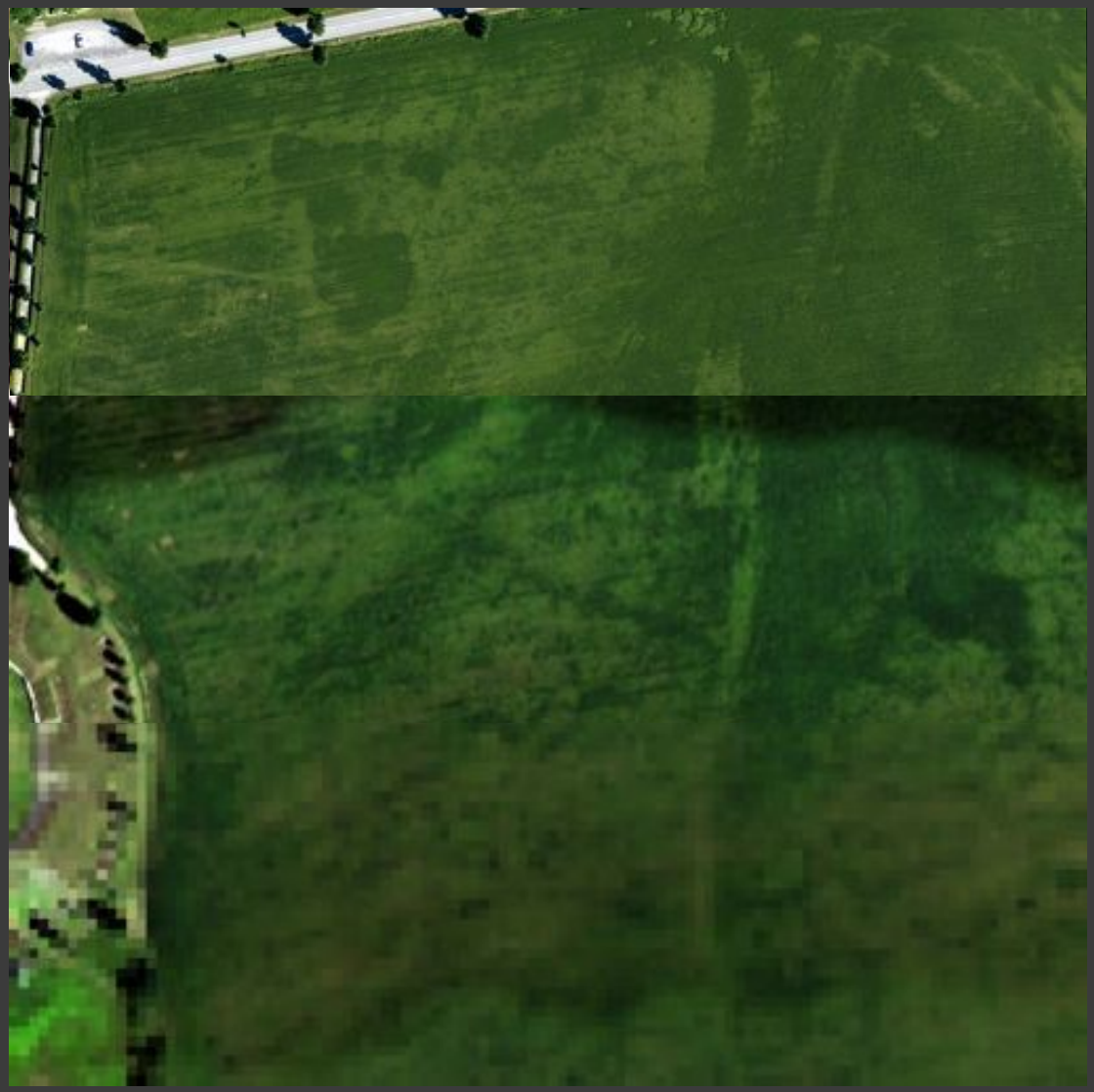
APPROACH 2 – SAMPLING PROGRAMME

- Create a spectral library
- Collection spectral signatures
  - Soils & plants
  - Archaeologically influenced and untouched
  - # conditions
  - # seasons
- Aim
  - Guide the data acquisition
  - Guide the processing
  - Allow to customly build DSCs
  - Tell something about the UltraViolet (250 nm – 400 nm)

APPROACH 2 – SUFFICIENT GSD (I)

- Conventional
  - GSD: 2 to 3 m
  - Insufficient for archaeology
- LBI
  - GSD < 50 cm
  - flying altitude is low enough
  - suitable detector
    - angular resolving power is high
    - fast integration time
    - high SNR

APPROACH 2 – SUFFICIENT GSD (II)



APPROACH 2 – SUFFICIENT GSD (III)

FUTURE

- Hyperspectral
  - Georeferencing
  - Radiometric calibration
  - ALS + AHS fusion
- Conventional aerial reconnaissance
  - Further develop DSCs
  - (Semi-)automatic georeferencing
  - Drone mapping
  - Automatic 3D extraction

CONCLUSION

- New sensors and image acquisition platforms
- Increasing
  - spatial resolution (meter level → cm level)
  - temporal resolution (weeks → days or hours)
  - spectral resolution (broad bands → few nanometers)
  - spectral range → visible to invisible
- Computer power and algorithms
  - process vast datasets
  - new ways of analysis
- Low cost <> $$$[3]
- 21st century → tools & methods

surpass conventional limits in aerial archaeology