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The rediscovery of an *Adoration of the Shepherds* by Jacques Jordaens: a multidisciplinary approach combining dendroarchaeology and art history

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Abstract

The implementation of multidisciplinary research approaches is an essential prerequisite to obtain comprehensive insights into the life and works of the old masters and their timeline in the production of the arts. In this study, traditional art history, cultural heritage, and natural science methods were combined to shed light on an *Adoration of the Shepherds* painting by Jacques Jordaens (1593–1678), which until now had been considered as a copy. From dendrochronological analysis of the wooden support, it was concluded that the planks in the panel painting were made from Baltic oak trees felled after 1608. An independent dating based on the panel maker's mark, and the guild's quality control marks suggests a production period of the panel between 1617 and 1627. Furthermore, the size of the panel corresponds to the dimension known as *salvator*, which was commonly used for religious paintings during the period 1615 to 1621. Finally, the interpretation of the stylistic elements of the painting suggests that it was made by Jordaens between 1616 and 1618. To conclude, from the synthesis of: (i) dendrochronological analysis, (ii) panel makers' punch mark and Antwerp Guild brand marks, (iii) re-examination of secondary sources, and (iv) stylistic comparisons to other Jordaens paintings, we suggest that the examined *Adoration of the Shepherds* should be considered as an original by Jordaens and likely painted in the period 1617–1618. The study is a striking example of the effectiveness of a multidisciplinary approach to investigate panel paintings.

Keywords: Multidisciplinary art studies, Dendrochronology, Baltic oak, Flemish seventeenth century art, Jacques Jordaens, Panel painting

Introduction

From the Fifteenth until the early seventeenth century, many paintings created by Flemish and Dutch masters were painted on wooden supports, so called panel paintings [1, 2]. Studies of panel paintings have generated valuable information about the age and origin of the wood, production site of the panels, the manufacturer of the panels, and in many cases can be instrumental

in determining whether an art object is genuine or not. However, to present a detailed story of an art object, several different research disciplines are required.

A method that has been frequently used to date wooden objects is dendrochronology, a scientific discipline in which annual rings from trees can be absolutely dated to calendar years [3, 4]. The method determines the year of wood formation for each annual ring in a wooden sample. For objects in which the most recent ring (i.e., outermost) is preserved the exact year and in some cases even the season of the year for tree felling can be determined [4, 5]. The precision of dendrochronology thereby surpasses most other dating methods and

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has thus become a well-established method for the dating of wooden constructions [6], historical buildings [7, 8], shipwrecks [9, 10], archaeological artefacts [11, 12], historical events [13, 14], climate dynamics [15, 16], as well as hazards and environmental changes [17, 18]. Since the 1970s, dendrochronology has also been regularly used to date the planks used as wooden supports (i.e., panels) for paintings [1, 2, 19–26]. As well as providing a date for an analysed wooden construction or object, dendrochronology provides information about the origin of the utilized timber (i.e., dendro-provenance), historical trading routes [5, 27–30], wood technology and further processing techniques used in woodworking workshops [11, 26].

When dendrochronology is applied as a dating tool for wooden cultural heritage objects, it is important to consider that the analysis generates a calendar year of when the tree was felled, at best [11, 31]. Regarding wooden supports used for paintings, the wood rarely contains the outermost ring or sapwood [32]. In such cases, dendrochronology can only provide an exact calendar date for the heartwood, from which a *terminus post quem* (TPQ) date (or earliest possible felling date) for the felling of the tree can be estimated. The dating of wooden supports used for paintings should therefore preferably be based on aggregated knowledge from several combined approaches. This study illustrates the multidisciplinary approach used by the Jordaens Van Dyck Panel Paintings Project (JVDPPP) for examining, dating, and attributing seventeenth century Flemish oil paintings, executed on wooden supports. Aside from dendrochronology, the methods applied by the JVDPPP are studies of the panel makers' punch mark and Antwerp Guild brand marks on the reverse of the panel, re-examination of secondary sources, and stylistic comparisons to other paintings. The JVDPPP is an international art historical initiative that is systematically studying the oil paintings on oak panels by two seventeenth century Flemish Masters, Jacques Jordaens (1593–1678) and Sir Anthony Van Dyck (1599–1641). As young men in Antwerp, both artists worked in the orbit of each other and with and for Sir Peter Paul Rubens (1577–1640), until the end of 1620 when Van Dyck departed for England. Through this research the JVDPPP is shedding new light on the lives and oeuvres of both artists and seventeenth century Flemish paintings on oak panels in general, including individual panel makers and the role of the supervisory Antwerp Guild of Saint Luke.

In this study, we implement our multidisciplinary research approach by presenting the examination of the *Adoration of the Shepherds*, from the Musei civica di Vicenza (Italy), recorded in the museum catalogue [33] as an unsigned copy after Jacques Jordaens. The aims of the examination were to: (i) determine the felling dates of the

trees used for the planks of the painting and their geographical origin, (ii) date the construction of the panel based on the panel makers' and Antwerp Guild brand marks on the reverse of the panel support, (iii) compare this data with other paintings by Jordaens and his Antwerp colleague, Sir Anthony Van Dyck, and (iv) study the authorship of the painting by applying traditional art historical scholarship and connoisseurship including the re-examination of secondary sources and comparative paintings. The combination of these independent approaches may allow to narrow down the timing of the production of the painting and thus, to conclude whether the *Adoration of the Shepherds* in Vicenza should be considered as a copy or an original painting by Jacques Jordaens.

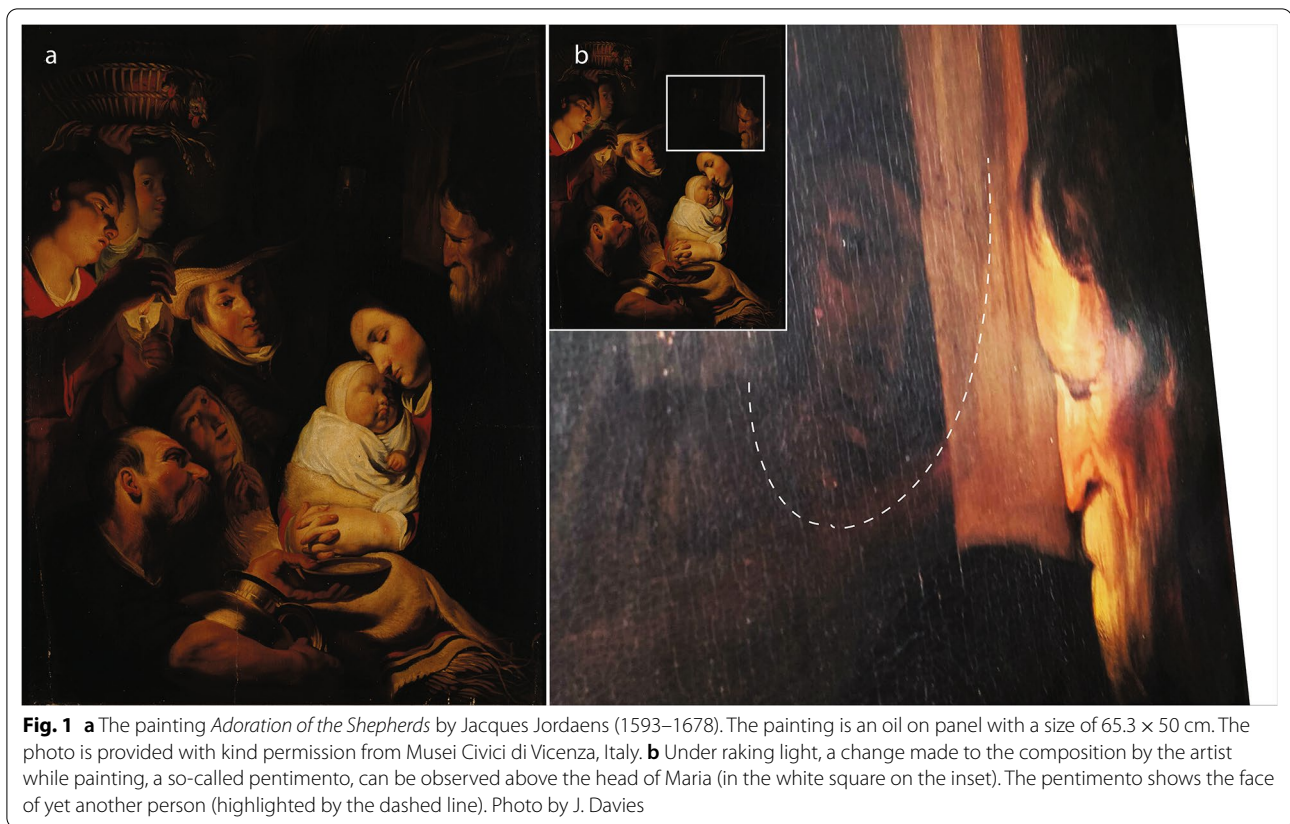
Material and methods

The examined painting

The *Adoration of the Shepherds* in the collection of the Musei Civici di Vicenza in Italy (Inventory number A 291, Fig. 1) was subject to a visual examination as well as a photo documentation of the wooden support to allow for a dendrochronological analysis. The original wooden support is obscured from sight by a modern wooden backing board which required removal. The wooden support of the oil painting is a panel with a height of 65.3 cm and a width of 50 cm. The panel consists of two jointly glued planks, here called *Adoration of the Shepherds* Plank 1 (AOTSP1) and 2 (AOTSP2), with individual sizes of 19.1 × 65.5 and 30.9 × 65.3 cm, respectively, and a thickness of about 8 mm (Fig. 2). Based on the macroscopic characteristics both planks were identified to be made from oak (*Quercus* spp.). An exact determination of the most common oak species in Europe, pendulate oak (*Quercus robur* L.) and sessile oak (*Quercus petraea* (Matt.) Liebl.) is macroscopically and microscopically not possible. However, the larger natural distribution range including north-eastern Europe likely indicates the use of pedunculate oak. Both planks were cut in a non-radial direction from the trunks of oak trees. This was most likely done with a plank saw which left distinct saw traces at both planks as can be observed at the reverse of the painting (Fig. 2). Compared to radially cut planks, which show upright growth rings, i.e., the angle between the tree rings and the plank edge is 80–90°, not strictly radial cut planks have a higher degree of shrinkage and a lower dimensional stability than radially cut planks [34].

Dendrochronological analysis of the wooden panel

As the annual tree rings could not be clearly distinguished at the original end grain and equipment for non-invasive analyses, such as X-ray CT tomography [35, 36] or XRF mapping [37] was not available, a more



traditional micro-invasive approach was initiated [38]. The treatment included that a circa 2 mm wide surface at the end grain of the planks (perpendicular to the radial growth direction of the trees) was carefully prepared using a handheld industrial razorblade (Fig. 2).

After paring the end grain of the planks to make the annual rings clearly visible, the photo recording of the tree-ring sequences along the end grain of the planks was carried out using a camera [39, 40], equipped with a 100 mm macro-lens, which was mounted on a tripod with a camera sled to allow for horizontal movements. Segments of 5 cm in width and an overlap of about 2 cm were photographed using different camera and light settings to enhance the visibility and contrast of the tree-ring width (TRW) patterns. A selection of photos with clearest view of the tree rings for each plank was merged into stacked images using the computer software Adobe Illustrator [41]. Between seven and 16 overlapping macro photos were used to create each of the stacked images.

A total of six stacked images, three from each plank, were created using macro photos taken with different light settings and exposure time. By using three stacked images for each plank, the TRW patterns of the two planks were consequently measured three times which were compared for eventual measuring errors and

thereafter averaged to one curve for each plank. The TRWs were measured with a precision of 0.01 mm using the image co-ordinate recording software CooRecorder [42]. The subsequent crossdating procedure, during which the TRW series were compared statistically and visually among each other and to different existing regional reference chronologies, was performed using the software TSAPWin Scientific [43]. The statistical analyses were primarily based on the Student's *t*-test, with adaptations after Baillie and Pilcher [44] and Hollstein [45], as well as Gleichlaufigkeit (Glk) [46]. The *t*-value is calculated from the correlation coefficient *r* but includes a measure of significance in relation to the length of the overlap between two compared tree-ring curves [44], whereas Glk (coefficient of parallel run) is a measure of the year-to-year synchronicity between two tree-ring curves based on the sign of agreement [46]. In general, *t*-values exceeding 3.5 are considered as significant [47]. All correlation results obtained between the TRW series of the two planks yielding *t*-values above 4 as well as significant ($p < 0.01$) Glk values were visually examined. The crossdating of the TRW series was performed using available TRW reference chronologies and TRW series from other paintings examined by the JVDPPP. Generally, for the production of temporary

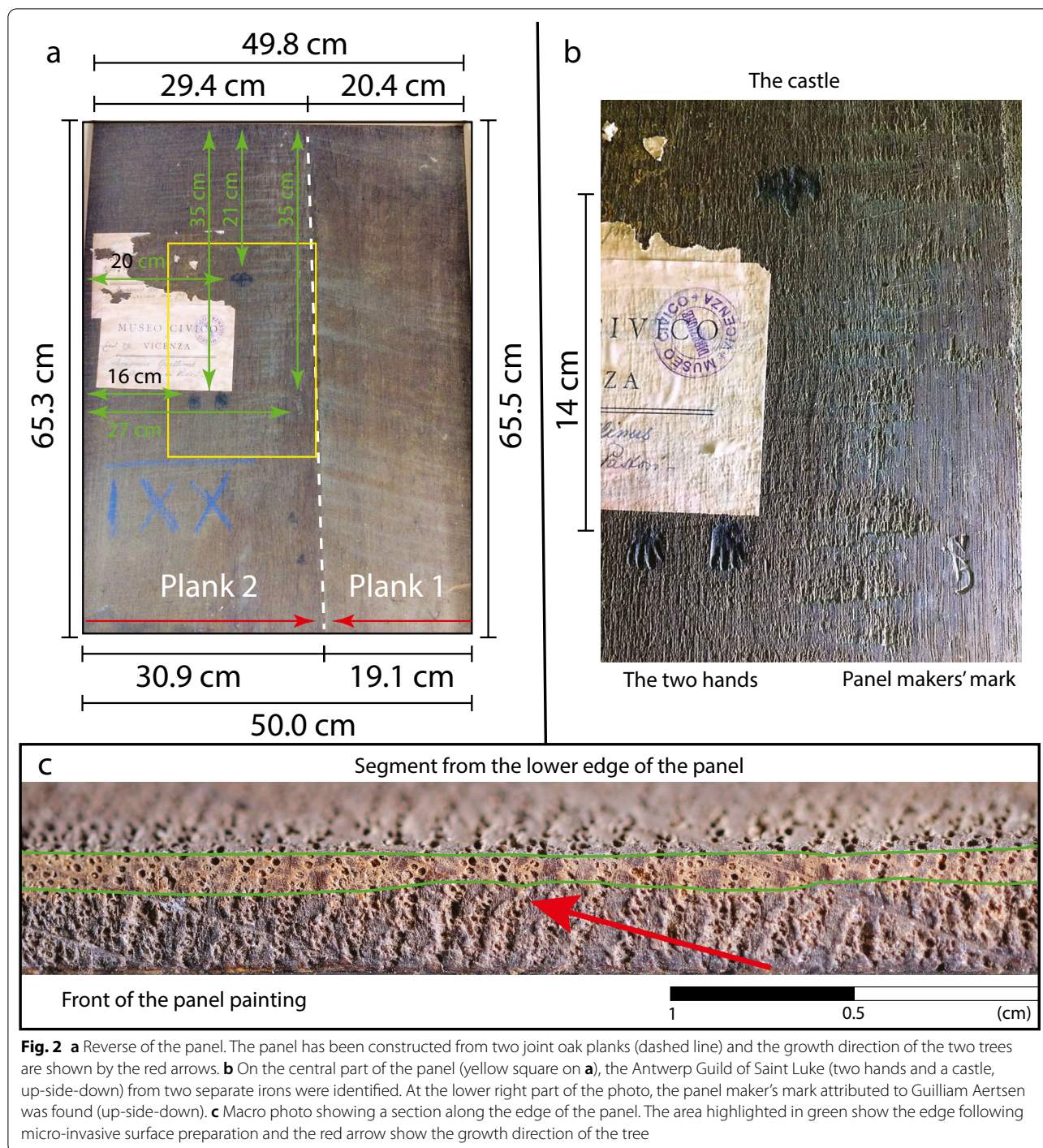


Fig. 2 **a** Reverse of the panel. The panel has been constructed from two joint oak planks (dashed line) and the growth direction of the two trees are shown by the red arrows. **b** On the central part of the panel (yellow square on **a**), the Antwerp Guild of Saint Luke (two hands and a castle, up-side-down) from two separate irons were identified. At the lower right part of the photo, the panel maker's mark attributed to Guiliam Aertsen was found (up-side-down). **c** Macro photo showing a section along the edge of the panel. The area highlighted in green show the edge following micro-invasive surface preparation and the red arrow show the growth direction of the tree

wooden supports, the removal of the sapwood and last formed ring before felling requires an estimation for the lost annual rings. This was done using the most recent sapwood estimates [26, 48]. In this way, a heartwood dating is applied, which provides only the earliest possible felling date of the trees, a so-called *terminus post quem* (TPQ).

The panel makers' punch mark and Antwerp Guild brand marks

After the backing wood attached to the frame was removed, the reverse of the original oak panel was revealed (Fig. 2). There a panel makers' individual punch mark and the quality control brand marks of the Antwerp Guild of Saint Luke were detected, which

may provide an independent dating of the production of the wooden support. The size and location of all observed marks and other eventual characteristics such as damage, stamps or inscriptions were measured and documented (Fig. 2).

Re-examination of secondary sources and stylistic composition

To obtain further information about the examined painting, comparisons of the stylistic composition with other paintings as well as the studies of the authorship of the painting by applying traditional art historical scholarship and connoisseurship was performed. These studies include the examination of secondary sources, web-databases, museum files, and literature reviews. This examination also includes further studies of the comprehensive collection of the Antwerp panel makers' and guild brand marks found on the reverse of the panels amassed by the project.

Results

Dendrochronological analyses

Two averaged TRW series with lengths of 165 and 252 years, respectively, were developed for the two planks (AOTSP1 and AOTSP2) of the wooden support (Table 1). The TRW series were crossdated covering the period 1341–1505 for AOTSP1 and the period 1351–1602 for AOTSP2 (Table 2; Fig. 3). While the TRW measurements of the two planks show no visually and statistically convincing overlapping positions between each other, the two TRW series revealed significant correlations to several reference chronologies from Baltic oak, i.e., the chronology referred to as Baltic 1 [22] (Fig. 3). Significant overlapping positions were also obtained with the reference chronology made from timber from western Lithuania (Pukienė, unpublished data), especially for AOTSP2 (Table 2). The two TRW series also show high correlations with measurements from planks from several paintings previously examined by the JVDPPP (Table 2).

The examined planks contain only heartwood, which strictly limits a dating to a TPQ. The minimum number of missing sapwood rings must therefore be added to the

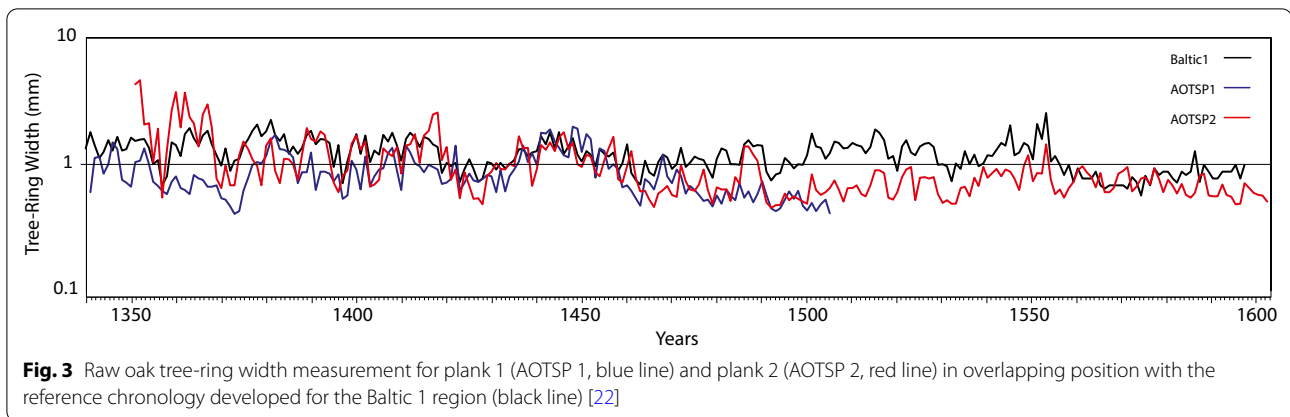
Table 1 Overview about the two planks in the examined painting of the *Adoration of the Shepherds*

Id. No	No rings	Sapwood	Dating (AD)	Felling (AD)	Provenance
AOTSP1	165 (+ 15) ^a	Missing	1341–1505 (+ 15) ^a	After 1526	Baltic
AOTSP2	252	Missing	1351–1602	After 1608	Baltic

^a Counted but not measured rings

Table 2 Correlation results of the TRW series obtained for the two planks (AOTSP1 and AOTSP2) with independent reference chronologies and TRW measurements from paintings investigated within the JVDPPP: overlap in years (OL in years), Gleichläufigkeit (Glk in %) including significance levels (two stars: $p < 0.01$; three stars: $p < 0.001$), t-test values after Baillie and Pilcher (TBP) and Hollstein (THO), and suggested date for the outermost tree ring

Sample	Reference	OL (yrs)	Glk (%)	TBP	THO	Date
AOTSP1	BALTIC 1 (Hillam and Tyers 1995)	165	69.7***	6.77	7.47	1505
AOTSP1	JVDPPP-BALTIC1 (unpubl., prelim. version)	165	67.6***	6.77	7.33	1505
AOTSP1	Western Lithuania (Klaipėda castle, Pukienė unpubl.)	165	64.8***	4.66	4.78	1505
AOTSP1	01T00119 <i>Christ Genoa Plank 1</i>	104	75.5***	10.6	10.4	1505
AOTSP1	11T00101 <i>Christ Genoa Plank 1 + 2</i>	143	68.9***	8.87	8.11	1505
AOTSP1	DH00302 <i>JJ_Adoration, The Hague Plank 2</i>	165	70.3***	5.06	5.92	1505
AOTSP1	2BR00001 <i>Jacqueline Plank 1 and Jean Plank 2 Brussels</i>	121	63.6**	4.77	5.16	1505
AOTSP2	BALTIC 1 (Hillam and Tyers 1995)	247	65***	9.54	9.08	1602
AOTSP2	JVDPPP-BALTIC1 (unpubl., prelim. version)	252	66.7***	11.3	11.6	1602
AOTSP2	Western Lithuania (Klaipėda castle, Pukienė unpubl.)	186	65.1***	7.15	7.18	1602
AOTSP2	Northern Poland/Eastern Pomerania-Gdansk-Wolin (Wazny; ITRDB)	252	58.9***	5.5	4.87	1602
AOTSP2	0LO00301 <i>Thomas Plank 1, London</i>	153	66***	7.78	6.11	1602
AOTSP2	AN00602 <i>John the Evangelist Plank 2, Antwerp</i>	243	65***	10.2	9.85	1602
AOTSP2	BL00302 <i>Jude Plank 1 + 2, Luxembourg</i>	180	66.1***	9.92	8.82	1602



dating to establish the earliest possible year for the felling of the trees. Thereafter the estimated time for transport and seasoning must be added to adjust the timing for the construction of the wooden support. Moreover, about 15 of the outermost rings on AOTSP1 (direction towards bark) could not be accurately measured and were therefore counted and also added to the measured tree rings prior to the estimation of the tree felling (Table 1).

The panel makers' punch mark and Antwerp Guild brand marks

The panel maker's punch mark on the reverse of the painting (Fig. 2) is attributed to Guiliam Aertssen [32] who was known to be active from 1612 to at least 1627 [49]. The use of the guild's quality control mark, the castle with the two hands of Antwerp made with two separate branding irons, was enshrined in an ordinance of 11 December 1617 [32]. The Guild's quality control and panel maker's marks combined therefore suggest a production period of the panel between December of 1617 and 1627 or longer.

The visual examination and stylistic composition of the painting

The obverse of the *Adoration of the Shepherds* (Fig. 1) was examined visually. From this initial inspection, it could be concluded that the stylistic composition of the painting exhibited strong stylistic similarities with several of the no less than 16 other known versions of the *Adoration of the Shepherds* by Jordaens [50], e.g., the signed versions dating to 1616 in the Metropolitan Museum of Art in New York (ill. 38 in [50]) and to 1618 in the National Museum in Stockholm (ill. 55 in [50]), as well as other paintings from the corresponding period. The striking chiaroscuro (the strong contrast of light and dark) influenced by Caravaggio (1571–1610), the vibrant colour and the figures of the shepherds and the Holy Family indicate

the brushwork of the young Jordaens before he established his own studio in 1620/21 [50]. From the visual examination, a distinct *pentimentum*, i.e., a change made to the composition by the artist while painting, was discovered (Fig. 1b). The *pentimentum*, a head which was subsequently painted over, is visible to the naked eye in a raking light.

Secondary documentary sources

The painting was first recorded in the museum's inventories in 1902, as a painting in the style of Erasmus II Quellinus (1607–1678). In 1957, the art historian Michael Jaffé informed the museum that he considered the painting to be a copy related to the *Adoration of the Shepherds* by Jordaens in the Museum Mayer Van Den Bergh in Antwerp. This attribution was accepted by the museum and published in the most recent catalogue of the collection's seventeenth and eighteenth Century paintings [33]. In a footnote in his 1982 monograph on the artist, the Jordaens scholar Roger d'Hulst indicated that he considered the *Adoration of the Shepherds* in Vicenza to be an autograph original by Jordaens rather than a copy. He compared it to a version in Athens which he dated about 1617 [50].

Discussion

Dendrochronological dating and estimated production period of the wooden support

Since both planks are missing the pith, sapwood, and waney edge, the precise years for germination and tree felling could not be determined. It was common practice among panel makers in Antwerp that all sapwood rings were removed, as sapwood is less durable because it is softer and more susceptible to biological deterioration than the resistant heartwood. Indeed, their removal was enshrined in the December 1617 ordinance issued to the Antwerp panel makers [32]. Also, tree rings close to

the pith were commonly removed because they are more prone to breaks. If a panel was found to contain planks with sapwood or was otherwise deficient, it would have been broken by the elder of the panel makers within the Guild rather than branded as being approved for use by a painter [32]. It is therefore common that both the pith and sapwood are absent on planks used for wooden supports for paintings. The increasing curvature of the innermost annual rings, however, indicate that the oldest rings of the planks are relatively close to the pith of the trees and that less than 30 years are missing [51].

The TRW series from the analysed planks could be dated by means of dendrochronology to 1505 and 1602, respectively. Due to the missing sapwood rings, earliest possible felling dates were estimated by adding an estimated minimum number of sapwood rings to the last measured heartwood ring. For the three Baltic countries and southern Finland, Sohar et al. [48] recommend a sapwood estimate of approximately 6–19 years, whereas for historical timbers from Poland sapwood estimates of about nine to 23 rings were calculated within 90% confidence limits [52]. Since the exact provenance for the timber cannot be determined because the Baltic oak reference were developed solely from exported material [22], a minimum of six sapwood rings was added to the last measured rings, and thus following the recommended Baltic sapwood statistic [26, 48]. The earliest possible felling date for AOTSP1 is 1526, after adding six sapwood rings as well as the unmeasured but counted 15 rings. Adding six sapwood rings to the last measured ring dated to 1602 of AOTSP2, the earliest possible felling date of 1608 was obtained. Since transport and seasoning of the oak planks have to be taken into account before

the panel makers could produce wooden supports of high quality [32], an estimated minimum number of two years have to be added to the TPQ date [53, 54]. In so doing, the time of the production of the wooden support is estimated to be after 1610 (Fig. 4).

The reason for the large difference in the obtained heartwood dates between the two planks (AOTSP1-2) remains unknown. Here speculations are manifold and include that a wide plank has been split into several narrow parts and that the innermost part from such plank has been used for AOTSP1 (width 19.1 cm), whereas the width corresponding to almost the entire radius of a tree has been used for the AOTSP2 (width 30.9 cm). Another possibility is that the outermost part of the plank used for AOTSP1 was removed to reduce the total width of the two planks to get the desired dimension of the wooden support, which correspond to a so called *salvator* size (around 64 × 49 cm) [55]. Another possibility is that the outermost section from AOTSP1 was removed due to damages, cracks, or growth anomalies that would lower the overall quality of the wooden support.

Dendroprovenance

The choice of the wood species used for manufacturing wooden supports for paintings largely depended on the abundance of high-quality timber that was available from various regions in different centuries. For example, in north-eastern Germany and southern Europe coniferous species such as pine or spruce were predominantly used for wooden supports [20, 21], whereas broadleaf species such as beech and oak were utilized in central and western Europe [2]. Oak was, however, the most widely used tree species in the areas now known as northern

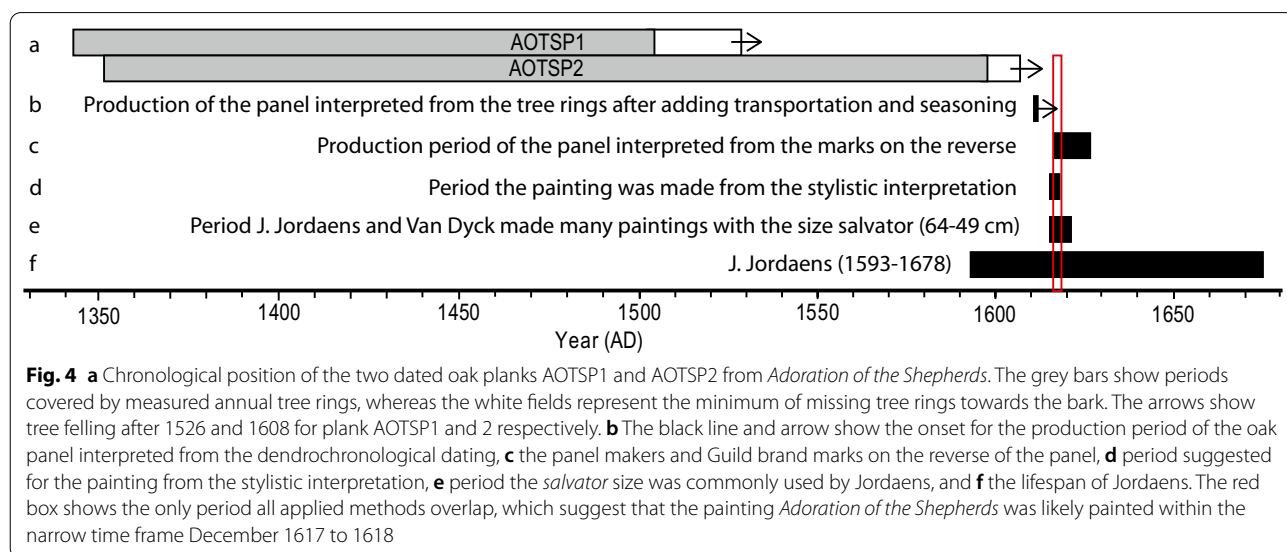


Fig. 4 a Chronological position of the two dated oak planks AOTSP1 and AOTSP2 from *Adoration of the Shepherds*. The grey bars show periods covered by measured annual tree rings, whereas the white fields represent the minimum of missing tree rings towards the bark. The arrows show tree felling after 1526 and 1608 for plank AOTSP1 and 2 respectively. **b** The black line and arrow show the onset for the production period of the oak panel interpreted from the dendrochronological dating, **c** the panel makers and Guild brand marks on the reverse of the panel, **d** period suggested for the painting from the stylistic interpretation, **e** period the *salvator* size was commonly used by Jordaens, and **f** the lifespan of Jordaens. The red box shows the only period all applied methods overlap, which suggest that the painting *Adoration of the Shepherds* was likely painted within the narrow time frame December 1617 to 1618

France, Belgium, the Netherlands, western Germany, and England [2, 11, 55]. The material was imported in vast amounts from the region located south-east of the Baltic Sea [29, 56, 57], here referred to as Baltic region. During much of the period of active Baltic timber trade (fourteenth to mid-seventeenth century) most of the Baltic region belonged to the Kingdom of Sweden and the Polish–Lithuanian Commonwealth. From the mid-seventeenth century, however, the wood panels were gradually replaced by canvas, which was less costly, less prone to deterioration (e.g., cracking and insect damage), as well as lighter and easier to transport [55].

Dendrochronological studies have proven that Baltic oak timber was commonly used for the production of wooden supports used by Flemish painters in the Fifteenth to seventeenth century [2, 57]. Moreover, a plethora of historical documents showed that there was a well-established trade of Baltic timber to harbours in England, the Netherlands, and Belgium during this period [27, 57]. At present, it is largely unknown from what region or forest the trees were originally taken since the existing Baltic oak reference chronologies were built on exported material too. However, old and slow growth trees with regular grain gave the Baltic oaks good manufacturing characteristics for the making of high-quality wooden supports [58]. The two planks used for the *Adoration of the Shepherds* are rather thick and show even but narrow annual tree rings which are on average 0.96 mm/year for AOTSP1 and 1.02 mm/year for AOTSP2, respectively. The trees used for the planks were slow grown and likely derived from dense forest stands considering a statistical average of a mean ring width of 1.56 mm per year for 7284 central European oak samples [13]. The two TRW series (AOTSP1 and AOTSP2) show significant correlations to a large number of reference chronologies (Table 2), foremost from Baltic oak [22] and timber from western Lithuania (Pukienė, unpublished data). The low correlation between the two planks as well as the slightly different t-values to the Lithuanian and Polish reference chronology suggests that the planks were taken from oak trees from different forest stands. The wood from which the Baltic 1 chronology was developed has been noted to progressively decrease in usage in Flemish panel paintings during the early seventeenth century before disappearing during the 1620s [22]. The significant correlations of the two planks with the Baltic 1 chronology therefore indicate that it is likely that the oaks used for the studied wooden support originated from the Baltic region and where probably shipped to Antwerp before or during the 1620s.

The two TRW series also show strong correlations with measurements from planks from several paintings previously examined within the JVDPPP (Table 2). In fact,

this systematic and comparative approach constitutes a major strength of the project. The TRW series from the first plank (AOTSP1), for example, correlates to measurements from planks from several Apostle paintings related to Sir Anthony Van Dyck. The best correlations were found to Plank 1 of the painting of *Christ* at the Palazzo Rosso in Genoa (Table 2). Moreover, the TRW series from Plank 2 (AOTSP2) show significant correlations to, for example, Plank 1 in *Thomas* in a private collection in London, and Plank 2 in *John the Evangelist* from a private collection in Antwerp (Table 2). The fact that the timber of the same geographical origin is found in paintings by Jordaens and Van Dyck indicates that the two painters bought their panels from the same panel maker or art merchant. This observation is confirmed by the same panel makers' mark found on the reverse of the two Apostle panels mentioned above and the *Adoration of the Shepherds* in Vicenza (Fig. 5, Table 2).

Production period estimated based on marks

The panel maker's mark at the reverse of the panel is attributed to Guiliam Aertssen [32], who became a Master in the Guild of Saint Luke in 1612 and was still active as a panel maker in 1627 [49]. The use of the Antwerp brand to approve panels for painting is enshrined in the December 1617 ordinance in which it is stated that 'henceforth nobody should be permitted to let whiten panels and the like and take them out of his house which had not first and foremost been inspected and branded by the elder of their trade' [32]. The Guild's quality control and panel maker's marks combined therefore suggest a likely production period of the panel between the end of 1617 and 1627 or perhaps later (Fig. 4).

The size of the panel, 65.3 × 50 cm, matches the size known as a *salvator* [55]. The *salvator* was commonly used for Apostles and smaller religious paintings by Jordaens and Van Dyck during the period 1615 to 1621 [50, 59], which is in agreement with the interpretations from the panel maker's mark.

Visual analysis and stylistic composition of the painting

The *pentimento* discovered on the examined painting (Fig. 1) indicates that the artist recomposed his thoughts during the painting process. This would most likely not be the case with copies and lent weight to the indications that the painting is in fact an original by Jordaens himself. Moreover, the signed Stockholm painting from 1618 is particularly relevant in that respect, because it shows a face of an old shepherd in the background of the same type and on a comparable position in the composition as the overpainted head in the painting in Vicenza. Moreover, stylistically the less detailed physiognomies in Vicenza are nearer to the style of the 1616 New York painting



which has the smaller “26-stuivers” standard measure. After having overpainted the head in the Vicenza painting, Jordaens may have reintroduced that overpainted motif with the help of figure studies in his studio in the Stockholm picture because of its larger standard measure (124 × 93 cm) of a *daelders maet* [60], which permitted him to introduce more figures within a less cropped composition field. This would well fit with a date of the Vicenza painting in between the 1616 New York and the 1618 Stockholm versions (unpublished observations by J. Vander Auwera). Finally, by adding the information the panel maker's mark and the Guild's quality control mark provide, the suggested period would be as narrow as 1617 to 1618 (Fig. 4).

Conclusions

This study underlines the strength of multidisciplinary examination approaches when working with wooden objects of cultural heritage, and that possible weaknesses in one method can be overcome by combining it with another and results from several research disciplines cross-validated. The *Adoration of the Shepherds* in the Musei Civici di Vicenza was subjected to dendrochronological analysis, research into the provenance of the panel maker's and Guild brand marks, consultation of secondary sources, and stylistic comparisons to other paintings by Jacques Jordaens. The dendrochronological analysis of the two oak planks determines a youngest estimated year for tree felling after 1608 and the Baltic region as the source of origin of the wood. Considering the time required for the transport and

seasoning of the timber, an earliest possible production of the wooden support from the dendrochronological results can be estimated to after 1610. The documented period of activity of the panel maker and the usage of the Antwerp Guild's quality marks indicate a production period between 1617 and 1627 (Fig. 4), which improves the estimates based on the dendrochronological dating. The first-hand stylistic comparison with other *Adoration of the Shepherds* by Jordaens, including e.g., the similarly sized version in the Museum Mayer Van Den Bergh, proposes a painting between 1616 and 1618 (Fig. 4) by a young Jordaens, painted at the age of around 25, which also fits into the estimated period of time. Furthermore, the size of the painting, a so called *salvator*, is another indicator that supports the suggested period as it was commonly used for religious paintings by Jordaens and Van Dyck during the years 1615 to 1621. From these findings combined with art historical research, the JVDPPP concludes that the *Adoration of the Shepherds* in Vicenza was probably painted within the period December 1617 to 1618 and should be considered as an original by Jordaens. Although this study represents a best-case scenario given the amount of information available on and about the panel (namely two sets of marks on the wood and other versions of the same painting), it exemplifies how multidisciplinary examinations and cross-validations that combine traditional art history, cultural heritage research, and natural science methodology can determine the authenticity of works of art and significantly delineate the time of the production of wooden objects.

Abbreviations

JVDPPP: Jordaens Van Dyck Panel Paintings Project; TRW: Tree-ring width; TPQ: *Terminus post quem*; AOTSP1: Adoration of the Shepherds plank 1; AOTSP2: Adoration of the Shepherds plank 2.

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Authors' contributions

The multidisciplinary approach presented was developed by all the authors. Dendrochronological analyses were performed by JE and AS, whereas the panel makers' punch mark and Antwerp Guild brand marks, re-examination of secondary sources, and stylistic composition were done by JD and JVA. The manuscript was jointly written by JE and AS, and feedback from JD and JVA. All authors read and approved the final manuscript.

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Availability of data and materials

The TRW data analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests

All authors declare that they have no competing interest.

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