Copernicus’s Mereological Vision of the Universe

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Abstract
Mereology is the philosophical study of part/whole relations. Copernicus, Mästlin, and Kepler addressed explicitly some of the logical issues in their support of heliocentrism. Their emphasis on harmony and commensurability to evaluate theories as more or less likely fits with their use of part/whole relations to argue for the greater reasonability or probability of heliocentrism. The essay summarizes the logical and metaphysical issues that earlier traditions discussed, and it uses those discussions to illuminate features of heliocentric theories that remain otherwise obscure even in Newton.

Keywords
mereology, part/whole relations, topics, Copernicus, Mästlin, Kepler, Newton

Introduction
I am delighted to dedicate this paper to John Murdoch, one of the foremost experts on medieval logic and especially of the metalinguistic techniques of the fourteenth century.

“Mereology” is a major subject of discussion in late antique and medieval philosophy. 1 Derived from the Greek méros (part), mereology

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1) Liddell and Scott’s Greek-English Lexicon (Oxford, 1883) lists “part” as only one of the many meanings of méros. Achille Varzi, “Mereology,” Stanford Encyclopedia of Philosophy, http://plato.stanford.edu/entries/mereology/, 1-5, provides a variety of meanings for “part” and “whole” in both technical senses and in ordinary language.
is the “science” of part/whole relations. Medieval thinkers analyzed relationships between parts and wholes with great acuity.\(^2\) Humanists’ diatribes against scholastic logic did not have a noticeable impact on university curricula until the seventeenth century. Even then, the curricula continued to emphasize the more useful parts of logic, especially dialectical inquiry and the use of topics in the construction of arguments.\(^3\) There were and continue to be unanswered questions about the arguments proposed by Nicholas Copernicus, Michael Mästlin, and Johannes Kepler in support of heliocentrism. In this paper I examine in some depth their arguments relying upon dialectical topics involving mereology or part/whole relations.

At Cracow and Bologna, Copernicus’s teachers instructed students on the use of dialectical topics for the construction of arguments. Although I think it unlikely that Copernicus knew the most technical literature, he may have had some acquaintance with the discussions at Cracow. Of course, Copernicus’s insights may have been intuitive in part, and shaped by his critique of Ptolemaic astronomy, but the structure of his book and the arguments employed there, especially in Book I (probably written in the late 1520s) contain evidence of his knowledge of standard dialectical topics. In my previous treatment of Copernicus’s arguments, I concluded that the most important, relevant to his criticisms of Aristotle and Ptolemy, is the topic \textit{from an integral whole}. In two papers I laid out the textual background for the claim that Copernicus held a notion of implication that relied on dialectical topics to argue for the probable truth of his hypotheses.\(^4\) Lacking a decisive observation in astronomy

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\(^4\) André Goddu, “Consequences and Conditional Propositions in John of Glogovia’s and Michael of Biestrzykowa’s Commentaries on Peter of Spain and their Possible
and strict scientific demonstration, Copernicus admitted into astronomy only those conditional propositions that receive their warrant from relations of relevance, containing and contained, inclusion, explaining to explained, and the following of consequents from antecedents without the addition of anything extraneous.

A Brief and Selective Survey of the Tradition

To situate this discussion in the context of Aristotelian and scholastic logic, I begin with an overview that explains my focus on dialectical topics, specifically on the topics from an integral whole and from an integral part.

Aristotle distinguished demonstrative, dialectical, rhetorical, and sophistical reasoning and arguments. He dedicated the Prior Analytics to the study of syllogistic, and challenged readers to transform valid arguments into syllogisms. He treated demonstration and induction in the Posterior Analytics, dialectical arguments in Topics, rhetorical arguments in Rhetoric, and fallacies in Sophistical Refutations. The purpose of the last treatise is to train students to recognize fallacies in arguments. Rhetorical arguments rely on techniques of persuasion that appeal to emotions, the moral character of the speaker, and logic for their effectiveness.5

The term “dialectic” has many connotations. In the Middle Ages it was often used interchangeably with “logic.” When considered as a distinct part of logic, “dialectic” may refer to all logic that is not strict demonstration or, more specifically, to all reasoning that begins from premises that are not necessarily true but probably true, true for the most part, or accepted by experts in their field. In this essay

Influence on Nicholas Copernicus,” Archives d’histoire doctrinale et littéraire du moyen âge, 62 (1995), 137-188; André Goddu, “The Logic of Copernicus’s Arguments,” Early Science and Medicine, 1 (1996), 28-68. Aside from the intrinsic topics from an integral whole and from an integral part, Copernicus also used the intrinsic topics from the proper attribute, from efficient cause, from final cause, and the extrinsic topic from authority.

I refer to “dialectic” in this last sense, and this is the sense that fits with the discussion of dialectical topics and that Aristotle treated in *Topics*.  

There is, in fact, a close relationship between dialectic and rhetoric. Many dialectical topics have counterparts among the rhetorical topics. Aristotle himself saw rhetoric as the counterpart of dialectic—rhetoric aims specifically at persuasion while dialectic provides the strictly logical arguments.  

Throughout the *Rhetoric* Aristotle refers readers to the *Topics*. Later in Book I, Aristotle says of rhetoric that it is an offshoot of both dialectic and ethical studies. The aim of a dialectical argument is primarily to provide reasons in support of a conclusion; a rhetorical argument aims to achieve agreement on the acceptability of a conclusion. Both aim at persuasion, but dialectic relies primarily on logic, whereas rhetoric relies also on emotive language and the moral character or reputation of the speaker to achieve consensus.

Aristotle gave priority to demonstration among the types of reasoning and argument, and scholastic commentators followed him to some extent. Yet the emphasis on demonstration does not seem to correspond to practice where dialectical and rhetorical arguments prevail. The requirements for demonstration, especially scientific demonstration in the strictest sense, are so rigorous that meeting them seems to be a seldom-achieved ideal. In most disciplines the premises from which arguments begin are widely shared assumptions or opinions that are probable and hence the arguments are dialectical, not demonstrative. In a number of contexts, however, medieval philosophers held some conclusions so universally that they were accorded a certainty appropriate to demonstrated conclusions when in fact they did not actually satisfy the strictest requirements. The techniques taught in *Topics* were intended to achieve propositions that are true, necessary, certain, appropriate to the

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7) *Rhetoric* I, 2.1356a20-30. There are at least ten explicit references to the *Topics* in the three books of the *Rhetoric*. 
phenomena, and universal, but the results of actual practice suggest again that the achievement fell short of the ideal.\(^8\)

On some accounts there is a hypothetical character to Aristotelian science that tends to get obscured by the emphasis placed on necessity and certainty.\(^9\) Some modern interpreters see in Aristotle’s views on deduction a distinction that corresponds to the deductive systems of the mathematical sciences, on the one hand, and to the hypothetico-deductive systems of the empirical sciences, on the other.\(^10\) The demonstrations that derive from premises that hold necessarily and without exception belong to strictly deductive systems. Demonstrations derived from premises that hold usually or for the most part belong to hypothetico-deductive systems. Dialectical method leads the scientist to the principles that are appropriate for the object of the science in question. If the principles hold universally and necessarily, then the system is strictly deductive, corresponding to what is meant by scientific demonstration—demonstration in the strictest sense where the conclusions possess certainty. If the principles hold usually or for the most part, then the system is hypothetico-deductive, and the conclusions possess only greater probability than alternative conclusions.\(^11\) Aristotle adopted scientific demonstration as the ideal, yet he cautioned readers to adopt the principles and methods appropriate to the scientific object in question.\(^12\) Because principles in natural philosophy and cosmology hold usually or for the most part, the following account restricts

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\(^9\) Serene, p. 510, expresses the point thus: “Aristotelian science was designed to explain a particular phenomenon by showing it to be a token of a type whose essential nature always necessitates that exact kind of phenomenon under the specified conditions.”


\(^12\) R.J. Hankinson, “Philosophy of Science,” in *Cambridge Companion to Aristotle*, 109-139, at 114-115 discusses the logic of “for-the-most-part” arguments, and maintains that Aristotle never worked out the details of the logic of these kinds of arguments.
the discussion to dialectical reasoning and argument. Two caution-
ary points bear repeating, however. First, the syllogistic form of the
arguments creates the impression that the arguments are demon-
strative in character. Second, dialectical inquiries and topics are
intended to generate the principles from which deductions follow,
and may thereby suggest that the principles are more demonstra-
tive in strength than they actually are.

Until scholars began routinely to learn Greek and return to the
originals, medieval masters and students were dependent on Latin
translations of Aristotle’s works. In late antiquity Boethius trans-
lated numerous Greek works into Latin, and he wrote his own trea-
tises on logic. Aristotle’s Topics provides rules that are supposed to
make it easier for debaters in dialectical disputation to discover
arguments.13 This notion of discovery influenced the ancients, but
Aristotle’s text is very long and unwieldy; followers began to sys-
tematize the topics in different ways to make them easier to use.
In his definitive work on dialectic, De topicis differentiis, Boethius
regards the finding of arguments as its main task. “Topic” means
“place.” The notion here is that by means of a topic we can find a
term that will mediate between two given terms in an argument.14
Boethius divides topics into maximal propositions or principles that
are self-evident, true generalizations and differentiae under which
maximal propositions can be grouped. The differentiae constitute
Boethius’s main instrument for finding arguments providing a term
or intermediate term between two terms of a question. The third
term joins the other two together in the form of a syllogism. In
specific cases where a differentia is used to find a third term, it may
be necessary to validate the argument, and that is the function of
the maximal proposition, namely as a sort of generalized rule. In
categorical syllogisms, maximal propositions are general premises

13) Smith, “Logic,” 57-62; Niels Green-Pedersen, The Tradition of the Topics in the Mid-
dle Ages (Munich, 1984), 37-126; Eleonore Stump, “Dialectic,” in The Seven Liberal
Arts in the Middle Ages, ed. David Wagner (Bloomington, 1983), 131; and Eleonore
14) Smith, “Logic,” 61-62; Stump, Dialectic, 57-66; Jan Pinborg, “Topik und Syllogis-
tik im Mittelalter,” in Sapienter ordinare, Festgabe für Erich Kleineidam, Erfurter The-
that guarantee the validity of the argument; in hypothetical syllogisms
they validate the connection between the antecedent and con-
sequent in the conditional premise of the argument. Hence, differ-
entiae help us find third terms to construct arguments, and maximal
propositions validate the argument discovered.\textsuperscript{15}

The most important introductory textbook on logic after the thir-
teenth century was Peter of Spain’s \textit{Tractatus}.\textsuperscript{16} It is divided into
two main parts, the first summarizing Aristotelian logic as inter-
preted by Boethius, and the second the scholastic terminism of the
Middle Ages. The first part, then, contains an introduction to
categorical syllogisms, and treatises on predicables, predicaments
(categories), syllogisms, topics (\textit{De locis}), and fallacies. The second
part includes treatises on supposition, relatives, ampliation or exten-
sions, appellation, restriction, and distribution, all of which derive
from the thirteenth-century common theories about properties of
terms.\textsuperscript{17}

Peter conceived of dialectic as an art rather than as a science.
“An argument,” he says, “is a reason producing belief regarding a
matter that is in doubt, that is, a middle proving a conclusion that
needs to be confirmed by means of an argument.”\textsuperscript{18} Peter followed
Boethius in dividing a topic into a maxim (maximal proposition)
and a differentia, and also dividing topics into three subcategories:
intrinsic, extrinsic, and intermediate. An intrinsic topic appears in
an argument that is taken from the nature of one of the terms of
the argument; extrinsic in an argument that is taken from what is
external to their nature; and intermediate is one that comes partly
from the nature of the term and partly from without.\textsuperscript{19} For Peter
a topic confirms an argument by providing a middle term through

\begin{footnotes}
\textsuperscript{15} Stump, “Dialectic,” 133-135.
\textsuperscript{17} Stump, “Dialectic,” 128-131.
\textsuperscript{18} Peter of Spain, \textit{Topics}, tr. Eleonore Stump, in \textit{The Cambridge Translations of Me-
dieval Philosophical Texts}, ed. Norman Kretzmann and Eleonore Stump (Cambridge,
\textsuperscript{19} Stump, \textit{Dialectic}, 139. In dividing topics into intrinsic, extrinsic, and intermediate,
Boethius had followed Themistius.
\end{footnotes}
which an enthymeme, an incomplete syllogism, can be transformed into a complete syllogism.\textsuperscript{20}

The intrinsicness of topics in the first subcategory does not mean that these topics produce demonstrations.\textsuperscript{21} Where they are dialectical, the syllogisms that are produced by means of intrinsic topics are probable, hence even intrinsic topics in such syllogisms are considered probable and only contingently related to a term in the conclusion. In demonstration, by contrast, intrinsic terms are always essentially and necessarily related to a term in the conclusion. As this clarification suggests, there is a metaphysical doctrine at work here. In strict demonstrations (\textit{demonstratio propter quid}) the middle term refers to a real cause of the connection between extreme terms. Even in demonstrations of the fact (\textit{demonstratio quia}) the middle term is an assertion about the essence of the subject by means of which we demonstrate an essential attribute of the subject. In dialectical arguments, however, the middle term does not refer to a cause and it is not an assertion of the essence of a subject but rather a sign of the connections between things and the validity of an inference. As a consequence, dialectical arguments produce at best only highly reliable opinions, not knowledge in the strict sense.\textsuperscript{22}

Peter distinguishes twenty-five differentiae, forty-three topics, and fifty-seven maxims. Under intrinsic differentiae he distinguishes between topics from substance and topics from concomitants of substance. Under the latter Peter enumerates \textit{from the whole} (universal whole, a species or subjective part, \textit{integral whole}, whole in quantity, whole in mode, whole in place, and temporal whole), \textit{from a cause}, \textit{from generation}, \textit{from destruction}, \textit{from uses}, and \textit{from associated accidents}. As an example of an integral whole, Peter provides the following example: “A house exists, therefore, a wall exists.” The topic is \textit{from an integral whole}, and the maxim is “If an integral whole is posited, then any one of its parts is also posited.”

\textsuperscript{20} Ibid., 140-146, where William of Sherwood makes explicit what is admittedly only implicit in Peter.
\textsuperscript{21} Pinborg, “T opike,” 178.
\textsuperscript{22} Stump, \textit{Dialectic}, 155.
That in brief and with focus on the topic *from an integral whole* is Peter's account of topics. Topics serve a function in arguments. A conclusion is a proposition that is proved by an argument. Before it is proved, however, it is in doubt, that is, we have a question about it. From the conclusion we identify extreme terms, and the exercise is to find a term that mediates between the extreme terms in the conclusion. Topics help us to find middle terms. An argument, then, is a reason that produces belief about a matter that is in doubt.

The relevance of such details to Copernicus's comments about method and to his arguments brings us to discussions at Cracow University in the 1490s. In evaluating conditional arguments and consequences, John of Glogovia in particular came to grips with the conditions for their validity. In commentaries on Peter of Spain's treatises, John claimed that the truth or falsity of a consequence is independent of the truth or falsity of its component statements, but is rather dependent on a *connection* between antecedent and consequent.23 The connection between antecedent and consequent is “based on the intentions (meanings, concepts) whose relationships are recognized by *topical maxims*” [emphasis added]—and the topics mentioned by John are essential superior to inferior, whole to essential part, *integral whole to part*, cause and effect, cause of following, correlative, inclusion, and containing and contained. Among the criteria for a sound consequence enumerated by professors at Cracow was the following minimal condition: what is signified by the consequent must be included in, contained by, or relevant to what is signified by the antecedent. Conversely, a good consequence admits nothing extraneous or irrelevant.24

This background helps to illuminate Copernicus’s controversial statement in the dedicatory letter to the Pope:25

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Hence in the process of demonstration or “method”, as it is called, those who employed eccentrics are found either to have omitted something essential or to have admitted something extraneous and wholly irrelevant. This would not have happened to them, had they followed sound principles.

The point is that scholastic philosophers used topics such as *from an integral whole* and conditions such as relevance between antecedents and consequents to evaluate the validity of conditional arguments and consequences.

We may also consider briefly another possibility. If Copernicus attended classes in law at Bologna, then he almost certainly received instruction in the application of dialectical topics to legal cases. In treatises on legal dialectic we encounter references to the standard medieval logical treatises, especially Peter of Spain, and to the same kinds of definitions and distinctions that we mentioned above. In addition, legal scholars developed topics specific to legal jurisprudence, some of which derive from humanist contributions on the editing and interpretation of texts. The topics *from similitude* and *from authority*, as one would expect from jurists, were the most important, but they often employ the topic *from an integral whole*. It is also a striking fact that jurists routinely assumed connection or relevance as a condition of validity for consequences. In short, Copernicus might have first encountered these techniques and forms of argumentation at Bologna, although it is likelier that his education at Cracow prepared him to follow lectures on the law and to apply dialectical topics to legal cases.

I began this part of my account by explaining why I was situating the discussion of mereology within the context of dialectical topics, a point to which I return later in the paper. As the introduction also indicates, however, mereology was a major philosophical subject in its own right. To complete this brief and selective survey, I now turn to philosophical analyses of part/whole relations in the western tradition.

The first explicit analysis of part/whole relations in western thought appears in Plato. In *Parmenides* (137a-145e) Plato pursues the

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consequences of contrary assumptions. If being has parts, then what is the relation of the whole to the parts? Is the whole just the collection of the parts or more than the sum of the parts? In *Theaetetus* (202e-205e) Plato notes the difference between a syllable and the letters in it. A syllable is formed from letters yet is distinct from them, for it has its own peculiar form or arrangement. Plato also concludes that there is a difference between a sum and a whole. In other words, an arithmetical sum is not the same as a whole that possesses unity (*bólon* or *sínolon*).

Aristotle took up these issues in several texts, too many to summarize briefly. I select texts essential for the results that follow, namely, those regarding integral whole and parts and the texts where Aristotle draws conclusions about the order of the universe and the natural motions of bodies. Although Aristotle did not discuss part/whole relations in a systematic way, his discussion of concrete wholes in *Topics* (VI, 13, 150a22-b36) forms the basis for the later dialectical topics from an integral whole and from an integral part: “The whole perishes when the parts do, but the parts do not necessarily perish when the whole has perished.” This assertion is the basis for the consequences, “If the whole is, then the part is; if the part is not, then the whole is not.” But the following are not valid: “If the whole is not, then the part is not; if the part is, then the whole is.” Aristotle adds that a whole compounded of parts in a particular way is not just a totality, sum, or collection of parts. In other

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28) *Topics* V, 5; VI, 11, 13-14; *Physics* I, 1, 4; II, 4; III, 5-6; IV, 5; *De caelo* I, 3; II, 14; *Metaphysics* I, 5; IV, 2, 5; V, 2-3, 23, 25-27; VII, 2; VIII, 1, 6; X, 1; XI, 10; XII, 8, 10; and XIII, 8; *Parts of Animals* 640b1-5; 646a25-30; *Rhetoric* II, 24.2.1401a23-b5; and *Poetics*, 6 and 12. In the analytical indexes of technical terms in his translations of *Metaphysics* (Ann Arbor, Michigan, 1960) and *Physics* (Lincoln, Nebraska, 1961), Richard Hope provides many more references to *mérōs*, *mörion* (*pars*, *particula*), *bólon* (*totum*), and *sínolon* (*a composite or integral whole, sometimes also rendered totum in Latin and totum integrale*).

29) *Rhetoric* II, 24, 1401a23-b5 supports these qualifications, but also points out examples of syllogisms that are not genuine, for example, from a whole action that is wrong concluding that each part is wrong.
words, a quantity (posón) is not what he understands by a composite whole (súnon).

Metaphysics (V, 15-16) clarifies this qualification by using the word “total” (hólon) to describe a quantity the parts of which can change position without affecting the aggregate. A total, in turn, is distinguished from organic substances composed of homogeneous parts such as tissue, flesh, and bone, thus generating the distinctions (Parts of Animals II, 1, 646a1-647b9) among three sorts of substantial composition: elemental, uniform (bone, flesh, and tissue), and non-uniform (organs). Things in which the whole is not like a heap or lump have some uniting factor (Metaphysics VIII, 6, 1045a8-12). Such texts are connected to the teleological dimension in Aristotle’s biological thinking but they have echoes in his cosmological views of Earth and the celestial spheres as primary beings—the world is a cosmos, a definite something, all things ordered together around a common center (Metaphysics XI-XII). We commonly divide the Aristotelian cosmos into two spheres (celestial and terrestrial), but Aristotle allows for many ways in which the celestial influence the terrestrial. For example, the motions of higher bodies are transmitted to lower bodies even down to the rotation of the upper terrestrial atmosphere, the Sun warms Earth, and many continued to believe in the astrological influences of the qualities and motions of celestial bodies.

In Metaphysics IV, 5, 1010a28-32 Aristotle criticizes his predecessors for having attributed to the whole that which is true only of the part:

We should add another criticism against those who hold these views: they have been reporting what they observe in only a few sensible things as if it were true of the whole cosmos. For it is only the region of what is sensible round about ourselves that is continually in process of destruction and generation; but this is, so to speak, not even a small part of the whole, so that it would have been more just to acquit this small bit because of the whole than to condemn the whole because of this small bit.30

30) Hope translation, 79-80.
Aristotle himself concluded that the heavens were made of an element different from the elements in the sublunar realm. For him, each simple body or element has only one natural motion, and the whole of an element, if united, and the part move naturally in the same direction, as, for example, the whole Earth together and a small clod (*De caelo* I, 3, 269b30-270a13). *De caelo* II, 14, 296b27-297a7 summarizes the argument succinctly:

If it is inherent in the nature of earth to move from all sides to the centre (as observation shows), and of fire to move away from the centre towards the extremity, it is impossible for any portion of earth to move from the centre except under constraint; for one body has one motion and a simple body a simple motion, not two opposite motions, and motion from the centre is the opposite of motion towards it. If then any particular portion is incapable of moving from the centre, it is clear that the earth itself as a whole is still more incapable, since it is natural for the whole to be in the place towards which the part has a natural motion.31

It should be noted, however, that constructive arguments from part to whole depend on the conception of a natural whole thing. By concluding that the heavens are made of a different fifth element, the aether, with a distinctive natural motion in circles around the center of the cosmos, Aristotle cut off arguments that the celestial motion follows the same patterns as terrestrial motion.

Although they departed from Aristotle on their notions of the relation between God and the created world, Neoplatonic and medieval authors devoted much attention to part/whole relations.32 Their motives varied, but a number of puzzles caught their attention. For Neoplatonists like Proclus, the whole is hierarchically related to the parts, an idea that could be easily adapted to Aristotle’s arrangement of the spheres down to the center of Earth. Boethius, sympathetic to such schemes, summarized and interpreted Aristotle’s doctrines on topics and division. As we indicated above, he devised in particular the formulas that would be repeated down to the


Copernican era. With regard to whole/part topics, Boethius organized the topics into rules for the discovery of arguments. He adopted Cicero’s division of topics, two of which are from the whole and from the enumeration of the parts. In discussing parts, Boethius distinguished between two ways: parts taken as species or as members. By “members” Boethius meant “real parts.” He discussed inferences from whole to parts and from parts to whole, often referring to examples of integral whole and integral parts. The scholastics adopted this category of topic, introducing a number of distinctions by way of ever more sophisticated examples. From the existence and nonexistence of whole and parts, they developed rules for valid and invalid constructive and destructive inferences respectively.

Already implicit in Aristotle, who, however, had applications to organic substances pre-eminently in mind, the consequences that we owe to Cicero and Boethius are the ones found later in Peter of Spain with the typical example of the house:  

1. If the house exists, then the parts (roof, walls, foundation) exist.  
2. If the house is not, then the parts are not.  
3. If the parts are, then the house is.  
4. If the part is not, then the house is not. Everyone agreed that (1) and (4) are valid, although some authors added qualifications. For example, Abelard regarded an integral whole as identical with a unique set of parts including the arrangement that individual parts have. (2) is then qualified to read: (2’) If the house is not, then the parts-of-this-house are not (which in this form is valid). Although (3) remains invalid, in the following sense it is valid: (3’) If the parts-of-this-house are, then the house is potentially. Later scholastics emphasized integral wholes that are actually composed out of their parts, implicitly recognizing that not all parts of a whole (totum) are plausibly parts of an integral whole (totum integrale), otherwise a monster results. For example, cobbling together hands, feet, and a head does not make up a human being.

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34) Peter of Spain, Tractatus, V, 64.
The claim about unique arrangement of parts can generate other puzzles noted by medieval philosophers. If I repair a house by replacing some parts, is it still the same house? Some changes (renovation) may indeed produce a new, different house. Such considerations led medieval philosophers to a variety of solutions. Some distinguished between principal (or vital) parts and less principal (non-vital) parts, one consequence of which is that the destructive application from the integral part (If the part is not, then the house is not) holds only for principal parts. For things that change, move, grow, or diminish, the distinction provides a way of preserving identity over time and for distinguishing between principal and less principal parts.36

Answers to questions about the composition of homogeneous and heterogeneous substances, and about continuous, contiguous, and discrete things often depended on how authors interpreted Aristotle. Aristotle thought the cosmos qua unified thing “has” a nature in the sense that the parts are ordered according to the substantial or qualitative forms that they possess as inferred from their observed motions and behaviors. Where Aristotle observed contrary simple motions (up and down), he concluded that the contrary motions must be due (aside from their generating cause) to contrary qualitative forms that account for a natural directionality in the things possessing those qualities. The observed circular motions of celestial bodies must be due to a form that has no contrary thus revealing a different substance the nature of which is to move in circles. Aristotle’s metaphysical analysis also led him to the existence of immaterial intelligences that are the cause of eternal circular motion. The contiguity of the celestial spheres is revealed in the way that the circular motions influence the motions of lower spheres down to comets in the upper atmosphere and even to the circular motion of the Earth’s atmosphere.37

Even within Aristotle’s lifetime, however, astronomers made observations that introduced complications into his picture. A few

37) De caelo I, 2; Metaphysics XII, 7-9.
astronomers departed radically from the geocentric view, but Plato’s insistence on uniform circular celestial motions,\footnote{\textit{Republic} VII, 529a-530d; Olaf Pedersen and Mogens Pihl, \textit{Early Physics and Astronomy} (New York, 1974), 26-30 and 65-67.} Aristotle’s physical interpretation of the Eudoxan-Calippan model, and his strong support of commonsense observation effectively constrained alternative theories and interpretations into different versions of geocentrism. On the other hand, Ptolemy’s more accurate mathematical geocentrism also successfully resisted criticism. Although some philosophers and astronomers continued to seek and construct alternatives, all of them remained geocentric.

Copernicus himself was committed to the uniform, circular motions of all of the celestial spheres. Ptolemy’s failure to preserve the uniform circular motions of the planetary and lunar spheres (the so-called Platonic axiom) without resorting to an equant model and other failures led Copernicus to a major cosmological revision in the service of an otherwise conservative reformation of astronomy.\footnote{Copernicus did not explain exactly how he arrived at his version of the heliocentric system. I have reviewed the reconstructions in "Reflections on the Origin of Copernicus's Cosmology," \textit{Journal for the History of Astronomy}, 37 (2006), 37-53. Only Copernicus’s acceptance of the Platonic axiom and spheres explains his insistence on preserving uniform, circular motions and use of eccentrics and epicycles in his models. On pp. 45-46, I order the steps in Copernicus’s path to his cosmological theory, showing in particular how Copernicus assembled and reflected on irregularities, inconsistencies, and several striking facts that neither Ptolemy nor any geocentrist could explain.}

I turn now to the role of mereology in Copernicus’s revision of cosmology.

\textbf{Copernicus's Use of Mereological Topics}

To apply the above summary of the tradition in a way that makes the issues as clear as possible, I resort here to simpler kinds of dilemmas. For example, the topics \textit{from an integral whole} and \textit{from an integral part} seem to imply that if, for example, Socrates loses a hand, then Socrates does not exist. One strategy for dealing with
this apparently absurd consequent is to define an integral part as the kind of part that cannot be removed without destroying the whole. As we saw above, authors who applied this strategy made distinctions between vital parts (applicable only to organisms) and less vital parts, or between principal as opposed to less principal parts. Or, to put it negatively, a non-integral part is one that we can remove and still have the same individual. This criterion does not remove all ambiguity. We could attempt to find some non-arbitrary criterion, but we would obscure an important lesson from these examples. The answer that we would give to such a question reveals our view of what it is to be an individual and of what constitutes the identity of an individual.

Copernicus’s mereological vision of the universe refers to an intuition about the universe as a composite or integral whole. By analyzing the intuition held by him and his followers, we can reveal features of their heliocentrism that otherwise remain obscure. We will also discover why they believed that their conclusions were more probable and likely than those of geocentrists. Finally, we will also appreciate why Michael Mästlin and Johannes Kepler found Copernicus’s answers persuasive, even compelling.

Copernicus finally explained the reasons, already implicit in Commentariolus, why he adopted heliocentrism in its clearest form some thirty-two years after he first proposed the heliocentric theory. In the Preface to the Pope, he repeats all of the complaints about the failures of his predecessors, but he expresses there with the greatest clarity to date, perhaps under Georg Rheticus’s influence, why his predecessors by their assumptions and methods had failed. They had failed to construct a unique, non-arbitrary, and commensurable structure befitting the exquisite craftsmanship of its architect. They had, as late scholastic authors had suggested, cobbled together

40 Note that the reasons for adopting heliocentrism constitute a reconstruction, not a description of the path to his heliocentric cosmology. In the reconstruction, Copernicus provides hints about how he arrived at the heliocentric theory, the astronomical details of which I have discussed in “Reflections” and in André Goddu, “Hypotheses, Spheres, and Equants in Copernicus’s De revolutionibus,” in Les éléments paradigmatisques thématiques et stylistiques dans la pensée scientifique, ed. Bennacer el Bouazzati (Rabat, 2004), 71-95.
from incompatible and irrelevant parts a thing that resembled a monster. They would not have failed, he alleges, if their method had been sound.\textsuperscript{41}

Copernicus uses repeatedly the topics \textit{from an integral whole} and \textit{from an integral part} like a chisel to fashion a heliocentrism that is likelier than geocentrism, and to refashion Aristotelian and non-Aristotelian accounts of natural elemental motion so that they fit into a heliocentric cosmos.

In the Preface Copernicus argues that the hypotheses should be relevant to the structure of the universe, and the resulting composite whole should possess commensurable parts. The topic \textit{from an integral whole} supports an inference from the composition of the whole having parts to the existence and place of a part. He compares the universe to the portrait of a single individual having relevant parts ordered harmoniously or commensurably with a picture with parts taken from different individuals resulting in a monster. In other words, the Copernican system is to the Ptolemaic system as a portrait of a harmonious individual is to the portrait of a monster.\textsuperscript{42} He supports this analogy and the inference on which it is based with additional arguments that as “the best and most systematic Artisan of all,” God arranged the parts of the world machine in a definite and unique order that we are capable of discovering because God created the system for our sakes. He clinches this series of arguments with the following inference: Because “the order and size of all the planets and spheres, and heaven itself is so linked together,” by virtue of the topic \textit{from an integral whole}, it follows “that in no portion of it can anything be shifted without disrupting the remaining parts and the universe as a whole.”\textsuperscript{43}

\textsuperscript{41} Rosen translation, \textit{On the Revolutions}, 4-5. This is the argument that relies on dialectical topics to argue for relevance between antecedent and consequent as a condition of validity.

\textsuperscript{42} That Copernicus means “harmonious” to be taken as “commensurable” is clear from the ratios that he assigns to the planetary spheres.

\textsuperscript{43} Rosen translation, \textit{On the Revolutions}, 5. Copernicus adopts the same arrangement for the entire book beginning with the general structure of the universe and in the remaining books treating the motions of the parts.
In I, 4 of *De revolutionibus*, Copernicus makes his first application of the topic *from an integral part*. After acknowledging the apparent disagreements between uniformly moving spheres and the observed non-uniform motions, Copernicus cautions us to examine the relation of Earth to the heavens carefully, otherwise we may make the error of attributing to the heavens what belongs to Earth thus violating the rule that permits only a negative inference from integral part to whole. That is to say, the error would be to attribute to the whole that which belongs to one of its parts only. Copernicus, however, soon qualifies this rule.

As he takes up the problem of relative motion (I, 5), the question, as Copernicus sees it, is whether we should attribute motion to a part or to the universe as a whole. In I, 6, Copernicus takes advantage of Ptolemy’s eccentric models and his admission that the Earth’s diameter is as a point in relation to the size of the universe. It follows, argues Copernicus, that it is impossible to say whether Earth is the exact geometrical center of the universe. If we cannot prove that it is the exact center, we cannot prove that it is always at rest in the middle. This is the reason why the ancients resorted to physical arguments to prove that Earth is at the center. Their arguments relied on claims about “natural” motions and that the elements have simple natural motions. Copernicus’s objections rest on what we call “natural.” To do so we must identify the nature of a thing correctly. How Earth in fact behaves must be ascertained before we can conclude what its nature is and what is natural to it. This suggests, however, not that all inferences from part to whole are invalid, but that before making such inferences about physical explanations, it is necessary to be sure that one’s facts are accurate. Only a careful critique that relies on already well-established features of the whole can guide us. In other words, only inferences from part to whole that result in conclusions inconsistent with established axioms or conclusions about the whole are invalid.

Copernicus almost certainly relied on ancient interpretations of Aristotle and accounts that are alternatives to his.\(^{44}\) He intends all

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of his objections to raise doubts in the mind of readers about the immobility of Earth based on the claim that a rectilinear motion is a simple natural motion. Rectilinear motions of objects seem rather to belong to objects that are not in their “proper condition and not in complete accord with their nature.” Circular motion belongs to wholes, rectilinear motion to parts, and hence they are relative to one another. After he draws all of the consequences from consideration of multiple centers of revolutions and the relativity of motions, he appeals to the “principle governing the order in which the planets follow one another” and “the harmony of the entire universe.” In short, Copernicus assumed from the outset that we can answer affirmatively a question about a part only by establishing the order of the whole. From the existence of the order of the whole we can infer the order of one of its parts. Copernicus’s reasoning depends on architectonic principles that subordinate some natural-philosophical hypotheses to astronomical considerations. His argument from integral whole to part retains a dialectical character for it depends on the greater probability of his architectonic principles.

Copernicus’s mereological vision of the universe refers, then, to his belief in a universe that is a unified and integral whole composed of discrete principal parts arranged in a definite commensurable order. A hypothesis that seems counterintuitive or contrary to commonsense perception can be shown to be probable by reference to the whole structure, for we can draw conclusions about the position and motion of a part only from consideration of the whole. Our conclusions about the whole, in turn, derive from a critique of accounts inferred from appearances of a part.

This analysis does not exhaust the logic of Copernicus’s arguments, but it does illuminate one of his principal logical resources in support of a heliocentric cosmology. To my knowledge, Michael Mästlin is the only author who noticed this strategy. In a preface

See also André Goddu, “Copernicus’s Annotations: Revisions of Czartoryski’s ‘Copernicana’,” *Scriptorium*, 58 (2004), 202-226 with eleven plates, where I analyze Copernicus’s annotations and reading of sources.

45) Whether Copernicus means that rectilinear motions are unnatural or merely less natural is unclear.
to the 1596 edition of Rheticus’s *Narratio prima* and Kepler’s *Mysterium cosmographicum*, Mästlin expresses this principal logical or dialectical warrant in Copernicus’s arguments:46

Is not the earth and the air around the earth the seat and the whole dwelling-place of all things that to us are heavy or light? But how are earth and the air around it related to the immense vastness of the whole world? They are as a point or small points, and calling them even smaller, if that were possible, would be more fitting. For those reasons do you not consider the Philosopher’s inference from such a little part or point to the whole world to be a weak argument? We cannot, therefore, conclude anything certain about the center of this most spacious world from those things that approach this little point or move away from it. This [tendency] of heavy and light things to seek their proper place, which by testimony of the Philosopher is the perfection of the thing, is really an inclination implanted in [all] things by nature, as Copernicus says with erudition in Book I, chapter 9, [and] belongs credibly also to the sun, the moon, and the other wandering stars, that they retain permanently the shape of a sphere as representing their most perfect form. If any such place is the [unique] center of the world, then it is by accident. Truly, Copernicus’s reasoning in astronomy proceeds, not from the minute parts to the whole, but on the contrary from the whole to the parts. But from this is easily recognized which is the more convincing, Copernicus’s procedure or that.

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of the usual hypotheses. Because Copernicus’s hypotheses enumerate, dispose, connect, and measure the order and size of all orbs and spheres in such a way that none of them can be changed or transposed without throwing the entire universe into confusion, [for all of these reasons] all doubt about position and order remains far removed.

Mästlin criticizes claims made by Aristotelians that the observations of bodies falling to Earth prove that Earth is the center of the universe. Such observations confirm at best that the observed bodies have a tendency to fall towards the center of Earth. What is the justification for inferring the whole from the part? Copernicus was right to argue from the whole to the parts. Mästlin follows that claim immediately with Copernicus’s hypotheses by means of which he enumerates, arranges, connects, and measures the order and magnitude of all orbs and spheres, such that no change can be admitted without throwing the entire universe into confusion. Mästlin fails to notice, however, that the inference about gravity depends on a constructive application of the topic from an integral part.

Copernicus’s vision of a structured and commensurable heliocentric universe persuaded Kepler. Kepler’s astronomy bears an almost ironic relation to Copernicus’s, yet he defended Copernicus on logical grounds:47

I particularly abhor that axiom of the logicians [dialecticians] that the true may follow from the false, because people have used it to go for Copernicus’s jugular, while I am his disciple in the more general hypothesis concerning the system of the world. I therefore considered it particularly worthwhile now to show the reader how it does happen here that the true follows from the false. First, you have already seen that what has followed is not exactly the truth.48

47 By “ironic” I am referring to his critique of the geocentric remnants in Copernicus’s theory.
Kepler goes on to explain that his own first supposition does not give the planet Mars the right latitude. “So it is not exactly the truth that follows from this false hypothesis.” Although he does not cite Aristotle here and, indeed, expresses his contempt for academic logicians, Kepler was in fact following Aristotle’s assertion that a false assumption will sooner or later be exposed by the consequences that follow from it.\(^{49}\) That was why he found it necessary to test extensively every relevant alternative hypothesis. By contrast, from what is true only the true will follow.

There is an even more profound sense in which Kepler followed Copernicus in logic, but to a conclusion that might have shocked Copernicus and did worry Mästlin.\(^{50}\) Kepler does not explain the logic of his move, yet it is clear from his procedure. If we can argue validly from an integral whole to one of its parts, Kepler concluded that there must be a unified set of physical principles that account for the motions of all of the planets. Once we have concluded from Copernican cosmology that Earth is a planet, then physical principles that account for motions of Earth must be true of the motions of other celestial bodies as well. Because all of the observable heavenly bodies appear to be spheres, the rectilinear component of falling bodies led Copernicus to speculate that gravity is a tendency that God implanted in all of the observable celestial bodies in the form of a sphere (Sun, Moon, and planets). His cosmos, however, is finite and the spheres of the fixed stars and the Sun are stationary, hence Copernicus did not conclude that all spheres rotate on their axes. Valid inferences from part to whole, then, rely on observation and depend on a critique of existing accounts, eliminating those that do not fit in the already established structure. Kepler concluded that the physical principles of motion discovered on Earth must be the principles of all motion.

Mereology is a vast and highly contentious area of philosophy. This essay offers a mere sketch, and provides only a glimpse of Copernicus’s mereological vision of the universe. For all that I hope

\(^{49}\) Aristotle, *Nicomachaean Ethics* I, 8, 1098b11-12.

that the paper suffices to reveal the power of mereology for Mästlin and Kepler, and, in conclusion, to anticipate its effect on Newton’s rules of reasoning in natural philosophy. Rule 3 reads in part:\textsuperscript{51}

\begin{quote}
The extension, hardness, impenetrability, mobility, and force of inertia of the whole arise from the extension, hardness, impenetrability, mobility, and force of inertia of each of the parts; and thus we conclude that every one of the least parts of all bodies is extended, hard, impenetrable, movable, and endowed with a force of inertia. And this is the foundation of all natural philosophy.
\end{quote}

Modern interpreters refer to this concept as “transdiction” and “projection.”\textsuperscript{52} It depends on the principle that “nature is always simple and ever consonant with itself,”\textsuperscript{53} and is, in fact, a version of the constructive application of the topic \textit{from an integral part}. 

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\textsuperscript{51} Isaac Newton, \textit{The Principia}, tr. I.B. Cohen and Anne Whitman (Berkeley, 1999), 795-796.
\textsuperscript{53} Newton, \textit{Principia}, 795.
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