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Opportunity to view the starry night sky is linked to human emotion and behavioral interest in astronomy

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Prior to the modern era, the stars in the night sky were readily visible across the globe, but light pollution has created disparities in the opportunity to see these astronomical objects with the naked eye. This alteration may measurably impact human behavior. We hypothesize that light pollution is related to the development of people's interest in astronomy, which often serves as a "gateway" to science more broadly. In a state-by-state analysis, we used location information to examine astronomy interest data for millions of US residents. Results show that, among populations with low light pollution, a feeling of "wonder about the universe" is prevalent ($r = 0.50$). We found that this human emotion mediates the association between low light pollution and behavioral interest in astronomy. Although the effects of light pollution on astronomy, biology, ecology, and health are well-known, the present work demonstrates that light pollution is also relevant to human scientific behavior, with broad implications for science education and society.

In addition to being a problem for ground-based astronomy[1–3], anthropogenic light at night is transforming world ecologies[4–6]. Even in locations hundreds of kilometers away from the main sources of artificial light—the urban areas—the propagation of light through the atmosphere degrades the visibility of the night skies[7]. This artificial light has consequences for biological processes as diverse as animal migration[8], pollination[9], circadian rhythms[10], and gene expression[11]. Artificial light at night also affects human health[12,13]. There is a growing consensus that this light can be considered a conventional environmental pollutant[14]. A major underexplored issue is how light pollution, which blocks humans' natural views of the starry night sky, might affect human behavior and even scientific curiosity.

Prior to incandescent street and building lighting, starlight served as a fixture of the nighttime for human groups around the globe[15]. Human civilizations relied on the stars to inform agricultural, navigational, and cultural practices[16]. In the industrial era, stars in the night sky began to disappear from the daily experience of urban populations[17,18]. This anthropogenic phenomenon is growing rapidly, and the stars are becoming a rare sight for many human populations[2,7,19]. These changes in the visibility of the starry night sky may plausibly affect human psychology and behavior, especially in relation to interest in one of humanity's oldest sciences—astronomy.

We hypothesized that there would be a specific psychological mediator between the loss of the visible starry night sky and dampened behavioral interest in astronomy: A feeling of "wonder" about the universe. Indeed, historic and modern astronomers have informally reported that their own inspiration for studying the universe was seeing the starry night sky and feeling "wonder" about the universe[20–24]. These narratives are consistent with theories in psychological science, which propose that wonder—a human emotion combining curiosity, amazement, and elation—is a strong motivator of human behaviour[25]. Wonder involves recognizing gaps in current understanding and endeavoring to bridge those gaps by acquiring new knowledge[26]. Here we hypothesize that the loss of the visible starry night sky reduces the opportunities for humans to feel wonder about the universe and dampens interest in astronomy, a "gateway science"[27].

Results

At the level of the individual person, there are no known measures of exposure to light pollution. Thus, we examined physical measurements of artificial night sky brightness, as reported at the state level in the US by Falchi and colleagues[28]. Consistent with their call to use their dataset to explore issues in the behavioral sciences[2,7,28],

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we focused on gradients of light pollution that allow the naked human eye to view nighttime stars at the zenith, i.e., low light pollution (Fig. 1a; also see Supplementary Information, Sect. 1.1 for measurement details).

Contemporaneously with Falchi et al.[28] collecting measurements, the Pew Research Center collected data from 35,071 US respondents using a rigorous survey that captured psychological measures from a representative sample of residents in each state[29]. This Pew survey included the psychological question "How often do you feel a deep sense of wonder about the universe?" measured on a 5-point Likert scale (Supplementary Information, Sect. 1.2). This measure varied by state across the US (Fig. 1b).

Light pollution and wonder about the universe

Our analyses of these two independent datasets show a positive association at the state level between low light pollution and feelings of wonder about the universe, $r = 0.50$, $p < 0.001$ (Fig. 1c). Importantly, the Pew survey also measured three other psychological questions that served as controls in the present study, because they were collected in randomized order on the same individuals who answered the question about wonder (specifically, Pew collected measures of gratitude/thankfulness, spiritual peace/well-being, and meaning/purpose of life, Supplementary Information, Sect. 1.2). These psychological variables also varied by state across the US (Supplementary Fig. 1), but there was no significant association ($ps > 0.27$) between low light pollution and any of these control covariates (Fig. 1c).

For completeness, we note that for a sample of 50 ($df = 48$), a Pearson r coefficient would need to meet or exceed $r = 0.28$ [absolute value] to achieve $p < 0.05$. Also, because the low light pollution data were skewed, necessitating interpretive caution, we re-calculated the r using a dichotomous median split for the light pollution data, and found that the correlation remained significant, see Supplementary Information, Sect. 2.

Wonder about the universe and astronomy interest

Psychological perspectives hold that emotions such as wonder can drive learning and exploration[30,31]. We hypothesized that wonder about the universe would be associated with behavioral interest in astronomy, and developed eight measures of such interest at the state level (Supplementary Information, Sects. 1.3–1.9).

The first measure was seeking to learn about astronomy. Using the billions of searches conducted on Google[32], we found that states with more wonder about the universe also have a higher proportion of total internet searches for "astronomy," $r = 0.52$, $p < 0.001$ (Supplementary Information, Sect. 1.3 and Supplementary Fig. 2a).

Second, we examined people's interest in contributing to astronomical knowledge. We found a positive association between state-level wonder about the universe and the percent of the state population that submits data to the NSF-NOIRLab's citizen scientist project Globe at Night[33], $r = 0.40$, $p = 0.004$ (Supplementary Information, Sect. 1.4 and Supplementary Fig. 2b).

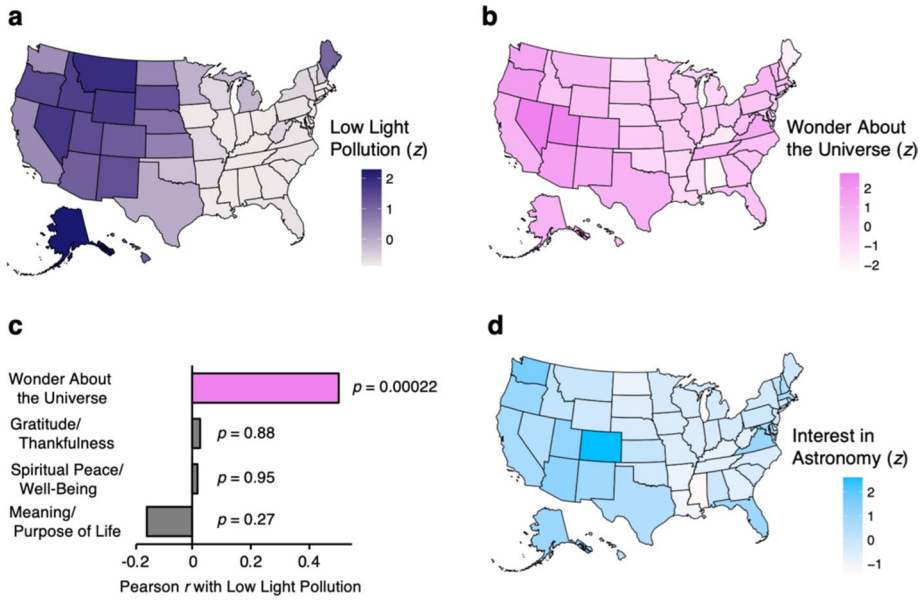

Figure 1. State maps of low light pollution, wonder about the universe, astronomy interest, and correlations between measures. (**a**) Map of US states showing low light pollution[28], purple (darker purple indicates less light pollution). (**b**) Map of US states showing respondents' sense of wonder about the universe from the Pew Research Center[29], pink (darker pink indicates more wonder about the universe). (**c**) Pearson correlations between low light pollution and wonder about the universe, and between low light pollution and other psychological emotions. (**d**) Map of US states showing composite measure of behavioral interest in astronomy, blue (darker blue indicates more interest in astronomy). All measures are z-standardized and defined in the Supplemental Information (also see Methods).

Third, interest in astronomy may be seen more broadly in popular culture, and Nobel laureate astrophysicist Kip Thorne consulted on a scientifically-grounded film depiction of exoplanetary exploration, *Interstellar*[34]. State-level wonder was positively associated with the state-level proportion of peoples' web video searches for *Interstellar*, $r = 0.50$, $p < 0.001$ (Supplementary Information, Sect. 1.5 and Supplementary Fig. 2c).

The fourth and fifth analyses were conducted on a measure of peoples' interest in voyaging to another planet. Specifically, signing up to have their name inscribed on a chip and sent to Mars affixed to NASA's *InSight* lander and *Perseverance* rover. State-level wonder about the universe was positively associated with the percent of the state population that submitted their name to voyage aboard *InSight*, $r = 0.56$, $p < 0.001$, and *Perseverance*, $r = 0.65$, $p < 0.001$ (Supplementary Information, Sect. 1.6 and Supplementary Fig. 2d,e).

Sixth, people can take concrete steps to send their physical selves into space by training to become an astronaut. In 2020, NASA invited astronaut applications from those with documented STEM backgrounds, and more than 12,000 applied to join this "Artemis Generation." We submitted a Freedom of Information Act (FOIA) request to NASA, and they released to us the number of astronaut applications from each of the states. State-level wonder about the universe was positively associated with the percent of people from each state with STEM-related backgrounds who applied to become a NASA astronaut, $r = 0.34$, $p = 0.017$ (Supplementary Information, Sect. 1.7 and Supplementary Fig. 2f.).

Seventh, the James Webb Space Telescope (JWST) is NASA's latest large strategic science mission[27], and millions of people "follow" the telescope via Twitter (now X). We found that state-level wonder about the universe was positively associated with the percent of the state population that follows @NASAWebb, $r = 0.53$, $p < 0.001$ (Supplementary Information, Sect. 1.8 and Supplementary Fig. 2g).

Eighth, wonder about the universe may correlate with general interest in NASA, which can be indexed by subscriptions to the NASA Newsletter. Via a FOIA request, we received more than 975K de-identified records from NASA and found that state-level wonder about the universe was positively associated with the percent of the state population subscribed to NASA's Newsletter, $r = 0.37$, $p = 0.009$ (Supplementary Information, Sect. 1.9 and Supplementary Fig. 2h).

Finally, we formed a composite measure of "behavioral interest in astronomy" (Fig. 1d; also see Supplementary Information, Sect. 1.10). As expected, there was a significant positive association between this state-level composite measure of behavioral interest in astronomy and state-level feelings of wonder about the universe (from the Pew survey), $r = 0.64$, $p < 0.001$ (Fig. 2a). Also as expected, there were no significant associations between behavioral interest in astronomy and the other variables from the Pew survey that served as controls in this study (Fig. 2b–d).

Mediation analyses

We used statistical mediation models to assess the connections among light pollution, wonder about the universe, and behavioral interest in astronomy, using 95% confidence intervals with 5,000 bootstrap samples[35]. If a variable is demonstrated to serve as a "mediator," it can be said to serve as a link between two other variables[35] (see Methods). We examined whether wonder about the universe mediates between light pollution and behavioral interest in astronomy, even when controlling for other possible demographic covariates.

In this mediation analysis, we tested whether the observed positive association between low light pollution and behavioral interest in astronomy, $r = 0.45$, $p < 0.001$, was mediated by wonder about the universe. As hypothesized, this effect was obtained: mediator effect $ab = 0.21$, 95% C.I. [0.09, 0.35] (Fig. 3a,b). Additionally, we examined potential confounders: education, poverty, race, population size, and population density (Supplementary Information, Sect. 1.11). When including these covariates, wonder about the universe was still a significant mediator between light pollution and behavioral interest in astronomy, mediator effect $ab = 0.14$, 95% C.I. [0.04, 0.28], and education was the only covariate associated with behavioral interest in astronomy (see Table 1). When we performed sensitivity analyses by analyzing the data using alternative models, we obtained substantively similar results (Supplementary Information, Sect. 3).

Discussion

Light pollution has adverse consequences for biological and ecological systems[4–13,36] as well as for the science of astronomy itself[1,2,37]. However, its effects on human behavior have been understudied. In this investigation, by combining data from the physical and psychological sciences, we showed that low light pollution is linked with the tendency of the population to feel wonder about the universe and to become interested in exploring it. This association exhibited some specificity—other psychological measures that had been measured in the same individuals at the same time in tandem with wonder about the universe were not associated with light pollution. The inclusion of multiple demographic covariates did not change the significant findings in the mediation model. That is, the mediation modelling still showed that a psychological factor (wonder about the universe) mediated the association between the physical environment (light pollution) and human behavior (interest in astronomy).

These findings suggest that humans' loss of the opportunity to see the starry night sky is related to peoples' behavior. From a human developmental and educational perspective, one is immediately drawn to the question of whether light pollution may influence the development of children's and adolescents' interest in science[38–41]. For example, seeing the starry night sky might prompt youths to think more about the physical universe, and to join relevant social/academic affinity groups to advance this knowledge as they develop academically[42,43]. One empirical study in central coastal California (a region of somewhat low light pollution) found that children as young as three- and four-years of age express curiosity about astronomical objects, asking caregivers for explanations (e.g., "Why do the stars shine?")[44]. The opportunity to see the stars in the night sky could engender interest in astronomy and greater chances of gaining practice in everyday scientific thinking. Indeed, many astronomers report that, in their youth, seeing the night sky triggered a feeling of "wonder" about the universe, and that this

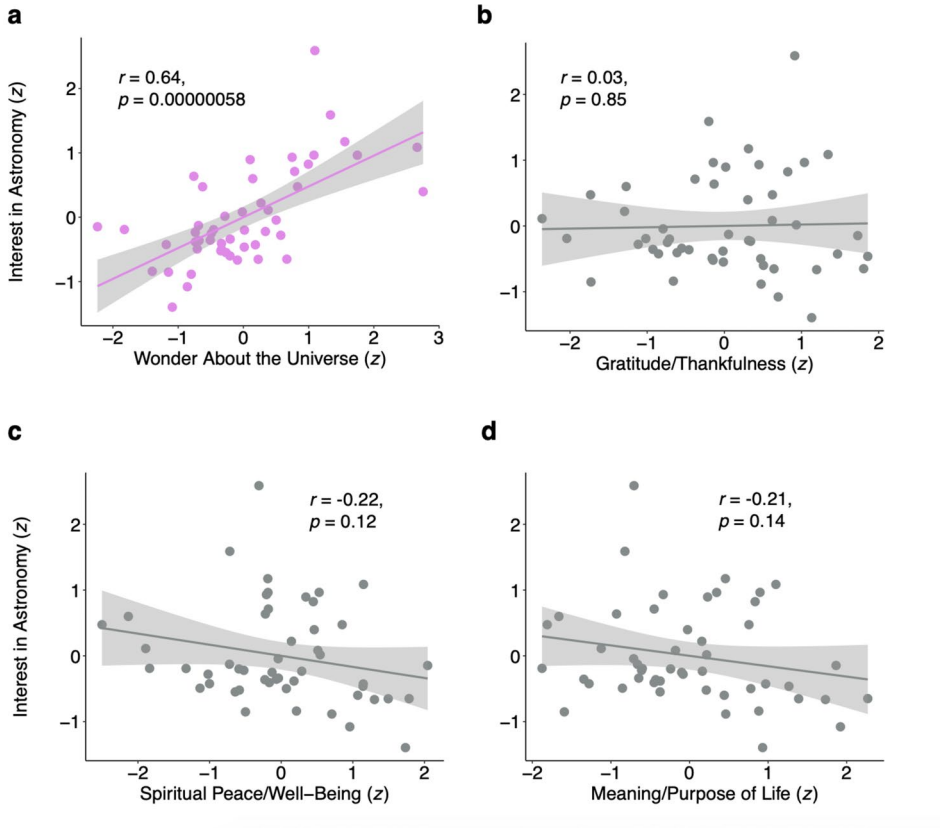

Figure 2. Scatterplots of association of wonder about the universe (and other emotions) with behavioral interest in astronomy ($N = 50$ states). (**a**) scatterplot showing significant correlation between wonder about the universe and composite measure of behavioral interest in astronomy (pink). (**b**–**d**) Scatterplots of the nonsignificant correlations between other control psychological measures and composite measure of behavioral interest in astronomy (gray). Shaded areas show 95% confidence intervals. All measures are *z*-standardized (see Methods).

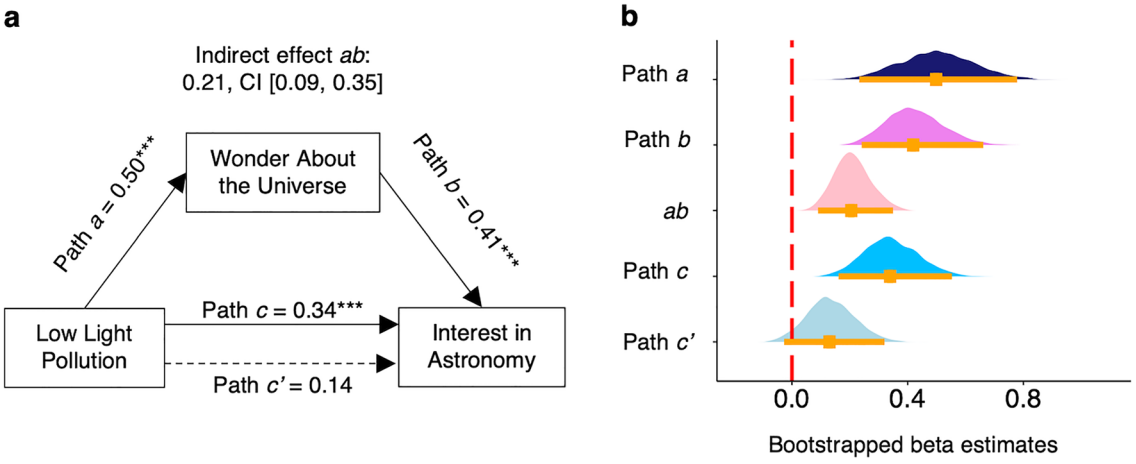

Figure 3. Mediation analysis. (**a**) Beta weights of the regression coefficients in mediation model showing low light pollution correlated with wonder about the universe (Path *a*) and wonder about the universe correlated with interest in astronomy (Path *b*), with the mediator (indirect) effect $ab = 0.21$. $^{***}p < 0.001$. (**b**) Smoothed density plots showing distribution of bootstrapped beta values produced in (**a**) by Hayes' PROCESS Model 4[35] with the following indicators: dashed vertical red line (beta value of zero), solid horizontal orange lines (95% confidence intervals of bootstrapped beta values), orange squares (medians of bootstrapped beta values).

Variable	*b*	*b SE*	*t*	*p*	95% C.I
Low light pollution	0.20	0.10	1.96	0.057	−0.01–0.40
Wonder about the universe	0.27	0.09	3.09	0.0036	0.09–0.45
Covariates					
Education	0.43	0.12	3.57	0.00091	0.19–0.67
Poverty	0.07	0.12	0.57	0.57	−0.17–0.30
Race	0.07	0.09	0.76	0.45	−0.11–0.24
Population size	0.05	0.09	0.57	0.57	−0.12–0.22
Population density	−0.09	0.10	−0.90	0.38	−0.29–0.11

Table 1. Model summary, including covariates, predicting behavioral interest in astronomy (using Hayes' PROCESS Model 4 procedure [35]). All measures were *z*-standardized. $N = 50$ states.

was a motivator for them aspiring to become a scientist[20–24,45]. Further psychological work is needed to understand how children's feelings of wonder and awe[46–48] interact with early caregiver support[44,49] and experiences in formal education[50,51] to promote interest and engagement with astronomy, the natural world, and the process of science to address questions about the universe.

Additionally, data from diverse cultures are needed. This is especially the case for Africa, Latin America, Oceania, as well as European countries where light pollution is rapidly encroaching upon formerly pristine dark skies[52,53]. To combat this, light pollution researchers[54] and architects[55] are proposing interventions on lighting practices. Keeping light pollution in check may nurture "citizen science"[1,2,33] which, itself, engenders public enthusiasm and financial support for science[27]. When interdisciplinary teams of scientists partner with communities most affected by light pollution (and other environmental challenges[56,57]) both science and society can benefit[58–62].

We acknowledge two limitations of the present work. First, our findings are at the level of the US states and do not apply to individual people, which logically constrains the inferences that can be drawn[63,64]. Research that examines light pollution, wonder about the universe, and astronomy interest within the same individual, rather than at the state level, is needed. A second limitation is that correlations do not specify causality, and it remains possible that those who have an interest in astronomy, or a sense of wonder about the universe, may choose to live in low light pollution states. To more directly address causality, longitudinal studies of people as they develop intellectual interests, coupled with random-assignment educational interventions, would be valuable.

Conclusion

Light pollution is recognized as an international concern. UNESCO representatives, government officials, and scientists jointly authored the La Palma Declaration, classifying the unpolluted night sky as an "inalienable right of humankind"[65]. Astronomers[1] and light pollution researchers[66] are calling for concrete actions to curb light pollution. As suggested here, increasing access to the starry night sky may also help to promote more equitable opportunities to feel wonder about the universe, which can motivate interest and engagement in science[20,67]. The present findings thus begin to suggest how light pollution is not only impacting biological and ecological processes, but also human behavior, science education, and society.

Methods

Analytic strategy

All analyses used the 50 US states[68]. All measures were *z*-scored to allow construction of the composite score, and to facilitate comparisons among the measures and between the states. Positive/negative *z*-scores indicate the values are above/below the central tendency of the distribution for that measure. Prior to mediation analyses, regression assumptions were checked and met.

Mediation analysis method

In mediation analysis[35], the predictor variable *X* is examined for its effect on mediator variable *M* (Path a), and *M* is examined for its effect on outcome variable *Y* (Path *b*). The mediator (indirect) effect, *ab*, is the product of Path *a* and Path *b*. The effect of *X* on *Y* is Path *c*. Path *c*' is the effect of *X* on *Y* while accounting for *M*. Mediation was tested with Hayes' PROCESS modeling tool (Model 4)[35].

Data availability

The datasets that support the findings of this study are available as raw data (Supplementary Table 1) and as the z-transformed analytic dataset (Supplementary Table 2).

Code availability

No special statistical code was used beyond that standardly embedded in R, RStudio, R packages (ggplot2, ggridges, usmap), SPSS 28.0.0.0, and Hayes' PROCESS 4.2. Geocodio software was used to convert latitude and longitude to geographical units (for Globe at Night). FileMaker (Version 19) was used to code text data into geographical units (for JWST and the NASA Newsletter).

Received: 14 January 2024; Accepted: 9 August 2024
Published online: 20 August 2024

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Acknowledgements

We thank E. Sanders and R. Brooks for valuable statistical advice. For feedback on earlier drafts, we are grateful to S. Hawley, P. Kuhl, C. Dweck, E. Brummelman, M. Hahn, E. Sanders, and R. Brooks. We thank the Stanford University Diversifying Academia, Recruiting Excellence (DARE) Doctoral Fellowship Program, the National Science Foundation's Broadening Participation Postdoctoral Research Award (Grant 1807789), and the Bezos Family Foundation for their generous support. The opinions expressed herein, including any implications for policy, are those of the authors and not of Pew Research Center or funders. The Pew Research Center and funders bear no responsibility for the analyses or interpretations of the data presented here.

Author contributions

R.C.B. and A.N.M. designed the research. R.C.B. performed research. R.C.B. analyzed data. R.C.B. and A.N.M. wrote the paper.

Competing interests

The authors declare no competing interests.

Additional information

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1038/s41598-024-69920-4.

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Supplementary Information

Opportunity to view the starry night sky is linked to human emotion and behavioral interest in astronomy

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1. Measures

We describe below how each state-level measure was defined and calculated.

1.1. Low light pollution. Falchi et al.[1] published a comprehensive atlas of gradients of light pollution (physical measurements of the brightness of artificial light in the night sky) for each US state and advocated for these data to be used in the behavioral sciences (p. 1)[2]. Their data were published in bins of different magnitudes[1,2]: (i) 0 to 1.7 μcd/m^2 ("pristine skies"), (ii) 1.7 to 14 μcd/m^2 ("relatively unpolluted at the zenith but degraded toward the horizon"), (iii) 14 to 87 μcd/m^2 ("polluted sky degraded to the zenith"), (iv) 87 to 688 μcd/m^2 ("natural appearance of the sky is lost"), (v) 688 to 3,000 μcd/m^2 ("Milky Way loss"), and (vi) > 3,000 μcd/m^2 ("night adaptation is no longer possible for human eyes."). Falchi et al. (p. 4)[2] described brightness bins iii-vi as "light-polluted skies" and advocated for policy to protect bin i and bin ii[1-3]. Because of this, we focused on these two bins, and refer to them as "low light pollution," after Falchi et al. (pps. 4 and 10)[2].

For each bin, Falchi et al.[1] provided the percent of the US state population living within the bin (hereafter "percent population") as well as the percent of the land area of each state falling within each bin (hereafter "percent land area"). We found that the percent population was highly correlated with the percent land area, for both bin i (r = 0.81, p < 0.001) and bin ii (r = 0.73, p <0.001). We therefore computed a mean of percent population and percent land area. This resulted in a variable termed "mean percent population and percent land area with pristine skies" (i.e., bin i [0–1.7 μcd/m^2]) and, separately, another variable termed "mean percent population and percent land area with skies relatively unpolluted at the zenith but degraded toward the horizon" (i.e., bin ii [1.7–14 μcd/m^2]). To yield the analytic measure of low light pollution (i.e., bin i and bin ii, following Falchi et al.[1-3]), we first summed these two variables (M = 13.65%, SD = 16.26%, *Range* = 0%–50.65%), and second, z-standardized the values to form the analytic measure of low light pollution at the state level.

1.2. Wonder and other positive emotion measures. To calculate the state-level measures, we used the Pew Research Center's nationally representative survey (N = 35,071), which was conducted between June 4th and September 30th, 2014 with a minimum of 300 respondents per state[4]. The year of this Pew research survey (2014) was the same year as Falchi et al.'s physical measurements of light pollution[1,2]. Pew estimated that the survey was representative of 97% of the non-institutional population of the US and released the dataset to the public as an SPSS file: *Dataset - Pew Research Center 2014 Religious Landscape Study National Telephone Survey - Version 1.1 - December 1 2016.sav*.

Within this dataset, the specific questions relevant to the current paper are variables *qi4a*, *qi4b*, *qi4c*, *qi4d*. The columns in the Pew datafile provide respondents' numerical answers to specific questions from the telephone interviewer: "Now, thinking about some different kinds of experiences, how often do you: 'feel a deep sense of spiritual peace and well-being,' (*qi4a*), 'feel a deep sense of wonder about the universe,' (*qi4b*), 'feel a strong sense of gratitude or thankfulness,' (*qi4c*), 'think about the meaning and purpose of life'

(*qi4d*)." The order of the four questions was randomized in the survey administration. The interviewer read off response categories to participants as: "Would you say at least once a week (coded as '1'), once or twice a month ('2'), several times a year ('3'), seldom ('4'), or never ('5')."

For analyses, we reverse-coded the data such that higher scores indicated more positive emotions. To derive the state-level measures, we followed Pew[4] and applied their weight variable, which was recommended by Pew as follows: "Analysts interested in national-level and state-level data…should weight the data using the variable WEIGHT"[4]. These state-level measures were *z*-scored, and are displayed in Fig. 1b and Supplementary Fig. 1.

1.3. Astronomy. Google Trends is a tool that indexes the popularity of search terms among trillions of searches (*https://support.google.com/trends/answer/4365533?hl=en*). The tool allows researchers to compare, in a selected country, the relative popularity of search terms between different subregions of the country. This involves a standardized process: When a query is made for a term, Google Trends examines a sample of Google's dataset and—based on the relative popularity of the query term to all other search terms—displays a normalized score ranging from 0 to 100 for each subregion in country (in the current case, we examined the 50 US states).

On the Google Trends interface, we queried "astronomy" (field of study)—constraining the query to searches conducted between January 1, 2015 and December 31, 2022 (i.e., following the 2014 assessment of the focal predictors low light pollution[1] and wonder about the universe[4]). This approach is attentive to the timing of assessments, consistent with Hayes' suggested practices for mediation analysis (p. 129-132)[5]. We ran seven different queries on seven days within a two-week period. As expected, these seven values were internally consistent, Cronbach's alpha = 0.99. We used the mean of these seven values as the measure of state-level web searches for astronomy, and *z*-standardized the measure for analysis. Data are displayed in Supplementary Fig. 2a.

1.4. Globe at Night. For this state-level measure, we used NSF-NOIRLab's Globe at Night project's publicly available data (2015-2021). We calculated the number of Globe at Night submissions per US state (based on respondents' latitude and longitude). These numbers were divided by the population of the state (see Section 1.11). The analysis was based on the *z*-standardized values. Data are displayed in Supplementary Fig. 2b.

1.5. Interstellar. To obtain the state-level measure, we repeated the process from Section 1.3, but for the term "Interstellar" (film) as a YouTube search query, for the same period as in Section 1.3, with data drawn on seven different days and averaged (Cronbach's alpha = 0.99). Analysis based on the *z*-standardized values. Data are displayed in Supplementary Fig. 2c.

1.6. Insight, Perseverance. At the state-level, NASA released the number of people from each state who submitted their name to be sent to Mars on a chip affixed to *InSight* and *Perseverance*. State number totals were divided by the population of the state (see Section 1.11). Analyses of both measures are based on the *z*-standardized values. Data are displayed in Supplementary Fig. 2d,e.

1.7. Artemis. In March 2020, NASA opened applications for the astronaut "Artemis Generation." Through a Freedom of Information Act (FOIA) request, we received the number of applications per state. Because NASA's call for applications focused on people with STEM degrees, we divided the number of applications in a state by the number of individuals in that state with bachelor's degrees of science, engineering, and related fields, as reported by the American Community Survey in 2020. Analysis used the *z*-standardized values. Data are displayed in Supplementary Fig. 2f.

1.8. JWST. We predetermined to examine the state-level sum of Twitter (now X) followers of @NASAWebb when its follower count reached 1.5M, which occurred on July 7th, 2022. Location data is publicly listed on each Twitter profile, for users who choose to self-report their location. We used www.followersanalysis.com to download these data and ran a script to code the data into states. We divided the total number of @NASAWebb followers of each state by the state population (see Section 1.11). The analysis used the *z*-standardized values. Data are displayed in Supplementary Fig. 2g.

1.9. Newsletter. We coded this state-level measure from a FOIA request, which yielded the self-reported locations of internet users who subscribed to NASA's Newsletter in 2019-2022. We coded the data and tabulated the number of subscribers per state and divided this number by the state population (see Section 1.11). The analysis used *z*-standardized values. Data are displayed in Supplementary Fig. 2h.

1.10. Composite of behavioral interest in astronomy. The state-level composite of astronomy interest was the average of the standardized values (*z*) for the eight measures listed in the foregoing Sections 1.3–1.9. The justification for combining the eight measures into a composite is: (i) the eight measures are correlated with each other (Supplementary Fig. 3), (ii) the Cronbach's alpha among the eight measures is high (Cronbach's alpha = 0.89), and (iii) principal component analysis suggested a one-factor solution, all factor loadings > 0.60.

1.11. State-level measures of education, poverty, race, population size, population density. The measures of the following five control covariates were drawn from three Census sources: (i) education (percent of population with a bachelor's degree), (ii) poverty (percent of the population in poverty), (iii) race (percent of population grouped as non-White, which was defined as follows): American Indian/Alaska Native, Asian, Black, Hispanic, Native Hawaiian/Pacific Islander, Multiracial, and Other), (iv) state population, and (v) population density. The three Census sources for this information were: (i) the American Community Survey (2014, i.e., the same year as the night sky brightness and wonder measures) (ii) the Annual Social Economic Supplement to the Current Population Survey (2014), and (iii) the Master Address File/Topologically Integrated Geographic Encoding and Referencing database (for land area measurements, in 2010). All measures were *z*-standardized for analysis. Supplementary Fig. 4 displays the zero-order correlations among these demographic variables and the composite behavioral interest in astronomy measure.

2. Alternative analysis of low light pollution and wonder about the universe. Regarding the main text section labelled "Light pollution and wonder about the universe," we note that the light pollution data deviate from the normal distribution. For this reason, we also used a simple dichotomous measure by sorting the 50 states into those below the median of low light pollution (n = 25) and those above the median of low light pollution (n = 25). We checked for statistically significant correlations between this dichotomous variable and each of the four emotions reported by Pew[4]. The results were substantively the same as reported with the continuous low light pollution variable in the main text. The positive association between light pollution (median split) and wonder about the universe was still significant, r = 0.39, p = 0.005, and none of the three other emotions was significantly associated with the dichotomous light pollution measure, ps > 0.12.

3. Sensitivity analyses for mediation model. As alternatives to the mediation models presented in the main text, we also examined three other mediation models.

First, we used the simple median split of the light pollution dataset to re-run the mediation model. With this dichotomous treatment, wonder about the universe continued to mediate the relation between low light pollution and behavioral interest in astronomy, mediator effect ab = 0.33, 95% C.I. [0.11, 0.60].

Second, we examined the impact of extreme values in the dataset by dropping three states (Colorado, Nevada, Utah) that could be considered outliers (i.e., > 2.50 *SD*s). When these were removed, wonder about the universe continued to mediate between low light pollution and behavioral interest in astronomy, mediator effect *ab* = 0.16, 95% C.I. [0.04, 0.33].

Third, although our hypothesis and the narratives from astronomers[6-11], suggested that the relation between low light pollution and astronomy interest would be mediated by the psychological experience of "wonder about the universe," one can test other alternative mediation models. Notably, low light pollution could be tested as the mediator between wonder about the universe and behavioral interest in astronomy. We conducted this analysis, and the results revealed no significant evidence for this alternative mediation, mediator effect *ab* = 0.07, 95% C.I. [-0.02, 0.17]. This is compatible with the core idea presented in the main text—that wonder about the universe, a psychological factor, is a mediator between low light pollution, an environmental predictor, and behavioral interest in astronomy, an outcome.

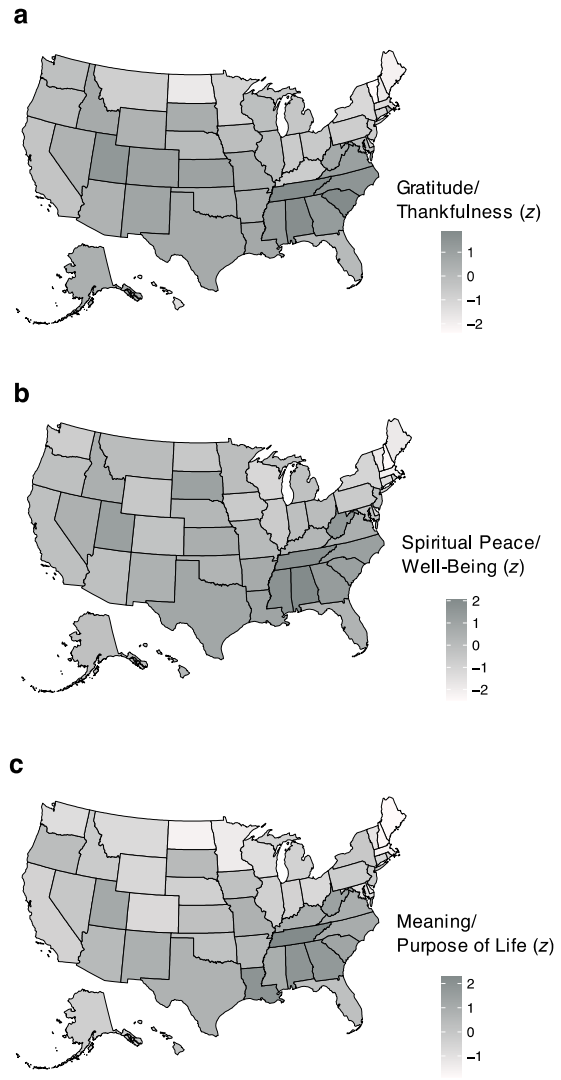
4. Study background and context. Here we provide a statement of the background motivation of the current research and more details about the development of the actual study, which was exploratory in nature and not preregistered.

This research had its initial roots in author R.C.B.'s experiences with seeing the night sky where he initially lived (semi-rural Mexico) and being struck by the absence of visible stars after moving to a light polluted area (central Los Angeles). Congruent with discussions by astronomers[6,11], he wondered whether experiences seeing the starry night sky might influence people's thoughts. The design of the present research was influenced by co-author A.N.M.'s work on psychological factors that motivate and/or dissuade individuals from engagement in STEM fields[12-14] and how curiosity and interest promote scientific thinking[15-17]. Also motivating us were our previous studies examining how environmental and cultural factors influence people's behavior[18-21].

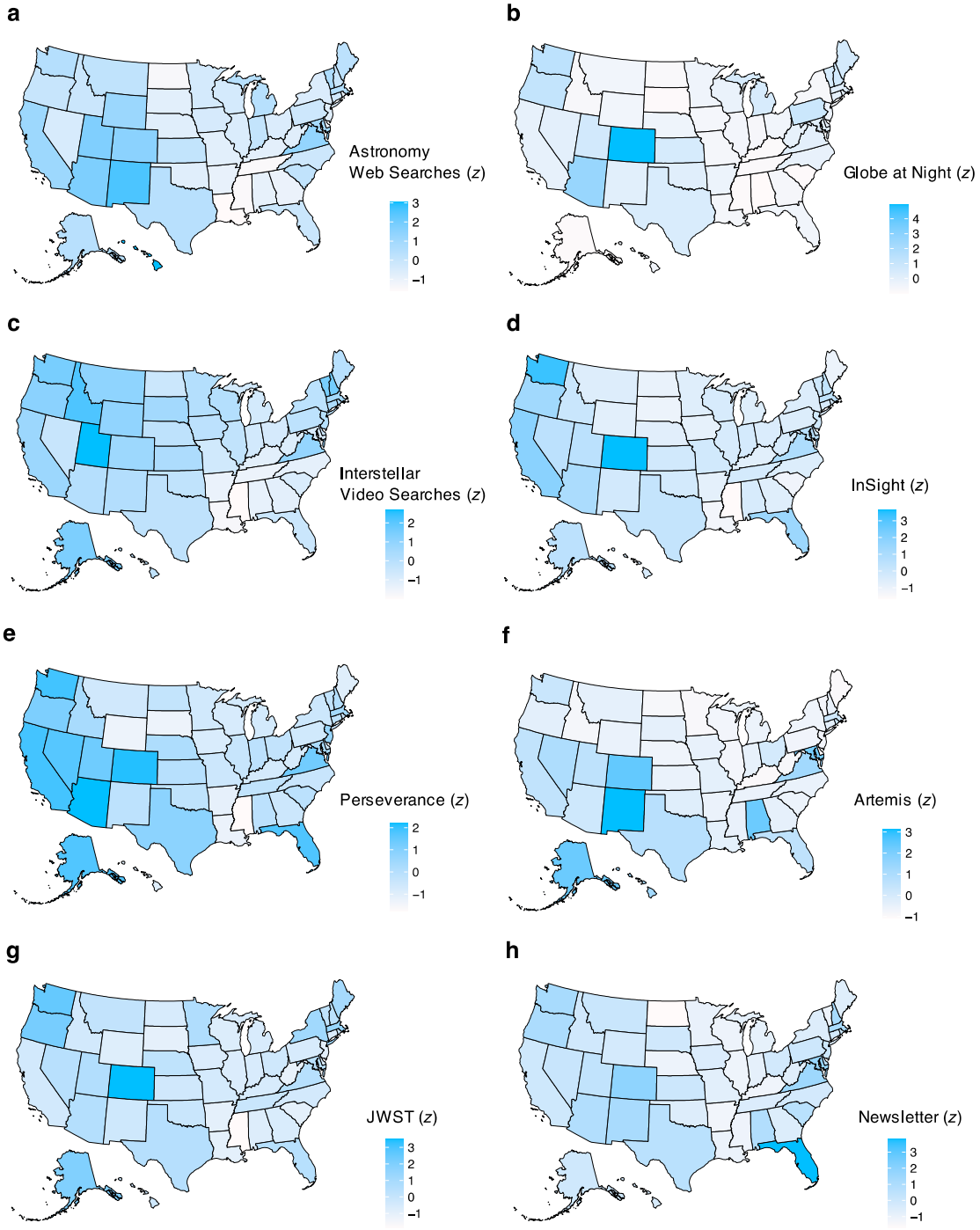
The concrete design and execution of the current research was enabled by Falchi et al.'s 2019 publication of light pollution measures at the US state-level[1], Pew's data on wonder about the universe[4], and NASA's plans to launch JWST in 2021. We understood that Falchi et al.'s data afforded us the opportunity to test the hypothesis outlined in the main text, namely that wonder about the universe (as measured by Pew) was a psychological mediator between low light pollution (as measured by Falchi et al.) and interest in astronomy (behavioral measures we could assemble through FOIA requests to NASA and other sources).

We launched the planned study by submitting public records requests to NASA in 2021 and 2022 (respectively: FOIA Tracking Number 21-JSC-F-00478 for the Artemis astronaut applications, and FOIA Tracking Number 22-HQ-F-00824 for the data on the NASA Newsletter subscriptions). The other measures of people's behavioral interest in astronomy, including information about the 1.5M Twitter (now X) "followers" of the JWST (@NASAWebb), the location data of citizen scientist submissions to NSF-NOIRLab, etc., were assembled as described in Supporting Information, Section 1.3–1.9.

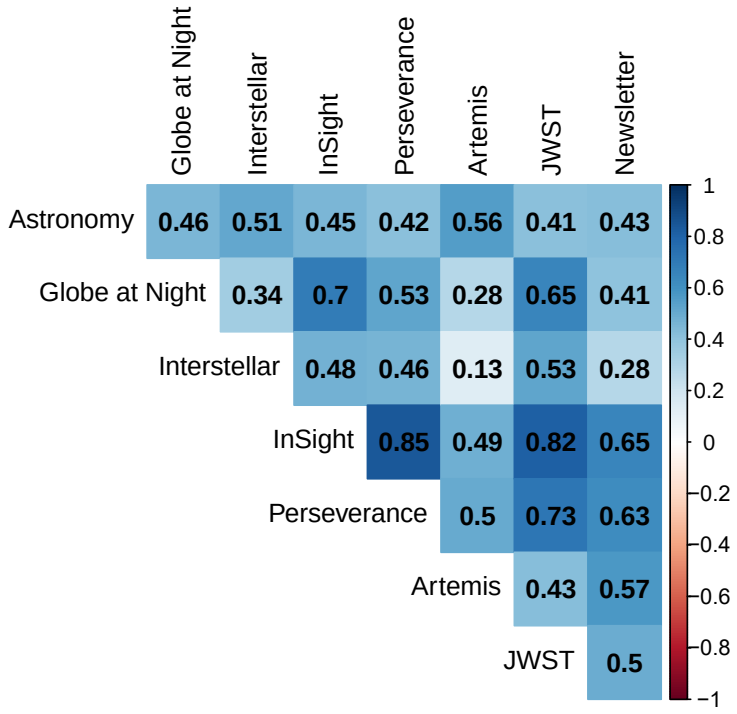
Although not preregistered, this research was designed to investigate the authors' hypotheses about how environmental factors influence human psychology and behavior, and provides a foundation for future preregistered studies that should be conducted.



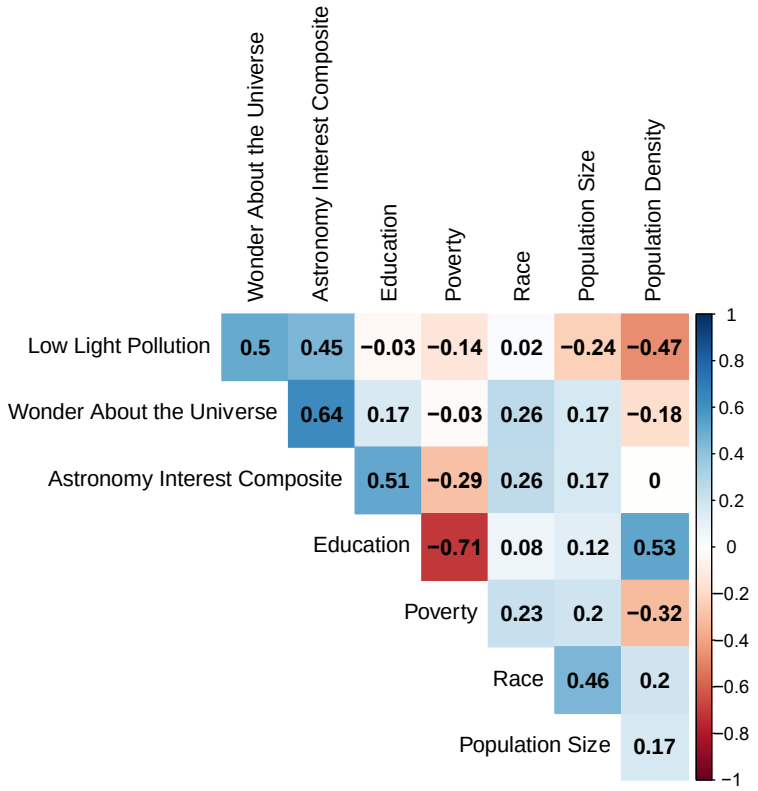
Supplementary Figure 1. State maps of the psychological emotions assessed in Pew 2014 survey in addition to wonder about the universe. Displayed are *z*-standardized scores for these three emotions, which were used as controls: (**a**) Gratitude/thankfulness, (**b**) Spiritual peace/well-being, (**c**) Meaning/purpose of life. See main text and Supplementary Information Section 1.2. for details.



Supplementary Figure 2. State maps of each component measure of interest in astronomy. Displayed are *z*-standardized scores for eight components of the "behavioral interest in astronomy" composite measure, for each state. (**a**) Web searches for field of study "astronomy." (**b**) Submissions to Globe at Night. (**c**) Video searches for film *Interstellar*. (**d**) Names sent to Mars on *InSight*. (**e**) Names sent on *Perseverance*. (**f**) Artemis Generation astronaut applications. (**g**) Twitter (now X) followers of James Webb Space Telescope (JWST). (**h**) NASA Newsletter subscribers. See main text and Supplementary Information Sections 1.3-1.9. for details.



Supplementary Figure 3. Pearson zero-order correlations (*r*) among the 8 component measures. Displayed are the intercorrelations among the 8 components of the composite score of "behavioral interest in astronomy" (see main text for details). All measures are *z*-standardized. $r_{(df = 48)\ \text{critical value}} = 0.28$.



Supplementary Figure 4. Pearson zero-order correlations (*r*) among low light pollution, wonder about the universe, composite score of behavioral interest in astronomy, and demographic covariates (see Section 1.11. for demographic details). All measures are *z*-standardized. $r_{(df = 48)\ \text{critical value}} = 0.28$.

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