University of Virginia
Department of Astronomy

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Report of the Spitzer Users Panel (SUP38):

The 38th meeting of the Spitzer Users Panel occurred in Pasadena June 28-29, 2018. This meeting followed the completion of the Cycle 14 proposal call, evaluation, and proposer notifications. That Cycle supports 6,000 hours of science observations combined with approximately 1,000 hours of more flexibly assigned director's discretionary time that enables emerging science opportunities not envisioned at the time of the proposal call. Under current plans these will be the last Spitzer science observations before the decommissioning of the observatory. Because of the impending end of the mission this Users Committee meeting focused, in part, on presentation and review of project closeout plans that would lead to final science observations approximately on November 30, 2019 and an end to Spitzer Science Center operations in January 2021. However, this meeting also convened shortly after the community learned that the JWST target launch date had been further delayed to March 2021, a shift of 2.5 years from the long-held October 2018 launch date that was in force at the time of the 2016 Astrophysics Senior Review. Given the fundamental role that Spitzer plays in supporting, and possibly more importantly streamlining, JWST science as well as in attracting and training the next generation of JWST observers, the committee also devoted substantial time to characterizing the community's stake and interest in extending Spitzer operations beyond November 30, 2019.

As has been the case for some time, the SUP was impressed by the efficiency of the SSC in all aspects of its end-to-end support for the community's use of Spitzer. The annual science return continues to be immense. The on-target efficiency yields more than 7000 science hours (out of 8760 hours in a year). An unparalleled level of user satisfaction is evident from proposal process, to scheduling, to data pipelining, to science result. The Cycle 14 proposal call, evaluation, and time assignment was, once again, well organized and efficient, reflecting the experience accumulated over many previous cycles. The 3.7:1 oversubscription of Spitzer demonstrates continuing healthy scientific demand for the facility. Creative applications are far from being exhausted, as illustrated by two of the science highlights from Spitzer over the past year. For example, one team has recently used Spitzer to determine precise masses for each of the seven Earth-sized planets in the TRAPPIST-1 system using transit timing variation measurements. Given precise radii from the transit observations these new Spitzer observations reveal the densities of these worlds and thus provide insight into their compositions. Spitzer also produced a detection of the gravitational wave event GW170817, associated with the merger of two neutron stars. These observations are an important component in constraining the nucleosynthetic products of this remarkable cosmic event. Looking forward, gravitational wave and transiting planet discoveries are in their infancy, the former being enhanced by the continuing sensitivity improvement of LIGO and the introduction of other gravitational wave facilities, while the latter is being bolstered substantially by the successful launch and upcoming operation of TESS. Spitzer has tremendous future potential.

The SUP was particularly impressed by the publication statistics presented at this meeting associated with the Legacy surveys for both the cryogenic and post-cryogenic missions. The productivity of these surveys, as measured by citations, proportionally far exceeds the investment in observing hours. Tremendous credit goes to the investigators and to the SSC for creating data products of such effective and enduring value. In fact, from a broader perspective, lifetime citation statistics for Spitzer are equally impressive with an h-index placing Spitzer in the top 5 among major NASA observational missions and by m-index, scaling for years in operation, exceeding any NASA mission including the Hubble Space Telescope. This statistic is all the more remarkable considering the annual investment for maintaining Spitzer operations is $15M.

Public outreach and engagement associated with Spitzer remains strong, with recent activities exploiting the TRAPPIST-1 Spitzer discoveries being a prime example. Several years ago, when the SUP was informed of the consolidation of public outreach activities within NASA, the SUP expected that the impressive local Spitzer public relations effort would be weakened and possibly dismantled. The breadth and depth of outreach activities presented at this meeting show just the opposite. The effective Spitzer-centric outreach group remains active and the centralized NASA outreach effort supplies a strong foundation to make the Spitzer team's activities as effective, if not more effective, than ever.

Cycle 14: The Spitzer Cycle 14 proposal submission and review results highlight the continued vibrancy and productivity of the observatory. With an oversubscription rate of nearly 4:1 Spitzer remains a highly coveted resource in astronomy. After eight cycles of proposal calls during the warm phase of the Spitzer mission the science remain fresh and innovative, and most importantly continues to evolve and adapt to an exciting and changing astrophysics landscape. For example, one approved Cycle 14 large program will use Spitzer's
exceptional 50 ppm staring mode photometric precision to conduct the first statistical survey for terrestrial-sized planets in and near the habitable zone of ultracool dwarfs (i.e. stars like TRAPPIST-1). At the same time, a majority of proposals focused on opportunities to support new/forthcoming capabilities such as TESS, LIGO, WFIRST and of course JWST, with over 1/3 of the proposals received focused on JWST ERS/GO/GTO capabilities. The SUP was particularly struck by the fact that of the 11 "large" proposals selected, five had first-time Spitzer PI's and five were women. Not only Is Spitzer's science vibrant but its demographics positively reflect that of the evolving astronomical community.

Guest Observer (GO) Funding: As a consequence of the reduced overall Spitzer funding level, GO funding has waned to a fraction of its original level. $6 million for GO funding in Cycle 11 (already far below cryogenic mission GO funding) declined to $3 million in Cycle 13, and GO support is currently zeroed out for Cycle 14, although the SSC is attempting, in collaboration with the Spitzer Project, to cobble together $1 million aimed primarily to support large GO programs.

The SUP is appreciative of the efforts to secure some funding and aware of the realities that have led to this situation. Still, the SUP wishes to reiterate the importance of user support since it translates directly to scientific output and possibly as importantly to the recruitment of young investigators into this JWST-oriented science arena via postdocs and graduate assistantships. Cycle 13 investigators contacted by the SUP reaffirm this perspective. These investigators have been able to use the modest support to keep existing pipelines running and deliver data products to the community/archive, but do not have the means to involve new young investigators and students in the effort. The approved Cycle 14 programs include one >1000 hour program and several 500+ hour programs; even for a mature facility like Spitzer, designing, executing, analyzing and publishing results from such large programs is a non-trivial amount of effort. Providing no funding to those programs is not in NASA's best interest nor is it in the best interest of the final science legacy of these programs. Finally, the Astronomy Data Analysis Program (ADAP) has modestly compensated for a fraction of the reduced user support, but ADAP support represents a fraction of recent historical user support and this year the timing of the ADAP call for proposals relative to the Cycle 14 observing allocations prevented Spitzer proposers from pursuing support through ADAP.

IRAC: IRAC continues to improve in capability as the SSC refines its understanding of the exquisite photometric and astrometric precision of the instrument. The continuing flood of exoplanetary science and discovery, for example, is a direct testament to the scientific efficacy of these quantitative improvements. The improved calibration and expansion of the operational boundaries of IRAC not only enables new science but expands the utility of Spitzer's archive.

The SSC presented the SUP with a number of ongoing activities associated with improving and documenting IRAC's capabilities including the development of several SPIE papers. The SUP encourages SSC to ensure that these latest papers characterizing IRAC are readily available at the SSC documentation site. Regarding remaining IRAC calibration and characterization tasks, the SUP had a difficult time assessing SSC's relative priority for the identified tasks, the detailed schedule and mapping of these tasks onto available resources, not to mention descope options available in the case of schedule or budgetary overruns on the highest priority tasks. The SUP would like some clarification as to these priorities. Some of these tasks touch on topics where considerable expertise already exists in the Spitzer user community. The SUP recommends that the IRAC team attempt to engage active participation of those experts to help ensure that the SSC tasks can be completed both efficiently and produce the most useful results. Documentation should follow close behind in priority, as it will enable users to carry out re-analyses and generally make optimal use of archival data.

End of Mission: As currently planned, Spitzer observing will end on November 30, 2019. The Spitzer Science Center has been developing plans for end of mission for some time as the certainty of extensions has been questionable and closeout has always been a possibility. As a result, the Committee found that plans for completing the observational phase of the mission – archiving and documentation in particular - to be quite mature and well thought out. As a reference point the SUP notes that the Spitzer Science Center delivered final products and documentation to the Infrared Science Archive at the end of the cryogenic mission. That transition was smooth and well-planned and the current exercise benefits from that experience. Given the tight resource situation the SUP wants to refrain from trying to re-organize what is a well-planned process. Instead, for issues such as the review of the completeness and accessibility of documentation for the warm mission the SUP members would like to make themselves available as a resource (and are happy to volunteer past SUP members as well) to provide for review and feedback.

As was the case at the end of the cyrogenic mission the SUP and SSC discussed whether potential key science observations or calibrations might have been overlooked during the warm mission. The likelihood that key science has been left on the table is much lower than at the end of the cryogenic mission since the instrument suite has substantially narrowed and nearly twice as many proposal cycles have elapsed. The SUP suggests highlighting this issue in future newsletters and calls for proposals for discretionary time, as well as mentioning, in particular, that discretionary time proposals are welcomed for calibration observations if they are deemed of critical legacy value to the project.

Currently NASA requires that spacecraft be permanently disabled at the end of mission so that they cannot be inappropriately commandeered. Spitzer was not designed to be "turned off" permanently. Developing a plan to disable a solar orbiting spacecraft that cannot be a threat to the Earth or other spacecraft seems to the SUP to not be the best use of the extremely thin resources available to the SSC and its highly streamlined staff. The SUP recommends that SSC work with the Spitzer Project to request a variance from NASA to place Spitzer in safe mode indefinitely instead of investing valuable resources in the effort to create a way to (unnecessarily) disable the spacecraft.

Prospects for continued operation: Spitzer's only consumable is nitrogen reaction-thruster gas and that gas reservoir has been only half depleted since the beginning of mission. The spacecraft's primary and backup electronic systems remain healthy. Spitzer's distance from Earth continues to increase placing some modest, but surmountable, constraints on downlink data bandwidth. SSC estimates that decreased bandwidth should not compromise anticipated science data volume requirements at least through the end of 2020. In order to communicate with Earth Spitzer now has to achieve pitch angle relative to the Sun well beyond the original limit of 30 degrees, exposing some "permanently" shaded parts of the spacecraft bus to solar radiation during the ~2 hour downlink interval. Annual tests at each successive year's maximum pitch angle have shown no degradation in data quality to date and only minimal detectable thermal impact at angles up to 48 degrees. A 53-degree test will be performed shortly, anticipating next year's maximum. In November 2020 the required pitch angle will only be three degrees greater. SSC has expressed confidence in the ability to continue science operations through the end of 2020 and believes that continued operations beyond 2020 are potentially viable with reduced downlink volumes that would still support core science.

Benefits of continued operations: The SUP believes that Spitzer continues to operate at peak science impact. The annual output is not a stale rehash of prior year's work, but new and innovative applications of Spitzer's remarkably precise abilities enhanced by new discoveries in other parts of the electromagnetic spectrum (and now from multi-messenger sources). Other missions such as TESS are providing new context and scientific opportunity. The SUP finds it truly revolutionary to consider TESS and Spitzer operating in tandem, but also distressing to consider the brevity of that overlap as currently schedule. The launch delay of JWST places continued operation of Spitzer beyond November 2019 in an urgent context. Much of the case for the most recent extension of the Spitzer mission, endorsed by the 2016 senior review, was based on Spitzer's pathfinding role to enhance the science output, as well as the observational efficiency, of JWST. NASA's response to the 2016 Astrophysics Senior Review stated, "The Spitzer mission will cease observations in mid-FY19 following successful commissioning of JWST," expressing the intent to maintain Spitzer operations to at least overlap with commencement of JWST science. The benefit from this overlap remains and is multi-fold:

- Spitzer's wide-field survey capability and long time-series (up to days) precision photometry capability are unique and complementary to JWST's observational capabilities. As with any powerful high-demand narrow-field telescope like JWST, survey capabilities lay the foundation for the scientific utility and initial application of the new facility. Operation of the survey facility, Spitzer, in response to discoveries just prior to the launch of JWST from TESS, LIGO, and the NEOWISE all-sky results among others should provide a rich reservoir of early targets, many unforeseen at this time.
- Spitzer's contributions enable JWST's time to be used more efficiently. A case study comes from the field of Earth-sized exoplanet transit timing. JWST's observing intervals for these objects will be tied to the ephemeris uncertainty for predicted transits. A seven-hour observing interval could be trimmed to 4 hours simply by having more precise transit ephemerides. If one amortizes the operations cost of JWST to $5 million per day ($10B over 5 years), the equivalent value of saving several days or weeks of JWST time, enabling other science, quickly exceeds the cost of extending Spitzer for a year.
- Spitzer continues to draw in young investigators, as evidenced by the demographics of the Cycle 14 successful proposers, and provides them the experience and perspective to exploit the science capabilities of JWST. Maintaining this subset of the community and keeping their science fresh into the JWST era will again maximize JWST's science return.

The 2016 Astrophysics Senior Review conclusions reinforce this perspective succinctly, "The SR2016 panel identified that the strongest scientific case for Spitzer is its value in JWST-preparatory science. Spitzer has demonstrated its superb capability in finding high redshift ($z>7$) galaxies when Spitzer long-wavelength measurements are combined with Hubble Space Telescope observations of the same galaxies. It is also superb at finding high redshift clusters of galaxies ($z>1.5$-2) and characterizing exoplanet transits, as well as other JWST-relevant activities. There is certainly a cost-benefit to utilizing a Spitzer resource to obtain significant savings in terms of JWST observing time and timely early mission results. With a 5-10 year limited mission, the cost per observing hour on JWST is substantial. Making the JWST mission more efficient leverages the billions invested in JWST, and will allow JWST to achieve its maximum scientific potential. The Spitzer microlensing campaigns also provide science of direct relevance to the WFIRST mission."

The SUP recommends strongly that SSC pursue the continued operation of Spitzer beyond November 2019.

As a final, bittersweet note…for the last several years the committee has interacted with SSC via John Stauffer as a point of contact. As of the time of the SUP meeting John had one more week of work before retiring from SSC. The committee wishes to thank John for his effective facilitation of the committee's work and communication with SSC over these many years and congratulate him on his (presumably continuing) record of science contributions and accumulated scientific legacy using Spitzer as well as a variety of other observational facilities.

Spitzer Users Panel

- Michael Skrutskie, Chair (University of Virginia)
- Mark Brodwin (U. Missouri Kansas City)
- Joshua Emery, (University of Tennessee Knoxville)
- Adam Kraus (University of Texas)
- Diana Dragomir (Massachusetts Institute of Technology)
- Sangeeta Malhotra (Goddard Space Flight Center)
- Stan Metchev (University of Western Ontario)
- Michael Werner (JPL), ex officio
- Aneta Siemiginowska (Chandra X-ray Observatory/Chandra X-ray Observatory Science Center, Smithsonian Astrophysical Observatory)
- Brad Whitmore (Hubble Space Telescope/Space Telescope Science Institute)