Enter your answers on the form provided. Be sure to write your name on the first blank at the bottom of the form, and fill in the bubble at the upper left with the exam version (A). If you need to erase an answer, please do so carefully and remove all of the old mark.

1. When matter falls into a black hole
   a. it quickly disappears from sight
   **b. great amounts of energy can be released**
   c. it passes out through a wormhole into another Universe
   d. it takes an unfamiliar form
   e. its light shifts to the blue

2. Superluminal - faster than light - motions appear when
   a. the geometry of motions sets up an optical illusion
   b. matter falls into a black hole
   c. there is such a violent explosion that pieces are expelled faster than light
   d. Einstein's laws are broken
   e. they never appear

3. The outer part of the rotation curve of a galaxy is flat; this fact indicates that
   a. where the curve is flat, the encircled mass increases with increasing distance from the center
   b. Newton's law of gravity is wrong
   c. there is a supermassive black hole at the center of the galaxy
   d. the galaxy is still in the process of forming
   e. practically all the mass of the galaxy is within the radius where the curve flattens out

4. The mass of a cluster of galaxies
   a. results in broadening the spectral lines from active nuclei in the cluster
   b. causes a glow around galaxies falling into the cluster
   c. creates such a large gravitational field that it makes the emission lines of the galaxies in the cluster shift wavelength significantly
   d. is entirely from its galaxy members
   **e. is mostly from the dark matter between the galaxies**

5. Gravitational lensing
   a. was a surprise discovery not predicted by Einstein's theories of relativity
   b. changes the color of the objects lensed
   c. is being built in to the next generation of digital cameras
   **d. produces peculiar arc-like images of galaxies at high redshift behind massive galaxy clusters**
   e. is useful for studying planets that pass in front of the sun

6. The large-scale distribution of the galaxies in space is a result of
   a. the gravitational attraction of great black holes that attract galaxies to their vicinity
   b. galaxies tending to slow each other down when they pass closely, making them tend to concentrate together
   c. the dark energy forcing the galaxies toward each other
   d. the structure of the early Universe
   e. galaxies of similar types tending to clump together
7. The Shapley-Curtis debate about our place in the Milky Way and the nature of “spiral nebulae”
   a. was important philosophically because the topics touched on our place in the Universe
   b. was decisively won by Shapley
   c. was decisively won by Curtis
   d. was an argument about the role of star formation in affecting our view of the cosmos
   e. had to do with the superiority of Harvard College Observatory

8. Henrietta Leavitt's period luminosity relation for RR Lyrae stars proved important because:
   a. it explained why some star fields looked different in pictures taken at different times
   b. it allowed the luminosity of these stars to be determined based on intrinsic properties, and thus their distances from their apparent brightnesses
   c. it showed that they moved on the HR diagram
   d. it allowed the astronomers of her time to test their models for the interiors of these stars, to see if they were made of hydrogen
   e. it was the first significant astronomical discovery by a woman

9. Galaxy distances are determined
   a. just by using Cepheid variables
   b. by measuring supernovae
   c. by a large variety of techniques that have to be used together, depending on the circumstances
   d. using the cosmic redshift
   e. with parallax

10. Active galaxy nuclei are powered by
    a. galaxy mergers
    b. matter falling into very massive black holes
    c. lots of star formation in the centers of galaxies
    d. energy left over from when the galaxy formed
    e. star collisions in the dense environment of galaxy nuclei

11. Disks form around young stars
    a. when a second star that formed in orbit breaks up
    b. when two stars nearly collide
    c. if the cloud from which the star forms is too massive for all of it to fall into the star
    d. when the new star passes through a dense cloud and it is attracted to the star
    e. from material that was spinning around the protostellar core too fast to fall into the star

12. The clearest evidence that quasars are at great distance is
    a. their small parallaxes
    b. that they lie in the centers of galaxies that are at large distances
    c. that their emission lines are shifted to the blue
    d. that they vary rapidly
    e. the faintness of the Cepheid variables in them

13. The rapid variability in the outputs of quasars and other active nuclei shows that
    a. the apparent variability is an effect of gravitational lensing
    b. they are exploding
    c. they are moving very fast
    d. the nuclear sources are small
    e. stars are blowing up in these regions
14. Most of the mass of the Milky Way is
   a. in its stars
   b. in the supermassive black hole in its center
   c. in the interstellar gas
   d. in a) through c)
   e. in the form of dark matter

15. The central galaxies of large clusters are
   a. merging large spiral galaxies
   b. always with active nuclei because gas from the cluster is falling into their nuclear black holes
   c. galaxies with immense tidal tails and other indications of recent interactions
   d. massive ellipticals that result from many mergers of smaller cluster members
   e. similar to other galaxies in the cluster

16. We think that dark matter is in the form of
   a. an undetected type of nuclear particle
   b. tiny black holes
   c. low mass brown dwarfs and wandering planets
   d. spectral lines suffering a gravitational redshift due to Einstein's law of relativity
   e. Newton's Law of gravitation being wrong

17. The Milky Way is a
   a. elliptical galaxy
   b. irregular galaxy
   c. barred spiral galaxy
   d. Sa galaxy
   e. we do not have much idea of what type it is

18. Galaxy collisions often
   a. trigger very high rates of star formation
   b. tear the galaxies apart so there is nothing left
   c. happen so rarely we do not know what they do
   d. drag most of the interstellar gas out of the galaxies
   e. strip planets away from their stars in the colliding galaxies

19. The distance to nearby galaxies like the one in Andromeda was determined from
   a. observing its main sequence stars
   b. measuring its parallax
   c. using Cepheid variables as standard candles
   d. comparing its apparent size with that of the Milky Way
   e. observing HII regions in it

20. The largest fraction of interstellar matter and highest rate of current star formation is in which type of galaxy?
   a. ellipticals
   b. spirals with prominent central bulges
   c. dwarf ellipticals
   d. active nucleus galaxies
   e. irregulars

21. If we wait a long time, the Local Group of galaxies will look
   a. basically the same as now
   b. different because the large galaxies will have “eaten” some of the smaller ones
   c. different because all the galaxies will have turned to spirals
   d. like it has vanished because it will have dissipated into intergalactic space
   e. full of small galaxies because collisions will break up the large ones
22. The nature of quasars was initially confusing because
   a. their emission lines were at peculiar wavelengths
   b. they were radio sources
   c. they varied rapidly
   d. they were very luminous
   e. they looked like stars

23. What do we call the bright, roughly spherical, collection of stars around the center of the Milky Way?
   a. disk
   b. halo
   c. bulge
   d. spiral arms
   e. dark matter

24. The black hole in the Galactic Center is
   a. not very massive
   b. glowing brightly as an active nucleus
   c. surprising un-energetic
   d. just passing through the region – it will be gone in a few million years
   e. there is no black hole in the Galactic Center

25. Most of the mass of the Universe appears to be in the form of
   a. galaxies
   b. dark matter
   c. baryons
   d. dark energy
   e. intergalactic hot gas seen in the X-ray

26. The order of formation of the parts of spiral galaxies is (from old to young):
   a. spiral arms, disk, bulge, halo
   b. disk, bulge, spiral arms, halo
   c. halo, disk, bulge, spiral arms
   d. halo, bulge, disk, spiral arms
   e. bulge, halo, spiral arms, disk

27. A star formed in a galaxy 30 million light years away. We receive a spectrum that is characteristic of a star 30 million years old. How old was the star when we received the spectrum?
   a. 50 million years
   b. 30 million years
   c. 80 million years
   d. 60 million years
   e. there is not enough information to tell

28. Which physical force dominates the process of star formation?
   a. strong nuclear
   b. weak nuclear
   c. electrical
   d. gravitational
   e. reactional

29. To form a real star, an object must be massive enough to
   a. have enough gravity to hold planets in orbit
   b. make an HII region
   c. explode as a supernova
   d. create enough pressure and heat in its core for hydrogen fusion
   e. burn hydrogen and helium into heavier elements
30. A "reflection nebula" is
   a. a cloud of interstellar grains aligned to reflect light similarly to a mirror
   b. a nebula that has symmetry along a central line that makes it look like it is reflected in a mirror
   c. a cloud of interstellar material that lets us look into regions we cannot see directly
   d. an interstellar cloud that absorbs energy from nearby stars and emits it in the infrared
   e. an interstellar cloud that scatters light toward us from a star near the cloud

31. Star formation is often aided by
   a. heating of an interstellar cloud by a star ejecting a planetary nebula
   b. an electrical vibration caused by thermal instability in interstellar gas
   c. planets passing through a molecular cloud and upsetting its equilibrium
   d. centrifugal forces caused by spinning cloud fragments
   e. a supernova explosion compressing nearby molecular clouds

32. A "standard candle" for an astronomer is
   a. a votive candle of the usual size and wax content
   b. a variable red supergiant star
   c. an astronomical object whose luminosity can be determined independent of knowing its distance
   d. a barred spiral galaxy
   e. a special candle of constant brightness maintained at the Bureau of Standards

33. Galaxy distances are important because
   a. they let us calibrate parallax measurements
   b. they tell us where to look to find stars with planetary systems
   c. they help address the philosophical questions about our place in the Universe and how it is built
   d. they show us which galaxies are coming toward us
   e. they identify which galaxies are colliding with each other

34. Distance measurements to the galaxies around us show that
   a. the Milky Way is isolated in space
   b. the Milky Way is the only large galaxy in our neighborhood
   c. the Milky Way is part of a galaxy group in which it and M31 are surrounded by many small galaxies
   d. we are moving rapidly toward a certain point in space, leaving the nearby galaxies behind
   e. the Milky Way is orbiting M31, and we see its projected position move relative to background galaxies

35. The sun is located
   a. in a globular cluster
   b. in the outer part of the Milky Way’s disk
   c. in the halo of the Milky Way
   d. near the center of the Milky Way
   e. at an unknown location within the Milky Way

36. Gravitational lenses in galaxy clusters are used
   a. to confirm that the clusters have huge amounts of dark matter
   b. to get a better view of the Big Bang
   c. to search for distant planets
   d. to study the theory of relativity
   e. to improve our determination of Hubble's Law

37. Interstellar dust makes the things behind it look
   a. bluer and fainter
   b. greener and brighter
   c. redder and fainter
   d. it blots them out completely
   e. redder and more diffuse
38. Why did astronomers in the 19th century believe that the solar system was close to the center of the Milky Way?
   a. they did not realize how interstellar dust cut off their view
   b. we are close to the center
   c. they did not have photographic plates to detect very faint stars
   d. their telescopes were too small to see the whole system
   e. they needed ultraviolet detectors

39. When clumps first collapse into young stars, their arrival on the main sequence is delayed because
   a. they cannot burn hydrogen because it has not settled into their cores yet
   b. they cannot burn hydrogen until a spark ignites it
   c. their activity level needs to rise before they can burn hydrogen
   d. their cores must shrink and heat up to burn hydrogen
   e. the hydrogen must be converted from molecular to atomic form to burn

40. The best place to look for stars just beginning to form is
   a. in empty space
   b. in a molecular cloud
   c. in a reflection nebula
   d. in a supernova remnant
   e. near the Sun

41. The period-luminosity relationships for RR Lyrae and Cepheid stars were easier to establish for stars in the Magellanic Clouds (nearby external galaxies) because
   a. there are more of these stars in the Magellanic Clouds than in the Milky Way
   b. the ones in the Magellanic Clouds are all at about the same distance
   c. they were easier to see in the Magellanic Clouds than in the Milky Way
   d. because the Magellanic Clouds are only visible south of the equator, they had been observed particularly well
   e. their proper motions are smaller, making comparisons over time with other stars more accurate

42. In very deep images that let us detect very distant and hence young galaxies, we find them to be
   a. very similar to nearby ones
   b. generally to be smaller and with less regular structure compared with nearby ones
   c. mostly to be ellipticals since bulges formed first
   d. all very obscured by the dust in their interstellar matter
   e. we cannot get a good enough sense of their nature to describe them well

43. Spiral arms occur in galaxies
   a. from small galaxies falling into large ones and leaving streamers of stars behind
   b. from long features that formed originally in the galaxies and have gotten wound up by its rotation
   c. where instabilities in the galaxy disk cause the material to “bunch up”
   d. where active nuclei have ejected material in jets
   e. because supernova explosions drive the interstellar material into large structures

44. The Galactic Center was hidden from astronomers for many years because
   a. it only emits in the radio and infrared
   b. it is a very diffuse region that is hard to pinpoint
   c. there were looking in the wrong places
   d. the Milky Way has a peculiar, atypical structure that made it hard to find
   e. it is hidden in the visible by clouds of interstellar dust

45. Ring-shaped galaxies and galaxies with tails of stars are evidence for
   a. galaxies forming from intergalactic matter
   b. nuclear activity in galaxies
   c. explosions across the face of previously normal galaxies
   d. galaxies taking part in the expansion of the Universe
   e. galaxy collisions
46. What is the evidence there is dark matter beyond the disks of spiral galaxies?
   a. inner disk stars orbit faster than the mass due to stars and gas can explain
   b. infrared telescopes detect mass beyond the galaxy disks
   c. the stellar mass distribution does not account for the rotation of the outer regions of gas in the galaxies
   d. disk stars orbit faster than stars in the galactic centers
   e. regions outside the disks obscure the light of galaxies behind them

47. Galaxies undergoing starbursts
   a. are full of bursting stars
   b. are usually ellipticals
   c. were identified through clusters of stars bursting out from them
   d. are forming massive stars rapidly and in exceptionally large numbers
   e. have less dark matter than other galaxies

48. Spiral arms are prominent in some galaxies because
   a. they mark where the dust is thin and we can see the stars better
   b. they show where young and bright stars have formed
   c. they represent bright blobs that have been wound into the spiral shape by the galaxy rotation
   d. Population III stars make them bright
   e. they mark where material has been ejected by the nucleus

49. A newly formed massive, hot star changes the surrounding interstellar gas into
   a. a molecular cloud
   b. a glowing cloud of excited gas called an HII region
   c. a dark globule seen as a shadow against the background light
   d. an HI region
   e. interstellar dust

50. To determine the direction and distance to the Galactic Center, Shapley used
   a. open stellar clusters
   b. spiral galaxies
   c. globular clusters
   d. very bright stars
   e. none of the above